CEPAL
REVIEW

ECONOMIC COMMISSION FOR LATIN AMERICA AND THE CARIBBEAN

UNITED NATIONS

ECLAC

N° 111
DECEMBER • 2013

ISSN 0251-2920

CEPAL

REVIEW

ECONOMIC
COMMISSION FOR
LATIN AMERICA
AND THE CARIBBEAN

UNITED NATIONS

ECLAC

Nº 111
DECEMBER • 2013

CEPAL

REVIEW

ECONOMIC
COMMISSION FOR
LATIN AMERICA
AND THE CARIBBEAN

UNITED NATIONS

ECLAC

ISSN 0251-2920

The *CEPAL Review* was founded in 1976, along with the corresponding Spanish version, *Revista CEPAL*, and it is published three times a year by the United Nations Economic Commission for Latin America and the Caribbean (ECLAC), which has its headquarters in Santiago, Chile. The *Review*, however, has full editorial independence and follows the usual academic procedures and criteria, including the review of articles by independent external referees. The purpose of the *Review* is to contribute to the discussion of socioeconomic development issues in the region by offering analytical and policy approaches and articles by economists and other social scientists working both within and outside the United Nations. The *Review* is distributed to universities, research institutes and other international organizations, as well as to individual subscribers.

The opinions expressed in the signed articles are those of the authors and do not necessarily reflect the views of the organization. The designations employed and the way in which data are presented do not imply the expression of any opinion whatsoever on the part of the secretariat concerning the legal status of any country, territory, city or area or its authorities, or concerning the delimitation of its frontiers or boundaries.

To subscribe, please visit the Web page: http://ebiz.turpin-distribution.com/products/197587-cepal-review.aspx

The complete text of the *Review* can also be downloaded free of charge from the ECLAC web site (**www.eclac.org**).

UNITED NATIONS

ECLAC

This publication, entitled the CEPAL Review, is covered in the Social Sciences Citation Index (SSCI), published by Thomson Reuters, and in the Journal of Economic Literature (JEL), published by the American Economic Association

United Nations publication
ISSN: 0251-2920
ISBN: 978-92-1-121847-3
e-ISBN: 978-92-1-056022-1
LC/G.2597-P

Printed in Santiago, Chile

ARTICLES

Explanatory notes

The following symbols are used in tables in the *Review*:

… Three dots indicate that data are not available or are not separately reported.

(–) A dash indicates that the amount is nil or negligible.
A blank space in a table means that the item in question is not applicable.

(-) A minus sign indicates a deficit or decrease, unless otherwise specified.

(.) A point is used to indicate decimals.

(/) A slash indicates a crop year or fiscal year; e.g., 2006/2007.

(-) Use of a hyphen between years (e.g., 2006-2007) indicates reference to the complete period considered, including the beginning and end years.

The word "tons" means metric tons and the word "dollars" means United States dollars, unless otherwise stated. References to annual rates of growth or variation signify compound annual rates. Individual figures and percentages in tables do not necessarily add up to the corresponding totals because of rounding.

Commercial bank financing for micro-enterprises and SMEs in Mexico

Ramón Padilla-Pérez and Rodrigo Fenton Ontañon

ABSTRACT

This article examines commercial bank lending strategies for micro-enterprises and small and medium-sized businesses (SMEs) in Mexico, and the factors that promote or hinder lending in this segment. With this in mind, in 2011 a detailed survey was conducted of commercial banks operating in Mexico. Although credit to micro-enterprises and SMEs still represents a small share of the loan portfolio, the survey results point to growing interest in broadening it. Three different business models were identified, with major differences in strategies for offering financial services to this segment of enterprises. The greatest barriers to increasing the credit supply are lack of information, creditor protection failures, informality, and the changes and disruptions that commercial banking has experienced over the past three decades.

JEL CLASSIFICATION G21, L29, O16

KEYWORDS Small firms, medium-sized firms, business financing, commercial loans, bank lending, businesses, surveys, Mexico

AUTHORS Ramón Padilla-Pérez is an Economic Affairs Officer with the International Trade and Industry Unit of the ECLAC subregional headquarters in Mexico. ramón.padilla@cepal.org

Rodrigo Fenton Ontañon is Vice President of Investment Banking with Bulltick Capital Markets and former Deputy Director General for Economic Affairs with the National Banking and Securities Commission (CNBV) of Mexico. rfenton@bulltick.com

I
Introduction

The economic literature of the past few decades has abounded with discussion of the financial sector's role in economic growth. The great majority of authors agree that the sector plays a key part in growth because it provides services that are essential in today's economy: among other functions, it facilitates trade and production specialization, promotes saving and capital accumulation, makes resource use more efficient and diversifies risk.

As a facilitator of industrial growth, the financial system plays a central role in establishing and strengthening firms. Production schemes, especially long-term, large-scale projects, need a system capable of capturing and allocating the resources of multiple savers (Bencivenga and Smith, 1991). Micro-enterprises and small firms usually have limited resources of their own and look to the financial system for the means to set up or grow their business.

The evidence available in the large body of literature on access to financing in Mexico supports consensus that the lending portfolio to the production sector is limited —especially in the case of micro-enterprises and small and medium-sized businesses (SMEs) (see, for example, Garrido and Prior, 2006; Lecuona, 2009). Although it has grown steadily in real terms since 2004, the total portfolio in this sector remains modest in relation to the size of the Mexican economy (banks' lending portfolio to private business represents around 7% of GDP).

This article analyses a particular aspect of the Mexican financial system's contribution to economic development —commercial banks' small business lending strategies— and examines the factors that stimulate or obstruct this lending. To this end, it summarizes the results of a technical collaboration project conducted by the National Banking and Securities Commission (CNBV) of Mexico and the Economic Commission for Latin America and the Caribbean (ECLAC).[1] The analysis is based on the results of a questionnaire designed by CNBV and ECLAC to examine the business strategy adopted by commercial banks in their dealings with micro-enterprises and SMEs and to obtain information that would refute or validate the importance of a series of previously identified factors.

A vast body of literature exists on Mexico's financial system,[2] addressing a broad range of subjects from its historical development to the functioning of specific aspects such as the system of guarantees. Yet none was found on the factors facilitating or hindering credit to firms on the basis of a survey of commercial banks.

This article has six sections including this introduction. Section II reviews the theoretical and empirical literature on the relationship between financial system development and economic growth, and identifies eight factors that could potentially be related to the supply of credit to the production sector. Section III sets forth the methodology used to collect empirical evidence. Section IV analyses the first part of the questionnaire results (the business model), and section V examines the importance of obstacles to credit in Mexico. Section VI concludes and suggest future lines of research.

☐ The authors are grateful to Pablo Peña, Saidé Salazar, Willy Zapata and Juan Carlos Moreno-Brid for their comments on preliminary versions of this article, and to Darío Luna, Raúl Hernández Coss, Luis Treviño, Sirenia Vázquez and Yearim Valles for their contributions in designing and planning the research. Support was also gratefully received at different stages of the project from Althea Spinozzi, Jesús Dávila, Jesús Santamaría and Verónica Vega. Lastly, the authors express their thanks to the Association of Banks of Mexico and the banks which took part in the study.

☐ The opinions expressed in this document are those of the authors and may not coincide with those of the organizations in which they work.

[1] The full report on the project is available in Fenton and Padilla-Pérez (2012).

[2] See, for example, Tovilla (2002); Garrido (2005); Ávalos and Hernández (2006); Castañeda and Ruiz (2006); Lecuona (2009); Suárez Dávila (2010), and Pavón (2010).

II

Financing for production development: importance and potential obstacles

The economic literature on the relationship between financial system development and economic growth is abundant and wide-ranging. The theoretical literature and the empirical evidence largely agree that the two are positively correlated, because the financial system plays a crucial role in reducing transaction and information costs, and facilitates efficient resource allocation. Nevertheless, some authors argue that the financial system's importance for economic growth has been overstated (Lucas, 1988; Chandavarkar, 1992).

The financial system has five main functions as an engine of industrial development.[3] The first is to reduce risk through coverage, commerce and diversification (Bencivenga and Smith, 1991). This function is essential for technological innovation, which is typically a long, slow process (Audretsch, Werner and Mahagaonkar, 2009).

The second function is to compile information and allocate resources. By reducing information asymmetries between lenders and borrowers, the financial system channels resources to the most productive sectors, encouraging economic efficiency and social well-being (Greenwood and Jovanovic, 1990; Habibullah and Eng, 2006).

The third function is to mobilize individual and grouped savers looking to invest their resources. The financial system brings together the resources of numerous savers for allocation to large and productive projects (Sirri and Tufano, 1995).

The fourth function is to reduce the costs of compiling the information needed to enforce contracts and oversee the behaviour of borrower firms. This function promotes capital accumulation and efficient resource allocation and, consequently, long-term growth (Levine, 1997; Rajan and Zingales, 1998).

The fifth and final function is to facilitate specialization by reducing transaction costs. Specialization allows firms to concentrate on production activity, by giving them the space to improve their processes and products and thus increase their productivity (Stiglitz, 1989; Greenwood and Smith, 1997; Cooley and Smith, 1998).

A broad literature exists on how the degree of development of a country's financial system affects its economic growth and the relationship between the two has been analysed minutely using various econometric techniques. Most empirical studies offer evidence that the two variables are positively correlated.[4]

The factors encouraging or hindering financing for small businesses may be grouped by supply side and demand side. On the supply side are formal and informal mechanisms of financing for firms and, on the demand side, the individuals and companies seeking financial resources to begin, operate or strengthen their production activities.

This study concentrates on factors that could limit the supply of commercial bank credit to micro-enterprises and SMEs. A comprehensive review of the literature identified eight such factors (see table 1). Several studies show that a multidimensional analysis is needed, because there is no single cause to explain the supply or absence of credit to the business sector. The list is to be construed as a set of hypotheses that are to be refuted or validated by the results of a questionnaire of commercial banks in Mexico, as explained in greater detail in the following section. The eight factors are described below.

TABLE 1

Mexico: factors potentially linked to credit supply to SMEs and micro-enterprises

Macroeconomic conditions
Transaction costs
Information asymmetries
Guarantee system
Origin of capital
Creditor protection
Cultural and regulatory factors
Historical factors

Source: prepared by the authors.

[3] This systematization is based on the work of Levine (1997).

[4] See, for example, Arestis, Demetriades and Luintel (2001); Benhabib and Spiegel (2000); Leitao (2010); Rajan and Zingales (1998); Saci, Giorgioni and Holden (2009); Bittencourt (2010); Blanco (2010); Habibullah and Eng (2006); Caporale and others (2009).

Business cycles heavily influence the availability of funds for credit (Garrido, 2005). The supply of financing tends to dwindle under very tight monetary policy, because banks themselves have less financing and financial resources are in shorter supply in the market in general (Barajas and Steiner, 2002). Monetary policy not only affects short-term interest rates, but also brings about changes in bank reserves and deposits and thereby the availability and cost of credit. Banks tend to reduce their credit supply in times of macroeconomic instability because risk is greater. In countries that suffer lengthy periods of instability or that are very vulnerable to economic shocks, credit to the business sector tends to be more limited and interest rates tend to be higher.

From the creditor's point of view, lending carries a variety of costs associated with evaluation, oversight and collections. Transaction costs may be divided into overheads, which exist regardless of the value of the transaction, and costs arising from lack of adequate information. For SMEs and micro-enterprises, overheads tend to be high in relation to the amount lent because firms in this segment usually apply for quite small loans. The cost rises further if there are no credit rating instruments to provide rapid, reliable information on the firm. Banks may therefore change high rates of interest to secure an attractive return from this segment, which makes financing more difficult for small businesses (Garmendia, 2006).

Lack-of-information costs have to do with the excessive administrative work involved in finding adequate documentation, and they affect a bank's decision on whether to assess the loan application at all. If the requesting firm has not compiled all the documents needed to obtain financing, the loan application review process drags on and increases the bank's costs in terms of the human resources monitoring and evaluating the project (Lecuona, 2009).

Information asymmetries arise when the borrower has more information than the lender. When the value and quality of a firm or project cannot be accurately calculated, banks have no guarantee of their future success. This problem is especially acute in the case of small businesses and reflects the general lack of information about them. Without solid data, the bank cannot evaluate a firm objectively, making it very difficult to establish the firm's future ability to generate returns (Audretsch, Werner and Mahagaonkar, 2009). The main information asymmetries facing private banks in lending to micro-enterprises and SMEs are: (i) the high cost of obtaining credit information, (ii) inconsistent financial information, and (iii) lack of access to third-party information (Malhotra and others, 2006). These asymmetries can lead to adverse selection or moral hazard (Stiglitz and Weiss, 1981; Lecuona, 2009).

Information asymmetry can lead to excess demand for credit, even where credit supply and demand are in equilibrium. This is known as "credit rationing" (Stiglitz and Weiss, 1981).

From the credit supply perspective, a number of obstacles can arise in relation to the system of guarantees. If a firm has no collateral to offer, the financial institution has less incentive to extend credit. It also has less incentive where the value of the collateral cannot be established. In addition, an ineffective public sector, weak institutions and failings in the legal system can make it very hard for financial institutions to realize guarantees in the case of default (World Bank, 2007).

Guarantees reduce borrowers' incentives to default, increase their motivation to succeed at a project and lower the costs of bankruptcy for the lender. Guarantees also address information asymmetry and uncertainty issues, and reduce the risk for the lender (Garmendia, 2006). However, micro-enterprises and SMEs often lack guarantees for loan application.

The literature on the implications of the origin of capital and the involvement of foreign banks in lending to SMEs is inconclusive, with studies coming down both in favour and against. Some authors assert that the entry of foreign banks can increase the supply of credit to SMEs and micro-enterprises because they tend to have comparative advantages in small business financing in terms of technologies and organizational structure (Berger and Udell, 2006).

Other authors argue that foreign banks are prejudicial to SMEs and micro-enterprises, because they tend to have a hierarchical organizational structure and treat collateral (which SMEs and micro-enterprises usually lack) as one of the most important factors in the lending decision. They also tend to be at a disadvantage vis-à-vis local banks when it comes to obtaining information (Beck, Demirgüç-Kunt and Martínez, 2010).

The existence of a guarantee system does not, in itself, expedite lending to the SME and micro-enterprise segment if there is no legal framework to enable creditors to recover the guarantees agreed should be borrower default. This is the case in countries with legal systems which tend to protect the borrower and where legal processes are lengthy and inefficient (Beck and de la Torre, 2007).

Haber (2005) mentions that in developing economies, even where the banking system has been freed up and banks behave in a prudent manner, in a context of weak

contractual rights often they will simply not lend to small businesses.

Cultural factors can affect lending if borrowers lack good payment behaviour or if firms are highly informal, which increases risk for the lender. The culture of informality in firms also affects credit supply, because banks and financial institutions are not willing to lend to firms lacking the proper documentation (tax receipts, audited financial statements, and so forth). In an informal culture, firms may leave assets undeclared to avoid taxes, and therefore cannot use them as collateral for banking purposes (World Bank, 2007).

Regulatory factors can also hinder the supply of credit to micro-enterprises and SMEs, if they create conditions or procedures that obstruct bank lending or make it less profitable. Financial repression can also affect the credit supply. McKinnon (1973) found that many countries have historically restricted financial sector operations through government intervention or regulation.

Long-term relations between bankers and businesses are important for lending, because they complement the numerical information —which banks use to evaluate firms— with qualitative information, including prestige and reputation, and help to reduce information asymmetry problems. Relations between bankers and businesses facilitate lending even in times of credit squeeze, as in financial crises (De la Torre, Martínez Pería and Schmukler, 2008).

A last factor that affects credit supply is political and economic stability. Generally speaking, banks lend more to business in countries that are politically very stable, where there is no risk of nationalization and their assets are more secure.

III
Methodology

This research project was undertaken in an effort to gain a fuller understanding of the strategies used by the commercial banking system in Mexico in its lending operations with micro-enterprises and SMEs. A number of surveys and studies on firms' access to bank credit in the country have been conducted, but they vary in terms of their coverage and the level of detail of the data compiled.[5] These studies have all, however, used a demand-side approach, in that their authors have canvassed different firms in order to determine whether or not they have bank loans.

This study departs from that approach in that it takes a look at the supply side of the picture by asking banks about their corporate lending practices. To the authors' knowledge, this is the first study in which credit supply is analysed on the basis of a representative survey of commercial banks in Mexico.[6] In determining what type of information would be useful and how to go about gathering it, the fact that there would be a relatively small number of observations (banks) was taken into account.

The National Banking and Securities Commission (CNBV) and the Mexican Banking Association (ABM) jointly identified the banks that lend to micro-enterprises and SMEs on the basis of regulatory reports and the two organizations' in-depth knowledge of the market. This target universe was made up of 17 out of the 40 banks operating in the country. According to ABM and CNBV, these 17 banks are the only ones that extend credit to micro-enterprises and SMEs. Those that do not engage in such lending operations were not included in the target universe.

ECLAC and CNBV designed and used two tools for gathering information on commercial banks that lend to micro-enterprises and SMEs: a questionnaire and an in-depth interview. In the end, information was obtained from 15 of the 17 banks that were contacted. Those 15 banks account for 97% of the commercial banking system's portfolio of loans to micro-enterprises and SMEs in Mexico.

[5] Examples include: the National Microbusiness Survey; the National Survey on Corporate Competitiveness, Funding Sources and Use of Financial Services; the evaluation of the credit-market cycle conducted by the Banco de México; and the Enterprise Surveys of the World Bank.

[6] Studies on the supply of credit available to small and medium-sized enterprises (SMEs) in Mexico, such as the study prepared by the Latin American Banking Association (FELABAN, 2007), have been conducted on the basis of a survey of Latin American banks, but they have not been as detailed, and their national samples have not been representative. There are also studies based on secondary data, such as that of Lecuona (2009).

The questionnaire contained 77 queries (a mixture of numeric and open-ended questions) designed to elicit information on bank managers' views on various matters.[7] The queries were grouped into three sections. One focused on the strategy used in dealing with micro-enterprises and SMEs, another on the banks' business models for this clientele, and the third on operational aspects of their loans to micro-enterprises and SMEs.[8]

ABM helped the interviewers to contact the most suitable executives in each bank, who were, for the most part, the managers in charge of the section of the bank responsible for business with micro-enterprises and SMEs or, in banks where no such section exists, the executives who deal with that segment of the market. Once the questionnaire had been sent, respondents took an average of four weeks to return it.

The in-depth interviews were conducted after the completed questionnaires had been received. Between June and August 2011, the authors visited the banks in order to delve more deeply into the responses given to the open-ended questions. These interviews lasted between 90 and 120 minutes.

[7] The questionnaire may be found in the complete report, which is cited in the first footnote of this article.

[8] A preliminary version of the questionnaire was shown to ABM, and the feedback that it provided was used to adjust some of the questions in the interests of clarity.

IV
Business model

One basic fact that must be borne in mind when seeking to gain an understanding of the business models used by commercial banks in Mexico is that they are highly heterogeneous. These banks differ from one another not only in terms of clearly observable attributes (the scale of their operations or their sources of capital) but also in terms of comparative advantages and their overall business approaches. These differences determine whether or not they lend to micro-enterprises and SMEs and, if so, what approach they will take to that segment of the market.

As noted earlier, there are more than 40 different banks in Mexico, but fewer than half of them (17) lend to micro-enterprises and SMEs, according to the information provided by ABM and CNBV.[9] Several foreign banks extend credit to this segment of the market in other countries but not in their Mexican branches. In conversations with executives from these banks, no one mentioned any specific restriction in that regard. Instead, the executives simply mentioned that their business activities in Mexico did not, for the time being, include that type of loan product, partly because they were concentrating on more profitable lines of business, such as investment banking.

Of the 15 banks that responded, 11 have a specialized business unit to handle operations with micro-enterprises and SMEs and a specific strategy for its dealings with them. These units are generally in charge of setting targets and benchmarks, identifying banking products, prospecting potential clients, and granting and monitoring loans in this segment. These banks usually also have a specialized sales force.

Commercial banks do not all define micro-enterprises and SMEs in the same way, since this depends on the operational criteria and business strategy used by each institution. Some use a firm's sales volume, while others base their definition on the amount of credit involved. For the purposes of this study, an attempt has been made to consolidate the classifications used by the banks in the sample.

At the time of the interviews, the banks reported that their total portfolio of micro-enterprise and SME loans amounted to 119 billion pesos distributed among 200,000 different loans. Their micro-enterprise and SME portfolios represented 19.4%, on average, of their total commercial loan portfolio, but for the individual banks, this percentage ranged from 2.5% to 75.6%.

In most cases, the bank executives emphasized that the first step in competing for new clients was to offer deposit-taking products such as current or savings accounts or salary payment accounts. The representatives of banks that do not have a special unit for micro-enterprise and SME loans were the only ones who openly admitted that the intention was not to provide the full range of services to those clients. None of the interviewees said

[9] This universe does not include all banks that offer microcredits, which constitute a segment that has differing characteristics and strategies.

that credit was their main or only product. In fact, 11 of these 15 banks offer more than five different products to their clients in the micro-enterprise and SME segment, such as current accounts, lines of credit, salary payment accounts and special business credit cards. Lines of credit and lines of working capital are the most common loan products.

On the basis of the survey results, the approaches taken by these banks in offering credit to the micro-enterprise and SME segment can be classified as corresponding to one of three business models. It should be emphasized, however, that these models do not necessarily represent a rigid, fixed classification of all their different lines of business.

(i) Large banks. Their strategy consists of serving as many clients as they can attract through their network of branch offices or specialized promotional personnel. They are able to benefit from economies of scale and are the biggest small-business lenders.

(ii) Banks with close ties to micro-enterprises and SMEs. These are niche banks devoted to promoting entrepreneurship and the production sector of the economy or regional banks that specialize in certain market segments. They use relationship lending to attract clients.

(iii) Banks that do not have specialized micro-enterprise/SME units. This category includes banks that offer loans to this segment only as an extension of their traditional lines of business in order to provide their existing clients with an additional service.

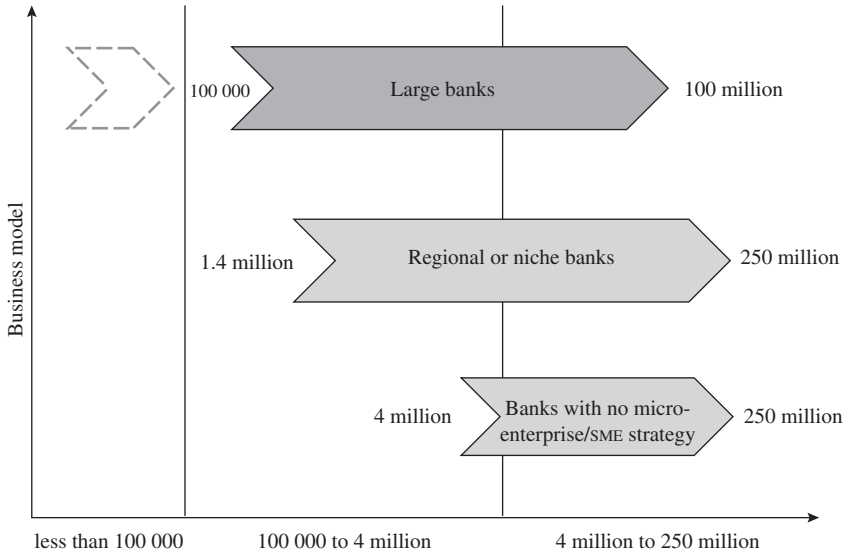
Figure 1 shows the range of clients served by the banks in these three categories. The large banks' clients include smaller firms, with some of them even beginning to deal with companies that have annual sales of less than 100,000 pesos. Banks that maintain ties with micro-enterprises and SMEs serve larger firms, while those without specialized units for this segment work only with firms having annual sales of over 4,000,000 pesos. This leads to the conclusion that the commercial banking system primarily lends to small and medium-sized firms in this segment, while it provides financing to no more than a small group of micro-enterprises.

Annual interest rates on loans to micro-enterprises and SMEs vary according to the size of the firm, the sector in which it operates and the type of business concerned. On average, the rates reported in the interviews are as follows:

Microenterprises:	16.3% – 26.8%.
Small enterprises:	11.1% – 17.3%.
Medium-sized enterprises:	8.8% – 13.2%.

FIGURE 1

Mexico: segments of micro-enterprises and SMEs served by banking institutions
(Mexican pesos)



Source: prepared by the authors.

V
Analysis of obstacles

This section aims to validate or refute the significance of each of the previously identified factors that are potentially linked to credit supply in Mexico, on the basis of the information obtained from the bank survey conducted for this study.

1. Macroeconomic conditions

The questionnaire included queries to identify how banks incorporate macroeconomic conditions into their decisions on lending to micro-enterprises and SMEs and to establish whether these conditions have encouraged or hindered lending. Seventy-one per cent of the banks surveyed (accounting for 82.9% of the micro-enterprise and SME lending portfolio) considered the performance of macroeconomic variables in setting targets and in the extension of loans to this business segment. Macroeconomic variables were generally used to set lending and deposit-taking targets, and to assess risk and allocate portfolios by sector and region.

The different variables are commonly used to estimate the macroeconomic risk associated with the portfolio of loans to micro-enterprises and SMEs and to establish total portfolio and lending amounts. For large firms, assessment and inclusion of macroeconomic variables in credit assessment is done on an individual, case-by-case basis. The executives of the banks canvassed also said that small businesses tend to be more vulnerable to macroeconomic shocks, and that this is taken into account in lending decisions.

When requested to describe an occasion on which macroeconomic variables had prevented lending, 53% of the banks interviewed (78.2% of the portfolio) cited the economic crisis of 2008-2009 and the public health emergency arising from the H1N1 influenza outbreak.

Sixty-nine per cent of the banks interviewed (90.3% of the portfolio) stated that poor macroeconomic performance dampened incentives to lend to micro-enterprises and SMEs. High volatility, uncertainty and slowing economic activity do affect the credit supply, and did so during recent economic crisis (1995 and 2008-2009). At the time of the interviews, however, (June-August 2011), economic conditions were brighter and were not constraining credit supply. Macroeconomic factors affect lending to micro-enterprises and SMEs and to large firms, but in the former case credit is more vulnerable to adverse economic conditions.

2. Transaction costs

Fifty-three per cent of the banks interviewed (73% of the portfolio) were able to estimate transaction costs as a proportion of the loans extended to micro-enterprises and SMEs. The remaining banks argued that this information was not available, because it was not a routinely performed calculation. Transaction costs are defined as the expenses the bank incurs to bring about a loan contract, not including funding costs[10] or default losses. The main components of transaction costs are: marketing and loan origination; loan underwriting, approval and extension; loan performance supervision and collection; and litigation for recovery of arrears.

On average, the transaction cost was 2.8% of the sum lent (2.9% in weighted average for the portfolio). However, that cost varied significantly (from 1% to 7%) among the banks interviewed. The largest component was marketing and loan origination, which —on average— make up 50% of the total transaction costs (51% in the weighted average), followed by loan underwriting, approval and extension (30% in the simple average and 27% in the weighted average), and loan performance supervision and collection (10% in the simple average and 12% in the weighted average) (see table 2). Only three banks gave an estimate of transaction costs for large firms as well. In all three cases, the costs were lower than for small businesses.

The minimum level below which is it not profitable to lend to micro-enterprises and SMEs varied among the banks interviewed, depending on their business model and size. The average cut-off point was 420,000 pesos (310,000 pesos in the weighted average for the portfolio), but ranging from 18,000 to 3 million pesos. Banks with smaller portfolios and fewer loans to micro-enterprises and SMEs tended to stipulate higher minimum loans than banks with large, numerous portfolios. 75% of the banks interviewed (76.5% of the portfolio) considered lending

[10] The funding cost is the financial cost the bank pays to its own creditors for the resources it lends.

to a micro-enterprise or SME more risky than lending to a large firm, but 58% (46.5% of the portfolio) estimated that it was also more profitable.

Executives in 57% of the banks (24.8% of the portfolio) stated that higher transaction costs represented a barrier to lending to small businesses. Among the banks interviewed there was a general opinion that lending to micro-enterprises and SMEs is a business of scale, inasmuch as a bank needs to have a large network of branches and executives trained to cater to this segment to reach worthwhile figures. Accordingly, transaction costs are not a barrier for banks with large and numerous micro-enterprise and SME portfolios, but they can be for banks with smaller portfolios.

TABLE 2

Mexico: composition of transaction costs in lending to micro-enterprises and SMEs, average for the firms interviewed
(Percentages)

	Simple average	Weighted average
Marketing and loan origination	50	51
Loan underwriting, approval and extension	30	27
Loan performance supervision and credit collection	10	12
Collection of credit arrears	7	7
Litigation for collection of defaulted loans	3	2

Source: prepared by the authors.

3. Information asymmetries

Three steps are generally taken to counter information asymmetries:

(i) All the banks interviewed offer other products to micro-enterprises and SMEs, as well as lines of credit. As noted earlier, 73% offer more than five different products. As well as leveraging the relationship with the firm, this strategy enables the bank to build up information about the firm's business performance and owners, or both, by tracking its checking, credit card and payroll transactions, for example.

(ii) All the banks interviewed ask micro-enterprises and SMEs to give evidence of having been in operation for at least two years in order to qualify for credit. This is premised on the general idea that 80% of small businesses disappear within the first two years. A firm over two years old is therefore deemed to be more likely to survive and, therefore, to be able to repay a loan.[11]

(iii) None of the banks interviewed lend to start-ups, because it is very difficult to assess the project's chances of success. Exceptionally, loans may be extended to businesspeople trying to start up a new business, with a jointly liable signatory who has good relations with the bank.[12] Four large banks participate in a scheme run by the Ministry of the Economy to extend financing to entrpreneurs,[13] but at the time of the interviews very few loans had actually been extended.[14]

Ninety-three per cent of the banks interviewed (98.9% of the portfolio) consult a credit bureau[15] to obtain background information on micro-enterprises and SMEs, their owners, or both. Almost three quarters (73%) of the banks interviewed (82% of the portfolio) said that the information from private credit and debtor information registries was reliable or very reliable (a rating of 4 or 5, on a scale of 1 to 5). 54% of the banks interviewed (58.1% of the portfolio) considered that the credit bureaux databases provided enough information on a micro-enterprise or SME to determine its risk profile, whereas the other banks considered this information insufficient and complemented it with another source of data.

[11] Refers to payments made by the borrower to the bank to reimburse the capital lent.

[12] A guarantor from whom the bank is entitled to demand resources on the same terms and conditions as from the borrower, or who can be legally obliged to cover payment of capital and interest.

[13] The Entrepreneur Financing Programme aims to encourage and promote commercial bank lending to entrepreneurs with technically, commercially and financially viable schemes. See www.economia.gob.mx for more information about this programme.

[14] See Tovilla (2002) and Pino (2002).

[15] Credit bureaus are defined in Mexican law as "credit information agencies" or *Sociedad de Información Crediticia* (SIC).

Eighty-seven per cent of the banks interviewed (94% of the portfolio) use credit score models for micro-enterprises and SMEs. The weight of the model's results in the lending decision varies from one bank to another and depends, among other things, on the amount of the loan and the size of the firm. Generally speaking, the larger the loan, the more other criteria are needed in addition to the credit score model.

In 64% of the interviews (87.1% of the portfolio) the bank stated that insufficient or poor quality information was a barrier to lending to micro-enterprises and SMEs. Information asymmetry is an obstacle for a small business with less than two years in operation, and for entrepreneurs. For older firms, there are sources of information and evaluation mechanisms that counter asymmetries. Private registries of information on credit and borrowers are considered a reliable source for assessing a firm and its owner.

4. Guarantee system

Sixty-four per cent of the banks interviewed (66% of the portfolio) stated that the collateral offered by a micro-enterprise or SME was very important (4 or 5, on a scale of 1 to 5) in securing loan approval. Some banks do not ask for collateral for certain types of firm or below certain amounts of loan, but they do assess the business in detail. The percentage of the portfolio of small businesses which have put up collateral varies greatly depending on the size of the bank, its business strategy and the length of time for which it has been lending to this segment.

In the midsize and small banks interviewed, 70% of the commercial small business portfolio was backed by a pledge on physical assets, but the amount varied from 25% to 100%. In large banks, these pledges are less significant (between 0% and 5% of the commercial portfolio, with an average of 1%).

By contrast, the percentage of the portfolio with government guarantees in large banks averages 74%, varying from 60% to 98%. Some of these banks even stated that, in recent years, all new loans to micro-enterprises and SMEs have been backed by government guarantees, mainly provided by Nacional Financiera, S.N.C. (NAFIN).[16] Among the smaller banks, the percentage of the portfolio secured by government guarantees is generally lower, averaging 40%. Among the banks interviewed, 67.2% of the portfolio total is backed by government guarantees. For some of the banks interviewed, NAFIN guarantees do not replace physical collateral, which they require in addition to the government guarantee.

In 40% of the interviews (45.2% of the portfolio), banks stated that collateral requirements are greater for micro-enterprises and SMEs than for large firms, because they are usually less stable, more informal and harder to assess.

Eighty per cent of the banks interviewed (75.4% of the portfolio) considered federal government guarantees more appropriate for micro-enterprises and SMEs than for large firms, because of the loan ceilings and because many SMEs would be unable to secure a loan at all without them.

In 90% of the banks interviewed (88.2% of the portfolio) federal government guarantees were preferred to other collateral; the rest considered the two equally useful. The general preference reflects the fact that small businesses often have collateral of poor quality at their disposal. In addition, the government guarantees function as liquid collateral, whereas a pledge on physical assets can require lengthy legal processes, and recovering government guarantees is thus quicker and more expedite. The government guarantees also show a positive impact on reserves.

In the case of default, 60% of the banks interviewed (50.5% of the portfolio) said that it was difficult or very difficult (rating of 1 or 2, on a scale of 1 to 5, where 5 is very easy and 1 is very difficult) to seize physical collateral in case of default. Banks argued that the process was slow and costly and collateral guarantees hard to dispose of.

Fifty-seven per cent of the banks interviewed (57.3% of the portfolio) stated that the collateral and government guarantee systems were sufficient to cover the risks of the small business portfolio. Opinions were more favourable among the large banks, which make more use of government guarantees. Banks which have less access to government guarantees generally stated less satisfaction with the guarantee system overall.

In addition to the questionnaire, other studies on credit guarantees in Mexico have found serious rule-of-law issues, which make it difficult to recover the guarantees written into loan contracts. It may be concluded that these issues directly affect banking activity and hinder credit expansion.

5. Origin of capital

Foreign-owned banks are responsible for most of the small business lending in Mexico owing to their predominance in commercial banking in general. Two thirds of the

[16] NAFIN is a Mexican development bank focused on promoting credit to the private sector.

foreign-owned banks interviewed said their business model for micro-enterprises and SMEs in Mexico was different to the one they used in other countries. This is because they have different programmes and instruments and use other channels to reach clients (for example, more electronic media).

Ninety-two per cent of the banks interviewed (87.3% of the portfolio) stated that the nationality of the capital does not affect their willingness to lend to micro-enterprises and SMEs. The origin of capital is not a barrier to credit supply, insofar as the strategies used by Mexican and foreign banks do not differ.

At least three elements must be considered in comparing Mexican- and foreign-owned banks to establish whether the origin of capital plays a role in small business lending strategies. First, whether multinational banks behave differently in different countries, including in their home market. Second, any comparison must take into consideration other observable characteristics that lead to different business models, such as bank size. By and large, the foreign-owned banks are the largest ones. Third, the behaviour of Mexican-owned banks varies in a manner comparable to that of foreign-owned banks. Accordingly, distinguishing the origin of the capital may not be as informative as other characteristics.

6. Creditor protection

The banks gave very varied responses to questions on creditor protection. The simple average figure for loans to micro-enterprises and SMEs entering default (the arrears portfolio) is 6%, but this ranges widely between banks, from 1.4% to 20%. The average weighted by size of defaulting loan portfolio is 4.7%. As noted earlier, the rate of successfully recovered guarantees attached to these loans is 76% on average, with differences ranging from 30% to 99% and a weighted average of 82%. The banks with the highest ratios of successfully recovered guarantees are those which make most use of government guarantees.

The average amount recovered from a defaulted loan to a micro-enterprise or SME is 49% of the unpaid balance, but ranges from 2% to 100% among the banks interviewed. Weighted by size of portfolio recovered, the average is 51.4%.

It takes 21 months, on average, to recover a defaulted loan to a micro-enterprise or SME (18.3 months when weighted by portfolio size), varying from 1 to 60 months among the banks interviewed. The simple average cost of recovery is 17% of the defaulted loan (10.2% weighted by portfolio size), varying from 0.5% to 60%.

Only 16% of the banks interviewed (13% of the portfolio) considered the laws or regulations applicable to recovery of loans from a micro-enterprise or SME useful or very useful (4 or 5, on a scale of 1 to 5). The weaknesses of the legal system included: the length of time it takes to enforce a guarantee; distant dates for seizure proceedings; difficulty in delivering notifications; obstacles to conducting seizures; and complex, slow and costly legal actions.

Seventy-one per cent of the banks interviewed (92.4% of the portfolio) maintained that a weak legal system for recovering defaulted loans represented a barrier to the supply of credit to micro-enterprises and SMEs. In sum, processes were slow and complicated, recovery times were long, and the legal route was very costly. These factors are not exclusive to the small business segment, however, but affect lending to large firms as well.

7. Cultural and regulatory factors

Informality affects the supply of credit to micro-enterprises and SMEs. Executives in 94% of the banks interviewed (74% of the portfolio) said that informality strongly influenced the lending decision (a rating of 4 or 5, on a scale of 1 to 5). Informality refers to firms that are not legally constituted or registered with the Ministry of Finance and Public Credit, have weak or unsystematic accounting practices or lack updated tax reports and financial statements.

Only 36% of the banks interviewed (57.1% of the portfolio) thought it important or very important (a rating of 4 or 5, on a scale of 1 to 5) to do away with the requirement for tax reports to boost small business lending. The percentage is low because several banks still ask for tax reports as evidence that a firm is legally established, even though this is not an official requirement.

Other cultural and regulatory factors which banks mentioned as affecting the credit include:

(i) The new methodology proposed by the authorities for parametric estimation of reserves to business loans contains variables that would increase the cost of lending to micro-enterprises and SMEs.
(ii) The highly complex tax legislation.
(iii) Insecurity, especially in the north of Mexico, limits some banks' credit supply or forced them to change their business assessment criteria.
(iv) The "won't pay" culture which characterizes many businesses and businesspersons.
(v) Lack of financial culture and professionalization on the part of micro-enterprises and SMEs.

Ninety-three per cent of the banks interviewed (96.8% of the portfolio) replied that cultural and regulatory factors, such as fiscal informality, lack of financial culture, or the "won't pay" culture prevailing in smaller firms formed obstacles to lending.

8. Historical factors

There is a high turnover among the staff and branches dealing with micro-enterprises and SMEs, with an average of 3.5 years on the job. Senior and middle managers tend to have been in place longer.

Departments for lending to micro-enterprises and SMEs, where they exist, are relatively new, even where this line of business is older the department itself. This is because of the changes in this area of business during the various deep transformations in Mexico's banking industry. Some banks have closed down and reopened their small business lending department in the past decade. Economic crises or problems with the business model have often led to lending being suspended and the strategy rethought.

Although 59% of the banks interviewed (82.3% of the portfolio) stated that staff stability in the lending segment was important or very important (4 or 5, on a scale of 1 to 5), thereby confirming the importance of relationship lending, the continual and deep-reaching changes in Mexican banking have not always permitted it.

Commercial banks in Mexico have undergone major transformations in the past three decades. Expropriation in 1982 was followed by a process of privatization in 1994 and 1995. Then in 1998 most of the restrictions of foreign investment were lifted, and by the start of the 2000s the main banks were being bought by foreign financial institutions (Cárdenas, 2010).

It may be concluded that the thoroughgoing transformations in Mexican banking in the past three decades, which have led to changes in the business model and in the staff dealing with firms, seem to militate against close relations between the banking and production sectors and, therefore the credit supply to micro-enterprises and SMEs.

In addition to the findings of the questionnaire, Brown and Domínguez (2010) argue that the banking crisis of 1994-1995 laid bare the need for change in the way financial institutions operated, which led to the creation of new government schemes and instruments to facilitate access to credit for micro-enterprises and SMEs.

VI
Conclusions

The research described herein offers detailed information on commercial bank strategies for lending to micro-enterprises and SMEs, on the basis of an in-depth, representative survey of commercial banks in Mexico. This empirical work, the first of its type in Mexico, serves to validate or refute the hypotheses regarding barriers to lending in this segment. This analysis represents the supply-side view (commercial banks) and should be complemented with the demand-side perspective (firms).

In this regard, CNBV and the Inter-American Development Bank (IDB) recently conducted a survey of firms to ascertain in more detail how financial services, including bank credit, are used. The results of this demand-side study coincide in some respects with the supply-side research. For example, the firms canvassed said that credit lines were the most used product and that informality largely limited access to bank credit. Conversely, firms perceive that the greatest obstacle to securing bank credit is lack of sufficient guarantees (CNBV/IDB, 2012).

The first group of results produced by the present research work offers accurate and detailed information on the business strategy of commercial banks in Mexico as regards lending to micro-enterprises and SMEs. For example, 11 of the 15 banks interviewed have a line of business for micro-enterprises and SMEs and a specialized strategy for them. 73% of the institutions surveyed offer micro-enterprises and SMEs five or more different products, aiming to provide comprehensive solutions and reduce information asymmetries. There is a widespread practice of extending credit only to firms that can show at least two years of operations, which precludes loans to entrepreneurs. Lines of working capital are the most common loan product.[17] There are major differences in the strategies followed by commercial banks in their dealings with micro-enterprises and SMEs, however, with

[17] This product gives the client access at any time to a contingency loan up to a pre-authorized amount, to cover short-term needs.

diverse business models and strategies. In this regard, banks may be grouped into three types: (i) large banks, (ii) niche banks devoted to promoting entrepreneurship and the production sector, or regional banks, and (iii) banks that do not have specialized micro-enterprise/SME units.

This study's second contribution is to validate or refute eight factors that could hinder commercial bank lending to micro-enterprises and SMEs in Mexico, on the basis of the information provided by the banks themselves. Economic crises, especially the crisis of 1994-1995, have had a significant, long-term effect on the credit supply for small businesses. Macroeconomic variables are taken into account in setting total lending targets, and in lending to specific sectors or types of firm.

Because lending to micro-enterprises and SMEs is a large-scale business, transaction costs are a barrier for banks with smaller small business loan portfolios, but not for those with larger portfolios. Insufficient or poor quality information limits credit supply for micro-enterprises and SMEs. This barrier is greater in the case of informal firms and those whose operations are relatively new (less than two years old) and for entrepreneurs. For older, more formal or more professional firms, there are reliable sources of information, including credit bureaux.

The guarantee system in Mexico is not an obstacle for most of the banks interviewed, especially for those with larger portfolios and those with access to the government guarantee scheme. The difficulty and complexity of recovering collateral not backed by the government is a matter of concern, however.

The study found no evidence that the origin of capital, in particular the predominance of foreign-owned institutions in commercial banking, affects the credit supply to micro-enterprises and SMEs. None of the banks interviewed, regardless of where their capital came from, mentioned a differentiated strategy for dealing with small businesses.

The banks interviewed had a poor opinion of the creditor protection system. Slow processes, high costs and long, complicated recoveries represented a barrier to lending to micro-enterprises and SMEs. With respect to cultural factors, fiscal informality, lack of financial know-how and the "won't pay" culture form obstacles to lending to this business segment.

Lastly, the historical transformations in commercial banking in Mexico in recent decades, with changes in the business model and the staff dealing with firms at all levels, appear to work against close relations between commercial banks and the production sector.

The third contribution of this investigation has been to open avenues of future research. The implications of particular regulations —such as bank reserve requirements or the documentation firms must present to apply for a loan— need to be analysed for the different levels of business lending. In this regard, the impact of implementing Basel III must be studied.

The evidence and conclusions on the importance of certain factors could be strengthened by means of international comparison studies. For example, how do the average 2.8% transaction costs for banks in Mexico compare with those in other countries? And, although there is no evidence of a strategy differentiated by origin of capital, how do practices, loan amounts and lending approaches to micro-enterprises and SMEs differ from those in other countries where international banks operate?

Another area of interest is the effect of government lending schemes in terms of generating lending in addition to credit that would have been extended without them. In other words, although these guarantees have been important in reactivating business lending, at what point might they begin to substitute or crowd out commercial bank efforts?

A final avenue for future work is a detailed analysis of the differences and similarities found by supply- and demand-side surveys of commercial bank lending practices.

Bibliography

Afuah, Allan (1999), *La dinámica de la innovación organizacional*, Mexico City, Oxford University Press.

Aghion, Phillipe and Patrick Bolton (1997), "A trickle-down theory of growth and development with debt overhang", *Review of Economic Studies*, vol. 64, No. 4, Oxford, Oxford University Press.

Arestis, Philip, Panicos Demetriades and Kul Luintel (2001), "Financial development and economic growth: the role of stock markets", *Journal of Money, Credit and Banking*, vol. 33, No. 1, Ohio, Ohio State University Press.

Audretsch, David B., Bonte Werner and Prashanth Mahagaonkar (2009), "Financial Signalling by Innovative Nascent Entrepreneurs", *Discussion Paper*, No. 7165, London, Centre for Economic Policy Research.

Ávalos, Marcos and Fausto Hernández (2006), "Competencia bancaria en México", *Estudios y Perspectivas series*, No. 62 (LC/MEX/L.722(Rev.2), Mexico City, ECLAC subregional headquarters in Mexico, June. United Nations publication, Sales No. S.06.II.G.155.

Banerjee, Abhijit and Andrew Newman (1993), "Occupational choice and the process of development", *Journal of Political Economy*, vol. 101, No. 2, Chicago, University of Chicago Press.

Barajas, Adolfo and Roberto Steiner (2002), "Credit Stagnation in Latin America", *Working Paper*, No. 02/53, Washington, D.C., International Monetary Fund.

Beck, Thorsten, Asli Demirgüç-Kunt and María Soledad Martínez (2010), "Foreign banks and small and medium enterprises: Are they really estranged?", Washington, D.C., World Bank.

Beck, Thorsten and Augusto de la Torre (2007), "The basic analytics of access to financial services", *Financial Markets, Institutions and Instruments*, vol. 16, Wiley.

Bencivenga, Valerie R. and Bruce D. Smith (1991), "Financial intermediation and endogenous growth", *Review of Economic Studies*, vol. 58, No. 2, Oxford, Oxford University Press.

Benhabib, Jess and Mark M. Spiegel (2000), "The role of financial development in growth and investment", *Journal of Economic Growth*, vol. 5, No. 4, New York, Springer.

Berger, Allen N. and Gregory F. Udell (2006), "Universal banking and the future of small business lending", *Financial System Design: The Case for Universal Banking*, Anthony Saunders and Ingo Walter (edit.), Burr Ridge, Illinois, Irwin.

Bittencourt, Manoel (2010), "Financial development and economic growth in Latin America: is Schumpeter right?", *Working Papers*, No. 191, Cape Town, Economic Research Southern Africa.

Blanco, Luisa (2010), "The finance-growth link in Latin America revisited and the role of institutions as a source of finance" [online] http//ssrn.can/abstract=1672839>.

Brown, Flor and Lilia Domínguez (2010), "Políticas e instituciones de apoyo a la pequeña y mediana empresa en México", *Políticas de apoyo a las pymes en América Latina. Entre avances innovadores y desafíos institucionales* (LC/G.2421-P), C. Ferraro and G. Stumpo (comps.), Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC). United Nations publication, Sales No. S.09.II.G.143.

Caporale, Guglielmo Maria and others (2009), "Financial development and economic growth: evidence from ten new EU members", *Discussion Papers of DIW Berlin*, Berlin, German Institute for Economic Research.

Cárdenas Sánchez, Enrique (2010), "La reestructuración económica de 1982 a 1994", *Historia crítica de las modernizaciones en México*, Clara García Ayluardo, Ignacio Marván Laborde and Erika Pani (coords.), Mexico City, Fondo de Cultura Económica/ Centro de Investigación y Docencia Económicas.

Castañeda, Gonzalo and Clemente Ruiz (2006), "Los avances y los asuntos pendientes para la profundización de los servicios financieros en México", *La extensión del crédito y los servicios financieros*, Paulina Beato and Pablo Adrián (coord.), Madrid, Ibero-American General Secretariat.

Chandavarkar, Anand (1992), "Of finance and development: neglected and unsettled questions", *World Development*, vol. 20, No. 1, Amsterdam, Elsevier.

CNBV/BID (National Banking and Securities Commission/Inter-American Development Bank) (2012), *Encuesta Nacional de Competitividad, fuentes de financiamiento y uso de servicios financieros de las empresas. Reporte de resultados*, Mexico City.

Cooley, Thomas F. and Bruce D. Smith (1998), "Financial markets, specialization, and learning by doing", *Research in Economics*, vol. 52, No. 4, Amsterdam, Elsevier.

De la Torre, Augusto, María Soledad Martínez Pería and Sergio Schmukler (2008), "Bank Involvement with SMEs: Beyond Relationship Lending", *Policy Research Working Papers*, No. 4649, Washington, D.C., World Bank.

FELABAN (Latin American Banking Federation) (2007), "*Tracking* sobre la predisposición de las entidades financieras de Latinoamérica y Caribe para la financiación de las pequeñas y medianas empresas", Caracas.

Fenton Ontañon, Rodrigo and Ramón Padilla-Pérez (2012), "Financiamiento de la banca comercial a micro, pequeñas y medianas empresas en México", *Estudios y Perspectivas series*, No. 135 (LC/MEX/L.1052), Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC).

Garmendia, Gonzalo (2006), "Acceso de las pequeñas y medianas empresas al financiamiento: Situación en América Latina y el Caribe", Ibero-American Guarantee Network, X Foro Iberoamericano de Sistemas de Garantía y Financiamiento para la Micro y Pyme, Castilla y León, Spain [online] http://www.redegarantias.com/index.php?not=123.

Garrido, Celso (2005), *Desarrollo económico y procesos de financiamiento en México: Transformaciones contemporáneas y dilemas actuales*, Mexico City, Siglo Veintiuno Editores.

Garrido, Celso and Francisco Prior (2006), *Bancarización y microfinanzas. Sistemas financieros para las MIPYMES como un dilema central para el desarrollo económico de México*, Mexico City, Editorial Porrúa.

Greenwood, Jeremy and Boyan Jovanovic (1990), "Financial development, growth and the distribution of income", *Journal of Political Economy*, vol. 98, No. 5, Chicago, The University of Chicago Press.

Greenwood, Jeremy and Bruce Smith (1997), "Financial markets in development and the development of financial markets", *Journal of Economic Dynamics and Control*, vol. 21, No. 1, Amsterdam, Elsevier.

Haber, Stephen (2005), "Mexico's experiments with bank privatization and liberalization, 1991-2003", *Journal of Banking and Finance*, vol. 29, No. 8-9, Amsterdam, Elsevier.

Habibullah, Muzafar Shah and Yoke-Kee Eng (2006), "Does financial development cause economic growth? A panel data dynamic analysis for the Asian developing countries", *Journal of the Asia Pacific Economy*, vol. 11, No. 4, Taylor & Francis.

Lecuona, Valenzuela Ramón (2009), "El financiamiento a las pymes en México, 2000-2007: El papel de la banca del desarrollo", *Financiamiento del Desarrollo series*, No. 207 (LC/L.2997-P), Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC). United Nations publication, Sales No. S.09.II.G.04.

Leitao, Nuno (2010), "Financial development and economic growth: a panel data approach", *Theoretical and Applied Economics*, No. 10 (551), Bucharest, Asociatia Generala a Economistilor din Romania (AGER).

Levine, Ross (1997), "Financial development and economic growth: views and agenda", *Journal of Economic Literature*, vol. 35, No. 2, Nashville, Tennessee, American Economic Association.

Lucas, Robert (1988), "On the mechanics of economic development", *Journal of Monetary Economics*, vol. 22, No. 1, Amsterdam, Elsevier.

Malhotra, Mohini and others (2006), *Expanding Access to Finance: Good Practices and Policies for Micro, Small, and Medium Enterprises*, Washington, D.C., World Bank.

McKinnon, Ronald I. (1973), *Money and Capital in Economic Development*, Washington, D.C., Brookings Institution.

Pavón, Lilianne (2010), "Financiamiento a las microempresas y las pymes en México (2000-2009)", *Financiamiento del Desarrollo series*, No. 226 (LC/L.3238-P), Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC). United Nations publication, Sales No. S.10.II.G.41.

Pino Hidalgo, Enrique (2002), "Financiamiento para la pequeña empresa: Una aproximación desde la sociedad civil", *Comercio Exterior*, vol. 52, No. 5, Mexico City, BANCOMEXT.

Rajan, Raghuram G. and Luigi Zingales (1998), "Financial dependence and growth", *American Economic Review*, vol. 88, No. 3, Nashville, Tennessee, American Economic Association.

Saci, Karima, Gianluigi Giorgioni and Ken Holden (2009), "Does financial development affect growth?", *Applied Economics*, vol. 41, No. 13, Taylor & Francis.

Sirri, Erik R. and Peter Tufano (1995), "The economics of pooling", *The Global Financial System: A Functional Perspective*, Dwight B. Crane and others (eds.), Boston, Harvard Business School Press.

Stiglitz, Joseph (1989), "Financial markets and development", *Oxford Review of Economic Policy*, vol. 5, No. 4, Oxford, Oxford University Press.

Stiglitz, Joseph and Andrew Weiss (1981), "Credit rationing in markets with imperfect information", *American Economic Review*, vol. 71, No. 3, Nashville, Tennessee, American Economic Association.

Suárez Dávila, Francisco (2010), *La reprivatización bancaria fracasada: Tragedia nacional en 3 actos*, Mexico City, Centro de Estudios Espinosa Yglesias.

Tovilla, Carlos M. (2002), "Las garantías de crédito en México", *Comercio Exterior*, vol. 52, No. 7, Mexico City, BANCOMEXT.

World Bank (2007), *Informality: Exit and Exclusion*, Washington, D.C.

A modelling framework for assessing the economic impact of climate change in the Caribbean

Roberto Roson

ABSTRACT

The ECLAC-Climate Impacts Assessment Model (CIAM) is a modelling platform that has been created to assess the economic consequences of climate change in the Caribbean. The model can be freely accessed, downloaded and even modified. The version available is a full-fledged model which can readily be used to conduct simulation exercises. This paper provides a general description of the model and an illustrative simulation exercise. Our results from this exercise highlight the fact that the Caribbean is a highly vulnerable region where climate change is expected to generate sizeable and negative economic consequences.

KEYWORDS Climate change, economic aspects, evaluation, ECLAC, mathematical models, simulation methods, Caribbean

JEL CLASSIFICATION C68, Q51, Q54, Q56, R13

AUTHOR Roberto Roson is an associate professor at the Department of Economics of Ca'Foscari University and Research Director at the Centre for Research on Energy and Environmental Economics and Policy (IEFE) at Bocconi University in Milan, Italy. roson@unive.it

I
Introduction

Climate change is a very complex phenomenon. Large-scale computer models are run to simulate future climate conditions under different scenarios and assumptions. Socioeconomic models are used to assess climate change impacts and the costs and benefits of mitigation and adaptation policies. Physical and social models are often integrated into complex integrated assessment models (IAMs).

A consistent finding among the many and diverse impact analyses is that the negative consequences of climate change will be felt primarily in the developing countries of Latin America and the Caribbean, Africa and Asia. This poses a problem of equity in international negotiations, like those of the United Nations Framework Convention on Climate Change, as developing countries are historically responsible for only a negligible share of global greenhouse gas emissions. Quantitative models can greatly help in identifying the burdens and benefits of global climate policies.

Unfortunately, the most vulnerable regions are also those where a rigorous assessment analysis is rendered difficult by lack of data and expertise. In the Caribbean, for example, no tool for assessing the social impacts of climate change has been available for a long time. More generally, there is a lack of quantitative socioeconomic models focusing on the Caribbean subregion. The use of simulation, optimization, econometric and forecasting models is not widespread in the area, even in institutions like the national central banks (with only a few notable exceptions, e.g., Jamaica). Not surprisingly, the databases necessary to support and implement applied models are lacking or inadequate. Policymakers are usually unaware of the existence of quantitative economic models and decision support systems.

This issue has been recently tackled by the ECLAC subregional headquarters for the Caribbean, with financial support from the Australian Agency for International Development (AusAid). ECLAC has commissioned a study to either develop a prototype model or modify an existing framework that will address climate change impacts in the Caribbean in a modelling framework. This paper provides a general description of the model created for this purpose, the ECLAC-Climate Impacts Assessment Model (CIAM), and an illustrative simulation exercise.

ECLAC-CIAM has been designed and developed on the basis of some fundamental concepts. First, a systemic approach has been followed. A systemic approach to modelling climate impacts is essential because climate change is a global phenomenon and the world economy is globalized. The economic effects of climate change in the Caribbean may be driven by physical impacts occurring in the United States, say, much more than by direct physical impacts in the Caribbean. However, most existing sectoral studies fail to capture these systemic relationships.

Second, we needed the model to be able to consider multiple impact effects simultaneously. This is necessary because climate change generates economic consequences in a variety of sectors and in different ways. In addition to sea-level rise, mention could be made of the effects on agricultural productivity (due to changing precipitation, increased evapotranspiration and carbon fertilization), on tourism demand (changing incomes, prices and tourism attractiveness), on energy demand (increased demand for cooling, decreased demand for heating), on human health and labour productivity (variations in mortality and morbidity), and so on. From a policy perspective, the simultaneous assessment of multiple impacts is necessary because: (1) there is often a need to evaluate the overall effect of climate change on a particular country or region; (2) knowing the contribution of each sectoral effect to the total may help in determining priorities for adaptation policies, and (3) different impacts may have counteracting effects.

Third, the model has been designed with a modular structure that can easily be accessed and understood by other researchers. In order to keep up with progress in the field of climate science, new elements can be easily inserted in the future, possibly by Caribbean researchers. Indeed, we hope to generate a "multiplier effect", with ECLAC-CIAM acting as a seedbed for further research and model development.

A major difficulty of simulating with complex mathematical models is that it can require specific, expensive software that scientists from developing countries may be unable to afford. We tried to circumvent this obstacle by basing ECLAC-CIAM only on auxiliary programs that can be downloaded and used free of charge. The program codes, all data and parameters, documentation and links to auxiliary software can be found and downloaded for free at: http://venus.unive.it/roson/ciam.html.

This paper is organized as follows. Section II provides a concise state-of-the-art review of the numerical models available for assessing the socioeconomic impacts of climate change. Section III describes the structure and operational functioning of ECLAC-CIAM. Section IV illustrates a simulation exercise which analyses the economic impacts of climate change in the year 2050. Section V concludes.

II
The state of the art

1. Applied economic models for climate change assessment

Several applied numerical models have been developed to assess the economic impact of climate change and related policies. These models differ in their scope, methodology, level of aggregation, treatment of technology and uncertainty, and degree of integration with climate models.

A first distinction can be drawn between simulation (positive) and optimization (normative) models. Simulation models are used to conduct "what if" experiments, by considering variations in climate or policy (or both). Almost all models with a computable general equilibrium (CGE) core, including ECLAC-CIAM presented here, are simulation models. Other models in this class are DART (Springer, 1998), ENVISAGE (Roson and van der Mensbrugghe, 2012), EPPA (Paltsev and others, 2005), GEMINI-E3 (Bernard and Vielle, 2008), GREEN (Burniaux and others, 1992; Lee and others, 1994), GTAP-E (Burniaux and Troung, 2002), GTEM (Pant, 2007) and ICES (Eboli, Parrado and Roson, 2010). Optimization models instead take a target, in the form of a function to be maximized or minimized. All models based on intertemporal utility maximization "à la Ramsey" fall into this class. Perhaps the most popular group of models of this kind is the Dice/Rice family, developed by William Nordhaus (Nordhaus, 1994; Nordhaus and Yang, 1996). Other models are EDGE (Jensen and Thelle, 2001), ENTICE (Popp, 2003), FUND (Anthoff and Tol, 2008), MERGE (Manne, Mendelsohn and Richels, 1995), PAGE (Hope and others, 1993), WIAGEM (Kemfert, 2001) and WITCH (Bosetti and others, 2006).

Simulation models are usually large-scale, regionally and industrially detailed models. From a mathematical point of view, they are large non-linear systems of equations, to be solved with general mathematical packages or specialized software (e.g., GEMPACK, PATH/GAMS). Optimization models, on the other hand, are typically very aggregated models, solved by means of non-linear programming algorithms (e.g., MINOS/GAMS, CONOPT/GAMS). The Rice/Dice models, for example, simply consider one aggregate good that can be used for either consumption or investment. Climate change impacts are also modelled in a rather crude way, using a single damage function, with the level of potential income falling as temperatures increase.

The various approaches differ in terms of integration with climate models. Some approaches are "soft-linked" with climate models. This means that a climate model (e.g., a global circulation model) is first used to generate a climate scenario, which is taken as given within the economic model. Results from the latter can then be fed into the climate scenario, in an iterative process. Other models are "hard-linked", meaning that they possess a climate module which is fully integrated into the system. Most optimization models have this feature, but so do some large-scale simulation models, like EPPA and ENVISAGE. The advantage of having mutually consistent economic and climate blocks inside the same model should be balanced against the loss of complexity in the climate component, which is usually a reduced-form general circulation model including only a limited number of equations.

When models consider the distant future, changes in available technology should be taken into account. Again, investment in green technologies could be fostered by economic incentives, possibly as part of a climate policy package. A few models (e.g., WITCH, ENTICE) explicitly address the issue of "endogenous technical change". However, estimation of model parameters is very difficult, being somewhat arbitrary and subjective. Other models consider the existence of "backstop technologies". These are technologies which are available today but are too costly to be viable under present economic conditions. Nonetheless, they may put an upper bound on the cost of more traditional technologies, like those based on

fossil fuels, which could become much more expensive in the future.

A special problem is associated with intertemporal optimization models, like Rice/Dice and PAGE. These models require the use of discount factors, which cannot be easily estimated from current interest rates when the optimization horizon is far into the future and investment returns are affected by several uncertainties. Especially since the publication of *The Economics of Climate Change*: *The Stern Review* (Stern, 2007), there has been a vigorous debate stressing how sensitive results from these models are to assumptions about discount factors. Furthermore, there is no single, correct scientific methodology that should be followed in the estimation process, because assumptions about discount factors are affected by (sometimes hidden) subjective value judgments.

2. Advantages and limitations of CGE models for climate change impact assessment

ECLAC-CIAM is a CGE model based on the GTAP formulation and extended to include a set of sectoral damage functions. As such, it shares all the advantages and disadvantages of other general equilibrium models in the field, which are associated with the key characteristics briefly summarized above.

On the positive side, the high level of disaggregation makes it possible to understand the complex structural interdependencies of globalized economic systems, and furthermore opens the way to a precise delineation of climate change impacts on a finely detailed industrial and geographical scale. Since CGE models are general-purpose tools not originally designed for climate change analysis, it is easy to assess how non-climate policies may affect the climate, and vice versa. The rich output of the simulation exercises can be further processed (as it is, indeed, in ECLAC-CIAM). For example, the exchange of "virtual carbon" can be estimated from the origin/destination matrices of trade flows (Atkinson and others, 2010), which is very useful information in the context of international climate negotiations.

On the negative side, CGE models are highly data-demanding, having been originally conceived for short-run policy analysis. Their use over a much longer time horizon may be problematic if significant changes in technology or consumer preferences substantially alter the economic structure from its current state. For this reason alone, they should not be regarded as forecasting tools or used to construct future economic scenarios.

3. Climate change assessment in the Caribbean

Basically, all recent studies on climate change effects in the Caribbean have been conducted with support from and under the auspices of ECLAC, often in association with other international bodies. The most recent publication is *The Economics of Climate Change in the Caribbean. Summary Report 2011* (ECLAC, 2011). Further research findings have been presented at international workshops, but not published as yet.

The 2011 summary report presents the results of climate change scenarios for the Caribbean, obtained with the use of a regional circulation model driven by two general circulation models (ECHAM4 and HADCM3). The model predicts an increase in average temperature by 2050, relative to the 1960-1990 baseline, of 1.78°C for the region as a whole under scenario A2 of the Intergovernmental Panel for Climate Change (IPCC) *Special Report Emissions Scenarios* (SRES) (IPCC, 2000) and 1.84°C under scenario B2 of the SRES. The picture for precipitation is mixed, with increases in some countries and decreases in others. It was also found that some increase in tropical cyclone intensity would be likely if the climate continued to warm.

The report includes a number of sectoral impact studies, namely those for agriculture, the coastal and marine environment, human health, tourism, transportation, water resources, and energy. These studies are hardly comparable, but nonetheless have the merit of focusing on the Caribbean, highlighting difficulties and challenges in the estimation of physical climate change impacts for the region.

III
Model structure

1. Overview

ECLAC-CIAM includes three modules, operating sequentially, as shown in figure 1.

The first module is used to translate values for climate variables into changes in economic parameters for the global macroeconomic component. The CGE module is then used to conduct a comparative static simulation, contrasting the state of the world economy before and after the change in the climate-related parameters. The following subregions and countries are considered in the CGE: North America, South America, Central America, the Caribbean, Guyana and Suriname (considered together), Belize, Europe, Africa, Asia, and Oceania. To obtain more geographical detail for the Caribbean subregion, the results from the CGE module are post-processed to produce approximate values for some macroeconomic variables (changes in real national income in particular) for individual States in the Caribbean aggregate. In the following, the functioning of each module is more specifically described.

2. Sectoral damage functions

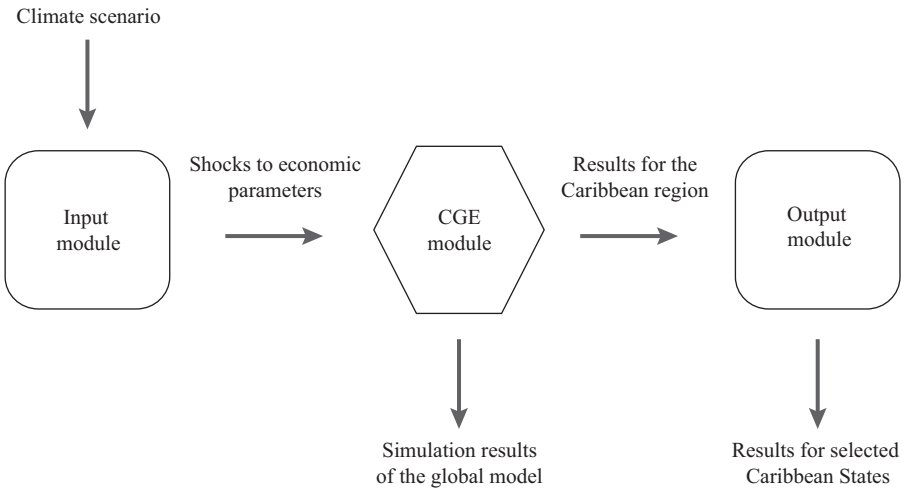
The first module in ECLAC-CIAM is used to generate exogenous shocks to a number of economic parameters and variables in the core CGE model, on the basis of a given climate scenario. This is done through the application of sectoral "damage functions".

A damage function is a relationship between some variable describing the climate state (in this case, the absolute global surface temperature change from its value in degrees Celsius in the year 2000) and certain parameters of the economic model (usually expressed as a percentage change from the baseline level). The type of sectoral impact determines which parameters are considered. For example, estimated changes in agricultural productivity translate into percentage changes for the multi-factor productivity parameter of "agriculture" in the CGE model. Effects on human health are interpreted as changes in labour endowment or productivity, and so forth.

In figure 2, for example, three damage functions for the agriculture sector are plotted, corresponding in

FIGURE 1

The modular structure of ECLAC-CIAM

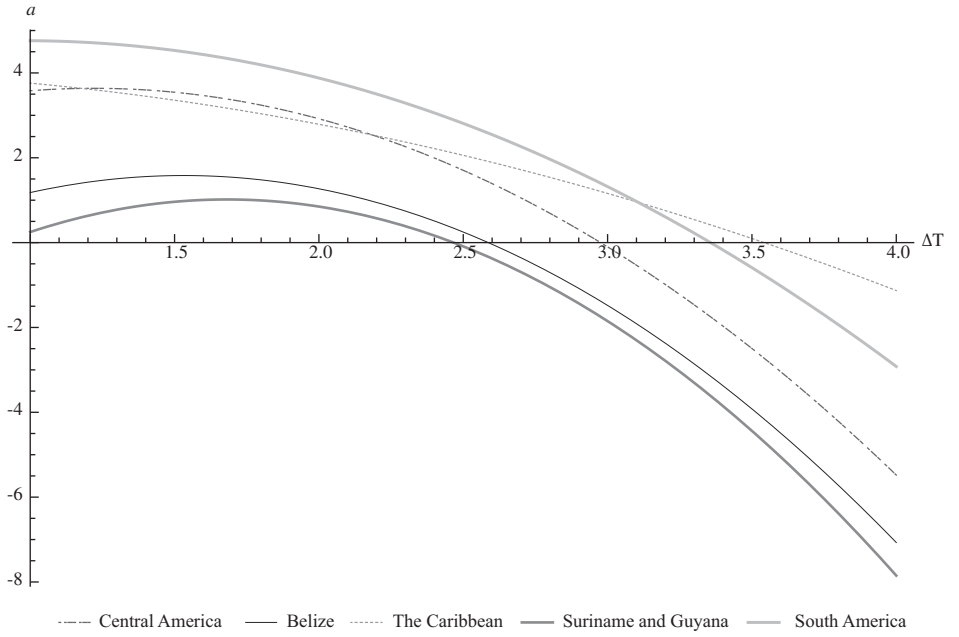


Source: prepared by the author.

CGE: computable general equilibrium.

FIGURE 2

Latin America and the Caribbean (selected countries and subregions): five damage functions (agriculture)



Source: prepared by the author.

the CGE model to the subregions of Central America, the Caribbean and South America, and the countries of Suriname and Guyana (considered together) and Belize.

The horizontal axis measures the change in temperature (in degrees Celsius) from the year 2000. The vertical axis measures the estimated percentage change in total agricultural productivity in the three countries. It should be noted that the estimates refer to the whole agriculture sector, not to a specific crop, and do not consider changes in the water supply or extreme events. The relationship between temperature and productivity in agriculture is a non-linear one: moderate increases in temperature (and in carbon dioxide concentration) are beneficial, higher temperature levels reduce agricultural productivity.

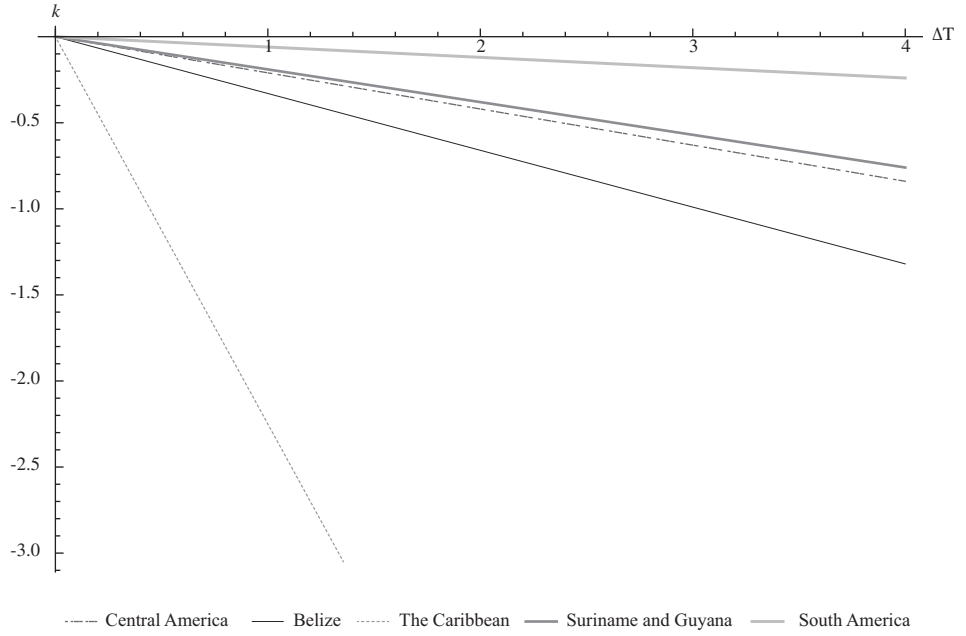
Other damage functions in ECLAC-CIAM are simple linear relationships, often because there is not enough information to estimate the various parameters of non-linear functions. For example, figure 3 plots the five damage functions for the sea-level-rise effect. In this case, the vertical axis measures the percentage loss in endowments of capital and land stocks in each country. It is clear that the small island States of the Caribbean are highly vulnerable to sea-level rise.

ECLAC-CIAM considers seven sectoral impacts, and each impact is associated with a specific damage function. In addition to agriculture and sea-level rise, the following impacts are taken into account:

- Water availability. This is a second source of variation for agricultural productivity, which is assumed to depend on estimated changes in runoff. According to current parameter values, an increase of 1°C in temperature would reduce agricultural productivity in the Caribbean by 0.21% because of lower water availability.
- Tourism. Changes in temperature are associated with changes in net receipts from foreign tourists, corresponding to foreign income transfers in the CGE model. A 1°C increase in temperature would reduce tourism receipts by US$ 8.6 billion in Central America, US$ 10 million in Belize, US$ 5.5 billion in the Caribbean and US$ 204 million in Suriname and Guyana, but would increase tourism receipts by US$ 26.8 billion in South America.

FIGURE 3

Latin America and the Caribbean (selected countries and subregions): five damage functions (sea-level rise)



Source: prepared by the author.

- Energy demand. This refers to changes in energy consumption by households, considering both cooling and heating needs. In the CGE model, any variation in energy consumption is accommodated through changes in all other expenses, so that the budget constraint for each household in each country holds. A 1°C increase in temperature would increase energy consumption by 0.21% in Belize and 0.24% in the Caribbean. It would reduce energy consumption by 0.23% in Central America, 0.25% in Suriname and Guyana and 0.02% in South America.
- Human health: additional cases (mortality and morbidity) of cold-related, heat-related and vector-borne diseases are translated into labour productivity changes in each region. A 1°C increase in temperature would reduce labour productivity by 0.58% in Central America, 0.57% in Belize, 0.13% in the Caribbean and 0.11% in Suriname and Guyana and the rest of South America.
- On-the-job productivity: this refers to labour productivity in open-air activities, which may be directly dependent on temperature and humidity. A 1°C increase in temperature would reduce (average) labour productivity by 0.43% in all five regions, except South America, where it would fall by 0.38%.

All figures are indicative and should be treated with caution. The parameters of the damage functions can be changed whenever more reliable information becomes available. At present, parameter values are estimated on the basis of a wide range of sectoral studies, and correspond to values used in the ENVISAGE integrated assessment model (Roson and Van der Mensbrugghe, 2012) developed at the World Bank.

Most of the sectoral studies used for this purpose make no explicit reference to the Caribbean or other tropical regions. For example, the parameters of the damage functions for agricultural productivity (figure 2) are obtained by weighted averaging of some crop response functions. Three crops have been considered: wheat, rice and maize. Although these are the three most widely grown crops in the world, they are certainly not representative of tropical agriculture. It is hoped that better data and more reliable parameter estimates will be made available in future versions of ECLAC-CIAM.

3. The core CGE model

The core of ECLAC-CIAM is a standard GTAP computable general equilibrium (CGE) model. This is a large macroeconomic model that includes thousands of

equations grouped into 213 categories. A complete formal description of the model is beyond the scope of this paper, but it can be easily found in Hertel and Tsigas (1997). The CGE model, which is not specifically designed for climate change analysis, provides a representation of the world economy and its interdependencies across regions, industries and markets.

Most parameters in the CGE model are calibrated. This means that their values are set in such a way that the model baseline replicates observed statistical data, such as consumption levels and trade patterns. Simulation exercises are performed by varying exogenous variables (e.g., tax rates, productivity factors and factor endowments) and by computing a counterfactual general equilibrium for the world economy in which product and primary factor markets alike invariably balance each other out. Therefore, a CGE model is primarily designed to study structural adjustment processes triggered by changes in some parameters rather than to forecast future economic scenarios.

Production in each regional industry is carried out by employing intermediate and primary factors. Intermediate factors are produced by other industries, domestic or foreign. The role of each factor in the production process is determined when the model is calibrated, i.e., when parameter values are set in accordance with observed industrial cost structures. Demand for production factors may change in simulation exercises because of variations in production levels and relative prices. Expensive factors are (partially) substituted by less expensive ones, on the basis of the assumed industrial production functions and "elasticity of substitution" parameters (determining how sensitive factor patterns may be to relative prices).

Because regional industries are large heterogeneous aggregates, goods produced in the same industry but in different regions are treated as distinct goods. Intermediate and final demand for any product is split within a nesting structure: first, relative prices determine how much is imported and how high domestic demand is; second, imports are allocated between different foreign sources, again on the basis of relative prices and elasticities of substitution (which may vary by region and sector). The prices of imported goods include international transport and trade margins, tariffs and non-tariff trade barriers.

In equilibrium, production volumes in each regional industry must match total demand, encompassing intermediate demand from other domestic and foreign industries, domestic and foreign household consumption, public expenditure, and domestic and foreign demand for (physical) investment. Equilibrium conditions are achieved by setting appropriate product and primary factor prices.

Primary resource endowments are normally given, although it is possible to change the partition between endogenous and exogenous variables in the model. Primary factors are internationally immobile but fully or partially mobile between industries in the domestic economy. In equilibrium, factor endowments must match the demand generated by the various domestic industries.

National income is the value of all domestically owned primary resources. This includes wages, capital returns, land and resource rents, and tax revenue. National income is allocated between private household consumption, public expenditure and savings. Consumption patterns are determined on the basis of utility function maximization subject to a budget constraint. Therefore, final consumption demand is sensitive to relative prices.

Regional savings are hypothetically pooled by a virtual international bank, which then distributes them to regional investments on the basis of expected future returns (linked to current returns). Therefore, regional savings and investments do not necessarily match. National accounting identities imply that any excess saving mirrors a foreign trade surplus, and vice versa. However, equilibrium conditions require the balance of payments, possibly including foreign transfers and remittances, to be zero. This condition is satisfied by adjusting international exchange rates.

When the model is calibrated, parameter values are set so that it endogenously computes production, consumption and investment levels in a way that is fully consistent with national accounts statistics. Counterfactual equilibria are obtained by changing the calibration values for exogenous parameters and variables.

This is exactly what happens when a simulation exercise is run with ECLAC-CIAM. Climate change damage functions are first used to estimate how variations in climate conditions (changes in the average surface temperature) affect a number of exogenous variables in the CGE model, such as labour productivity, total agricultural productivity, land and capital endowments, and so on. All changes in exogenous variables are simultaneously inserted into the CGE model, which is then used to compute consistent levels for variables such as relative prices, income and utility levels, investments, international trade patterns, production volumes, tax revenues, and so on. This rich array of results provides a global picture of the economic consequences of climate change.

4. Downscaling

Although the output of a CGE simulation may be quite sizeable, it may not provide results at the desired level of detail in some circumstances. For example, it would be interesting to know the effects of climate change on individual States within the Caribbean aggregate region. This is not directly possible, because calibration of the CGE model requires very detailed national accounting data, which are not available for individual States in the Caribbean.

Nonetheless, some results may be indirectly obtained through the application of microsimulation techniques. In ECLAC-CIAM, microsimulation techniques are used to obtain indirect estimates of changes in real income, i.e., gross domestic product (GDP), for the following small island States of the Caribbean that have been selected for analysis:

- Antigua and Barbuda
- Barbados
- Bermuda
- Caribbean small island States
- Cuba
- Dominica
- Dominican Republic
- Grenada
- Jamaica
- Saint Kitts and Nevis
- Saint Lucia
- Saint Vincent and the Grenadines
- Trinidad and Tobago

This is made possible by the fact that GDP is just the sum of the value added produced by all industries in a country. The CGE model provides, in addition to estimates of GDP (real and nominal) for all subregions in the set, estimates of changes in industrial value added for all subregions, including the Caribbean. From the World Development Indicators (WDI) database of the World Bank, meanwhile, it is possible to obtain the sectoral composition of national income for all the above countries and for the six industries of the CGE model. A reasonable approximation to the change in national income can therefore be obtained by calculating a weighted average of changes in industrial value added, where the weights are given by sectoral shares of national GDP. This operation is performed by the output module of ECLAC-CIAM.

5. Data requirements

Deployment of ECLAC-CIAM requires data to implement the CGE model, together with information to estimate parameters for the damage functions and to conduct the post-processing analysis. Parameters for damage functions have been obtained from a number of different studies covering various climate change impacts. The downscaling procedure is based on data for the value added composition of national GDP in the Caribbean States.

Many of the parameters of the core CGE models are calibrated, although elasticities of substitution are an exception, as they are taken from the literature or from conventional reference values. Calibrating a CGE model entails a choice of parameter values such that the model endogenously computes trade flows, consumption and production volumes that are fully consistent with available input-output or social accounting matrices. The calibration process may be long and cumbersome (and dependent on data availability), but global, standardized data resources are now available, which makes matters much easier. ECLAC-CIAM has been calibrated using the GTAP 8 Data Base.

Since 1992, the Global Trade Analysis Project (GTAP) consortium, headed by Purdue University in the United States, has been collecting national accounts with a view to building and maintaining a global social accounting matrix (SAM) database. The GTAP 8 Data Base is the eighth major public release of the GTAP Data Base since the project began. A GTAP Data Base is created on the basis of domestic databases or input-output (I-O) tables, which are combined with international datasets on macroeconomic aggregates, bilateral trade, energy, agricultural input-output and trade protection for the new reference years. Interim releases of the database are constructed as significant updated datasets become available. Improvements are also made in data sourcing, scope and construction procedures. In GTAP 8, the data come from a variety of sources, including the World Bank, national statistical agencies, the International Trade Centre (ITC)/Centre for International Prospective Studies and Information (CEPII), the United Nations Commodity Trade Statistics Database (COMTRADE), the International Energy Agency (IEA), the Organization for International Co-operation and Development (OECD) and many others, and are reconciled within a consistent framework. The whole process of construction is quite complex and is fully documented at www.gtap.org.

IV
An illustrative simulation exercise

To illustrate how ECLAC-CIAM works and what kind of results it can produce, this section presents an example of a simulation exercise.[1] Let us consider IPCC SRES scenario A2 for the year 2050, which involves an average temperature increase of 1.2°C relative to the year 2000. The damage functions express this scenario in terms of changes in economic variables, namely:

- An increase in land productivity of 3.38% in Central America, 1.03% in Belize, 0.68% in the Caribbean, 0.41% in Suriname and Guyana and 4.64% in South America.
- A decrease in capital stock of 0.25% in Central America, 0.40% in Belize, 2.69% in the Caribbean, 0.22% in Suriname and Guyana and 0.08% in South America.
- A decrease in labour productivity of 1.10% in Central America, 1.20% in Belize, 0.67% in the Caribbean, 0.64% in Suriname and Guyana and 0.58% in South America.
- A decrease in demand for tourism services of 1.38% in Central America, 1.43% in Belize, 3.34% in the Caribbean and 7.52% in Suriname and Guyana, and an increase of 2.22% in South America.
- A decrease in energy production of 0.05% in Belize, Suriname and Guyana, 0.06% in the Caribbean and Central America and 0.04% in South America.

These (like the corresponding values for all other regions) constitute exogenous shocks for the general equilibrium model. Once the CGE model has been run, estimates for several economic variables become available. For example, table 1 reports the estimated changes in production volumes in the agriculture, energy, light manufacturing, heavy manufacturing, market services and non-market services sectors in three subregions and three countries of Latin America and the Caribbean (results are available for all regions and industries in the model, however).

[1] This exercise can be easily replicated by interested readers.

TABLE 1

Latin America and the Caribbean (selected countries and subregions): variations in industrial production volumes
(Percentages)

	Central America	Belize	The Caribbean	Suriname and Guyana	South America
Agriculture	-0.13	-1.83	0.39	-0.6	-1.84
Energy	1.21	0.09	4.1	0.79	-2.75
Light manufacturing	0.61	0.26	2.0	3.29	-1.24
Heavy manufacturing	1.72	-0.27	3.71	6.57	-2.51
Market services	-1.64	-1.38	-4.22	-7.33	1.67
Non-market services	-0.95	-1.1	-1.82	-0.99	-0.69

Source: prepared by the author.

It should be noted that the exogenous change in land productivity does not match the estimated change in agricultural production by volume. A similar reasoning applies to energy production and market services. This is because the model accounts for changes in relative competitiveness and in the terms of trade. In the Caribbean, for example, falling demand for market services (a consequence of the reduced attractiveness of Caribbean tourist destinations) leads to lower production volumes in agriculture (a supplier to the tourism industry). It also implies a real devaluation of the local currency, lowering production costs and fostering international competitiveness in the energy and manufacturing sectors.

Table 2 shows percentage changes in household consumption levels by industry. Lower consumption levels indicate reduced well-being. Changes in relative prices also result in shifting consumption patterns.

Simulation results show that climate change effects might bring about a quite sizable reduction in consumption levels, especially in the Caribbean. ECLAC-CIAM can also provide a more detailed welfare analysis, for instance by

TABLE 2

Latin America and the Caribbean (selected countries and subregions): variations in household consumption volumes
(Percentages)

	Central America	Belize	The Caribbean	Suriname and Guyana	South America
Agriculture	0.21	-0.23	-1.1	-0.64	0.6
Energy	-0.87	-1.55	-4.12	-1.95	0.17
Light manufacturing	-0.38	-1.16	-2.55	-1.29	0.22
Heavy manufacturing	-0.89	-1.8	-4.13	-2.16	-0.05
Market services	-0.72	-1.71	-3.37	-1.91	-0.26
Non-market services	-0.86	-1.91	-3.05	-1.77	-0.35

Source: prepared by the author.

computing the "equivalent variation" (EV) for each region, which is a money-metric index of welfare impacts. The EV is the change in income that would have produced the same variation in utility levels, at constant prices. The finding is that climate change by the year 2050 will generate economic consequences equivalent to a loss of about US$ 7.5 billion a year in Central America. EV losses for the other subregions and reference countries are: US$ 17 million in Belize, US$ 6.7 billion in the Caribbean, US$ 84 million in Suriname and Guyana and US$ 4.2 billion in South America.

Clearly, the magnitude of the loss depends on the size of the regional economy. To better appreciate the effects on welfare, table 3 displays the EV relative to national income, which amounts to the percentage change in real GDP. In addition to results for the aggregate subregions and countries, we present the estimated variation for individual countries within the Caribbean, obtained from the output module of ECLAC-CIAM, as well as other estimates, whose meaning is explained in what follows.

The "Overall" column shows the estimated change in regional GDP. We can see that the impact on Caribbean GDP is quite large: by 2050, because of climate change, national income is forecast to be about 3% lower than its hypothetical level in the absence of climate change. The corresponding results for Belize, Guyana and Suriname are also quite significant, whereas the impact on Central and South America is significantly smaller.

The "Upper" and "Lower" columns refer to a sensitivity analysis on the simulation results. In this example, we informed the model software that

TABLE 3

Latin America and the Caribbean (selected countries and subregions): variations in real national income
(Percentages)

	Overall	Lower	Upper	Land	Labour	Capital	Tourism
Central America	-0.73	-0.84	-0.63	0.03	-0.43	-0.18	-0.16
Belize	-1.46	-1.69	-1.24	-0.33	-0.75	-0.17	-0.22
The Caribbean	-2.92	-3.47	-2.37	0.04	-0.43	-1.49	-1.05
Antigua and Barbuda	-3.20	-3.72	-2.74	-0.09	-0.43	-1.51	-1.24
Barbados	-3.11	-3.64	-2.61	-0.06	-0.43	-1.50	-1.18
Bermuda	-3.76	-4.17	-3.51	-0.11	-0.46	-1.54	-1.55
Caribbean small island States	-2.71	-3.31	-2.06	-0.03	-0.42	-1.48	-0.96
Cuba	-3.22	-3.71	-2.77	0.03	-0.44	-1.51	-1.21
Dominica	-3.20	-3.67	-2.80	0.25	-0.45	-1.50	-1.13
Dominican Republic	-2.68	-3.28	-2.04	0.05	-0.42	-1.48	-0.92
Grenada	-3.15	-3.66	-2.67	-0.02	-0.43	-1.51	-1.19
Jamaica	-2.97	-3.52	-2.43	0.01	-0.43	-1.49	-1.09
Saint Kitts and Nevis	-3.17	-3.69	-2.68	-0.10	-0.43	-1.51	-1.23
Saint Lucia	-3.29	-3.78	-2.87	-0.04	-0.44	-1.51	-1.27
Saint Vincent and the Grenadines	-3.14	-3.65	-2.67	0.05	-0.44	-1.50	-1.16
Trinidad and Tobago	-1.61	-2.45	-0.52	-0.17	-0.37	-1.42	-0.42
Suriname and Guyana	-1.66	-2.05	-1.27	-0.08	-0.40	-0.12	-1.06
South America	-0.19	-0.30	-0.08	-0.01	-0.36	-0.04	0.22

Source: prepared by the author.

uncertainty existed about the correct values for some shocked parameters. More specifically, we assumed that changes in labour productivity and demand for market services could take any value in the range +/-50% of the baseline estimate. In other words, we replaced a single value for the variation in specific parameters with a (rectangular) probability distribution. The model could then infer the probability distribution of output variables associated with the distribution of input shocks. This was obtained by running the simulation several times with alternative input values, using Stroud's statistical quadrature technique (Stroud, 1957; DeVuyst and Preckel, 1997). Consequently, information is produced not only about central values for all output variables, but also about other statistical moments, like the standard deviation. In table 3, the "Lower" column shows the estimated change in real GDP minus its estimated standard variation, whereas in the "Upper" column the standard variation is added. Therefore, the two values represent the bounds of a likelihood interval for the estimated change in regional GDP.

The remaining four columns on the right present results for some other simulation exercises in which only one class of climate change effects is taken into account at a time. In the "Labour" column, for example, estimates of variations in real GDP are obtained by varying only labour productivity parameters, while keeping all other parameters (e.g., land productivity) unchanged. In this way, it is possible to single out the contribution of a specific climate change effect to the overall result. We can see that variations in labour productivity are indeed the most important economic effect of climate change in Belize and Central and South America. Losses of capital stock associated with sea-level rise are the most important impact in the Caribbean, whereas a drop in tourism demand is the most important factor in Suriname and Guyana.

V
Conclusions

ECLAC-CIAM is a modelling platform which has been produced to assess the economic consequences of climate change in the Caribbean. The model is aimed at filling a knowledge gap by making it possible to produce a quantitative assessment of the economic effects of climate change.

It is clear that the model can be improved in several different ways: better quality of economic data, more reliable estimates of the direct physical effects of climate change, improved climate scenarios, finer industrial and regional disaggregation, etc.

Nonetheless, the current version of ECLAC-CIAM, which can be freely accessed, downloaded and even modified, is already a fully working, state-of-the-art model. As such, it can be readily used to conduct simulation exercises like the one presented in this paper. From this simple illustrative simulation, a number of key findings can be obtained. Our results confirm that the Caribbean is a highly vulnerable region in which climate change is expected to generate sizeable and negative economic consequences. Sea-level rise, bringing about losses of land and capital infrastructure stocks, and a decline in the tourism industry are the two most significant factors. These results can inform mitigation and adaptation policies at both the regional and the international level.

The model is very flexible and other simulation exercises could easily be designed, with changes to the time horizon, climate scenario or sectoral impacts, for example. All other exogenous parameters in the CGE model can be modified as well, which is especially helpful when it comes to exploring the interactions between climate and other policies (e.g., fiscal reforms, trade liberalization, productivity growth).

It is also possible to "swap" endogenous and exogenous variables in the model. For example, in the standard closure the model computes equilibrium wages to ensure full employment of the given labour stock. If, instead, (actual) wages are specified ex ante, labour demand may become endogenous. The difference between the total labour supply and estimated demand is readily interpreted as involuntary unemployment.

Bibliography

Anthoff, D. and R.S.J. Tol (2008), "The impact of climate change on the balanced-growth-equivalent", *Papers*, No. 228, Dublin, Economic and Social Research Institute.

Atkinson, G. and others (2010), "Trade in 'virtual carbon': empirical results and implications for policy", *Policy Research Working Paper Series*, No. 5194, Washington, D.C., World Bank.

Bernard, A. and M. Vielle (2008), "GEMINI-E3, a general equilibrium model of international-national interactions between economy, energy and the environment", *Computational Management Science*, vol. 5, No. 3, Springer.

Bosetti, V. and others (2006), "WITCH: a world induced technical change hybrid model", *The Energy Journal*, vol. 27, Cleveland, International Association for Energy Economics.

Burniaux, J.-M., G.. Nicoletti and J. Oliveira Martins (1992), "GREEN: a global model for quantifying the costs of policies to curb CO_2 emissions", *OECD Economic Studies*, No. 19, Paris, Organization for Economic Cooperation and Development (OECD).

Burniaux, J.-M. and T.P. Truong (2002), "GTAP-E: An energy-environmental version of the GTAP model", *GTAP Technical Paper*, No. 16, West Lafayette, Indiana.

DeVuyst, E.A. and P.V. Preckel (1997), "Sensitivity analysis revisited: a quadrature-based approach", *Journal of Policy Modelling*, vol. 19, No. 2, Amsterdam, Elsevier.

Eboli, F., R. Parrado and R. Roson (2010), "Climate change feedback on economic growth: explorations with a dynamic general equilibrium model", *Environment and Development Economics*, vol. 15, No. 5, Cambridge, Cambridge University Press.

ECLAC (Economic Commission for Latin America and the Caribbean) (2011), "The Economics of Climate Change in the Caribbean: Summary Report 2011" (LC/CAR/L.299), Port of Spain, ECLAC subregional headquarters for the Caribbean, September.

Hertel, T.W. and M.E. Tsigas (1997), "Structure of GTAP", *Global Trade Analysis: Modeling and Applications*, T.W. Hertel (ed.), Cambridge, Cambridge University Press.

Hope, C., J. Anderson and P. Wenman (1993), "Policy analysis of the greenhouse effect: an application of the PAGE model", *Energy Policy*, vol. 21, No. 3, Amsterdam, Elsevier.

IPCC (Intergovernmental Panel on Climate Change) (2000), *IPCC Special Report Emissions Scenarios*, Geneva.

Jensen, J. and M.H. Thelle (2001), "What are the gains from a multi-gas strategy?", *FEEM Working Paper*, No. 84, Milan, Fondazione Eni Enrico Mattei.

Kemfert, C. (2002), "An integrated assessment model of economy-energy-climate - The model WIAGEM", *Integrated Assessment*, vol. 3, No. 4, Routledge.

Lee, H., D. van der Mensbrugghe and J. Oliveira Martins (1994), "The OECD GREEN model: an updated overview", OECD *Development Centre Working Papers*, No. 97, Paris, OECD Publishing.

Manne, A.S., M. Mendelsohn and R. Richels (1995), "MERGE - A model for evaluating regional and global effects of GHG reduction policies", *Energy Policy*, vol. 23, No. 1, Amsterdam, Elsevier.

Nordhaus, W.D. (1994), *Managing the Global Commons: The Economics of Climate Change*, Cambridge, Massachusetts, The MIT Press.

Nordhaus, W.D. and Z. Yang (1996), "A regional dynamic general-equilibrium model of alternative climate-change strategies", *American Economic Review*, vol. 86, No. 4, Nashville, Tennessee, American Economic Association.

Paltsev, S. and others (2005), "The MIT emissions prediction and policy analysis (EPPA) model: version 4", *Report*, No. 125, Cambridge, Massachusetts, MIT Joint Program on the Science and Policy of Global Change.

Pant, H. (2007), "GTEM: Global Trade and Environment Model", *Technical Report*, Canberra, Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES).

Popp, D. (2003), "ENTICE: endogenous technological change in the DICE model of global warming", *NBER Working Paper*, No. 9762, Cambridge, Massachusetts, National Bureau of Economic Research.

Roson, R. and D. van der Mensbrugghe (2012), "Climate change and economic growth: impacts and interactions", *International Journal of Sustainable Economy*, vol. 4, No. 3, Inderscience Enterprises Ltd.

Springer, K. (1998), "The DART general equilibrium model: a technical description", *Kiel Working Papers*, No. 883, Kiel, Kiel Institute for the World Economy.

Stern, N. (2007), *The Economics of Climate Change: The Stern Review*, Cambridge, Cambridge University Press.

Stroud, A.H. (1957), "Remarks on the disposition of points in numerical integration formulas", *Mathematical Tables and Other Aids to Computation*, vol. 11, No. 60, Providence, American Mathematical Society.

Inequality in education in Costa Rica: The gap between students in public and private schools. An analysis of the results of the Programme for International Student Assessment (PISA)

Andrés Fernández A. and Roberto Del Valle A.

ABSTRACT This article presents the main results of the Programme for International Student Assessment (PISA) for Costa Rica in 2009 and then goes on to analyse the gap between the scores of students attending private schools and those attending public schools. However, the estimation of an education production function using these data shows that this gap is not entirely attributable to whether schools are public or private, but that instead the students' family environment, personal traits and, in particular, the student's grade level at the time that the PISA test was taken are all quite influential.

KEYWORDS Education, quality of education, scholastic achievement, educational achievement, measurement, public schools, private schools, education statistics, Costa Rica

JEL CLASSIFICATION I21, I24, O38

AUTHORS Andrés Fernández A. holds a degree in economics from the University of Costa Rica. affa17@gmail.com
Roberto Del Valle A. holds a degree in economics from the University of Costa Rica. roberto.dva@gmail.com

I
Introduction

For the first time ever, Costa Rica took part in the Programme for International Student Assessment (PISA) in 2010 under the PISA 2009 PLUS Project, which administered the test to a sample of Costa Rican 15-year-olds from various schools in the country. In December 2011, the test results were published. The results showed that Costa Rica had the second-highest score in Latin America in reading and sciences and the fifth-highest in mathematics, although it still ranked far below the member countries of the Organization for Economic Cooperation and Development (OECD).

Apart from the overall results, the data obtained from the PISA assessment, together with the information supplied by the questionnaires to which students and school administrators responded, provide some idea of the quality of the Costa Rican educational system and provide an opportunity for gauging not only how well or poorly its system measures up against those of other countries, but also for determining what kinds of educational differences exist within Costa Rica itself.

While it is true that the gap in scores separating Costa Rica from developed countries is quite wide and merits a more detailed examination, an analysis of the educational gaps existing within a country can yield more relevant findings for the formulation of educational policies designed to narrow the quality gap and offer the same educational opportunities to all young people in that country.

The objective of this article is to undertake a detailed analysis of young Costa Ricans' performance on the 2009 PISA test, the main factors influencing that performance and the differences between the scholastic achievement levels of students in public and private schools.

Following this introduction, section II offers an overview of the educational system in Costa Rica. Section III provides an explanation of what the PISA assessment entails and details the scores obtained by Costa Rican students on that test. Since this was the first time that these data have been compiled, and the results of the assessment have not been widely publicized, a comparison of the overall results for Costa Rica with those of other countries in the region is presented in section IV.

In section V, we construct an education production function for use in analysing the determinants of students' performance on the PISA test. In section VI, we present the results obtained at the national level and then use Fields' decomposition technique to analyse the determinants of students' performance differentials. Our findings are presented in section VII.

☐ The authors are grateful to Ronulfo Jiménez Rodríguez, Professor of Economics at the University of Costa Rica, for his comments and insights regarding the PISA results and to Pablo Zoido, a PISA Analyst, for the guidance he provided regarding the processing of the data.

II
Education in Costa Rica

1. The Costa Rican education system

In Costa Rica, the school system is divided into preschool, a basic general education (primary and lower-secondary) level, upper-secondary school and higher education. Preschool and the basic general education level are both compulsory, and they, as well as upper-secondary school, are free and are funded by the State.

The basic general education level is composed of three compulsory cycles. Cycle I (first, second and third grades) and cycle II (fourth, fifth and sixth grades) are included in primary school. Upon completion of cycle II, students receive a primary school diploma. Cycle III (seventh, eighth and ninth grades) is the last compulsory cycle. A secondary education is composed of cycle III and cycle IV (known as "diversified education"). Cycle IV lasts from two to three years and is subdivided into three streams: the academic stream and the arts stream each take two years (tenth and eleventh grades) to complete, while the technical stream (which is given

in vocational schools) is three years in length (tenth, eleventh and twelfth grades). Students in this last stream can choose to specialize in industrial, commercial or agricultural courses. Students complete the academic stream upon successfully sitting the final baccalaureate examination, whereupon they earn a secondary school diploma. Students in the arts and technical streams can also earn a secondary school diploma if they pass the final baccalaureate examination. Students in the technical stream are awarded a technical school diploma upon their successful completion of their studies.[1]

2. Costa Rica and international assessments

The PISA test is not the first international assessment in which Costa Rica has participated. Third- and fourth-grade Costa Rican students took part in the Latin American Laboratory for Assessment of the Quality of Education (LLECE), which was administered by what is now the UNESCO Regional Bureau for Education in Latin America and the Caribbean in 1997, and third- and sixth-graders took part in the Second Regional Comparative and Explanatory Study (SERCE) between 2004 and 2008.

In the first assessment, the results for Costa Rica were not included in the score reports or in the statistical parameters for the various studies that were prepared because the data which the country provided did not meet the required technical standards of LLECE. In the second assessment, Costa Rica was one of the highest-ranking countries in the region (students in 16 countries were evaluated), with its third- and sixth-grade students scoring in third place in mathematics and in second place in reading (UNESCO, 2008).

3. Studies on the quality of education in Costa Rica

The first effort to estimate the effect of different factors on scholastic achievement in Costa Rica dates back to 1980 (Díaz and Jiménez, 1980). Based on their estimate of an education production function using data at the cantonal level, the authors of that study concluded that both school inputs and socioeconomic factors influence scholastic achievement. Moreira (2009) has analysed how various factors influenced the scores obtained on the national baccalaureate mathematics test in 2004 by eleventh-grade students attending academic day schools. Using a multilevel analysis, the author finds that endogenous factors such as students' academic records and, more specifically, the fact that students have or have not repeated a grade and the educational level of their parents, correlate with their scores.

No studies that have drawn on the databases of international assessments for Costa Rica have been conducted, however, and this research effort is therefore one of the first to contribute to the debate concerning educational quality and inequality.

[1] In addition to traditional schools, there are a number of other programmes that are open to young people and adults who, for whatever reason, were unable to follow a formal course of study. These mechanisms include night schools and special programmes such as remedial primary and secondary school courses for adults, distance learning programmes, open classrooms, the New Opportunities Programme and the Comprehensive Education Centre for Young People and Adults (CINDEA).

III

The Programme for International Student Assessment (PISA)

1. What is PISA?

The Programme for International Student Assessment (PISA) is a joint initiative of the OECD member countries aimed at measuring how prepared 15-year-old students (who are about to complete their compulsory education) are to cope with the challenges involved in living in today's society.

The assessment is forward-looking: rather than trying to measure specific areas of knowledge based on each school's curricula or programmes of study, it focuses on evaluating students' ability to use their knowledge and skills to meet life challenges.

PISA surveys and assessments are conducted every three years. They all measure skills and knowledge in the areas of reading, sciences and mathematics, but each

time emphasis is placed on one of these three subject domains, with nearly 60% of the assessment being devoted to that subject. The first assessment, in 2000, focused on reading; the second, in 2003, concentrated on mathematics; and the third, in 2006, placed greater weight on the sciences. These three tests made up the first full cycle of PISA assessments.

The second cycle of assessment tests started off in 2009; the focus of this round was on reading. This was the first time that Costa Rica had taken part in PISA. The last test was conducted in 2012.

In addition to using a written test to measure students' abilities and knowledge, PISA also sends out questionnaires to students and school administrators in order to gather information that it can then use to analyse the test results and place them in their proper context.

2. The PISA 2009 results: Costa Rica's ranking

Originally, 64 countries (9 of them in Latin America) participated in the 2009 assessment. In 2010, another 10 countries took part in the PISA 2009 PLUS project; students in these countries took the same tests that their counterparts had in 2009. Costa Rica was the only Latin American country to join the PISA 2009 PLUS project.

The values attached to the students' performance on the test are called "plausible values" and are regarded as continuous latent variables, which means that they are dealt with as measureable quantities for which no measuring instrument exists;[2] in the PISA assessment, the items are not evaluated as specific scores but instead using comparative scales. In order to facilitate the interpretation of the students' scores, the scales for reading, mathematics and science have been designed so that the average score will be 500 points for OECD member countries, with a standard deviation of 100 points. This means that two thirds of students in OECD member countries obtain between 400 and 600 points (OECD, 2009, p. 136).

[2] In this type of educational assessment, which is based on the Rasch statistical model, students do not earn additional points for each correct answer; instead, points are awarded on the basis of the type of answer given. The Rasch model is used to create scales for measuring the possible answers that students might give based on the level of difficulty of the question or item.

In the reading assessment, the Latin American countries were all in the bottom half of the ranking, with all of them obtaining average scores below the mean for OECD member countries (see table A.1 of the annex). Chile had the highest ranking among the Latin American countries, with 449 points, followed by Costa Rica with 443 points.

In the mathematics assessment, Uruguay was the highest-ranking Latin American country, with 427 points. Costa Rica, with just 409 points, ranked fifth among the Latin American countries and 55th overall; this was its lowest ranking of all. In science, the situation was similar to the results for the reading assessment: Chile was in first place, with 447 points, and Costa Rica was in second with 430 points.

— *Proficiency scales*

In addition to reporting the students' overall score, the PISA assessment also provides information on competencies by placing students on a scale that describes what they know and what they can do.

These scales are called "proficiency scales" rather than "performance scales" or "achievement scales" because they provide information on what the students know and what they can do at certain levels rather than on how they performed on the (one-time) assessment. This approach is used because the objective of the PISA assessment is to gauge students' overall level of competence rather than their performance on a specific test.

PISA defines seven levels of reading proficiency, ranging from level 1b (ability to perform elementary tasks that require very basic reading skills) to level 6, which involves sophisticated tasks that can generally be completed only by highly proficient readers. The PISA programme classifies level 2 as the baseline level of competency at which students are beginning to exhibit reading skills that will enable them to play an effective role in real-life situations.

In Chile and Costa Rica, nearly one third of the students display levels of proficiency that are below the baseline (level 2), and that another third are at that level. This means that one out of every three students does not have the basic cognitive tools in the area of reading needed to cope with future life challenges and another third has just barely reached that skill level.

IV

Analysis of the PISA results for Costa Rica

1. Construction of the sample used in the PISA assessment

The PISA sample is drawn from a target population of students ranging from 15 years and three months to 16 years and two months of age who attend established schools and are in seventh grade or above. For the sake of convenience, reference will be made to this target population as being made up of 15-year-old students.

The sample for education studies is generally not based on a simple random sampling of the target population. Instead, the sample is constructed in two stages. In the first stage, a sample of schools is selected from a complete list of all the schools attended by the target population of students. For the PISA test, all the schools have a probability of being selected that is proportional to their size. In addition, a standard minimum participation rate at the school level of 85% is used in order to reduce the non-response bias. In the case of Costa Rica, the effective school participation rate was 99.43%.

In the second stage, the sample of students in the selected schools is chosen at random. PISA studies indicate that a minimum of 35 students of 15 years of age are chosen in each participating school. In Costa Rica, 4,578 students were assessed, which amounts to a participation rate at the student level of 94.45% (the minimum standard established by PISA is 80%).[3]

Selected data concerning this sample group of students are provided in table A.2 of the annex. In this and all other tables included in this article, the standard deviation is given in brackets.[4]

In all, 53% of the students who were assessed were female, and 85% of the students were enrolled in public schools. Although the usual grade level of a 15-year-old in Costa Rica is ninth grade, students in almost all grade levels were assessed, although the great majority were in the ninth or tenth grades (75%). Most of the students who were in seventh grade were there because they had had to repeat one or more grades.

2. Analysis of education gaps

Various types of gaps in education may exist. Some of the most common are gender gaps, gaps that can be categorized on the basis of the area or sector in which a school is located and gaps between different types of schools.

Table 1 outlines the PISA test performance differentials, disaggregated by gender and by type of school, for each of the knowledge domains that were assessed. Differentials corresponding to school locations are not provided because the PISA programme does not compile information on students' area of residence.

— Gender gaps

In the 2009 assessment, females outperformed males on the reading test in all of the participating countries. As shown in table 1, the gender gap in reading skills in Costa Rica amounts to 14 points. Costa Rica is one of the countries in which this gap is the narrowest, however.

In contrast, males outperformed females in mathematics and science, with women scoring, on average, 26 points below males in mathematics and 17 points below them in science.

— Gaps by type of school

The widest gaps appear when students' scores are disaggregated by the type of school that they attend. In all three domains, students attending private schools outperformed, on average, those attending public schools. In reading, the differential was 86 points; in mathematics, it was 79 points; and, in science, it was 84 points.

Only 5%, 16% and 8% of the students attending private schools scored below the baseline proficiency

[3] The coverage index for the population of 15-year-olds was 0.53 points. This is a limitation shared by studies that use these databases, since they exclude the population of 15-year-olds who are not attending established schools, who have dropped out, who never attended school or who were otherwise excluded from the education system. This could generate a selection bias. This study is therefore representative only of students attending established rural or urban academic or vocational day schools.

[4] All the averages cited in this article are weighted averages computed using the final student weightings (W_FSTUWT) of the PISA databases. In order to calculate the standard deviation, the balanced repeated replication (BRR) method recommended by PISA was employed with 80 other replicates (W_FSTR1, W_FSTR2…,W_FSTR80) as specified in chapters 7 and 8 of the *PISA Data Analysis Manual* (OECD, 2009).

TABLE 1

Costa Rica: average scores on the 2009 PISA test and education gaps, by domain

Category	Reading		Mathematics		Science	
	Score	Gap	Score	Gap	Score	Gap
General	443		409		430	
	(3.2)		(3.0)		(2.8)	
Gender						
Female	449	14	397	-26	423	-17
	(3.0)		(3.1)		(2.8)	
Male	435	(2.3)	423	(2.1)	440	(2.4)
	(3.7)		(3.4)		(3.3)	
Type of school						
Public	429	-87	397	-79	418	-84
	(3.1)		(2.8)		(2.7)	
Private	516	(6.5)	476	(6.3)	502	(6.2)
	(5.7)		(5.8)		(5.7)	

Source: prepared by the authors on the basis of the 2009 PISA assessment database.

Note: the standard deviation is shown in brackets.

levels for reading, mathematics and science, respectively, whereas the corresponding percentages for public-school students were 38% in reading, 61% in mathematics and 45% in science.

Thus, 73% of private-school student scored in one of the top four proficiency levels for reading (versus 25% of public-school students), 50% of private-school students did so for mathematics (versus 11% of public-school students) and 61% of private-school students did so for science (versus 16% of public-school students).

3. Public-school/private-school differentials

The survey form includes questions about the presence in the home of certain items that may facilitate learning. For example, respondents are asked whether the students have a room of their own or a desk where they can study. In both cases, nearly 90% of private-school students had these two items, where the figure was below 70% for public-school students (see table A.3 of the annex).

Another factor identified in the literature as influencing scholastic achievement is access to information and communications technologies (ICTs). In this case, the gap between public- and private-school students is even wider: nearly 100% of Costa Rican students who attend private schools have computers that they can use for their studies, and 91% have Internet connections in their homes, whereas just slightly more than half of their counterparts who attend public schools have computers (56%), and less than one third of them (31%) have Internet hook-ups in their homes.

An analysis of the employment status of the students' parents indicates that more of the fathers of private-school students are employed full-time (83%, compared to 70% of the fathers of public-schools students); the same is true of their mothers (45% versus 25%). In addition, more of the mothers of public-school students do not work outside the home (62% versus 41% of the mothers of private-school students) (see table A.4 of the annex).

The percentage of fathers of private-school students who have no more than a primary education is around 12%, whereas the percentage of fathers of public-school students in that category is over 50%, and 13% of that group has not completed any level of education at all. At the other end of the spectrum, approximately 15% of the fathers of public-school students have at least some higher education, whereas this figure is about 60% in the case of parents who send their children to private schools.

Two of the factors that differ the most between public and private schools are the percentage of teachers who have a postgraduate degree of some sort (37% in public schools versus 50% for private schools) and the availability of computers in the schools; in public schools, there is an average of 1 computer for every 5 students of 15 years of age, whereas, in private schools, the ratio is 4 computers for every 5 students in that age group.

V
The education production function

1. Basic considerations

The education production function (EPF) is the tool that most researchers use to measure the quality of education and its determinants. Todd and Wolpin (2003) outline a number of fundamental considerations relating to this function that will be summarized here.

Theories about the quality of education and its determinants are based on an analogy between the process by which human beings acquire knowledge and skills and the production process of a business, and they therefore focus on the mix of production factors or inputs that are used in conjunction with a given production technology to generate a product or output. In the case of education production functions, these factors are used to produce a given cognitive output which is then measured by means of a given test or assessment.

In order to measure the quality of education using an EPF, a range of information is needed on the factors to which each individual has been exposed since birth that could influence that individual's cognitive achievement at a given point in time. In other words, past and present information on family- and school-related factors is needed, as well as information on the individual's initial endowments, in order to evaluate the effects of those factors on his or her cognitive performance.

The databases used to conduct EPF analyses usually contain information on school- and family-related factors, but only data provided by one-time measurements; in addition, and especially in the case of family-related factors, the information is contemporary, that is, data on those factors at times prior to the assessment are not available. This is why many studies that use EPF analyses treat education-related factors at earlier stages of a person's life as unobservable values and make assumptions that allow them to be disregarded or set aside.

2. General model

The general model used to analyse cognitive achievement assumes that an individual's performance, as measured by a specific assessment at a given age, is the result of a cumulative process of knowledge acquisition.

Let T_{ija} be the measurement of the performance of individual "*i*", who lives in home "*j*" and is "*a*" years old. F_{ija} is the vector of family-related factors at a given age, and S_{ija} is the vector of school-related factors. The vectors that represent the cumulative data on each of the factors at age "*a*" are $F_{ij}(a)$ and $S_{ij}(a)$. The individual's initial endowment of abilities or skills is represented by u_{ij0}. Taking into account the error measurement for the test results (ϵ_{ija}), the education production function is expressed as follows:

$$T_{ija} = T_a[F_{ij}(a), S_{ij}(a), u_{ij0}, \epsilon_{ija}] \quad (1)$$

The empirical application of this method runs up against two problems, however:

(i) the genetic endowment of an individual is not measurable and is therefore an unobservable variable;

(ii) the data on the various factors are incomplete, either because a full range of data is unavailable or because the data on certain factors are missing.

In order to deal with these problems, three approaches for specifying the model, each based on differing variants and assumptions, are discussed in the literature on production functions (Todd and Wolpin, 2003, pp. F16, F27).

The specification used in this study is a contemporary one based on the assumption that the ultimate assessment of cognitive achievement as measured using a test or other form of evaluation is related solely to the contemporary status of family- and school-related factors.

Bearing this assumption in mind when the time comes to analyse the results, the education production function can be expressed using the following equation:

$$T_{ija} = T_a(F_{ija}, S_{ija}) + \epsilon'_{ija} \quad (2)$$

where ϵ'_{ija} is an additive error term. In this specification, the error term includes all omitted factors (the past history of such factors, the initial endowment of capacities and the error measurement).

While it is true that this specification is subject to certain limitations, this does not nullify the function's explanatory power inasmuch as, to date, very little research has been done on the quality of education in Costa Rica. It is therefore hoped that this study can offer some practical guidelines for future research.

3. Determinants of the quality of education

Studies that use education production functions usually group all the different factors that could influence a student's learning process into three main categories: family-related and student-specific factors; school-related factors; and institutional and educational policy-related factors. A description of some of these factors, based on the compilation prepared by Vegas and Petrow (2007), follows.

— Family-related and student-specific factors

These factors have to do with traits of students and their families that are present before the students enter the school system. The age at which students begin their primary education and the preparation they receive before they do so have come to be seen as highly influential factors (Urzúa and Veramendi, 2011).

Recent research has evaluated the effect that a student's interaction with peers has on his or her performance (the peer effect).[5] Family-related factors and the support given to a child in the home are usually the most influential factors in terms of cognitive achievement, however. A family's socioeconomic status and household income are the most commonly used proxy variables for these factors.

These variables, in and of themselves, cannot fully capture the unobservable dynamics that take place within the household or what is really going on within its confines in terms of parents' involvement in their children's education and the support they provide. It is important to attempt to avoid underestimating the influence exerted by parents on their children's achievements (Urzúa and Veramendi, 2011, p. 83).

— School-related factors

These factors have to do with schools' endowments and resources, which ultimately influence students' achievement levels. They can be divided into two categories: the characteristics of the schools, and the characteristics of the teachers.

The variables that are most commonly used to capture the effect of schools' characteristics are the number of books that they possess, their libraries, and other types of infrastructure, such s study halls, the size of classrooms and the equipment that they contain, technological facilities, etc. However, some studies have shown that the influence exerted by the availability of ICTs on scholastic achievement is limited or virtually nil (Cristia, Czerwonko and Garofalo, 2010; Cristia and others, 2012).

Teachers, on the other hand, can have a strong influence on their students' performance, since they are directly involved on an ongoing basis in their students' learning process. Teachers who do not have the necessary skills or who use ineffective teaching methods can therefore have a negative impact on their students' performance, and the opposite is equally true.

— Institutional factors and education policy

The organizational structure of a school system has a significant impact on how and what students learn. Institutional factors that can influence students' performance include the distribution of decision-makers' responsibilities in such areas as finance, expenditure and staff movements (hiring and dismissal of teachers) and how much independence schools have in the selection of teaching methods.

Another institutional factor that has gained in importance is the practise of tracking (i.e., the assignment of students to different schools based on their academic level).[6] Tracking is not used in Costa Rica, however.

4. Literature on the education production function

The Coleman study (Coleman, 1966) was one of the first explorations of this subject, and it still has a significant influence on research dealing with academic achievement. It suggests that differences in school-related factors have very little to do with differences in achievement and that family-related factors have a greater influence.

Other studies have reached much the same kinds of conclusions. In his review of the studies that had been conducted up to the mid-1980s, Hanushek (1986) found that evidence of the effect which expenditure per student or other school-related factors have on educational achievement is extremely weak and that this effect disappears altogether when differences in family-related factors are taken into account. More recently, Lee and Barro (2001), who analysed the assessment of the results obtained on the third Trends in International Mathematics and Science Study (TIMSS) in a large number of countries, show that family-related

[5] Epple and Romano (1998); Mizala and Romaguera (2002).

[6] Hanushek and Woessmann (2005 and 2010).

variables (income, parents' level of education) exert a strong effect on academic achievement. In a study for the Economic Commission for Latin America and the Caribbean (ECLAC), Formichella (2011) examined data on Argentine students' scores on the 2006 PISA test and found that students who live in homes with a more conducive learning environment and more education-related resources do better in school.

Thus, in contrast to findings regarding the importance of family-related factors, the evidence on how much influence is exerted by school-related factors is mixed and often inconclusive (Greenwald, Hedges and Laine, 1996; Kremer, 1995; Card and Krueger, 1996).

5. Fields' decomposition technique

The literature on inequality, and especially on income inequality, has traced the development of a range of different decomposition methods (Shorrocks 1980, 1982 and 1984; Fields, 2003; Morduch and Sicular 2002). Inequality can be decomposed by subgroups, income sources, causal factors and sociodemographic characteristics; it can also be decomposed at different levels of aggregation. Heshmati (2004) provides an overview of the various methods. In this study, we have opted for Fields' decomposition technique.

This technique, which was developed by Gary S. Fields (2003), is used to decompose the contribution of each explanatory variable to the overall inequality of each dependent variable. It is usually based on the Mincer wage equation and applied in order to determine different variables' roles in accounting for income inequality. In the case of students' performance as measured by the PISA test, the equation (3) is constructed as follows in order to yield the Fields decomposition:

$$\ln\left(T_{ia}\right) = \sum_{j=1}^{n} C_{ia} * X_{iaj} + \varepsilon_{ia} = \sum_{j=1}^{n} C_{ia} * Z_{iaj} \quad (3)$$

where: $\ln(T_{ia})$ is the natural logarithm of the plausible value;

X_{iaj} are the variables j linked to person i at age a (in years);

C_{ia} are the coefficients for each variable; and

ε_{ia} is the portion of the variation in students' performances that cannot be explained by the variation among the variables included in the equation.

After applying the variance to each side of the above equation and performing a few mathematical calculations, we have:

$$1 = \frac{\sum_j Cov\left[C_j Z_j, ln\left(T\right)\right]}{Var\, ln\left(T\right)} \cong \sum_j S_j \quad (4)$$

where each S_j is the "relative weight of the factor in the variation" and is given by:

$$S_j = \frac{Cov\left(C_j Z_j, ln\left(T\right)\right)}{Var\left(ln\left(T\right)\right)} \quad (5)$$

The previous equation (5) can be interpreted as the measurement of the proportion of the variance of the logarithm of the plausible value that is explained by each regressor variable j. It should be noted that, if the S_j of the residual is excluded, then the sum of the relative weights is exactly equal to the measure of the goodness of fit of the regression (R^2).

This equation can thus be used to estimate the relative weight of each variable in the model in the explanation of students' cognitive performance.

6. Limitations of the model

Fields' decomposition technique, like other parametric decomposition techniques, has the disadvantage of imposing a functional form upon the knowledge acquisition process, whereas non-parametric or semi-parametric approaches avoid doing so (although the calculations may be extremely complex) (Contreras and Gallegos, 2011, p. 29).

One limitation of the functional form used here is that it does not incorporate a consideration of the dependence of the observations in each group, given the presence of a multi-level structure. A linear model may not be the best way of measuring the relationship between performance on the PISA test and the selected variables.

Nonetheless, the main reason why we have chosen this decomposition technique is that we can use it to quantify the effect of each of the regressors on inequality in education, since it allows us to include dichotomous variables that can then be used to decompose the isolated effect of each explanatory variable.

VI

The results at the national level

The students' scores on the PISA text were used as the dependent variable.[7] The education production function was estimated both for the entire model, which includes all the students in the sample, and for two subsamples: students attending public schools and students attending private schools. Because of space limitations, only the coefficients for the entire model are given in table A.5 of the annex.[8]

The first point that should be made clear is that 41% of the differentials in students' cognitive performances is explained by the variables included in the model for the reading test, which means that 59% correspond to the equation's error term and thus refer to variables that are not in the model. The model's fit for the mathematics and science tests was 43% and 37%, respectively.

A number of variables proved not to be significant in explaining differences in performance. These included the higher occupational status of some parents, the availability of an Internet connection in the home and the number of computers available in the schools.

When Fields' decomposition technique was applied to the model that included all the students, the following results were obtained (see table A.6 of the annex).

In all three domains, differences in the educational achievements of the students who took the PISA test were mainly accounted for by family- and student-related factors.

Although females scored higher than males on the reading test, this cannot be attributed to their gender, since the weight of the variable "female" in the education production function for reading skills is less than 1%. On the other hand, there does seem to be more evidence that gender had an impact on the test results in the areas of science and, in particular, mathematics (4.3%).

The model indicates that the grade level of the student is the factor that has the greatest effect in terms of differences in educational achievement. Table 2 shows the average scores by grade level:

TABLE 2

Costa Rica: averages scores on the 2009 PISA test of 15-year-old students, by grade level, 2009

Year	Reading		Mathematics		Science	
Seventh	344	(5.3)	330	(4.5)	346	(4.6)
Eighth	392	(4.1)	367	(3.5)	387	(3.5)
Ninth	442	(2.6)	409	(2.9)	433	(2.7)
Tenth	483	(3.7)	443	(3.6)	462	(3.1)
Eleventh	498	(15.9)	453	(19.0)	487	(19.7)

Source: prepared by the authors on the basis of the 2009 PISA assessment database.

Note: the standard deviation is shown in brackets.

As may be seen from the table, the average scores rise steadily by grade level. The ages of the students were not included as a variable in the model because the age range covered by the PISA programme is so short that it would be unlikely to capture the desired effect. Five variables were included, however, that classify each student on the basis of the student's grade level at the time and he or she took the test. This is a better way of capturing the expected average scholastic performance of each student, since it is more likely that those who are in ninth or tenth grade when they are 15 years of age will not have not had to repeat a grade and will have a sufficient knowledge base in the areas of reading, science and mathematics to boost their skill levels and, hence, their scholastic performance. On the other hand, most students who were in seventh or eighth grade at the time that they took the test had repeated at least one grade and were less knowledgeable than students

[7] The dependent variable corresponds to the natural logarithm of the plausible value. For each domain, 405 weighted least squares regressions were run using the weightings of the PISA programme database. The regression was also estimated using the plausible value as a dependent variable without applying the natural logarithm. This made it possible to corroborate the fact that the model's fit and the significance of the variables did not change when the natural logarithm was applied to the plausible value.

[8] The full sample of 4,578 students was reduced to 4,351 observations owing to data loss. (In all, 227 observations (5% of the total) were lost, with most of this loss corresponding to family-related and personal variables.) Some variables were not included in the final model in order to avoid a greater loss of data.

in higher grades, which puts them at a disadvantage in terms of test scores.

The PISA assessment is designed to measure capacities and abilities rather than specific knowledge. However, the results suggest that students in higher grades obtain higher scores, and this is the most influential factor in accounting for differences in scholastic performance after controlling for the other factors (gender, nationality, household possessions, public/private school, etc.). The student's grade level accounts for 20.9% of the inequality in scores on the PISA reading assessment.

The results also indicate that repeating a grade does not resolve students' shortcomings in terms of capacities and abilities, which is what would be required in order for them to score better on the assessment. In addition, the knowledge acquired in each grade could influence the students' analyses and answers on the test, which would also give an advantage to those in higher grades.

When the school-related factors were measured, two variables stood out from all the rest: the type of school (public or private) and the educational resources present in the schools. The first of these variables is the main focus of this study, whose objective is to measure how a student's scholastic performance is affected by the fact that he or she attends a public or private school owing to differences in the quality of education that these two types of schools offer. For the reading scores, 4.11% of the variation in performance was accounted for by this variable (see table A.6).

Therefore, the type of school is not a strong enough determinant of inequality in students' performances on the PISA assessment to support the statement that the gap between the scholastic performance of public- and private-school students is primarily due to the fact that private schools offer a better education. In the case of the mathematics test, this variable accounted for 3.3% of the variation in PISA scores; for the science test, it accounted for 6% of the differential.

The quality of schools' educational resources was the second-most important of the school-related variables: differences in the quality of these resources accounted for nearly 4% of the variation in the three domains, while institutional factors have barely any impact on the students' scores at all.

In sum, the overall model indicates that family-related factors and the students' own characteristics are the variables that account for the largest percentage of differences in students' PISA test scores. This finding is in line with the evidence provided by other studies of this type.

Finally, Fields' decomposition technique was also applied to the public-school and private-school samples (see table A.7 of the annex). For public-school students, the variables included in the model account for smaller percentages of the differences being analysed: 29% for reading, 34% for mathematics and 27% for science. Family-related factors and the student's own characteristics (especially the student's grade level) continue to account for a larger portion of the variation in scores (27%, 29% and 24% for reading, mathematics and science, respectively). The role of school-related factors in accounting for differing performances is more limited.

The variables in the model are a better fit in the case of differentials in the performance of students attending private schools (54%, 52% and 51% in reading, mathematics and science, respectively), especially since, in this case, institutional factors do turn out to be significant.

For the reading scores, the students' gender did not have an impact on the results (as is also true for the general model), but for mathematics and science, this variable was much more influential.

Differences in the kinds of possessions present in the private-school students' households also play a role in accounting for differing scores (7%, 5% and 5% in reading, mathematics and science, respectively), while for the mathematics and science tests, grade-level differences were less influential (9% and 11%, respectively) than they were for the reading test (16%).

In the category of school-related factors, private schools with more and better books, computers and laboratories account for 7%, 9% and 5% of the differentials in the students' scores on the reading, mathematics and science tests, respectively. This is because not all private schools in Costa Rica have the same kinds of resources. The variation seen in private schools in this respect is much greater than it is in public schools, whose available resources are much more uniform.

Institutional factors take on importance in private schools for two reasons: first, these schools enjoy more latitude in terms of the policies that they implement, whereas institutional policies for public schools are standardized; and, second, parent's involvement in the schools' administration has a positive effect on the students' learning process. This could be because parents of students who are attending private schools

may tend to be more engaged in their children's learning process so that they can monitor the services for which they are paying.

In all three assessment domains, the most influential institutional factor is the availability of extracurricular activities, such as bands and choruses, sports teams, debate clubs, etc. (9.5%, 8.8% and 4.5% for reading, mathematics and science, respectively), followed by the methods used for evaluating students and teachers, how much independence schools have in deciding how to distribute the resources at their disposal and the degree of academic selectivity.

VII
Conclusions

The Programme for International Student Assessment (PISA) has focused on gauging the quality of education in different countries around the world. Its results allow countries and their citizens to see how their education systems measure up against those of other nations. Costa Rica's participation in this initiative represents a major stride forward, since this will provide its policymakers with a clear picture of the quality of the education offered in the country and the main determinants in that regard.

The PISA programme provides valuable information for future studies on the quality of education in Costa Rica. It is vital that the Ministry of Public Education continues to take part in this programme so that the progress made by the education system can be tracked over time, which will then make it possible to determine how effectively the resources allocated for the education of young Costa Ricans are being used.

The data indicate that the gap between public- and private-school students in Costa Rica is wide. The gap is primarily a function of differences in family-related factors, personal attributes or features of the students, or both, and, among these, especially their grade levels at the time that they take the test. The data obtained from the questionnaires indicate that 26% of the public-school students who participated in the PISA assessment have repeated one or more grades in secondary school, whereas only 10% of the private-school students has done so.

The results clearly indicate that a relationship exists between students' grade levels and their academic performance. This underscores how enormously costly it is for students to repeat one or more grades. Having students repeat a grade denies them, to a certain extent, access to knowledge about core subjects and the opportunity to develop the skills that they will need to improve their academic skills. Furthermore, repeating a grade may not be the best approach for dealing with students' academic shortcomings and has, in addition, a demotivating effect.

Resources to provide support for students who have fallen behind in order to reduce repetition rates may be a key tool for improving the quality of Costa Rica's education system. The implementation of changes in the regulations on grade retention and promotion in the public school system since 2009 may help to improve student performance in the future. Before 2009, students in secondary school who failed more than three subjects had to repeat the entire school year, and the Costa Rican education system was therefore highly exclusive. Now, however, thanks to the changes in the regulations, students need not repeat the entire school year. Instead, they will repeat only those subjects that they failed, while continuing on with their other classes in the next grade (except for classes for which the subjects that they failed were prerequisites).

The findings of this research project indicate that these changes in the regulations governing the education system may prove to be of key importance in improving student performance; their actual effect could be measured on the basis of future PISA assessments.

In addition, the difference between the education offered by private schools (which have more and better resources at their command) and the education offered by public schools is not a very important factor when it comes to accounting for the gap in performance between public- and private-school students. In other words, the results demonstrate that, when it comes to finding explanations for differentials in educational performance, socioeconomic conditions exert a much greater influence than differences in the resources available to schools.

It would be advisable for PISA to send out questionnaires to students' parents, in addition to students and school administrators, so that a more thorough analysis could be made of how family-related factors influence

students' performance, since these factors have such an enormous explanatory value in terms of scholastic achievement. A questionnaire of this type could provide valuable information about students' homes, activities that parents engage in with their children, discussions about students' progress at school, and even household incomes and the distance that students have to travel to go to school.

Finally, it should be noted that the data gathered by the PISA assessment are reliable enough to be useful in designing policies to narrow the education gaps between different sectors of Costa Rican youths, improve the allocation of public funds and boost the quality of public education. As stated by the Ministry of Public Education in its institutional report for 2006-2010 (Ministry of Public Education, 2010), the country's objective in taking part in international assessments is to use the information that they provide as inputs for efforts to improve teaching and learning experiences, whether by means of curricular reforms, professional development strategies and ongoing training opportunities, or the allocation of resources to provide students with learning support and the application of education policy in the classroom. The information compiled by the PISA assessment is an invaluable input for efforts to improve public education in Costa Rica.

ANNEX

TABLE A.1

Average scores of Latin American countries on the 2009 PISA tests, by domain

Reading				Mathematics				Science			
Latin America	General	Country	Average score	Latin America	General	Country	Average score	Latin America	General	Country	Average score
1	43	Chile	449	1	48	Uruguay	427	1	44	Chile	447
2	44	Costa Rica	443	2	50	Chile	421	2	48	Costa Rica	430
3	49	Uruguay	426	3	53	Mexico	419	3	50	Uruguay	427
4	50	Mexico	425	4	54	Trinidad and Tobago	414	4	55	Mexico	416
5	54	Trinidad and Tobago	416	5	55	Costa Rica	409	5	58	Trinidad and Tobago	410
6	56	Colombia	413	6	61	Argentina	388	6	59	Brazil	405
7	57	Brazil	412	7	63	Brazil	383	7	60	Colombia	402
8	63	Argentina	398	8	64	Colombia	381	8	62	Argentina	401
9	69	Panama	371	9	70	Peru	365	9	68	Panama	376
10	70	Peru	370	10	71	Panama	360	10	71	Peru	369

Source: prepared by the authors on the basis of the 2009 PISA assessment database.

TABLE A.2

Costa Rica: descriptive statistics for the 2009 PISA assessment, by category

Category	Percentage	Standard deviation
Gender		
Female	53.0	(0.6)
Male	47.0	(0.6)
Type of school		
Public	84.6	(1.4)
Private	15.4	(1.4)
Grade attended		
Seventh	8.5	(0.8)
Eighth	16.0	(1.0)
Ninth	34.1	(1.2)
Tenth	40.9	(1.8)
Eleventh	0.4	(0.1)
Twelfth	0.0	(0.0)

Source: prepared by the authors on the basis of the 2009 PISA assessment database.

TABLE A.3

Costa Rica: descriptive statistics for the assessment, disaggregated by public/private school, student traits and household characteristics, 2009
(Percentages) [a]

Characteristic	Public		Private	
Student				
Female	5.2	(0.7)	51.8	(1.8)
Attended preschool	74.7	(1.3)	91.0	(2.0)
Repeated a grade in school	18.0	(1.2)	4.0	(1.4)
Repeated a grade in lower secondary school (cycle III)	26.0	(1.3)	10.0	(1.5)
Family				
Lives with both parents	68.6	(1.1)	78.5	(1.8)
Lives with mother only	21.2	(0.8)	17.1	(1.3)
Lives with father only	2.1	(0.3)	2.0	(0.7)
Does not live with parents	8.1	(0.5)	2.4	(1.3)
Household assets				
Room of student's own	69.5	(1.0)	88.2	(1.3)
Desk	60.1	(1.3)	93.1	(1.5)
Computer	56.5	(1.4)	97.3	(0.6)
Internet	31.0	(1.3)	90.9	(1.4)
Art	39.0	(1.1)	81.1	(1.7)
Motor vehicle	45.5	(1.1)	86.7	(1.9)
Bathtub or shower	62.8	(1.6)	98.0	(0.6)

Source: prepared by the authors on the basis of the 2009 PISA assessment database.

Note: the standard deviation is shown in brackets.

[a] These percentages denote the percentage of students who possess these characteristics, meet these requirements or have these objects in their home.

TABLE A.4

Costa Rica: employment and level of education of parents of students participating in the 2009 PISA assessment, disaggregated by type of school

(Percentages)

Fathers					Mothers				
Status	Public		Private		Status	Public		Private	
Labour market					Labour market				
Works full time	69.9	(1.0)	82.9	(1.5)	Works full time	25.1	(0.8)	44.6	(3.0)
Works part time	16.9	(0.7)	8.5	(0.7)	Works part time	13.0	(0.7)	14.6	(1.5)
Does not work	13.2	(0.8)	8.6	(1.3)	Does not work	61.9	(1.0)	40.7	(2.8)
Occupational status [a]	36.9	(0.4)	57.8	(1.2)	Occupational status [a]	37.6	(0.7)	57.9	(1.3)
Highest level of education reached					Highest level of education reached				
None	13.6	(0.7)	0.8	(0.3)	None	13.1	(0.8)	0.9	(0.4)
Primary	39.4	(1.0)	12.9	(1.6)	Primary	42.7	(1.1)	10.0	(1.8)
Secondary, technical, associate degree	29.9	(1.0)	25.8	(1.7)	Secondary, technical, associate degree	29.2	(1.0)	30.3	(1.6)
Pre-graduate, graduate or postgraduate	17.0	(0.8)	60.5	(3.1)	Pre-graduate, graduate or postgraduate	15.0	(0.8)	58.8	(2.5)

Source: prepared by the authors on the basis of the 2009 PISA assessment database.

Note: the standard deviation is shown in brackets.

[a] Measured by the PISA International Socio-Economic Index of Occupational Status (ISEI). The indices ranged from 16 to 90 points.

TABLE A.5

Costa Rica: determinants of scholastic achievement. Coefficients of the education production function, 2009

Dependent vaiable: natural logarithm of the plausible value of the 2009 PISA assessment [a]	Full model					
	Reading		Mathematics		Science	
Constant	5.732	(0.03)	5.805	(0.03)	5.802	(0.03)
Family-related factors and student traits						
Female	0.019	(0.00)	-0.074	(0.00)	-0.054	(0.00)
Costa Rican nationality	0.007 [t]	(0.01)	-0.001 [t]	(0.01)	-0.001 [t]	(0.01)
Attended preschool	0.017	(0.01)	0.021	(0.01)	0.011	(0.01)
Eighth	0.097	(0.01)	0.077	(0.01)	0.088	(0.01)
Ninth	0.173	(0.01)	0.151	(0.01)	0.165	(0.01)
Tenth	0.248	(0.01)	0.223	(0.01)	0.222	(0.01)
Eleventh	0.299	(0.03)	0.269	(0.03)	0.294	(0.03)
Occupational status	0.000 [t]	(0.00)	0.000 [t]	(0.00)	-0.000 [t]	(0.00)
Mother's level of education:						
Completed primary	0.000 [t]	(0.01)	0.016	(0.01)	0.015 [t]	(0.01)
Completed secondary	0.014 [t]	(0.01)	0.037	(0.01)	0.014 [t]	(0.01)
University	0.018 [t]	(0.01)	0.041	(0.01)	0.025	(0.01)
Books in the home:						
10 to 25	0.015	(0.01)	-0.003 [t]	(0.01)	0.016	(0.01)
25 to 100	0.023	(0.01)	0.020	(0.01)	0.021	(0.01)
100 to 200	0.037	(0.01)	0.021 [t]	(0.01)	0.043	(0.01)
200 to 500	0.055	(0.01)	0.033	(0.01)	0.053	(0.01)
More than 500	0.067	(0.03)	0.033 [t]	(0.03)	0.071	(0.03)
Index of household possessions	0.009	(0.00)	0.010	(0.00)	0.002 [t]	(0.00)
Index of educational resources in the home	-0.011	(0.00)	-0.010	(0.00)	-0.006 [t]	(0.00)
Computer in the home	0.019	(0.01)	0.017	(0.01)	0.021	(0.01)
Internet connection in the home	0.005 [t]	(0.01)	0.009 [t]	(0.01)	0.017	(0.01)
Peer effect	0.003	(0.01)	0.004	(0.01)	0.003	(0.01)
School-related factors						
Characteristics of the school						
Public school	-0.051	(0.01)	-0.039	(0.01)	-0.074 [t]	(0.01)
Only school in the area	0.004 [t]	(0.01)	-0.006 [t]	(0.01)	-0.002	(0.01)
Headmistress	0.011	(0.01)	0.015	(0.00)	-0.001 [t]	(0.01)
Index of educational resources in the school	0.017	(0.00)	0.018	(0.00)	0.018	(0.00)
Computers available for use in studying	0.000 [t]	(0.00)	0.000 [t]	(0.00)	-0.000 [t]	(0.00)
Learning process adversely influenced by lack of insufficient supply of:						
Books	0.002 [t]	(0.01)	-0.008 [t]	(0.01)	-0.013 [t]	(0.01)
Science laboratory	-0.008 [t]	(0.01)	-0.005 [t]	(0.01)	0.014 [t]	(0.01)
Computers	0.004 [t]	(0.01)	-0.008 [t]	(0.01)	0.015 [t]	(0.01)
Characteristics of teachers						
Learning process adversely influenced by unqualified teachers of:						
Reading	0.010 [t]	(0.01)	0.010 [t]	(0.01)	0.003 [t]	(0.01)
Mathematics	-0.011 [t]	(0.01)	-0.019	(0.01)	-0.017 [t]	(0.01)
Science	0.003 [t]	(0.01)	0.026	(0.01)	0.015 [t]	(0.01)
Institutional factors						
Tracking	0.001	(0.01)	0.002	(0.01)	0.002 [t]	(0.01)
Index of school leadership	-0.009	(0.00)	-0.009	(0.00)	-0.001 [t]	(0.00)
Index of extracurricular activities	0.019	(0.00)	0.013	(0.00)	0.016	(0.00)
Index of school responsibility for:						
Curriculum and evaluation	0.001 [t]	(0.00)	-0.002 [t]	(0.00)	-0.001 [t]	(0.00)
Distribution of resources	-0.011	(0.01)	-0.014	(0.01)	-0.005 [t]	(0.01)
No. of observations	4 351		4 351		4 351	
Adjusted R^2	0.412		0.429		0.371	

Source: prepared by the authors on the basis of the 2009 PISA assessment database.

Note: the standard deviation is shown in brackets.

[a] For each domain, 405 weighted least squares regressions were run.

[t] Variable not significant at 5%.

TABLE A.6

Costa Rica: decomposition of the effect of each EPF factor on scholastic performance of 15-year-olds, 2009
(Percentages)

	Reading	Mathematics	Science
Family-related factors and student traits	30.91	31.84	27.04
Female	0.87	4.36	2.11
Attended preschool	0.74	1.02	0.39
Grade attended	20.90	17.54	16.61
Occupational status	0.22	0.19	0.00
Mother's level of education	1.14	2.39	1.17
Books in the home	2.71	1.88	2.64
Possessions and educational resources in the home	2.41	3.13	2.41
Peer effect	1.92	1.33	1.71
School-related factors	9.40	10.23	9.35
Characteristics of the school	8.92	9.55	8.92
Public school	4.11	3.31	6.04
Only school in the area	0.03	0.00	0.01
Headmistress	0.16	0.20	0.00
Index of educational resources in the school	4.45	4.22	3.42
Computers available for use in studying	0.13	0.19	0.00
Lack of books, laboratory, computers	0.04	1.63	-0.55
Characteristics of teachers	0.48	0.68	0.43
Institutional factors	0.89	0.83	0.71
Total	41.2	42.9	37.1

Source: prepared by the authors on the basis of the 2009 PISA assessment database.

EPF: education production function.

TABLE A.7

Costa Rica: decomposition of the effect of each EPF factor on scholastic performance of 15-year-olds, disaggregated by type of school, 2009
(Percentages)

	Reading		Mathematics		Science	
	Public	Private	Public	Private	Public	Private
Family-related factors and student traits	27.41	34.71	29.96	29.02	24.58	29.83
Female	0.87	0.05	4.84	8.94	2.11	7.43
Costa Rican nationality	0.22	0.03	0.14	0.11	0.04	0.01
Attended preschool	0.61	4.75	0.81	1.41	0.31	0.05
Grade attended	20.01	16.50	18.05	8.72	17.32	11.42
Occupational status	0.33	0.27	-0.23	0.26	-0.20	-0.32
Mother's level of education	0.91	0.01	2.08	0.72	1.00	0.09
Books in the home	1.78	3.83	1.54	1.14	1.87	3.80
Possessions and educational resources in the home	2.56	6.86	2.49	4.79	1.99	4.98
Peer effect	0.12	2.41	0.24	2.93	0.14	1.92
School-related factors	1.14	6.71	2.71	8.87	1.48	11.88
Characteristics of the school	0.81	6.34	2.2	7.49	1.13	7.31
Only school in the area	0.02	0.03	0.01	0.10	0.00	1.95
Headmistress	0.11	0.09	0.14	-0.17	0.00	0.48
Index of educational resources in the school	0.31	0.01	1.36	0.00	1.02	0.23
Computers available for use in studying	0.29	-0.68	0.06	-1.00	0.04	-0.07
Lack of books, laboratory, computers	0.08	6.89	0.63	8.56	0.07	4.72
Characteristics of teachers	0.33	0.37	0.51	1.38	0.35	4.57
Institutional factors	1.23	13.02	1.98	14.64	1.55	9.28
Total	29.78	54.44	34.65	52.53	27.61	50.99

Source: prepared by the authors on the basis of the 2009 PISA assessment database.

EPF: education production function.

Bibliography

Card, D. and A. Krueger (1996), "School resources and student outcomes: an overview of the literature and new evidence from North and South Carolina", *Journal of Economic Perspectives*, vol. 10, No. 4, Nashville, Tennessee, American Economic Association.

Coleman, J. (1966), *Equality of Educational Opportunity*, Washington, D.C., Department of Health, Education and Welfare.

Contreras, D. and S. Gallegos (2011), "Wage inequality in Latin America: a decade of changes", *CEPAL Review*, No. 103 (LC/G.2487-P), Santiago de Chile, April.

Cristia, J., A. Czerwonko and P. Garofalo (2010), "Does ICT Increase Years of Education? Evidence from Peru", *OVE Working Papers*, No. 110, Washington, D.C., Inter-American Development Bank (IDB).

Cristia, P. and others (2012), "Technology and child development: evidence from the one laptop per child program", *IDB Working Paper Series*, No. 304, Washington, D.C., Department of Research and Chief Economist, Inter-American Development Bank (IDB).

Díaz Porras, R. and R. Jiménez Rodríguez (1980), "Consideraciones económicas sobre el sistema educativo costarricense", thesis for the degree of *licenciatura*, San José, Schools of Economics, University de Costa Rica.

Epple, D. and R. Romano (1998), "Competition between private and public schools, vouchers, and peer-group effects", *American Economic Review*, vol. 88, No. 1, Nashville, Tennessee, American Economic Association.

Estado de la Nación (2011), *Informe III. Nuevos Instrumentos para el Análisis de la Education en Costa Rica*, San José, Programa Estado de La Nación.

Fields, G.S. (2003), "Accounting for income inequality and its change: a new method, with application to the distribution of earnings in the United States", *Research in Labor Economics*, vol. 22, Bingley, Emerald.

Formichella, M. (2011), "Do private schools in Argentina perform better because they are private?", *CEPAL Review*, No. 105 (LC/G.2508-P), Santiago, Chile.

Greenwald, R., L. Hedges and R. Laine (1996), "The effect of school resources on student achievement", *Review of Educational Research*, vol. 66, No. 3, Washington, D.C., American Educational Research Association.

Hanushek, E. (1986), "The economics of schooling: production and efficiency in public schools", *Journal of Economic Literature*, vol. 24, No. 3, Nashville, Tennessee, American Economic Association.

_____ (1979), "Conceptual and empirical issues in the estimation of educational production functions", *The Journal of Human Resources*, vol. 14, No. 3, Madison, University of Wisconsin Press.

Hanushek, E. and L. Woessmann (2010), "The Economics of International Differences in Educational Achievement", *NBER Working Paper*, No. 15949, Cambridge, Massachusetts, National Bureau of Economic Research.

_____ (2005), "Does Educational Tracking Affect Performance and Inequality? Differences-in-Differences Evidence Across Countries", *nber Working Paper*, No. 11124, Cambridge, Massachusetts, National Bureau of Economic Research.

Heshmati, A. (2004), "A Review of Decomposition of Income Inequality", *IZA Discussion Paper*, No. 1221, Bonn, Institute for the Study of Labor (IZA).

Kremer, M. (1995), "Research on schooling: what we know and what we don't. A comment on Hanushek", *World Bank Research Observer*, vol. 10, No. 2, Washington, D.C., Oxford University Press.

Lee, J. and R. Barro (2001), "Schooling quality in a cross-section of countries", *Economica*, vol. 68, No. 272, London, London School of Economics and Political Science.

Ministry of Public Education (2010), *Educando en tiempos de cambio: memoria institucional 2006-2010*, San José.

Mizala, A. and P. Romaguera (2002), "Equity and Educational Performance", *Working Paper* No. 136, Santiago, Chile, Centre for Applied Economics, University of Chile.

Morduch, J. and T. Sicular (2002), "Rethinking inequality decomposition, with evidence from rural China", *Economic Journal*, vol. 112, No. 476, St. Andrews, Royal Economic Society.

Moreira Mora, T. (2009), "Factores endógenos and exógenos asociados al rendimiento en matemática: un análisis multinivel", *Revista Educación*, vol. 33, No. 2, San José, University of Costa Rica.

OECD (Organization for Economic Cooperation and Development) (2012), *PISA 2009 Technical Report*, Paris, OECD Publishing.

_____ (2009), *PISA Data Analysis Manual: SPSS and SAS*, Paris, OECD Publishing.

Shorrocks, A. (1984), "Inequality decomposition by population subgroups", *Econometrica*, vol. 52, No. 6, New York, The Econometric Society.

_____ (1982), "Inequality decomposition by factor components", *Econometrica*, vol. 50, No. 1, New York, The Econometric Society.

_____ (1980), "The class of additively decomposable inequality", *Econometrica*, vol. 48, No. 3, New York, The Econometric Society.

Todd, P.E. and K.I. Wolpin (2003), "On the specification and estimation of the production function for cognitive achievement", *The Economic Journal*, vol. 113, No. 485, St. Andrews, Royal Economic Society.

UNESCO (United Nations Educational, Scientific and Cultural Organization) (2008), *Los aprendizajes de los estudiantes de América Latina y el Caribe*, Santiago, Chile, UNESCO Regional Office for Education in Latin America and the Caribbean.

Urzúa, S. and G. Veramendi (2011), "The impact of out-of-home child care centers on early childhood development", *IDB Working Paper Series*, No. IDB-WP-240, Washington, D.C., Inter-American Development Bank (IDB).

Vegas, E. and J. Petrow (2007), *Raising Student Achievement in Latin America: The Challenge for the 21st Century*, Washington, D.C., World Bank.

Walker, M. (2011), *PISA 2009 PLUS Results*: *Performance of 15-year-olds in Reading, Mathematics and Science for 10 Additional Participants*, Melbourne, ACER Press.

Woessmann, L. (2011), *Schooling Resources, Educational Institutions, and Student Performance: The International Evidence*, Kiel, Kiel Institute for the World Economy.

Motherhood wage penalties and labour market segmentation: Evidence from Argentina

María del Pilar Casal and Bradford L. Barham

ABSTRACT

This article explores the connection between labour market segregation and motherhood wage penalties in Argentina across the formal and informal sectors. It uses ordinary least square and quantile regression estimation strategies and deploys Blinder-Oaxaca and Ñopo decompositions to identify sources of wage differences. The finding is that there is strong evidence of labour market segmentation and that motherhood wage penalties differ substantively across the sectors and between different wage quantiles. In particular, formal-sector working mothers do not experience wage penalties, while informal ones do. The motherhood wage penalty increases with the number of children, especially younger children, and is greatest at the bottom and next greatest at the top of the conditional wage distribution.

KEYWORDS

Women, motherhood, women's employment, labour market, wages, gender-based discrimination, business enterprises, informal sector, econometric models, Argentina

JEL CLASSIFICATION

J31, J16, O17

AUTHORS

María del Pilar Casal is an Honorary Associate Fellow at the Department of Agricultural and Applied Economics of the University of Wisconsin-Madison. casal@wisc.edu

Bradford L. Barham is a Professor at the Department of Agricultural and Applied Economics of the University of Wisconsin-Madison. barham@aae.wisc.edu

I
Introduction

Rapid growth in women's labour market participation is one of the world's major transformations of the past half century (Goldin, 2006). Economic and social relationships have changed dramatically in many spheres of life, offering women much more power and control over their lives, but certainly not without important limitations and differences depending on the type of jobs they secure and the family they come from and help to create (Babcock and Laschever, 2003). Women still face major challenges in securing gender equality, and motherhood appears to be a "natural" explanation for why working females could be in a disadvantaged position (Budig and England, 2001). Thus, the extent to which institutional factors such as laws, rules and norms that protect mothers can shape wage outcomes and labour market experiences for women is a question of critical importance for policy everywhere.

This article is the first to examine motherhood wage penalties in a Latin American context where labour market segmentation could lead to distinct outcomes across sectors as a result of differing institutional rules. Specifically, it investigates whether segmentation of the labour market into formal and informal sectors leads to dissimilar experiences for Argentine mothers and non-mothers by analysing their wage outcomes. During the 1990s, liberalization and structural adjustment policies affected the dynamics of Argentine labour markets in major ways, gave rise to increasing poverty and inequality, and led to insecure and substandard employment outcomes (De Pablo, 2005). A combination of increasing unregistered employment and unemployment —driven in part by a significant increase in women's labour force participation— and a decline in the purchasing power of wages characterized this era, when formal employment shrank and unregistered, or informal, employment increased notably in scale (Faur, 2008a). In view of these changes, it is useful to investigate whether the division of the labour market into formal and informal sectors gives rise to distinctive motherhood penalties. This is done by examining formal- and informal-sector wages for mothers and non-mothers in Argentina between 1995 and 2003, a period that spans the main liberalization policies set in motion in the early 1990s (Pastor and Wise, 1999).

The main empirical questions addressed are: (i) Do women working in the informal sector earn significantly lower wages than formal workers, as predicted by traditional labour market segmentation theory? (ii) Is there a motherhood wage penalty in either or both sectors? (iii) If so, is the penalty distinct for formal and informal workers? Our hypothesis is that the answers to all the above questions are affirmative because of the ways in which segmented labour markets differentially protect mothers working in the formal and informal sectors. Specifically, women are expected to fare better in the formal sector, where legal and customary protections may allow them to earn higher wages and sustain them during motherhood.

To investigate these issues, Mincerian wage estimations are undertaken with a series of different specifications. In addition to ordinary least square (OLS) wage estimations, quantile methods are used to explore the potential for distinct motherhood penalties in different segments of the wage distribution, as these make it possible to focus specifically on identifying "glass ceilings" at the higher end and "sticky floors" at the lower end of the spectrum.[1] A Blinder-Oaxaca (BO) decomposition is employed to examine wage differentials in two parts, one that identifies the human capital and other measurable factors that can drive wage differences and a second that recovers an unexplained component, which is associated with discrimination. Finally, BO decomposition is complemented by a non-parametric alternative decomposition developed by Ñopo (2008). This allows for a better explanation of motherhood wage differentials, since it also shows how much of the gap calculated is accounted for by the outcomes of mothers and non-mothers outside the common support.

The empirical results are consistent with traditional labour market segmentation theory and the hypothesis that women working in the informal sector earn significantly less than their formal worker counterparts. Moreover, women in the informal sector experience a statistically

[1] The sticky floor hypothesis concerns potential barriers to the advancement of women such as family commitments, attitudes, stereotyping and organizational structures in groups with lower education and wages. The glass ceiling hypothesis concerns the discrimination that women and minorities in more educated groups often face in trying to move up the hierarchy of an organization, especially when they have more children, by comparison with men and with childless women.

significant motherhood wage penalty, while in the formal sector most of the estimated coefficients associated with motherhood and children are not significant. The quantile regression (QR) results vary substantively across the conditional wage distribution; the poorest 10% of the informal women sample are the ones who suffer the largest motherhood wage penalties. These results are largely consistent across this whole era of liberalization reforms, though some notable differences emerge in comparisons of wage penalties before and after the collapse of the Argentine peso in the late 1990s. Overall, the formal and informal sectors have distinct wage structures that are consistent with a different set of institutions and rules shaping the labour market experiences of women and mothers.

The remainder of the article is organized as follows. Section II discusses the motherhood wage penalty and labour market segmentation literatures. Section III describes the empirical strategy and methodology. Section IV discusses the main features of the data and Section V presents the results. Section VI offers conclusions.

II
Literature review

1. Labour market segmentation

Labour market segmentation theory challenges neoclassical economic theory and its reflection in human capital theory by arguing that workers and jobs are not matched smoothly by a universal market mechanism (Rosenzweig, 1988). Instead, jobs and labour differ across markets. The traditional view highlights a dual split between primary (or independent) and secondary (or subordinate) segments and contends that the boundaries between the segments substantively limit occupational mobility (Bauder, 2001). One implication is that formal-sector labour markets exhibit some form of wage rigidity in which wages remain above the market clearing level. In this conventional view from the literature, unregulated wage employment and self-employment are treated as a free-entry residual sector that is informal in character. Given mobility and wage rigidities in the formal sector, labour markets become inefficient, resulting in the need for structural reforms. However, recent work has questioned the traditional view and argued that duality can also be present in the informal sector itself (Pagés and Stampini, 2007; Fields, 2008).

The empirical evidence on labour market segmentation is diverse, and not all researchers find evidence of higher wages for formal-sector workers. Given that worker mobility is usually correlated with wage differences between sectors, the size of the wage gap itself is also an indicator of labour market segmentation. Maloney (1999), using data from Mexico, cannot prove or disprove segmentation based on earnings differentials, because movement into self-employment from every other sector is associated with a substantial and significant rise in per-hour after-tax remuneration. Gong and van Soest (2002) show that in urban Mexico wage differentials increase with educational level, especially in the formal sector. For instance, other things being equal, a highly educated man can earn approximately 150% more than a man with the lowest education level in the formal sector, while in the informal sector a man with a similar level of education earns only 44% more. The pattern is similar for women, although standard errors are much larger given the small number of observed wages. Packard (2007) offers a cross-sectional examination of wage differentials in Chile, and the results of the correction for sample selection bias highlight the finding that self-employed workers earn up to twice as much as employees on contracts (formal employees). However, interpreting these results requires caution, since he finds a positive sample selection bias towards self-employment and employment without a contract.

Botelho and Ponczek (2011) measure the degree of segmentation in the Brazilian labour market using a genuine panel of individuals. They find the average wage differential between formal and informal workers to be 7.8%, suggesting a small degree of segmentation in the Brazilian labour market. They argue that the segmentation phenomenon is closely related to Brazil's labour laws, which leave little room for direct negotiations between firms and employees. Pagés and Stampini (2007) study labour market segmentation using panel data from three Eastern and Central European and three Latin American countries. They find evidence of a wage premium in the formal sector relative to the informal one only in

Latin America, with no statistical difference across skill levels and no significant wage premium in Eastern and Central European countries. Thus, estimates of the wage premium in Latin America range from 6% to 12% for unskilled workers and from 9% to 20% for the skilled. Finally, focusing on the case of Argentina, Pratap and Quintin (2006) test the hypothesis that workers earn higher wages in the formal than in the informal sector. While the parametric models suggest there is a formal premium, and it remains after controlling for individual and firm characteristics, the semi-parametric tests used in this article indicate either a negative or a small and insignificant formal premium.

2. The motherhood wage penalty

The issue of gender wage gaps has constituted a much-studied area of research, but far more so in developed countries than in developing ones. Advances in women's educational attainments and increased opportunities for women in the labour market have narrowed the wage gap between men and women and improved women's representation in high-status occupations (Ridgeway and Corell, 2004). Some researchers have argued that the wage gap between men and single women is not significant; nevertheless, the differences in earnings between men and married women remain high (Gangl and Ziefle, 2009). Given the traditional role of women as caregivers, in addition to the traditional wage gap, mothers seem to be the ones who experience most disadvantages, and this "motherhood penalty" has been identified in wage differentials between mothers and non-mothers that control for other human capital factors typically explaining wage differentials.

The great bulk of research on the motherhood penalty focuses on the United States (Waldfogel, 1997 and 1998; Kennelly, 1999; Budig and England, 2001; Anderson, Binder and Krause, 2002 and 2003; Correll, Benard and Paik, 2007), although evidence of a motherhood penalty is also found in the United Kingdom, Germany and Scandinavian countries (Budig and England, 2001; Beblo, Bender and Wolf, 2009). Gangl and Ziefle (2009) have developed an original approach to the motherhood wage penalty that involves cross-country analysis using data from the United States, Germany and Britain. Finally, Piras and Ripani (2005) explore the effects of motherhood on labour force participation and wages in Brazil, Peru, the Plurinational State of Bolivia and Uruguay. Although this was the first paper to focus on the motherhood wage penalty in Latin America, it does not distinguish between potential outcomes in formal and informal markets, where distinct institutional norms hold.

As summarized in Budig and England (2001) and Correll, Benard and Paik (2007), there are several possible explanations for the motherhood penalty. On the one hand, worker explanations are based on differences in endowments, behaviours and characteristics between mothers and non-mothers. First, women who decide to have children interrupt their work experience because they have to spend time at home taking care of their children. Second, motherhood and household duties may leave women exhausted or distracted while working, decreasing their productivity and work effort. Third, women might forego higher-paying employment in favour of family-friendly jobs that allow them to work fewer hours and spend more time at home. On the other hand, discrimination explanations are based on the notion that even though mothers may be equally productive, employers may (for strategic reasons) pay them less than non-mothers and men of similar productivity in the labour market.

Empirical studies offer evidence for both the worker and discrimination explanations. Using longitudinal surveys from the United States, Waldfogel (1997) concludes that an unexplained motherhood wage penalty persists after controlling for human capital, unobserved heterogeneity and part-time employment, with a 4% penalty for one child and a 12% penalty for two or more children. Budig and England (2001) use the same longitudinal surveys as Waldfogel. Studying a different time period, they find a 7% wage penalty per child. Approximately one third of the loss of earnings is explained by job experience, while the remaining two thirds are likely to arise from productivity or employer discrimination issues, or a combination of the two. Anderson, Binder and Krause (2002) find that lower-skilled workers do not suffer a motherhood penalty, while university-educated mothers of two or more children experience a 15% wage penalty. Gangl and Ziefle (2009) establish that the motherhood penalty ranges from 9% to 18% per child across Germany, the United Kingdom and the United States, with Germany exhibiting the highest cost for maternity compared to American and British mothers. Piras and Ripani (2005) show that, without controlling for segmentation, there is a motherhood wage penalty in Peru for mothers of children aged under 7. In the cases of Brazil and the Plurinational State of Bolivia, they find evidence of wage premiums for mothers, and there are no significant results for Ecuador. Finally,

contrary to the previous finding, Amuedo-Dorantes and Kimmel (2005) examine 19 rounds of the 1979 National Longitudinal Surveys (NLS) and find that university-educated mothers in the United States, far from experiencing a motherhood wage penalty, earn a premium when compared to university-educated childless women, and that fertility delay boosts their pay even further.

The literature reviewed above differs from our article insofar as the evidence for motherhood wage premiums could be explained by labour market segmentation if formal-sector rules protect the rights of mothers and informal-sector rules do not, but that kind of explicit consideration of distinct rules is not part of any of the aforementioned articles, whereas it is the primary focus of this article.

III

The empirical strategy: methodology

The basic earnings equation used here and in most wage studies derives from Mincer (1974) and is presented in equation (1) below. In studying labour markets, economists usually define "discrimination" as the presence of different wage rates for workers with the same productivity or ability but with different personal characteristics (such as age, race, sex, nationality, etc.). To determine if there is a wage penalty for having additional children in the two sectors, we include a dummy variable for motherhood in equation (1).

Using the traditional augmented Mincerian earnings equation, the first approximation is the following semi-logarithmic linear and additive model:

$$\ln w_{ij} = \alpha_{ij} + \beta_{1j} M_{ij} + \beta_{2j} H_{ij} + \beta_{3j} F_{ij} + \beta_{4j} J_{ij} + \mu_{ij} \quad (1)$$

where i indexes individual women, j indicates two types of employment (formal "F" and informal "I") and μ is an error term. Specifically:

- The dependent variable $\ln w_i$ is the natural logarithm of the real hourly wage of woman i;
- M is a set of dummy variables taking a value of 1 if woman i is the mother of one child, two children or three or more children aged under 15, and a value of 0 otherwise;
- H is a vector of human capital variables (age, the square of age, education, occupation);
- F is a vector of family categorical variables (civil status, head of household); and
- J is a vector of job characteristic variables (length of time in the same job, full versus part-time worker, public versus private sector, firm size, and economic sectors: services, manufacturing and commerce).

In investigating whether women working in the informal sector earn significantly less than formal workers, the aim is to test the following null hypothesis:

$$H_0: \ln\hat{w}_I - \ln\hat{w}_F < 0 \quad (2)$$

as compared to the alternative hypothesis:

$$H_A: \ln\hat{w}_I - \ln\hat{w}_F \geq 0$$

The idea is that, as predicted by traditional labour market segmentation theory, hourly earnings should be significantly higher for those employed in the formal sector. Wage premiums for women employed in the formal sector would support the possibility of segmented labour markets in Argentina.

Moreover, the estimated coefficient of the motherhood dummy variable in equation (1) is expected to be negative in the informal sector and (if specified by the number of children) to increase with the number of children. Faur (2008b) highlights the gender-specific regulations applying to maternity in Argentina. While men are entitled to "family allowances", and the provision of social insurance and pensions for the household is organized around them, women have maternity rights, with mothers being entitled to 90 days' paid maternity leave before or after childbirth, or both. However, enforcement of the law is effective only for those employed in the formal sector (Faur, 2008b, p. 52), and this difference could mean a smaller wage penalty in the formal sector. Indeed, it is possible, one the one hand, that there may be no significant wage differential between mothers and non-mothers in the formal sector, for the following three reasons: (i) pregnant women employed in the formal

sector are protected from dismissal; (ii) women from wealthier households may not need to be absent from the labour market during pregnancy or may be able to work part-time once they have children because of their ability to afford private childcare or hire domestic help;[2] and (iii) with ongoing help with domestic duties and childcare, women in the formal segment might be less tired at home and more productive at work.

On the other hand, it seems likely that there is a motherhood wage penalty in the informal segment, given that none of the considerations enumerated above is likely to apply to informal workers who are mothers. Likewise, compared to non-mothers, those in the informal segment who have children might be exposed to discrimination by employers since these may perceive or argue that mothers cost more money and are unlikely to be able to work full-time. Also, the difference in characteristics between mothers and non-mothers could be more evident in the informal sector than in the formal sector because women employed in the informal sector are more likely to be less educated and have more children. Faur (2008b) finds that married women in Argentina are the ones who allocate the greatest proportion of their day to childcare, but this occurs especially in poor households, where many young children do not attend early education programmes, while mothers who work largely do so in the informal sector. Thus, different institutional and social barriers might prevent the poorest women (especially mothers) from accessing employment in the high-wage segment and accentuate the class, gender and motherhood discrimination they face as a result.

In the motherhood penalty literature, most estimation efforts have attempted to address the wage effect of maternity and control for the potential endogeneity of the motherhood variable. The ideal situation would be to use longitudinal data and fixed-effect panel regression methods to control for self-selection, cohort effects or other types of unobserved heterogeneity besides labour participation choices (Gangl and Ziefle, 2009). Unlike those used in some recent work on motherhood wage penalties from the United States and Europe (Walfogel, 1997; Budig and England, 2001; Anderson, Binder and Krause, 2002 and 2003; Gangl and Ziefle, 2009), the Argentine household employment data do not have the necessary longitudinal structure. Instead, the sampling strategy is based on rolling cross-sections with regular replacement of respondents.

Our initial approach is thus to estimate the Mincerian wage equation (1) using the classical ordinary least square (OLS) estimation or conditional mean regression. To complement the OLS equation we use the quantile regression (QR) method.[3] Many useful features of QR models justify this utilization (Buchinsky, 1998; Falaris, 2008; Yasmin, 2009; Olbrecht, 2009). First, QR allows the β parameters to vary at different points of the conditional distribution of the dependent variable, and makes it possible to investigate whether workers' productive characteristics have effects that change across the conditional distribution. Second, QR is less sensitive than OLS to outliers in the dependent variable since it minimizes the weighted sum of absolute deviations. Moreover, when the error terms are non-normal, QR also gives a more efficient estimator than least squares. Lastly, QR has a linear programming representation that makes estimation easy.

In classical linear regressions, the sample mean is the solution to the problem of minimizing the sum of squared residuals, while the median is the solution to the problem of minimizing the sum of absolute residuals. In the case of the other quantiles, given that the symmetry of the absolute value yields the median, minimizing the sum of asymmetrically weighted absolute residuals would yield the quantiles:

$$\min_{\xi \in \Re} \sum_{i=1}^{n} \rho_{\tau}\left(y_i - \xi\right) \tag{3}$$

where the function ρ_{τ} (.) is the absolute value function that yields the τth sample quantile as its solution.

In the case of the least square regression, given the random sample $\{y_1, y_2, \ldots y_n\}$ and the following equation:

$$\min_{\mu \in \Re} \sum_{i=1}^{n} \left(y_i - \mu\right)^2 \tag{4}$$

if we solve equation (4) then we obtain the sample mean *E(Y)*, which is an estimate of the unconditional population mean. Let us replace the scalar μ by a parametric function $\mu(x, \beta)$:

$$\min_{\beta \in \Re^p} \sum_{i=1}^{n} \left(y_i - \mu\left(x_i - \beta\right)\right)^2 \tag{5}$$

[2] Faur (2008b) indicates that although the situation with early education facilities in the City of Buenos Aires is quite good in comparison with that in other jurisdictions in Argentina, the childcare coverage available, especially in the education sector, is far from universal. There has been an increase in the demand for places at childcare centres during recent years, and most of this has been met by the private sector. There is growing unmet demand for places at State-run day-care centres and kindergartens from those unable to pay for the care of their children.

[3] In explaining quantile regression we mostly follow Koenker and Hallock (2001) and Wooldridge (2000).

From equation (5), we get an estimation of the conditional expectation function $E(Y\backslash x)$. In quantile regressions, we continue in the same way. We replace the scalar ξ in equation (3) by the parametric function $\xi(x_i, \beta)$ and set τ to ½. Finally, to get the other conditional quantile functions, we replace the absolute value by $\rho_\tau(\cdot)$:

$$\min_{\beta \in \Re^p} \sum_{i=1}^{n} \rho_\tau\left(y_i - \xi\left(x_i - \beta\right)\right) \tag{6}$$

The resultant minimization problem, when $\xi(x_i, \beta)$ is formulated as a linear function of parameters, can be solved by linear programming methods.

1. The Blinder-Oaxaca wage gap decomposition

Since we are particularly interested in comparing earnings between groups (specifically, formal versus informal and mothers versus non-mothers), we also employ the classical decomposition technique for wage differentials proposed by Blinder (1973) and Oaxaca (1973). The Blinder-Oaxaca (BO) decomposition divides the wage differential between two groups into a portion that is "explained" by groups' dissimilarities in productivity characteristics and an "unexplained" residual portion, which is typically used as a measure of discrimination (Jann, 2008).

Suppose we are interested in comparing two demographic groups, *A* and *B*. We can estimate the following equations for each group:

$$Y_i^A = \beta_i^A + \sum_{i=1}^{n} \beta_j^A X_{ji}^A + u_i^A \tag{7}$$

$$Y_i^B = \beta_i^B + \sum_{i=1}^{n} \beta_j^B X_{ji}^B + u_i^B \tag{8}$$

Given the linear equations (7) and (8), the mean outcome difference can be defined as the difference in the linear predictions at the group-specific means of the regressors. Specifically, the raw differential *(R)* is given by:

$$R = E\left(Y^A\right) - E\left(Y^B\right) = \beta_0^A - \beta_0^B + \sum_j \beta_j^A \left(\overline{X}_j^A - \overline{X}_j^B\right) + \sum_j \overline{X}_j^B \left(\beta_j^A - \beta_j^B\right) = U + E + C \tag{9}$$

where $U = \beta_0^A - \beta_0^B$; $E = \sum_j \beta_j^A \left(\overline{X}_j^A - \overline{X}_j^B\right)$; $C = \sum_j \overline{X}_j^B \left(\beta_j^A - \beta_j^B\right)$

Equation (9) has a "three-fold" decomposition. The first component *U* is the unexplained part of the differential captured by the shift coefficient. The second component *E* is the portion attributable to differing endowments (quantity effect). The last component C is the portion of the differential attributable to differing coefficients. *E* is the "explained part" of the decomposition, justified by certain worker characteristics associated with productivity, while *U+C* is the "unexplained part", attributable to discrimination and also the potential effects of differences in unobserved variables and specification errors in the model (Jann, 2008; Esquivel, 2009). The Oaxaca-Blinder decomposition tells us that unobserved components are important but do not account for the bulk of wage differences. Nevertheless, the decomposition does not reveal whether what is at issue is classic discrimination by employers or unobserved heterogeneity in productivity associated with the performance of mothers.

2. The Ñopo wage gap decomposition

The non-parametric matching-on-characteristics technique from Ñopo (2008) is an alternative to the BO decomposition.[4] BO estimates earnings equations for all individuals in groups A and B without restricting itself to those with comparable characteristics, while Ñopo (2008) takes into account the differences in the distribution of individuals' characteristics. Following Ñopo (2008), we split the motherhood wage gap into four elements:

$$\Delta = \left(\Delta_x + \Delta_M + \Delta_{NM}\right) + \Delta_0 \tag{10}$$

where Δ_x is the part of the wage gap that is explained by differences in the distribution of mothers' and non-mothers' characteristics over the common support ("*E*" in the linear BO decomposition), Δ_M is the part of the wage gap explained by differences in characteristics between the two groups of mothers (those who have characteristics that can be matched to non-mothers' characteristics and those who do not), Δ_{NM} is the part of

[4] In explaining the Ñopo decomposition we mostly follow Ñopo (2008).

the wage gap explained by differences in characteristics between the two groups of non-mothers (those who have characteristics that can be matched to mothers' characteristics and those who do not) and Δ_0 is the "unexplained part" that cannot be accounted for by differences in the observable individual characteristics ("*U*" in the linear BO decomposition).

The matching procedure for estimating the four elements comprises the following steps. First, we select one mother from the sample without replacement. Second, we select all non-mothers who share the same characteristics as the mother selected in the first step. Third, we construct a synthetic non-mother whose wage is the average of that for all the non-mothers in the second step and match her to the original mother. Fourth, we put both individuals (mother and synthetic non-mother) in a new sample of matched individuals. We then repeat the foregoing steps until we exhaust the original sample of mothers.

As a consequence of this matching algorithm, we obtain four sets of individuals: matched mothers, matched non-mothers, unmatched mothers and unmatched non-mothers. Notice that the sets of matched mothers and non-mothers show no difference in the distribution of characteristics.

IV
Data

The data for this paper come from the Permanent Household Survey (EPH), a nationally representative survey carried out in 31 urban areas by the National Institute of Statistics and Censuses (INDEC). We evaluate the Greater Buenos Aires data. Since it is not possible to compare the same woman through the years, we use cross-sectional data from October surveys between 1995 and 2003. Changes in survey methodology meant that the series could not be continued beyond 2003; however, focusing on this time period does allow women's wage outcomes before and after the Argentine peso crisis (1995-1998 and 1999-2003, respectively) to be analysed.[5]

Because we are primarily interested in the relationship between segmented labour market dynamics and the motherhood penalty, we exclude women who are owners or employers, younger than 18 or older than 50. We further restrict the sample to four different household situations for women: women who live alone, women who live with their husbands without children, women who live with their husbands and children, and women who live with their children without a husband.[6] We exclude extended families (those comprising more than the nuclear family) because it is not possible to identify from the survey which woman is the mother.[7] One important constraint resulting from these exclusions is that low-income women might be underrepresented in the survey, since they often live in households containing members of their extended families.[8] Following this criterion and considering all women in the sample, the real monthly household income of the excluded subsample is 1,128 pesos, while that of the final subsample is 1,274 pesos. The average real hourly wage is 3.50 pesos for women in the excluded sample and 4.60 pesos for those in the final subsample.[9]

There are many ways to define employment in terms of formality and informality. In this article, the definition of informality follows the International Labour Organization

[5] The key differences are in the survey questions and sampling methodology. Prior to 2003, the survey was carried out twice a year, in May and October. Households were generally gone from the sample after two time periods. After 2003, the EPH was carried our four times a year, with respondent households being surveyed twice in two consecutive semesters in year 1 and twice in the same semesters in year 2 and again in year 3 before being rotated out of the sample. This shift should make it possible to do panel data analyses of post-2003 labour market data.

[6] Working daughters aged over 18 are not included in the sample.

[7] Since the individual survey does not contain information about which individual is the mother, we mapped the household and individual survey data to determine whether women were mothers and how many children under 15 they had.

[8] The occurrence of extended families decreased by almost 33% between 1970 (32.1%) and 1991 (21.5%), however (Torrado, 2003, quoted by Faur, 2008).

[9] We excluded 701 of a total female sample of 4,409. The figures are in real Argentine pesos, adjusted for inflation using the consumer price index (CPI) deflator. As a reference, the United States dollar-Argentine peso exchange rate was 1.00 peso to US$ 1 before 2002, 3.40 pesos to US$ 1 in 2002 and 2.95 pesos to US$ 1 in 2003 (Source: Central Bank of Argentina).

(ILO) criteria and takes into account the enterprise-based definition (firm size) and the job-based definition (lack of registration). In the case of employees, we use the job-based definition, and the formal sector consists of employees who enjoy all legally mandated benefits, which may include pensions, paid vacations, workplace insurance, health insurance and Christmas bonuses.[10] The informal sector includes employees who lack some or all of these legally mandated benefits plus all self-employed workers. Given that the EPH survey does not contain any questions about benefits for the self-employed, we base their inclusion in the informal sector on the firm size definition, and anyone working in a firm with less than five employees is also included in that sector. In this sample, 80% of the self-employed work by themselves and 20% work in firms of two to five employees. As a consistency check, we compared the two ILO definitions. In firms with less than six employees, roughly 10% of female employees obtained all legally mandated benefits. By contrast, only 21% of female employees working at firms with more than five employees stated that they lacked one or more legally mandated benefits. In other words, while 90% of women in firms with less than six employees did not receive full benefit packages, 80% of women in firms with six employees or more received full benefits. It appears that our use of small firms as an indirect measure of informal employment in the case of the self-employed is a reasonable assumption when it comes to the experience of women in the Argentine labour market.[11]

Table 1 shows the means, standard deviation and t-difference test between the estimated means of the descriptive variables of formal versus informal women workers.[12] Of a total of 3,733 women, 1,551 are formal workers and 2,182 are informal. There is a significant difference between the average real hourly wages of formal women (5.26 pesos) and informal women (4.16 pesos), and this is initial evidence for a segmented labour market, with formal workers earning more on average than informal workers. In the case of women in the formal sector subsample, 49% are mothers of at least one child aged under 15, and of those mothers 28% have one child, 16% have two and 6% have three or more. In the case of women working in the informal sector, 61% are mothers, 27% with one child, 20% with two and 14% with three or more. Note that this last category of mothers with three or more children is significantly larger for informal than for formal workers (14% versus 6%). As regards the age of the children, 28% of women in the formal sector and 32% in the informal sector have children aged under 5, and 21% of formal and 29% of informal women have children aged between 6 and 14.

When education is considered, significant differences are found, especially between individuals with low and high levels of education: 12% of formal women have a low level of education, versus 42% of informal women, while the proportions with a high level of education are 40% and 15%, respectively. This is evidence for a key factor driving labour market segmentation, which is explored in Casal (2011). When the husband's education is taken, it transpires that significantly more informal-sector women than formal-sector women married husbands with a low level of education, with significantly more formal-sector women marrying highly educated men. Where length of time in the same job is concerned, finally, the results were as expected, with formal workers averaging 7.81 years and informal workers 4.10 years. This initial evidence from the comparison of sample means shows that the formal and informal groups of women workers are statistically different in terms of wages, education, husband's education and length of time in the same job, and all these differences fit the segmented labour market hypothesis.

In analysing wage differentials between women in the following section, we undertake quantile regression estimations and describe the conditional real hourly wage distribution across different intervals of the formal- and informal-sector wage distributions. The two distributions are plotted in figures 1 and 2, and we use the two-sample Kolmogorov-Smirnov non-parametric test to compare the equality of distribution functions. From the results, it seems that we cannot accept the null hypothesis that the formal and informal real hourly wage distributions are drawn from the same distribution (p value = 0). A review of the charts suggests that the distributions are asymmetrical and most of the population is concentrated in the lower segments of the distribution, especially in the case of the informal sector. This finding supports the use of the quantile regressions, especially for consideration of issues related to glass ceilings at the top of the wage distribution and sticky floors, i.e., wage penalties at the bottom.

[10] All legally mandated benefits included in the Employment Contract Act No. 20744.
[11] See Casal (2011) for further details on the definition of informality.
[12] Table A.1 in the annex gives a detailed description of the variables used in this article. This section will describe only the main variables used for the research.

TABLE 1

Argentina (Greater Buenos Aires): descriptive statistics, 1995-2003
(Sample means and standard deviations)

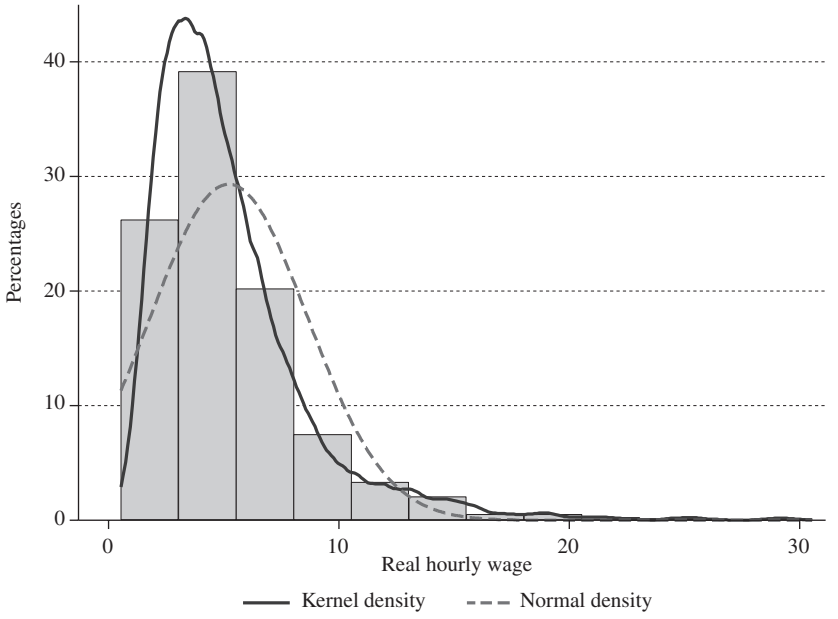
Variable	All No = 3 733		Formal No = 1 551		Informal No = 2 182		Formal = Informal	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Difference test	t-statistic
dformal	0.42	0.49						
rhourwage	4.62	4.08	5.26	3.56	4.16	4.39	1.10	8.03***
dmother	0.56	0.50	0.49	0.50	0.61	0.49	-0.11	[-6.73]***
dmother_one	0.27	0.45	0.28	0.45	0.27	0.44	0.01	0.13
dmother_two	0.18	0.39	0.16	0.36	0.20	0.40	-0.04	[-3.00]***
dmother_more	0.11	0.31	0.06	0.24	0.14	0.35	-0.08	[-7.32]***
dmother_5	0.30	0.46	0.28	0.45	0.32	0.47	-0.05	[-2.97]**
dmother_6-14	0.26	0.44	0.22	0.41	0.28	0.45	-0.07	[-6.74]***
age	36.69	8.15	36.56	8.08	36.77	8.24	-0.21	[-0.65]
agesq	1 413	593	1 402	592	1 420	595	-17.85	[-0.76]
dsingle	0.12	0.32	0.13	0.34	0.11	0.31	0.02	[1.67]*
dmarried	0.74	0.44	0.73	0.44	0.74	0.44	-0.01	[-1.06]
ddivorced	0.14	0.35	0.14	0.35	0.15	0.35	0.00	[-0.19]
head	0.27	0.44	0.28	0.45	0.26	0.44	0.02	[-1.31]
education1	0.29	0.46	0.12	0.32	0.42	0.49	-0.30	[- 21.3]***
education2	0.46	0.50	0.48	0.50	0.43	0.50	0.05	3.23***
education3	0.25	0.43	0.40	0.49	0.15	0.35	0.25	18.23***
yearsinjob	5.61	7.11	7.81	7.46	4.10	6.75	3.71	16.43***
dfulltime	0.69	0.46	0.84	0.37	0.59	0.49	0.24	16.40***
dparttime	0.31	0.46	0.16	0.37	0.41	0.49	-0.24	[-16.45]***
dpublic	0.20	0.40	0.35	0.48	0.08	0.28	0.27	22.04***
dprivate	0.80	0.40	0.65	0.48	0.91	0.28	-0.27	[-22.05]***
dfirm_small	0.33	0.47	0.02	0.12	0.55	0.50	-0.53	[-41.21]***
dfirm_medium	0.15	0.36	0.08	0.28	0.20	0.40	-0.12	[-9.88]***
dfirm_large	0.49	0.50	0.86	0.35	0.22	0.41	0.64	50.61***
dmanufacturing	0.13	0.33	0.12	0.32	0.14	0.34	-0.02	[-1.44]
dcommerce	0.16	0.36	0.11	0.32	0.19	0.39	-0.07	[-5.97]***
dservice	0.72	0.45	0.77	0.42	0.68	0.47	0.09	5.88***
manager	0.04	0.20	0.09	0.28	0.01	0.12	0.07	11.53***
professional	0.09	0.28	0.09	0.29	0.08	0.27	0.01	1.43
administrative	0.33	0.47	0.58	0.49	0.15	0.35	0.43	31.49***
service	0.52	0.50	0.23	0.42	0.74	0.44	-0.51	[-36.11]***
bluecollar	0.02	0.14	0.01	0.12	0.02	0.15	-0.01	[-1.64]*

Source: prepared by the authors on the basis of the Permanent Household Survey (EPH).

Note: for an explanation of the variables, see table A.1 of the annex.
* Significant at 10%. ** Significant at 5%. *** Significant at 1%.

FIGURE 1

Argentina (Greater Buenos Aires): frequency distribution of formal women's real hourly wages



Source: prepared by the authors on the basis of the Permanent Household Survey (EPH).

FIGURE 2

Argentina (Greater Buenos Aires): frequency distribution of informal women's real hourly wages

Source: prepared by the authors on the basis of the Permanent Household Survey (EPH).

V
Results

Tables 2 to 4 report the estimated earnings functions for OLS and quantile regressions. The wage estimations in table 2 include an analysis of all women together and then separate wage estimations for the formal and informal sectors. As a starting point for discussing the results, we note that most of the estimated coefficients for control variables in table 2 are significant, and the selected variables seem to explain wages in a manner consistent with conventional Mincerian estimation efforts.[13] As an example, for the education indicator variables, the highest wage premiums are for those who have completed university.

In all the estimation results, the empirical evidence supports the traditional segmented labour market hypothesis that women working in the informal sector earn significantly less than their formal-sector counterparts. On the evidence of table 2, there is a wage premium in the formal segment of about 16%. When we examine the OLS results for all women together and do not differentiate between the informal and formal sectors, we find a motherhood wage penalty that increases with the number of children (3.8% for one child, 9.6% for two children and 19.4% for three or more children).

More telling are the econometric results that emerge when we examine the two market segments separately. As predicted, the estimated coefficients associated with motherhood and children are not significant in the formal sector. In other words, the hypothesis that there would not be a motherhood wage penalty in the formal sector is consistent with the empirical evidence. By contrast, women in the informal sector experience a statistically significant motherhood wage penalty in all of the specifications. We find that the wage penalty is not the same for all mothers, as having more children increases the estimated penalty (7.8% for one child, 15.5% for two children and 26.3% for three or more children).

In 1999, following the 1998 international crisis in East Asia, Brazil and Russia, Argentina's GDP fell by 3.4% and the country entered an all-out recession which lasted until July 2002, according to the National Institute of Statistics and Censuses (INDEC). Table 3 presents the whole period under study and also splits the sample into the subperiods before and after the shock: 1995-1998 and 1999-2003. The coefficient estimates for the motherhood wage penalty, as reported in table 3, appear to be relatively stable over time, showing a higher penalty in the period before the shock (10.1% versus 5.7% for one child, 16.4% versus 13.1% for two children and 27.3% versus 26.0% for three or more children). The estimated coefficients associated with motherhood and children are non-significant across all the formal-sector regressions.

The quantile regression results in table 4 offer a closer look at the motherhood wage penalty across the wage distribution. As in the OLS results, formal-sector women workers do not experience statistically significant motherhood wage penalties. Across the full time period of the data, two different specifications of motherhood (one by the number of children and one by their age) show no significant wage penalties for mothers working in the formal sector. Overall, the quantile regression results for formal-sector women confirm the absence of a wage penalty for motherhood.

By contrast, mothers in the informal sector do experience statistically significant wage penalties, and those penalties are greatest for women in the lower wage quantiles. For example, the penalty for having three or more children in the informal sector is greatest at the bottom of the conditional wage distribution, with the poorest mothers (tenth percentile) experiencing a penalty of 44.8% and those in the richest quantile (ninetieth percentile) one of 13.5%. The pattern of the penalty is different for mothers of two children, for whom both the glass ceiling and sticky floor hypotheses seem to apply, as the penalty decreases up the wage distribution from 17.5% at the tenth percentile to 17.3% at the twenty-fifth, 10.7% at the fiftieth and 8.8% at the seventy-fifth, but then increases again at the ninetieth percentile to 16.1%. In the case of mothers with one child, the wage penalty is between 3.9% and 9.5%, but the coefficients are generally not significant, the exception being the largest difference at the twenty-fifth percentile, where women with one child earn 9.5% less than non-mothers. One way of summarizing the motherhood wage penalty for informal-sector women is that it increases with the number of children and is likely to be greatest at the bottom of the wage spectrum.

[13] Note that all the results have to be interpreted in relation to the base category: a blue-collar single woman, non-mother, public employee with less than complete secondary education, employed full-time at a small services firm.

TABLE 2

Argentina (Greater Buenos Aires): ordinary least squares (OLS) earnings function, 1995-2003

Dependent variable: natural log of real hourly wages	All	Formal	Informal
dformal	0.157		
	[0.028]***		
dmother_one	-0.038	-0.004	-0.078
	[0.026]	[0.030]	[0.038]**
dmother_two	-0.096	-0.017	-0.155
	[0.033]***	[0.040]	[0.046]***
dmother_more	-0.194	0.009	-0.263
	[0.041]***	[0.045]	[0.054]***
age	0.028	0.020	0.038
	[0.012]**	[0.016]	[0.017]**
agesquared	0.000	0.000	0.000
	[0.000]**	[0.000]	[0.000]**
dmarried	0.011	0.074	-0.047
	[0.041]	[0.060]	[0.054]
ddivorced	-0.066	0.059	-0.180
	[0.041]	[0.051]	[0.058]***
head of household	0.092	0.067	0.095
	[0.036]**	[0.054]	[0.047]**
education2	0.189	0.319	0.157
	[0.029]***	[0.037]***	[0.035]***
education3	0.532	0.589	0.724
	[0.039]***	[0.043]***	[0.072]***
dprivate	0.233	0.083	0.321
	[0.027]***	[0.028]***	[0.055]***
yearsinjob	0.015	0.009	0.018
	[0.002]***	[0.002]***	[0.004]***
dfirm_medium	-0.005	-0.014	0.085
	[0.039]	[0.064]	[0.046]*
dfirm_large	0.033	0.003	0.130
	[0.033]	[0.052]	[0.046]***
dmanufacturing	-0.280	0.046	-0.488
	[0.039]***	[0.043]	[0.053]***
dcommerce	-0.354	-0.133	-0.478
	[0.037]***	[0.044]***	[0.049]***
dparttime	0.434	0.191	0.549
	[0.026]***	[0.035]***	[0.032]***
manager	0.793	0.689	0.873
	[0.095]***	[0.103]***	[0.169]***
professional	0.752	0.636	0.622
	[0.093]***	[0.105]***	[0.130]***
administrative	0.415	0.315	0.422
	[0.083]***	[0.093]***	[0.111]***
service	0.187	0.046	0.276
	[0.080]**	[0.091]	[0.101]***
year	-0.052	-0.024	-0.070
	[0.005]***	[0.006]***	[0.007]***
constant	103.462	47.365	139.429
	[9.422]***	[11.274]***	[13.588]***
Observations	3 707	1 560	2 147
R^2	0.440	0.410	0.440

Source: prepared by the authors on the basis of the Permanent Household Survey (EPH).

Note: for an explanation of the variables, see table A.1 of the annex. The standard errors are listed below the estimates in brackets, and are robust to heteroskedasticity. The reference category is a blue-collar single woman with less than complete secondary education, employed full-time at a small services firm, public worker and non-mother.
* Significant at 10%. ** Significant at 5%. *** Significant at 1%.

TABLE 3

Argentina (Greater Buenos Aires): ordinary least squares (OLS) earnings function before and after the shock, 1995-2003

	1995-2003		1995-1998 (pre-shock)		1999-2003 (post-shock)	
	Formal	Informal	Formal	Informal	Formal	Informal
Mother of one child	-0.004	-0.078**	-0.051	-0.101*	0.040	-0.057
	(0.030)	(0.038)	(0.042)	(0.052)	(0.044)	(0.055)
Mother of two children	-0.017	-0.155***	-0.077	-0.164***	0.022	-0.131*
	(0.040)	(0.046)	(0.054)	(0.060)	(0.058)	(0.067)
Mother of three or more children	0.009	-0.263***	-0.045	-0.273***	0.036	-0.260***
	(0.045)	(0.054)	(0.061)	(0.072)	(0.066)	(0.077)
R^2	0.415	0.443	0.400	0.442	0.461	0.440
Observations	1 560	2 147	825	1 069	735	1 078
Mother of child aged under 6	-0.002	-0.180***	-0.032	-0.232***	0.017	-0.139**
	(0.032)	(0.042)	(0.043)	(0.055)	(0.046)	(0.061)
Mother of child aged 6 to 14	-0.013	-0.099**	-0.087*	-0.090*	0.055	-0.094*
	(0.033)	(0.039)	(0.045)	(0.053)	(0.048)	(0.056)
R^2	0.415	0.441	0.400	0.443	0.461	0.436
Observations	1 560	2 147	825	1 069	735	1 078

Source: prepared by the authors on the basis of the Permanent Household Survey (EPH).

Note: the standard errors are listed below the estimates in brackets, and are robust to heteroskedasticity. The reference category is a blue-collar single woman with less than complete secondary education who is a non-mother, public worker and is employed full-time at a small services firm. The control variables are the same as in table 2.
* Significant at 10%. ** Significant at 5%. *** Significant at 1%.

The quantile regression results were also disaggregated by time period, pre- and post-peso crisis. The results (also depicted in table 4) do not differ much from those just described. There is some evidence of a motherhood wage penalty among the lowest quantile of formal-sector women in the pre-crisis period that is not there later. Otherwise, across the rest of the formal-sector quantiles, there are no statistically significant motherhood wage penalty effects in either of the two time periods. The informal sector, however, shows strong evidence in both time periods of motherhood wage penalties that are of similar size and statistical significance across the quantiles, with the largest penalties being experienced by women with three or more children. As in the OLS results, the penalty is greater in the pre-shock period. The differences in the coefficients before and after the shock are not significant, but a larger gap prior to the crisis could reflect general downward pressure on wages affecting the formal sector during this period.

TABLE 4

Argentina (Greater Buenos Aires): quantile regression earnings function, 1995-2003

	OLS	Quantile regression				
		10	25	50	75	90
Formal						
Mother of one child	-0.004	-0.047	-0.025	-0.033	-0.051	0.047
	[0.030]	[0.045]	[0.033]	[0.033]	[0.048]	[0.062]
Mother of two children	-0.017	-0.056	-0.006	-0.004	0.009	0.006
	[0.040]	[0.062]	[0.038]	[0.050]	[0.045]	[0.061]
Mother of three or more children	0.009	0.068	0.077	0.004	-0.074	-0.121
	[0.045]	[0.080]	[0.060]	[0.050]	[0.067]	[0.082]
Adjusted R^2 (OLS)	0.415	0.232	0.263	0.256	0.248	0.267
Observations	1 560	1 560	1 560	1 560	1 560	1 560
Informal						
Mother of one child	-0.078**	-0.054	-0.095**	-0.039	-0.069	-0.063
	[0.038]	[0.067]	[0.046]	[0.035]	[0.043]	[0.055]
Mother of two children	-0.155***	-0.175	-0.173***	-0.107**	-0.088*	-0.161**
	[0.046]	[0.109]	[0.054]	[0.044]	[0.048]	[0.065]
Mother of three or more children	-0.263***	-0.448***	-0.289***	-0.183***	-0.152***	-0.135*
	[0.054]	[0.110]	[0.077]	[0.048]	[0.052]	[0.078]
Adjusted R^2 (OLS)	0.443	0.249	0.241	0.270	0.267	0.291
Observations	2 147	2 147	2 147	2 147	2 147	2 147
Formal						
Mother of child aged under 6	-0.002	-0.073	-0.025	-0.027	-0.042	0.041
	[0.032]	[0.049]	[0.038]	[0.038]	[0.046]	[0.060]
Mother of child aged 6 to 14	-0.013	0.005	0.002	-0.023	-0.036	-0.004
	[0.033]	[0.063]	[0.032]	[0.034]	[0.043]	[0.054]
Adjusted R^2 (OLS)/pseudo R^2 (quantile regression)	0.415	0.230	0.263	0.256	0.247	0.265
Observations	1 560	1 560	1 560	1 560	1 560	1 560
Informal						
Mother of child aged under 6	-0.180***	-0.305***	-0.236***	-0.103***	-0.125***	-0.126**
	[0.042]	[0.092]	[0.055]	[0.038]	[0.047]	[0.062]
Mother of child aged 6 to 14	-0.099**	-0.027	-0.104**	-0.069	-0.077	-0.104
	[0.039]	[0.071]	[0.048]	[0.046]	[0.048]	[0.064]
Adjusted R^2 (OLS)/pseudo R^2 (quantile regression)	0.441	0.246	0.240	0.268	0.267	0.290
Observations	2 147	2 147	2 147	2 147	2 147	2 147
Formal	1995-1998 (pre shock)					
Mother of one child	-0.051	-0.139*	-0.036	-0.029	-0.123**	0.028
	[0.042]	[0.072]	[0.044]	[0.049]	[0.062]	[0.099]
Mother of two children	-0.077	-0.152*	-0.026	-0.005	0.002	-0.058
	[0.054]	[0.092]	[0.067]	[0.064]	[0.078]	[0.072]
Mother of three or more children	-0.045	-0.068	0.055	0.004	-0.142	-0.144
	[0.061]	[0.134]	[0.092]	[0.063]	[0.092]	[0.118]
Adjusted R^2 (OLS)	0.400	0.214	0.249	0.246	0.242	0.276
Observations	825	825	825	825	825	825
Informal						
Mother of one child	-0.101*	-0.142	-0.105	-0.085*	-0.071	-0.060
	[0.052]	[0.105]	[0.070]	[0.052]	[0.058]	[0.095]
Mother of two children	-0.164***	-0.218	-0.204**	-0.101	-0.110*	-0.151
	[0.060]	[0.133]	[0.094]	[0.064]	[0.060]	[0.106]
Mother of three or more children	-0.273***	-0.520***	-0.269*	-0.165**	-0.165**	-0.167
	[0.072]	[0.159]	[0.139]	[0.074]	[0.071]	[0.113]
Adjusted R^2 (OLS)	0.442	0.262	0.261	0.278	0.283	0.315
Observations	1 069	1 069	1 069	1 069	1 069	1 069
Formal						
Mother of child aged under 6	-0.032	-0.140**	-0.039	0.015	-0.035	-0.049
	[0.043]	[0.067]	[0.057]	[0.046]	[0.065]	[0.079]
Mother of child aged 6 to 14	-0.087*	-0.105	-0.021	-0.054	-0.129*	-0.126
	[0.045]	[0.095]	[0.053]	[0.050]	[0.069]	[0.087]
Adjusted R^2 (OLS)/pseudo R^2 (quantile regression)	0.400	0.213	0.248	0.248	0.241	0.275
Observations	825	825	825	825	825	825

Table 4 (*concluded*)

	OLS	Quantile regression				
		10	25	50	75	90
Informal						
Mother of child aged under 6	-0.232***	-0.372***	-0.266***	-0.129**	-0.143***	-0.172**
	[0.055]	[0.125]	[0.080]	[0.056]	[0.049]	[0.078]
Mother of child aged 6 to 14	-0.090*	-0.106	-0.101	-0.098*	-0.094	-0.089
	[0.053]	[0.099]	[0.070]	[0.055]	[0.065]	[0.092]
Adjusted R^2 (OLS)/pseudo R^2 (quantile regression)	0.443	0.258	0.263	0.278	0.282	0.314
Observations	1 069	1 069	1 069	1 069	1 069	1 069
Formal	1999-2003 (post-shock)					
Mother of one child	0.040	0.024	0.023	0.012	0.056	0.037
	[0.044]	[0.075]	[0.051]	[0.058]	[0.068]	[0.070]
Mother of two children	0.022	0.038	0.042	0.004	0.033	-0.017
	[0.058]	[0.086]	[0.061]	[0.065]	[0.091]	[0.097]
Mother of three or more children	0.036	0.042	0.051	0.035	-0.053	-0.131
	[0.066]	[0.116]	[0.095]	[0.101]	[0.115]	[0.113]
Adjusted R^2 (OLS)	0.461	0.295	0.302	0.291	0.276	0.289
Observations	735	735	735	735	735	735
Informal						
Mother of one child	-0.057	0.060	-0.119*	0.012	-0.058	-0.096
	[0.055]	[0.099]	[0.067]	[0.056]	[0.065]	[0.089]
Mother of two children	-0.131*	-0.170	-0.188**	-0.068	-0.084	-0.130
	[0.067]	[0.164]	[0.076]	[0.069]	[0.083]	[0.089]
Mother of three or more children	-0.260***	-0.451**	-0.279**	-0.212**	-0.151*	-0.149
	[0.077]	[0.191]	[0.117]	[0.090]	[0.092]	[0.104]
Adjusted R^2 (OLS)	0.440	0.254	0.234	0.268	0.269	0.282
Observations	1 078	1 078	1 078	1 078	1 078	1 078
Formal						
Mother of child aged under 6	0.017	0.017	-0.012	-0.010	-0.009	0.092
	[0.046]	[0.076]	[0.055]	[0.064]	[0.073]	[0.082]
Mother of child aged 6 to 14	0.055	0.092	0.070	0.033	0.077	0.043
	[0.048]	[0.081]	[0.061]	[0.050]	[0.059]	[0.072]
Adjusted R^2 (OLS)/pseudo R^2 (quantile regression)	0.461	0.296	0.304	0.292	0.276	0.288
Observations	735	735	735	735	735	735
Informal						
Mother of child aged under 6	-0.139**	-0.215	-0.162**	-0.119**	-0.044	-0.085
	[0.061]	[0.134]	[0.079]	[0.059]	[0.076]	[0.080]
Mother of child aged 6 to 14	-0.094*	-0.043	-0.138**	-0.055	-0.047	-0.145*
	[0.056]	[0.098]	[0.067]	[0.054]	[0.066]	[0.082]
Adjusted R^2 (OLS)/pseudo R^2 (quantile regression)	0.436	0.247	0.231	0.265	0.267	0.283
Observations	1 078	1 078	1 078	1 078	1 078	1 078

Source: prepared by the authors on the basis of the Permanent Household Survey (EPH).

Note: the standard errors are listed below the estimates in brackets, and are robust to heteroskedasticity. The standard errors for the quantile regressions are computed using data analysis and statistical software (STATA) and are based on 100 bootstrap replications. The reference category is a blue-collar single woman with less than complete secondary education who is a non-mother, public worker and is employed full-time at a small services firm. The control variables are the same as in table 2.
* Significant at 10%. ** Significant at 5%. *** Significant at 1%.

1. Another look at the motherhood wage penalty

So far, we have carefully examined variations in the motherhood wage penalty by the number of children. An alternative approach is to consider penalties associated with the age of children or the timing of childbearing. Because childcare requirements are related to the age of children, different patterns may emerge for mothers of young as opposed to older children, especially considering that enrolment in a kindergarten is mandatory in Argentina when a child turns 5.[14] Accordingly, we redivided the sample into groups of mothers of children aged under 6, mothers of children aged between 6 and

[14] Article 16 of the National Education Act, No. 26206, provides that school is compulsory from the age of five.

14, and non-mothers, and then repeated the estimations (tables 3 and 4).

As before, there is no concrete evidence of a motherhood wage penalty in the formal sector, while the coefficients for motherhood penalties are significant in the informal subsample. For instance, table 3 shows that having a child aged under 6 is associated with a penalty of 18%, while in the case of older children the wage penalty is 9.9% (OLS). If the periods before and after the economic shock are considered separately, the penalty seems to have been relatively stable over time in the case of mothers of older children (9%), decreasing however from 23.2% in 1995-1998 to 13.9% in 1999-2003 for mothers of younger children.

The quantile regression estimates in table 4 indicate significant wage differences associated with motherhood in the informal sector over the wage distribution. For mothers of children aged under 6, the penalty is 30.5% in the tenth percentile, 23.6% in the twenty-fifth, 10.3% in the fiftieth, 12.5% in the seventy-fifth and 12.6% in the ninetieth, again offering supporting evidence for the sticky floor hypothesis in the informal sector. In the case of mothers of older children, meanwhile, only one coefficient estimate is significant, namely that for the twenty-fifth quantile (10.4%). The informal sector shows strong evidence in both time periods (pre- and post-crisis) for motherhood wage penalties across the quantiles, with the largest penalties being experienced by women with children aged under 6.

As might be expected, then, the motherhood wage penalty is greater when children are younger. Nevertheless, as Budig and England (2001) highlight, it could be the case that mothers, and especially mothers of children who are not old enough to go to school, seek "mother-friendly" jobs. In other words, they may be looking for less taxing jobs with flexible hours, few travel requirements and other mother-friendly attributes. If those mothers are more willing than others to take these mother-friendly jobs, they will earn less. In the case of Argentina, Faur (2011) indicates that implementation of crèches for the children of working parents has never been widespread in Argentina: coverage of five-year-old children has been extended but State provision of educational services for children under 3 is still limited throughout the country, so that households with younger children need the help of family members or private care providers. In the 1990s, the inadequacy of State-run childcare services resulted in the expansion of community crèches and private childcare facilities (Faur, 2011). The consequence was a widening of the gap between women in poor families and those in middle- to high-income ones. Women from middle- and high-income households normally have greater scope to integrate work in the marketplace with family responsibilities by defamilializing care, given their greater access to institutionalized public or private care services of various kinds, or by engaging domestic helpers. For their part, women in lower-income sectors might stay at home and care for their children, participate in community arrangements to secure food and services for them, or join the labour market and secure child care (Faur, 2011).

If a comparison is made with the empirical results from the other papers mentioned in section II, the magnitude of the motherhood wage penalty for informal-sector female workers is invariably larger than it is in other countries where the empirical analyses do not control for formality. However, it also seems to be important to consider the evolution of female labour force participation, fertility patterns and the increasing probability that a woman will have her first baby at an older age. The ideal estimation would be a double selection model covering the probability of being in the labour force and of being a mother and taking account of sample selection as well as the endogeneity of the choice to become a mother. Unfortunately, we cannot estimate this model because it requires at least two instrumental variables that were not available in our survey. Additionally, given the characteristics of the EPH survey, it is not possible to identify patterns of delayed childbirth because there is no information about the age of the oldest child in the case of women with children aged over 14. The best approximation is to consider the same set of wage regressions but look at different female age cohorts.[15] When this is done, the findings suggest that younger cohorts of mothers are likely to experience a higher wage penalty than older mothers.

2. The Blinder-Oaxaca decomposition

We are interested in comparing earnings between groups, and the Blinder-Oaxaca decomposition can be used to divide the wage differential between two groups into the "explained part", justified by certain worker characteristics associated with productivity, and the "unexplained part", which may be attributable to discrimination but also to the potential effects of differences in unobserved variables and specification

[15] The regressions are available upon request, but the results are in many cases not significant.

errors in the model (Jann, 2008; Esquivel, 2009).[16] Table 5 illustrates the Blinder-Oaxaca decomposition for the main groups: formal versus informal and, within those segments, mothers versus non-mothers. The first column is a decomposition of the formal-informal wage differential that seeks to prove the null hypothesis of equation (2), namely that earnings are significantly higher for formal than for informal workers. The mean predictor of the natural log of hourly wages is 1.05 pesos for informal workers and 1.48 pesos for formal workers, yielding a negative and significant difference of -0.43. When the Blinder-Oaxaca decomposition is carried out, both parts are significant: 67% is explained by differences in personal, job or sectoral characteristics, while 33% is unexplained and could be considered evidence of labour market segmentation.

Since the aim is to understand not only the earnings differences between segments but also the posited motherhood wage penalty, the second and third columns of table 5 consider mothers versus non-mothers. As expected, given our central hypotheses, there are no significant differences between the predicted means of mothers and non-mothers in the formal sector. However, there is a motherhood wage penalty in the case of informal workers; the predicted natural log of the hourly wage is 1.15 pesos for non-mothers and 0.98 pesos for mothers. The positive wage gap of 0.16 in favour of non-mothers is significant, and almost the entire difference (75%) is significantly unexplained or associated with possible discrimination. Thus, these findings bear out the original hypothesis of a motherhood wage penalty in the informal sector, and most of this penalty is attributable to discrimination or unobserved factors.[17] It is also worth noting that this 0.16 differential in the informal sector is at the upper end of the distribution of the motherhood wage penalty estimates reported above.

[16] The results have to be interpreted with caution, however, because, as Esquivel (2009) emphasizes, attributing discrimination to the second component assumes that the first part, associated with supply-side factors, is free of discrimination. "[It] is particularly problematic if certain attributes of occupations are included as 'explained factors' in this first component, like industry, for example, because this implicitly assumes that segregation is due to the voluntary decisions of men and women" (Bergmann, 2004, quoted in Esquivel, 2009, p.18).

[17] In an attempt to identify the group of mothers experiencing the greatest motherhood penalty, we also estimated the Blinder-Oaxaca decomposition for different groups of formal and informal women: (a) mothers of one child versus all other women; (b) mothers of two children versus all other women and (c) mothers of three children versus all other women. In the formal sector, it seems evident that the main conclusion is as shown in table 6: mothers do not appear to experience wage penalties. In the informal sector, the largest motherhood penalty is found among mothers of three or more children, since the estimated predicted natural log of the hourly wage difference is significant and is equal to 0.32. About 47% is explained by differences in endowments, while 53% of the decomposition is unexplained. As indicated previously, the Blinder-Oaxaca decomposition does not identify whether the unexplained part is discrimination by employers or unobserved heterogeneity in productivity.

TABLE 5

Argentina (Greater Buenos Aires): Blinder-Oaxaca decomposition, formal and informal, 1995-2003

Group	Informal (1) vs formal (2)	Formal	Informal
		Non-mother (1) vs mother (2)	Non-mother (1) vs mother (2)
ln (rhourwage) Prediction_1	1.05	1.47	1.15
	[0.02]***	[0.02]***	[0.03]***
ln (rhourwage) Prediction_2	1.48	1.49	0.98
	[0.02]***	[0.02]***	[0.02]***
Difference	-0.43	-0.02	0.16
	[0.02]***	0.03	[0.04]***
Decomposition			
Explained [a]	-0.29	-0.03	0.04
	[0.03]***	[0.02]	[0.03]
Unexplained [b]	-0.14	0.01	0.12
	[0.03]***	[0.03]	[0.03]***

Source: prepared by the authors on the basis of the Permanent Household Survey (EPH).

Note: the standard errors are listed below the estimates in brackets, and are robust to heteroskedasticity.
[a] Quality or endowments effect explained by group differences in the predictors.
[b] Discrimination effect: unexplained effect attributed to discrimination and unobserved variables.
*** Significant at 1%.

3. The Ñopo decomposition

The central variable is the natural log of real hourly wages, and we are analysing the wage gap between mothers and non-mothers working in the formal and informal sectors. Three combinations are taken in the matching: set I takes age and year, set II adds education measured by three dummy variables, and set III adds the head of household dummy variable. As Marquez Garcia, Ñopo and Salardi (2009) highlight, the greater the number of characteristics used in the matching, the smaller the chances of finding exact matches. Notice in table 6 that the common support (CS) percentage of mothers decreases from approximately 92% in set I to 50% in set III for the formal and informal subsamples, while the CS percentage of non-mothers decreases from 90% to 42% in the formal sector and from 95% to 57% in the informal sector.

When the formal subsample is considered, it transpires that non-mothers earn only 0.02% more than mothers. After matching on age and year, 1% is accounted for by differences in the support (Δ_M = -0.1% and Δ_{NM} = 1.1%) and differences in the distribution of individual characteristics in the common support explain 3% (Δ_X), while Δ_0 = -4% is the unexplained motherhood wage gap. Interestingly, when we add more characteristics (age, year, education and head of household), the unexplained gap is even smaller at Δ_0= -1.2%. Most is accounted for by the components that exist because of unmatchable mothers (Δ_M = -4.6%) and non-mothers (Δ_{NM} = 3.6%).

When the informal sample is considered, the wage gap is found to be much greater here than in the formal sector: mothers earn 14.4% less than non-mothers. The largest share of the decomposition is accounted for by the unexplained component, and Δ_0 accounts for -15.8% in set I, -13.6% in set II and -17.5% in set III. As for the components associated with unmatched individuals, following inclusion of education and the head of household dummy the part of the gap for which there are mothers who cannot be matched with non-mothers Δ_M yields a positive sign (1.5% in set II and 6.1% in set III) while Δ_{NM} yields a negative sign (-3.3% in set II and -6.7% in set III). Interestingly, the lowest share is given by a positive Δ_X of 2.3% when only year and age are considered, 1.1% when education is added in and 3.7% when the head of household dummy is included.

Note that Δ_X is always positive in both samples, and this could be understood as non-mothers having better endowments. Once again, these observations offer evidence in favour of our central hypotheses, since there are significant differences between the predicted means of mothers and non-mothers in the informal sector, and the unexplained wage gap component is significantly higher in the informal segment.

TABLE 6

Argentina (Greater Buenos Aires): motherhood wage gaps, formal and informal, 1995-2003
(Percentages)

	Formal		
	(I) Age and year	(II) Plus education	(III) Plus head of household
Δ	-0.02	-0.02	-0.02
Δ_0	-4.01	-3.83	-1.1
Δ_M	-0.10	-4.00	-4.60
Δ_{NM}	1.10	4.50	3.57
Δ_X	2.99	3.32	2.21
Percentage CS mothers	91.97	67.62	49.48
Percentage CS non-mothers	89.94	64.20	42.29
	Informal		
	(I) Age and year	(II) Plus education	(III) Plus head of household
Δ	-14.40	-14.40	-14.40
Δ_0	-15.78	-13.59	-17.48
Δ_M	-1.06	1.46	6.11
Δ_{NM}	0.13	-3.34	-6.74
Δ_X	2.32	1.08	3.72
Percentage CS mothers	91.81	64.90	46.85
Percentage CS non-mothers	95.45	76.20	57.06

Source: prepared by the authors on the basis of the Permanent Household Survey (EPH).

Note: wages gaps were estimated using the Ñopo decomposition, controlling for different sets of characteristics.

VI
Conclusions

This article is unique in that it integrates two different topics, the motherhood wage penalty and segmented labour markets in the recent Argentine context of national policies pursuing flexible labour markets and the consequent deterioration of workers' rights. In general, we cannot reject the traditional hypothesis of labour market segmentation and a wage premium for formal-sector women workers. Our central finding is that women working in the informal sector are the ones who suffer a motherhood wage penalty. It appears that regulations protecting the rights of these mothers go unenforced and they are less able to afford domestic help and childcare that might enable them to become more productive at work. Women who have more children show a greater likelihood of being in a temporary job, perhaps because they have to allocate more time to taking care of the family in the home. It is also true that not all women have the same employment opportunities, and those who belong to the lowest income segments have to work under more insecure and informal conditions because of their need to contribute to household income.

We use different estimation methods, including analysis of frequency distributions, OLS and quantile regressions. We combine the OLS results with the Blinder-Oaxaca decomposition to explore the explained and unexplained sources of wage gaps. The regression analysis shows that not all women experience the motherhood wage penalty. In the case of formal-sector workers, the coefficients on the motherhood dummy are not significant; it appears clear that those mothers do not experience wage penalties. In the case of the informal subsample, wage penalties are significant and grow with the number of children. Moreover, the motherhood penalty is not the same across the conditional wage distribution since it tends, especially for informal women, to be greater at the extremes. These results are consistent with the glass ceiling and sticky floor hypotheses of the labour market literature.

Additionally, considering the Blinder-Oaxaca decomposition, the difference between formal and informal wages is significant, and while 67% of the difference is explained, 33% is unexplained and could be attributed to discrimination. When motherhood and its effects on women's wages are considered, there are significant results in the informal subsample, mainly for the estimated coefficient of motherhood, while there are no significant estimates in the formal group. In the case of the informal segment, there is strong evidence of a motherhood wage penalty, and it is almost entirely (75%) driven by unexplained factors or discrimination. Similar results arise with the Ñopo decomposition; most of the motherhood wage penalty in the informal sector is unexplained, and when we add more characteristics to the match it is greater than the actual gap ($\Delta = -14.4\%$ and $\Delta_0 = -17.5\%$).

Overall, this article shows that the most vulnerable women are informal-sector workers. Their vulnerability is observed not only in their wages, which are lower than formal-sector women's, but also in a motherhood wage penalty that rises with the number of children and is greatest when children are young. Institutional labour market rules thus appear to be a crucial determinant of wages for women in Buenos Aires. These results suggest a welfare rationale for caution in pushing for increased labour market flexibility. Such reforms might drive standards down towards those applied to mothers in the informal sector, reducing pay and professional opportunities.

ANNEX

TABLE A.1

Explanation of variables

Variable	Description
rhourwage	Real hourly wage.
ln_rhourwage	Natural log of the real hourly wage.
dformal	Dummy: 1 if the woman is employed in the formal sector and 0 otherwise.
dmother	Dummy: 1 if the woman is the mother of at least one child aged under 15 and 0 otherwise.
dmother_one	Dummy: 1 if the mother has one child aged under 15 living at home and 0 otherwise.
dmother_two	Dummy: 1 if the mother has two children aged under 15 living at home and 0 otherwise.
dmother_more	Dummy: 1 if the mother has more than two children aged under 15 living at home and 0 otherwise.
dmother_5	Dummy: 1 if the mother has at least one child aged under 6.
dmother_6-14	Dummy: 1 if the mother has at least one child aged 6 to 14.
age	The woman's age in years.
agesq	The square of the woman's age in years.
dsingle	Dummy: 1 if the woman is single and 0 otherwise.
dmarried	Dummy: 1 if the woman is married and 0 otherwise.
ddivorced	Dummy: 1 if the woman is divorced and 0 otherwise.
head	Dummy: 1 if the woman is the head of her family and 0 otherwise.
education1	Dummy: 1 if the woman has incomplete secondary education or less and 0 otherwise.
education2	Dummy: 1 if the woman has complete secondary education or some university-level education and 0 otherwise.
education3	Dummy: 1 if the woman has completed a university degree and 0 otherwise.
yearsinjob	Number of years working in the current job.
dfulltime	Dummy: 1 if the woman works more than 20 hours per week and 0 otherwise.
dparttime	Dummy: 1 if the woman works less than 20 hours per week and 0 otherwise.
dpublic	Dummy: 1 if the woman is employed in the public sector and 0 otherwise.
dprivate	Dummy: 1 if the woman is employed in the private sector and 0 otherwise.
dfirm_small	Dummy: 1 if the woman is employed in a firm with one employee and 0 otherwise.
dfirm_medium	Dummy: 1 if the woman is employed in a firm with two to five employees and 0 otherwise.
dfirm_large	Dummy: 1 if the woman is employed in a firm with more than five employees and 0 otherwise.
dmanufacturing	Dummy: 1 if the worker is employed in the manufacturing sector and 0 otherwise.
dcommerce	Dummy: 1 if the worker is employed in the commerce sector and 0 otherwise.
dservice	Dummy: 1 if the worker is employed in the service sector and 0 otherwise.
manager	Dummy: 1 if the woman is a manager and 0 otherwise.
professional	Dummy: 1 if the woman is a professional worker and 0 otherwise.
administrative	Dummy: 1 if the woman is an administrative worker and 0 otherwise.
service	Dummy: 1 if the woman is a services worker and 0 otherwise.
bluecollar	Dummy: 1 if the woman is a blue-collar worker and 0 otherwise.

Source: prepared by the authors.

Bibliography

Amuedo-Dorantes, C. and J. Kimmel (2005), "The motherhood wage gap for women in the United States: the importance of college and fertility delay", *Review of Economics of the Household*, vol. 3, No. 1, Springer.

Anderson, D., M. Binder and K. Krause (2003), "The motherhood wage penalty revisited: experience, heterogeneity, work effort and work-schedule flexibility", *ILR Review,* vol. 56, No. 2, Cornell, Cornell University.

_____ (2002), "The motherhood wage penalty: which mothers pay it and why?", *American Economic Review*, vol. 92, No. 2, Nashville, Tennessee, American Economic Association.

Babcock, L. and S. Laschever (2003), *Women Don't Ask: Negotiation and the Gender Divide*, Princeton, Princeton University Press.

Bauder, H. (2001), "Culture in the labor market: segmentation theory and perspectives of place", *Progress in Human Geography*, vol. 25, No. 1, Sage.

Beblo, M., S. Bender and E. Wolf (2009), "Establishment-level wage effects of entering motherhood", *Oxford Economic Papers*, vol. 61(S1), Oxford University Press.

Bergmann, B. (2004), "Two varieties of 'feminist'", *Newsletter*, vol. 14, No. 4, Lincoln, Nebraska, International Association for Feminist Economics.

Blinder, A. (1973), "Wage discrimination: reduced form and structural estimates", *Journal of Human Resources*, vol. 8, No. 4, Wisconsin, University of Wisconsin Press.

Botelho, F. and V. Ponczek (2011), "Segmentation in the Brazilian labor market", *Economic Development and Cultural Change*, vol. 59, No. 2, Chicago, The University of Chicago Press.

Buchinsky, M. (1998), "Recent advances in the quantile regression models: a practical guideline for empirical research", *The Journal of Human Resources*, vol. 33, No. 1, Wisconsin, University of Wisconsin Press.

Budig, M. and P. England (2001), "The wage penalty for motherhood", *American Sociological Review*, vol. 66, No. 2, Washington, D.C., American Sociological Association.

Casal, M. (2011), *Motherhood Wage Penalty and Labor Market Segmentation in Argentina*, Madison, University of Wisconsin-Madison.

Correll, S., S. Benard and I. Paik (2007), "Getting a job: is there a motherhood penalty?", *American Journal of Sociology*, vol. 112, No. 5, Chicago, The University of Chicago Press.
De Pablo, J. (2005), *La economía argentina: En la segunda mitad del siglo XX*, Buenos Aires, La Ley.
Esquivel, V. (2009), "Care workers in Argentina", *Argentina Research Report*, No. 4, Geneva, United Nations Research Institute for Social Development (UNRISD), draft.
Falaris, E. (2008), "A quantile regression analysis of wages in Panama", *Review of Development Economics*, vol. 12, No. 3, Wiley Blackwell.
Faur, E. (2011), "A widening gap? The political and social organization of childcare in Argentina", *Development and Change*, vol. 42, No. 4.
_____ (2008a), "Historical context: economic, demographic and social structures and trajectories, and social policies in Argentina", *Argentina Research Report*, No. 1, Geneva, United Nations Research Institute for Social Development (UNRISD), draft.
_____ (2008b), "The care diamond: social policy regime, care policies and programmes in Argentina", *Argentina Research Report*, No. 3, Geneva, United Nations Research Institute for Social Development (UNRISD), draft.
Fields, G. (2008), "Segmented labor market models in developing countries", *ILR School Collection*, No. 162, Cornell, Cornell University.
Gangl, M. and A. Ziefle (2009), "Motherhood, labor force behavior, and women's careers: an empirical assessment of the wage penalty for motherhood in Britain, Germany, and the United States", *Demography*, vol. 46, No. 2.
Gong, X. and A. van Soest (2002), "Wage differentials and mobility in the urban labour market: a panel data analysis for Mexico", *Labour Economics*, vol. 9, No. 4, Amsterdam, Elsevier.
Goldin, C. (2006), "The quiet revolution that transformed women's employment, education, and family", *American Economic Review*, vol. 96, No. 2, Nashville, Tennessee, American Economic Association.
Heckman, J. (1979), "Sample selection bias as a specification error", *Econometrica*, vol. 47, No. 1, New York, The Econometric Society.
INDEC (National Institute of Statistics and Censuses) [online] http://www.indec.mecon.ar.
Jann, B. (2008), "A Stata implementation of the Blinder-Oaxaca decomposition", *ETH Zurich Sociology Working Papers*, No. 5, Zurich, Swiss Federal Institute of Technology.
Kennelly, I. (1999), "That single-mother element: how white employers typify black women", *Gender and Society*, vol. 13, No. 2, Sage Publications.
Koenker, R. and K. Hallock (2001), "Quantile regression", *Journal of Economic Perspectives*, vol. 15, No. 4, Nashville, Tennessee, American Economic Association.
Maloney, W. (1999), "Does informality imply segmentation in urban labor markets? Evidence from sectoral transitions in Mexico", *World Bank Economic Review*, No. 13, Washington, D.C., World Bank.
Marquez Garcia, L., H. Ñopo and P. Salardi (2009), "Gender and racial wage gaps in Brazil 1996-2006: evidence using a matching comparisons approach", *Working Paper*, No. 4626, Washington, D.C., Research Department, Inter-American Development Bank.
Mincer, J. (1974), *Schooling, Experience, and Earnings*, New York, Columbia University Press.
Ñopo, H. (2008), "Matching as a tool to decompose wage gaps", *Review of Economics and Statistics*, vol. 90, No. 2, Cambridge, Massachusetts, The MIT Press.
Oaxaca, R. (1973), "Male-female wage differentials in urban labor markets", *International Economic Review*, vol. 14, No. 3, Philadelphia, University of Pennsylvania/University Institute of Social and Economic Research Association.
Olbrecht, A. (2009), "Do academically deficient scholarship athletes earn higher wages subsequent to graduation?", *Economics of Education Review*, vol. 28, No. 5, Amsterdam, Elsevier.
Packard, T. (2007), "Do workers in Chile choose informal employment? A dynamic analysis of sector choice", *Policy Research Working Paper*, No. 4232, Washington, D.C., World Bank.
Pagés, C. and M. Stampini (2007), "No education, no good jobs? Evidence on the relationship between education and labor market segmentation", *IZA Discussion Paper*, No. 3187, Bonn, IZA Institute for the Study of Labor.
Pastor, M. and C. Wise (1999), "Stabilization and its discontents: Argentina's economic restructuring in the 1990s", *World Development,* vol. 27, No. 3, Amsterdam, Elsevier.
Piras, C. and L. Ripani (2005), "The effects of motherhood on wages and labor force participation: evidence from Bolivia, Brazil, Ecuador and Peru", *Sustainable Development Department Technical Papers Series*, No. 109, Washington, D.C., Inter-American Development Bank.
Pratap, S. and E. Quintin (2006), "Are labor markets segmented in developing countries? A semiparametric approach", *European Economic Review*, vol. 50, No. 7, Amsterdam, Elsevier.
Ridgeway, C. and S. Correll (2004), "Unpacking the gender system: a theoretical perspective on gender beliefs and social relations", *Gender & Society,* vol. 18, No. 4, Sage Publications.
Rosenzweig, M.R. (1988), "Labor markets in low-income countries", *Handbook of Development Economics,* Hollis Chenery and T.N. Srinivasan (eds.), vol. 1, New York, North-Holland.
Torrado, S. (2003), *Historia de la familia en la Argentina moderna (1870-2000)*, Buenos Aires, Ediciones de la Flor.
Waldfogel, J. (1998), "Understanding the 'family gap' in pay for women with children", *The Journal of Economic Perspectives*, vol. 12, No. 1, Nashville, Tennessee, American Economic Association.
_____ (1997), "The effect of children on women's wages", *American Sociological Review*, vol. 62, No. 2, Washington, D.C., American Sociological Association.
_____ (1995), "The price of motherhood: family status and women's pay in young British cohort", *Oxford Economic Papers*, vol. 47, No. 4, Oxford, Oxford University Press.
Wooldridge, J. (2000), *Introductory Econometrics: A Modern Approach*, South Western College.
Yasmin, B. (2009), "Trade liberalization and the lead role of human capital and job attributes in wage determination: the case of Pakistan's labor market", *The Lahore Journal of Economics*, vol. 14, No. 1, Lahore, The Lahore School of Economics.

Gender differences in workplace choices under crisis conditions

Lilia Domínguez V. and Flor Brown G.

ABSTRACT

Working from home is an option that differs from other forms of employment. This type of employment is driven not only by globalization and outsourcing, but also by unequal gender relationships within the home. Two multi-logistic regressions were used to determine how the distribution of in-home working arrangements differs by sex and by male/female age range, level of education, marital status and degree of urbanization of the place of residence. The results suggest that these characteristics have a differential influence on men's and women's employment decisions. The results also indicate that the crisis had a strong impact on the employment levels of home-based workers, especially male homeworkers, at the same time that it boosted employment in the services sector.

KEY WORDS

Women, home-based employment, women's employment, manufacturing, tertiary sector, statistics, Mexico

JEL CLASSIFICATION

101, 116, J20, C35

AUTHORS

Lilia Domínguez V. is a postgraduate researcher and professor with the School of Economics of the National Autonomous University of Mexico (UNAM). ldv@unam.mx

Flor Brown G. is a postgraduate researcher and professor with the School of Economics of the National Autonomous University of Mexico (UNAM). brown@unam.mx

I
Introduction

The informal economy accounts for 48.5% of total employment in Latin America (Tokman, 2008). It includes workers who do not have of the social security coverage, training, unemployment insurance, health-care insurance or pensions provided for in labour laws and who are therefore in a highly vulnerable position. This segment of the labour market is dynamic and heterogeneous. It encompasses independent workers employed in subsistence activities, domestic workers, homeworkers, wage earners and independent workers employed in small businesses and workers in formal-sector companies who are not entitled to benefits (ILO, 2005). The size of this sector is worrisome, but an additional cause of concern is the fact that, as a result of the globalization process, new forms of recruitment are gaining in importance at the same time that governments are de-regulating labour markets in order to increase the flexibility of employment arrangements and facilitate outsourcing to small informal firms or home-based workers. As a result, although the informal sector grew by only 1.7% between 1990 and 2008, forms of employment in the region in which wage levels are substandard or unpredictable rose from 11% to 15.1% (Tokman, 2008).

The Mexican economy is no exception. Estimates vary to some extent, but they all indicate that informal employment makes up a large proportion of the economy. According to Tokman (2008), informal-sector employment accounted for 43.7% of total employment, and forms of employment providing substandard or unpredictable wages accounted for 14.8% in 2008. Cardero and Espinosa (2013) estimate that informal employment accounted for 64% of the total in 2009, given the number of people who lack access to employment-based welfare and health-care programmes.

Part of the context for this situation is provided by the neoliberal structural reforms that were introduced in response to the 1982 external debt crisis. These reforms brought about a change in the driving forces behind the economy and ushered in greater stability in some macroeconomic indicators, such as the external public debt, the public deficit and inflation. Nonetheless, production and employment indicators have fallen short of expectations (Ocampo and Ros, 2011). One of the reasons is that economic growth has been fairly moderate compared to the growth rates marked up by the emerging economies of Asia and even those of Latin America. Between 1988 and 1994, the gross domestic product (GDP) climbed by 3.4%; between 1994 and 2000 (the period during which the country was involved in the North American Free Trade Association (NAFTA), which coincided with an economic boom in the United States, GDP rose by 3.6%, and it edged up by just 2.2% in 2001-2011.

Even worse, the new pattern of export-led growth has not generated sufficient labour demand to meet the needs of a growing population, since demand has risen fairly slowly in the past 25 years, with average growth rates of 2.7% for 1988-1993, 2.2% for 1995-2000, and 1.7% from 2001 to 2011. Meanwhile, the open unemployment rate (which does not provide information on underemployment) climbed from 2.2% to 5.2% in 2001-2011.

At the same time that an increasing imbalance between a growing labour force and shrinking labour demand has been taking shape, more and more women are becoming involved in the production and distribution of merchandise (De Oliveira and Eternod, 2000; Rendón and Salas, 2000; García, 2001). Women's labour participation rate began to rise in the 1980s, and this increase has spread to all age groups and martial status categories. While a variety of social, cultural and demographic factors account for this shift, the decline in real wages since the 1982 crisis has made it necessary for more and more women to enter the workforce during a time of economic instability in which access to unemployment insurance and universal benefit coverage is often unavailable. The shifts occurring in the labour market have had an impact on both sexes, but women undeniably make up a majority in the categories of vulnerable workers (García, 2001).[1]

☐ We are grateful to our colleagues, Jenny Cooper and Julio López, for the support that they provided throughout the preparation of this study and to our anonymous referees for their insightful observations, which enabled us to improve this paper. We also owe a debt of gratitude to the Technological Innovation and Research Projects Support Programme of UNAM for the funding provided for Project IN306911-3.

[1] The sectors accounting for the majority of women in informal employment are commerce (which saw an increase from 31% in 2000 to 34.3% in 2009), services (21.3% in 2009) and manufacturing (13.3%) (Cardero and Espinosa, 2013).

The informal labour sector includes work done from home for the market. This kind of activity has been going on ever since the start of the industrial revolution and has taken on new forms as it adapts to changes in labour demand. As one crisis follows after another, own-account work has come to represent a large share of the labour participation rates of adult women and their male children (García, 2001). According to the National Occupation and Employment Survey, today this type of work is performed by 14% of the labour force in Mexico (4.4 million people as of 2010), which means that nearly one third of all informal workers are working from home. Furthermore, the sexual division of labour is clearly reflected in home-based employment, with women homeworkers (10.2%) far outnumbering their male counterparts (2.6%).[2] In manufacturing, home-based work is common in the wearing apparel, leather and footwear, furniture and machinery industries; in the services sector, it is prevalent in retail groceries, stationery, clothing and professional services.

By contrast, 12.8% of all employed males work at the home of their employer, whereas only 3.9% of employed women do. These employees include domestic workers, drivers and wage earners employed in home-based microenterprises.

This form of gender-based segregation raises an issue in terms of our understanding of what modes of employment are characteristic of home-based employment as opposed to other options, such as working in an office, a factory or some other institution outside the home or of remaining outside the workforce. The objective of this study is to examine the factors influencing men's and women's decisions as to where and how to work[3] and or whether to remain outside the labour force. More specifically, the options that will be analysed are: home-based work in the manufacturing or services sectors, working outside the home and not working.

Another objective is to determine how the 2008 crisis affected home-based work and work outside the home. As is well known, Mexico was the hardest-hit of all the Latin American countries, with its total GDP and manufacturing sector's GDP plunging by 5.9% and 9.9%, respectively, in 2008-2009 (National Institute of Statistics and Geography (INEGI)), while its unemployment rate jumped from 4% to 5.5% (a 20% increase). Informal employment and the substandard conditions associated with it also expanded during that time, and it is therefore to be expected that the scale and determinants of this form of employment have also changed.

In line with Edwards and Field-Hendrey (2002) and Rani and Unni (2009), a multinomial model is used in this study for the years 2005 and 2010. This model makes it possible to undertake a simultaneous analysis of decisions to work from home in the manufacturing or services sectors or outside the home versus decisions to remain outside the workforce. The data source used is the National Occupation and Employment Survey for those same years. The literature on home-based employment in Mexico is very limited, which poses a challenge for any attempt to conduct an econometric analysis of the factors underlying this form of employment in the manufacturing and services sectors. The literature does, however, contain one very interesting study, based on a special-purpose survey, that analyses home-based working conditions in the manufacturing sector, the nature of such work and the accompanying labour relations (see Benería and Roldán, 1992).

As will be discussed in section II, the reasons why home-based employment exists are complex and involve a range of different factors. In section III, we describe the different forms of employment: home-based employment in the manufacturing or services sector, employment outside the home and non-participation in the labour force. The methodology and results of the multinomial model that is used to determine the probability that men or women will choose one or another of these modalities are discussed in section IV. Some final comments and observations are presented in section V.

[2] According to the National Occupation and Employment Survey, over 80% of this type of work takes the form of own-account employment.

[3] It is important to remember that women (and some men) engage in unpaid work in their own home (e.g., childcare, caring for older adults in the home, housework, etc.). This kind of domestic work is just as valuable as work done in the marketplace, but, for the sake of clarity and the purposes of this study, the term "home-based work" is used to refer exclusively to paid work performed in the home for the market.

II

Basic aspects of home-based work

Some Marxist authors have suggested that home-based work has increased in response to the requirements of the globalized capitalist system, in which managers need to be able to outsource goods and services from a flexible, low-cost supply of labour in a way that allows them to bypass labour laws and avoid providing benefits (Pearson, 2004). According to this view, the expansion of home-based employment is an outgrowth of informal labour, which is the crucial factor to take into consideration in order to arrive at an understanding of the relationship between globalized production and home-based employment (Benería, 1981; Carr, Chen and Tate, 2000).

Clearly, trade liberalization has exerted downward pressure on production costs, which increases the attractiveness of outsourcing in the informal sector on disadvantageous terms and conditions for workers (Pearson, 2004; Benería and others, 2000). In Mexico, as in other third-world countries that are part of global value chains in the textile and clothing industry (Dedeoglu, 2010), the presence of *maquiladoras* has allowed the garment industry to increase its use of outsourced home-based work for specific tasks (sewing on buttons, making hems, sewing on lace and embroidery) (López, 2005; Juárez, 2004). Care should be taken to avoid overstating the importance of international outsourcing as a major reason for the existence of home-based employment, however, since it is known that most exports have a very high content of imported inputs, which puts local suppliers at a disadvantage; this, in turn, depresses local demand for goods and services and weakens the intra- and inter-sectoral links of domestic production chains (Aroche and Cardero, 2007). Outsourcing is thus most common in specific niches, such as, for example, the garment industry, where for each male employee there are 2.65 women, according to data compiled by INEGI.

An additional factor in the appearance of new forms of home-based work in Mexico —especially in the case of highly educated men who work in the services sector— has to do with new ways of organizing production activities based on flexible specialization (Piore and Sabel, 1984) and the technological changes that have ushered in the fragmentation of the production process, the decentralization of production and the vertical de-integration of business enterprises (Gereffi, Humphrey and Sturgeon, 2005; Langlois, 1995), which then opt to purchase certain services in the market that they used to produce in-house. In addition, companies' efforts to establish more flexible working conditions and save both time and space, in conjunction with the growing utilization of information technologies in various easily monitored areas of corporate activity, are opening the way for some of their employees to work from home. The idea of "remote workers" (i.e., employees who work away from the office) has been around for quite some time, but until recently the term was simply a synonym for working from home or teleworking. It is not a question of outsourcing a service but instead of relocating it from the office to a home. Advances in mobile technology are also making virtual meetings (and the savings in travel expenses and working hours associated with them) more and more common (Cerda, 2011).

In this article we will focus on the approach adopted by Atasü Topçuoglu (2005), who believes that the relationships between economic globalization, the increasing scale of informal economic activity and home-based employment are all important factors but are not in themselves sufficient explanations for this phenomenon, which has, after all, been in existence since before the industrial revolution (Thompson, 1963; Louw and De Vries, 2002). The prevalence of patriarchal gender relations is another factor that blocks women from participating in the workforce on an equal footing with men and that contributes to the invisibility of women's informal home-based employment, which is sometimes chosen because there is no alternative, rather than because it is an attractive option. As noted by Hartmann (1979), women occupy a dual position in the labour market. They rely on their husbands' wages, which is why it is they who do the housework, but, at the same time, their household duties place them in a weaker position within the labour market, which translates into lower wages vis-à-vis their male counterparts. In other words, home-based work offers a way for women to work and earn an income without challenging the prevailing patriarchal ideology (Kantor, 2003).

As a result, the labour market is not gender-neutral. There are informal and cultural norms that lead to gender segregation in some sectors of the economy and

employment, in addition to vertical gender segregation (Elson, 1999). Sociocultural constructs of gender roles and stereotypes establish who the decision-makers are and to whom economic assets belong (Benería and Roldán, 1987).

Viewed from this vantage point, it can be seen that there are a range of variables involved in the explanation of why there is a segment of the population that earns its livelihood through home-based employment. Recent studies have looked at the sociodemographic characteristics of home-based workers (e.g., level of education, age, religion, racial identity and the labour costs of home-based work), which are important considerations in the case of women who, unlike men, have to combine household tasks with their market-based employment activities. This can mean that the reservation wage may be lower than it is for employment outside the home. A pioneering study by Edwards and Field-Hendrey (2002), in which they used data from the 1990 population census of the United States, is based on the concept that participation in the labour market has a fixed cost and takes a close look at women's decisions about working in the home. They find that women who have children or other dependents or who live in rural areas are more likely to work from home than elsewhere. The study also indicates that women with children, other dependents or a spouse are more likely to engage both in unpaid domestic work and home-based gainful employment. The authors focus on the attractiveness for women of the option of staying at home so that unpaid domestic work can be combined with gainful home-based employment.

Rani and Unni (2009) have used a similar model in analysing the situation in India, but they also take the economic situation into consideration in gauging how important a role economic reforms may have played in the frequency of the practice of outsourcing. They focus on the determinants of men's and women's decisions as to whether to work in the manufacturing or services sectors from home or away from home. The authors find that women's decisions regarding home-based employment are influenced, at a micro level, by their cultural environment (castes, religion), their level of education and the fixed cost of working at home; these considerations are not taken into account by men when making this same decision. In other words, these authors found evidence that corroborates how strongly women are influenced by existing patriarchal systems.

At a macro level, Rani and Unni (2009) compare past periods in which trade was not as open with the situation in more recent times and find that there is no significant correlation for women home-based workers but that there is one for male home-based workers. This suggests that the small but increasing percentage of men engaging in home-based work may be driven by economic reforms that have altered male employees' role in the organization of production. In other words, while the sociocultural factors that influence women's decisions about engaging in home-based employment are quite evident, those that may affect men's decisions in this respect are not, and their decisions may be based on responses to the demand for outsourced labour generated by industries' efforts to cut labour costs in an increasingly globalized market.

On the basis of these two studies, an attempt will be made here to explain the dynamic of home-based and non-home-based work from a gender perspective at both the microand macro levels. A more detailed account will be provided in section IV.

III

Stylized facts about home-based and non-home-based employment in the manufacturing and services sectors: 2005-2010

Even though a growing number of women entered the labour market in the late twentieth century, women's participation in the labour force remains fairly limited; only 38% of women were employed, versus 86% of men, as of 2005. During the next five years, however, female employment climbed faster than male employment, and the employment figures had therefore changed to 42% for women and 84% for men by 2010, which suggests that

the crisis had a stronger impact on the latter. The number of women working from home in the manufacturing and services sectors fell slightly, slipping from 15% of the total in 2005 to 12% in 2010 (see table 1). The proportion of men working from home remained steady at 3%, but their distribution changed: whereas 5% of them were working in manufacturing and 1% in services in 2005, in 2010 the corresponding percentages were 1% and 2%, respectively. In other words, there was a 3.7% annual decrease in the number of men working from home in the manufacturing sector and an increase in those engaged in an own-account home-based services business; even though women's participation rate in this latter category fell by seven percentage points, it continues to be more than twice as high as the overall average (see table 1).

In all, 97% of men, compared to 85% of women, worked outside the home (i.e., in a factory or in an office or in the informal sector on the street or in the home of their employer) in 2005; the corresponding figures for 2010 were 97% and 88%, respectively (see table 1). This means that the percentage of women working outside the home rose slightly during this period, which would not be expected to occur during a crisis. One possible explanation is that these women switched over from doing own-account work to employment in the home of their employer or to working as informal street peddlers or to employment in the formal sector in offices or factories. During this period, the proportion of the total employed labour force represented by women climbed from 32% to 34%, which is still less than their average participation rate in the economy as a whole.

Over 80% of the women who are not in the workforce classify themselves as "unavailable for employment" because they are students, are retired or, in the majority of cases, are married and stay at home to take care of their children and the house. The number of men who place themselves in this category is much smaller, as may be seen from table 1.

In the five-year period under study (see table 1), the number of unemployed persons increased considerably (12%), with the rise in joblessness for women (14%) being sharper than it was for men (11%).[4] Within this category, the proportion of women who were available for work rose by 5% and the proportion who were unavailable declined. Just the opposite occurred in the case of men, with the proportion who classified themselves as unavailable increasing by 3%, on average, per year.

Since the focus of this study is on home-based workers, a subsample[5] of the National Occupation and Employment Survey will be used for the years 2005[6] and 2010 which is composed of heads of household and their spouses. Observations for working-age children or other members of the household have not been included, since it is assumed that they would not be in a position to start up a business in a home that does not belong to them. It is acknowledged that there may be exceptions, with children running a business out of their parents' home, but these cases are not thought to be significant in number.

The National Occupation and Employment Survey covers 105,342 households and then uses an expansion factor to extrapolate the data to the population as a whole. The number of observations in the sample used here was 81,223 male heads of household or spouses and 95,834 female heads of household or spouses. Table 2 provides information on the composition of the households in the sample. As is to be expected, many more men (96%) than women (25%) are heads of household. A large percentage of the households (55% of male-headed households and 43% of female-headed households) have dependents in need of care (defined as children below the age of 12 and older adults living in the household who do not work).[7] Most of these dependents are children.

Male and female workers exhibit different distributions of various attributes (see tables 3 and 4). Men who are not in the workforce tend to be over 45 years of age (80%), which may be due to the difficulty that older men have in finding a job. The age distribution of women who are not in the workforce, on the other hand, is fairly even, which reflects many women's decision to take care of their children rather than to work, as has been corroborated by numerous studies (Maldonado and Rendón, 2004). The age group which has the largest number of home-based workers for both men and women is 35-44 years, but men tend to work until they are over 60, which is not the case for women. Women who work outside the home tend to be younger than their male

[4] The unemployment rate was 2.2% in 2005 and 3.5% in 2010; the rate for women was slightly higher (2.3% in 2005 and 3.7% in 2010, versus 2.2% and 3.4%, respectively, for men). This unemployment rate is lower than the average rate for the economy because the youth unemployment rate (persons between the ages of 15 and 24) in Mexico has historically been slightly more than twice as high as the rate for persons aged 25 or over, and the subsample includes a larger proportion of people over 25 years of age.

[5] This is a subsample because the National Occupation and Employment Survey gathers information on all members of each household. In the remainder of this article, however, this subsample will be referred to simply as "the sample".

[6] This survey was first conducted in 2005.

[7] This group was defined as jobless persons over 65 years of age.

TABLE 1

Mexico: position of women and men in the labour market, 2005 and 2010
(Totals and percentages)

Position in the labour market	2005			2010			Average annual growth rates (*percentages*)			Female participation rate (*percentages*)	
	Women	Men	Total	Women	Men	Total	Women	Men	Total	2005	2010
Total employees (1)	9 099 360	17 343 695	26 443 055	10 612 677	18 363 725	28 976 402					
Percentage of total EAP	38	86	60	42	84	61					
Total employees (percentages)	100	100	60	100	100	100					
Home-based work	15	3	7	12	3	6	-2	1	-1	71	69
Manufacturing	6	5	3	5	1	3	-2	-4	-3	65	67
Commerce and services	9	1	4	7	2	4	-1	6	1	77	70
Outside the home	85	97	93	88	97	94	4	1	2	32	34
Not in workforce											
Not in workforce (2)	14 617 468	2 886 969	17 504 437	14 958 061	3 585 210	18 543 271					
Percentage of total EAP	62	14	40	58	16	39	1	4	1	84	81
Not in workforce (percentages)	100	100	100	100	100	100					
Unemployed	2	13	3	3	18	6	14	11	12	36	38
Available	12	17	13	15	18	16	5	5	5	78	78
Not available	86	69	83	82	64	79	-1	3	0	86	84
EAP (1+2)	23 716 828	20 230 664	43 947 492	25 570 738	21 950 765	47 524 322	2	2	2	54	54
	100	100	100	100	100	100					

Source: National Occupation and Employment Survey, 2005 and 2010, National Institute of Statistics and Geography (INEGI).

EAP: economically active population.

TABLE 2

Mexico: composition of households in the sample
(Percentages)

	Average: 2005-2010	
	Men	Women
Head of household	96	25
Spouse	4	75
Children 7 years of age or younger	22	19
Children aged 8 to 12	24	20
Adult dependents	8	3
Total	55	43

Source: National Occupation and Employment Survey, 2005 and 2010, National Institute of Statistics and Geography (INEGI).

counterparts (most of these women areunder 45 years of age) and younger than female home-based workers.

One of the changes that can be seen to have taken place during this five-year period is that the people who started up a business in their homes tended to be older. This was particularly true of women. Home-based employment in manufacturing or services accounted for 34% of the total for women in the 45-years-and-over age group in 2005, and this figure had risen to nearly 50% by 2010, whereas for men the corresponding increase was from 50% to 58%. The question arises as to whether or not this trend is attributable to the scarcity of job opportunities during the crisis.

Generally speaking, higher levels of education correlate with higher incomes and better working

TABLE 3

Mexico: characteristics of female workers, 2005 and 2010
(Percentages of the total)

Women	Not in workforce		Home-based work in manufacturing		Home-based work in services		Outside the home	
	2005	2010	2005	2010	2005	2010	2005	2010
Age groups								
15-25 years	10	9	8	4	6	4	5	6
25-35 years	22	19	29	20	25	18	25	23
35-45 years	22	20	33	28	31	27	37	33
45-60 years	26	27	23	33	29	35	28	31
Over 60 years	20	25	7	15	9	16	5	7
Total	100	100	100	100	100	100	100	100
Levels of education								
Less than primary	12	11	10	15	8	9	6	5
Primary	46	41	42	47	40	43	25	26
Lower-secondary	20	23	27	22	23	24	15	23
Upper-secondary or technical school	7	9	7	7	9	9	10	13
Professional	15	16	14	9	20	15	44	33
Total	100	100	100	100	100	100	100	100
Marital status								
Single	3	4	7	5	10	6	3	11
Married	71	67	64	64	60	61	71	58
Consensual union	13	15	11	13	11	13	13	14
Separated	3	3	7	6	8	7	3	7
Widow	9	10	8	10	6	10	9	6
Divorced	1	1	3	2	5	3	1	4
Total	100	100	100	100	100	100	100	100
Size of place of residence								
Population of over 100 000	57	55	63	36	68	57	57	65
Population between 15 000 and 99 000	12	12	14	13	12	13	12	13
Population between 2 500 and 14 999	12	12	12	21	10	13	12	11
Population of less than 2 500	19	21	11	30	10	17	19	11
Total	100	100	100	100	100	100	100	100

Source: National Occupation and Employment Survey, 2005 and 2010, National Institute of Statistics and Geography (INEGI).

TABLE 4

Mexico: characteristics of male workers, 2005 and 2010
(Percentages of total)

Men	Not in workforce		Home-based work in manufacturing		Home-based work in services		Outside the home	
	2005	2010	2005	2010	2005	2010	2005	2010
Age groups								
15-25 years	4	4	4	2	3	2	3	6
25-35 years	6	6	20	15	18	13	18	22
35-45 years	9	10	26	28	25	25	25	29
45-60 years	21	23	32	35	35	38	35	32
Over 60 years	60	57	18	20	19	22	19	11
Total	100	100	100	100	100	100	100	100
Levels of education								
Less than primary	17	13	5	7	7	5	17	5
Primary	48	44	30	46	37	30	48	32
Lower-secondary	12	15	22	28	21	21	12	26
Upper-secondary or technical school	6	8	14	11	12	12	6	14
Professional	17	20	29	8	23	32	17	23
Total	100	100	100	100	100	100	100	100
Marital status								
Single	7	9	4	4	6	7	4	5
Married	72	70	81	73	75	68	76	72
Consensual union	8	10	12	16	14	16	15	18
Separated	3	2	1	3	2	4	2	2
Widower	9	8	1	2	2	3	2	2
Divorced	1	1	1	2	1	2	1	1
Total	100	100	100	100	100	101	100	100
Size of place of residence								
Population of over 100 000	64	61	70	51	55	66	62	57
Population between 15 000 and 99 000	15	11	14	16	12	13	12	12
Population between 2 500 and 14 999	11	12	10	16	12	10	11	12
Population of less than 2 500	10	16	7	17	21	11	15	19
Total	100	100	100	100	100	100	100	100

Source: National Occupation and Employment Survey, 2005 and 2010, National Institute of Statistics and Geography (INEGI).

conditions; education has also proven to be a highly important factor in women's decisions to enter the labour market (Maldonado and Rendón, 2004). If a lower-secondary-school education or less is taken as a point of reference, then, as is to be expected, the figures show that men and women who are not participating in the workforce tend to be less educated, with some 25% having a primary-school education. In the case of female home-based workers, 77% have not completed upper-secondary school. In the case of more highly educated workers, in 2005 the percentage of men engaged in home-based employment in manufacturing and especially in services was larger than the percentage of women engaged in these activities. Interestingly, the proportion of heads of household with completed upper-secondary and/or specialized educations increased from 35% to 44%. This could stem from the decentralization of production and the vertical de-integration of businesses that was referred to earlier. It could also reflect more highly educated people's decision to opt for self-employment in response to the crisis. Yet another factor is likely to have been that people with more schooling may often be more driven to improve their situation and achieve financial independence (García and Pacheco, 2000). This is in line with the fact that women heads of households working outside the home are more highly educated than female home-based workers and than their male counterparts.

Tables 3 and 4 indicate that marriage is the most common marital status, followed by consensual unions. With the exception of unemployed persons, in all other categories there are more men than women, which means

that there are more employed women without partners; women who are separated or divorced, in particular, tend to be working, either in the home or elsewhere.[8] Because of the family responsibilities that go along with marriage, it is to be expected that a smaller percentage of married women are employed (García and De Oliveira, 1994). Thus, whereas 84% and 82% of unemployed women were married or in a consensual union in 2005 and 2010, respectively, the corresponding figures for employed women were 76% and 74% for those same years. This differential is not present among men. Over the period covered by the study, there was a continuous increase in the proportion of married women who worked from home and a continuous decrease in the proportion who worked outside the home or were unemployed.

Finally, it is also important to analyse the rural/urban distribution of the population in order to take account of the advantages or disadvantages associated with residence in a location having different levels of access to services, different cultures and traditions, and differing ranges of job opportunities.

The percentage of men tends to be higher in urbanized areas. Much of the home-based work that is performed takes place in large cities, especially in the services sector, which is where two thirds of male and female heads of household are employed. Over the period of analysis, this trend in the services sector became more and more marked. This was not the case for the manufacturing sector, where 62% of female heads of household were working from home in large cities in 2005 whereas only 36% were doing so in 2010. The trend for male heads of household was similar. In other words, home-based work in the manufacturing sector became less urbanized.

[8] Whereas 13% of single women were unemployed in 2005 and 14% were in 2010, the percentage of single women working in any of the types of activities analysed in this study rose, on average, from 16% in 2005 to 18% in 2010.

IV

The decision to work from home: a multinomial model

1. Methodology

The multinomial logit model that was used in this study is based on the idea that the four different options (home-based work in the manufacturing or services sectors, non-home-based employment and non-participation in the labour market) have no hierarchical order. The purpose of using this model was to compute the probability of an individual opting for any one of these alternatives. The explanatory variables are exogenous factors that influence labour supply under all the circumstances mentioned: reservation wage, fixed costs of working outside the home and macroeconomic conditions.

In order to estimate the first variable, we look at age, level of schooling and how urbanized the worker's area of residence is, which can be used to express the cost of commuting. As various authors have noted, individuals gain personal and work experience as they age that enhances their employability; however, it is also true that, after a point, the ageing process is associated with a physical and intellectual deterioration that can lessen older adults' chances of continuing to be economically active (Millán, 2010). Thus, the effects of age can be expected to be non-linear, since the reservation wage will increase with age up to a point and will then begin to decrease with age.

In addition, higher levels of schooling can be expected to be associated with a greater likelihood that a person will work outside the home, and home-based work can be expected to be associated with lower levels of schooling than non-home-based employment.

As compared to residents of urban zones, people residing in less urbanized areas have a lower reservation wage for home-based-work than for non-home-based work. There are fewer job opportunities in rural areas, however, and working from home in the services industry in such areas is not common; it is more likely that rural home-based workers will be employed in the manufacturing sector. Because of commuting costs, it is to be expected that there will be a greater probability that people in urban areas will work from home in the services sector or will work outside the home (Rani and Unni, 2009).

The fixed costs involved here are represented by variables relating to reproductive labour and the work involved in caring for children and other dependents. Because the presence of dependents raises the level of fixed costs, it can be expected to increase the probability that the person concerned will choose to work from home rather than not participating in the labour force and to decrease the probability that such a person will work outside the home. The fact that a person has a partner may result in increased housework and therefore be an obstacle to undertaking a job, but especially a job outside the home. Since women have traditionally shouldered the responsibility of caring for the home, a link is not expected to exist between these variables and men's decisions regarding employment. Some studies suggest that the presence of adult dependents in the home can lighten the childcare workload (Knaul and Parker, 1997), but if the older adults are in poor health, fixed costs may be greater because the need to care for them could be an impediment to employment. Other studies have not found evidence of this (García and Pacheco, 2000).

Other factors that could influence women's participation in the labour market are fluctuations in employment levels and the business cycle (Bover and Arellano, 1995).

In this study, macroeconomic conditions are represented by GDP growth at the state level, weighted by the labour-force participation rate.[9] On a macroeconomic scale, if home-based work is a refuge from unemployment, then the number of people engaged in such work would be expected to rise sharply in states where GDP growth is low or average. On the other hand, if home-based labour is a supplement for formal-sector businesses that subcontract informal labour or outsource goods and services, then it would be expected to be more prevalent in states where GDP growth is high or average. There is no a priori hypothesis for male/female differentials.

Finally, we posit that the financial difficulties triggered by the crisis may have altered the way in which some variables influence the probability of home-based employment. For example, Anderson and Levine (1999) find that the presence of young children in the home and the associated cost of childcare will lessen the probability of participation in the labour market. This would mean that, for women, the crisis may have increased the probability that they would work from home and reduce the probability that they would engage in employment outside the home. On the other hand, if the crisis has depressed the level of household income, the presence of small children may be a less influential factor in adult women's decision to join the labour force (García and De Oliveira, 1994).

The model's dependent variable uses a number of values: "1" for home-based employment in the manufacturing sector; "2" for home-based employment in the services sector; "3" for employment outside the home; and "4" for non-participation in the labour market. The description of the variables used for each group is given in table 5.

[9] Reliable statistics on home-based work prior to 2005 are unavailable, so this exercise cannot be performed for prior periods.

TABLE 5

Independent variables of the multi-logit model

Reservation wage	Fixed costs of working outside the home	Macroeconomic conditions
Age	Children 7 years of age or younger = 1	Low-growth states: GDP growth lower than 4.14 = 1
Age^2	Children aged 8 to 12 years = 1	Average-growth states: GDP growth of 4.15 or higher = 1
Level of education: Up to primary = 1	Dependent older adults (over 65 years of age and not working) = 1	High-growth states: GDP growth of 9.04 or higher
Level of education: 1st to 3rd of lower-secondary = 1	Married = 1	
Level of education: Upper-secondary = 1	Single = 1	
Level of education: University or postgraduate degree	Consensual union = 1	
Place of residence: population >100 000 = 1	Divorced = 1	
	Widow/widower+ = 1	

Source: prepared by the authors.

GDP: gross domestic product.

2. Results of the estimation of the model

Four multi-logit regressions were run: one for women and one for men in 2005 and one for women and one for men in 2010. Each regression yielded results for the four different employment options. There were 78,279 observations in 2005 and 75,950 in 2010 for female heads of household, and 64,116 observations in 2005 and 59,342 in 2010 for male heads of household.[10] In order to avoid any bias that might be generated by the heterogeneity of the population concerned, standard errors were estimated using the robust method developed by Huber and White (Huber, 1967; White, 1982; Langlois, 1995).

All the results were satisfactory except those for the regression for males in 2005. The pseudo R^2 for the multinomial logistic regression, which measures the relationship between the likelihood value of the model as a whole vis-à-vis the restricted model with constants for 2005 and 2010, was 9.3% in both years for women and 3.6% for men in 2005 and 15.7% for men in 2010. The coefficients as a whole were statistically significant in all four regressions as measured using the Wald test statistic. Since this is a non-linear model, the interpretation of the coefficients is not straightforward. For example, a positive coefficient does not necessarily imply an increased probability. The results in terms of the marginal effects that imply a change in probability due to a modification in a unit of the independent variables will therefore be presented here. These results are shown in tables 6 and 7.[11]

(a) Reservation wage

Both women and men who have completed secondary or higher education were less likely to decide to take a home-based job in the manufacturing sector in either 2005 or 2010, which indicates that this type of job has a low reservation wage because of its largely unskilled nature. By the same token, the marginal effect on the probability of home-based work in the services sector was negative in both those years for more highly educated women heads of household (those who hold a university or postgraduate degree), with marginal effects of -1.0 in 2005 and -1.2 in 2010. More educated men were more likely than their female counterparts to engage in home-based work in the services sector in both 2005 and 2010, however. In fact, the marginal effects on the likelihood of this form of home-based employment were 0.03 and 0.08 for persons who have completed upper-secondary school and 0.65 and 0.43 for those with specialized educations. The latter can be regarded as a high-value-added niche market (consultancies, work performed by architects, doctors, lawyers and information technologies specialists, among others) that is being supplied by outsourced services by own-account or remote workers, as noted earlier.

The probability of working outside the home is negatively correlated with low levels of education, while there is a clear preference among women who have a specialized education (marginal effects of 22.54 and 19.33) or who have completed their upper-secondary education (9.48 and 9.34 in 2005 and 2010, respectively) to work outside the home, although this preference was slightly less marked in 2010 than it was in 2005. This was not the case for heads of household, for whom the marginal effects were smaller or negative: -3.87 and 1.38 for those holding a university degree and -1.63 and 1.39 for those holding an upper-secondary-school diploma. These results corroborate other studies' findings regarding the importance of a more advanced education for women (García and Pacheco, 2000) and suggest that, whereas men consider other factors when deciding to work outside the home, for more highly educated women, their education is a very influential factor in their choice of such occupations.

Apart from the labour force, the positive marginal effects for men of having completed upper-secondary school or university were quite strong in 2005 (2.03 and 4.65); this was not the case for men with a university degree in 2010, although the marginal effect was very small and may have been attributable to their acceptance of lower-paying jobs. The figures back up the hypothesis that women with low levels of education account for a larger percentage of the unemployed. While the marginal effect of having no more than a primary education is, on average, 3.6, the marginal effects of having a university or postgraduate education are -20 and 26, respectively. In other words, the more educated a woman is, the less likely she is to be unemployed (see tables 6 and 7).

As was expected, the regressions for home-based work for both men and women reflect a non-linear relationship with age in 2005 and in 2010. This is true for all of the three options being analysed here. There are some subtleties that should be noted, however. On the one hand, the marginal effect of age on the probability of working from the home is greater for female heads of household, which means that these women tend

[10] The STATA software that was used to compute the estimates, discards an observation if full information for some variables is lacking. See *Stata User´s Guide, Release 12* [online].

[11] These estimates are given in the annex.

to continue to participate in the labour market when they are older. On the other hand, during the period of analysis there was an increase in the probability that people would be working at an older age, and this was particularly true of women heads of household. There were two exceptions, however: heads of household who work from home in the manufacturing sector, where the marginal effect on this probability declined from 0.08 to 0.06, and women working in the services sector (with a decrease from 0.28 to 0.26).

Age was associated with a lower probability of being unemployed in 2010 than in 2005, but this effect was not apparent in the case of women. In fact, the unemployment rate tended to increase more sharply for women than for men once the turning point in the age-related trend was reached. If men are seen as the sole breadwinner, then it could be that, as older adults, they are regarded as the ones who should earn the income needed to meet the needs and demands of the family members with whom they live (Millán, 2010).

In terms of commuting costs, the probability that women will work from their homes in the manufacturing sector is negatively correlated —slightly less so in 2010 than in 2005— with an increased degree of urbanization (the marginal effects are -1.40 and -1.35). In the case of men, this variable was significant only in 2010 and to a lesser degree (-0.11). This suggests that female heads of household who live in less urbanized areas attach considerable value to not having to travel to workplaces outside their homes; in some cases, the materials that they need in order to do their work are delivered to them, as is the practice in the clothing industry, while, in others, they are creating indigenous craftwork. Unlike home-based employment in the manufacturing sector, in the two years under study, home-based work in the services industry was primarily practised in more urbanized areas (with populations of over 100,000); this was true both of women (marginal effects of 0.38 and 0.37) and of men (0.40 and 0.32), although there was a decline in 2010 (see tables 6 and 7).

The probability that women heads of household will work outside the home in these areas was greater, particularly in 2010 (3.88 and 7.23). For male heads of household, the effect was positive in 2005 (3.18), but negative in 2010 (-2.41). One possible reason could be that male post-crisis unemployment rates were higher in more urbanized areas. Finally, women living in unurbanized areas were more likely to remain outside the workforce; this was generally true of men in 2005 as well, but not in 2010.

(b) Fixed labour costs

The presence of small children (under 8 years of age) did not influence the probability of female heads of household engaging in home-based work in the manufacturing sector and had very little influence in the case of employment in services (0.32) in 2010. However, the presence of small children did reduce the likelihood that they would engage in employment outside the home by a factor of nearly 20 in 2005 and 2010 (-5.23 and -6.17). The probability that women with small children would be unemployed in the two years under analysis was thus quite high (5.13 and 5.76). For men, the marginal effects were not significant for the manufacturing sector or the services sector. No clear pattern emerges for the effect that this variable has on the probability of working outside the home or remaining outside the workforce altogether, since these values were statistically significant only in 2010 and were negative in one case (-0.73) and positive in the other (0.64). The data therefore confirm that the presence of small children limits women's participation in the labour market, but not necessarily their participation in home-based employment. Unlike García and De Oliveira (1994), we found no evidence that the difficulty of working when one has small children decreases during hard economic times.

In the case of children between the ages of 8 and 12, the results for women were as expected, with the presence of children in this age bracket being compatible with home-based work in the manufacturing and services sectors in both 2005 and 2010; their presence appears to have been an obstacle to women's involvement in work outside the home only in 2005, which suggests that the crisis motivated women to enter the labour market, as their probability of being unemployed declined (-0.90) as a result. The results for men were once again statistically significant. The difference between the higher marginal effect for women and the lower marginal effect for men confirms that women end up shouldering most of the responsibility for childcare.

The effect which involvement in a consensual union or marriage has on the probability of working in or outside the home differed substantially between the sexes. The marginal effects were negative in both years for women heads of household who were married or in a consensual union and were greater in respect of work outside the home (-20.1 and -16.5, on average, respectively) and unemployment (21.5 and 18.0, on average). No correlation was found for women between being single and the probability of home-based employment, but there was a correlation being their single status and the probability that they were working outside the home. Thus, women

TABLE 6

Marginal effects of the estimates for women: 2005-2010

	Home-based work in manufacturing		Home-based work in services		Outside the home		Not in workforce	
	2005	2010	2005	2010	2005	2010	2005	2010
Primary	0.09	0.11	-0.15*	0.37	-3.67***	-4.08***	3.73***	3.60***
Upper-secondary	-0.63**	-0.57***	-0.31	-0.40	9.48***	9.34***	-8.55***	-8.37***
University or postgraduate	-1.27***	-1.17***	-1.0	-1.23***	22.54***	19.33***	-20.26***	-16.93***
Age	0.13***	0.14***	0.28***	0.26***	3.85***	4.00***	-4.26***	-4.40***
Age^2	0.00***	0.00***	0.00***	0.00***	-0.05***	-0.05***	0.05***	0.06***
Place of residence	-1.41***	-1.35***	0.38***	0.37**	3.88***	7.23***	-2.85***	-6.24***
Children aged 7 years or younger	0.05	0.32	0.04**	0.1	-5.23***	-6.17***	5.13***	5.76***
Children aged 8 to 12 years	0.23***	0.38***	0.15	0.28*	-0.65**	0.24	0.27	-0.90**
Consensual union	-0.45**	-0.41*	-1.20***	-0.91***	-16.26***	-16.80***	17.91***	18.13***
Married	0.56***	-0.15***	-1.19***	-0.90***	-20.12***	-20.25***	21.87***	21.30***
Divorced	0.43	-0.3	0.98***	0.08	12.53***	8.57***	-13.94***	-8.36***
Separated	0.45	0.39	1.80***	0.37	11.51***	10.16***	-13.76***	-10.91***
Single	0.32	0.38	1.10**	0.18	14.72***	14.41***	-16.13***	-14.96***
Low-growth state	0.30**	0.43***	-0.03	0.23	1.99***	2.88***	-2.25***	-3.53***
Average-growth state	1.60***	1.61***	1.70***	1.30***	1.15**	1.08**	-4.45***	-3.99***

Source: estimates computed on the basis of information from the National Occupation and Employment Survey and from the National Institute of Statistics and Geography (INEGI).

Note: p*** < 0.01; p** < 0.05; p* < 0.10.

TABLE 7

Marginal effects of the estimates for men: 2005-2010

	Home-based work in manufacturing		Home-based work in services		Outside the home		Not in workforce	
	2005	2010	2005	2010	2005	2010	2005	2010
Primary	0.17	0.04	-0.08	-0.19	-1.45***	-0.91***	1.36***	1.05***
Upper-secondary	-0.43**	-0.24	0.03*	0.08*	-1.63***	1.39***	2.03***	-1.23***
University or postgraduate	-1.43***	-0.97***	0.65***	0.43***	-3.87***	1.38***	4.65***	-0.84**
Age	0.08***	0.06***	0.04**	0.11***	0.29***	0.42***	-0.41***	-0.58***
Age^2	0.00***	0.00*	0.00***	0.00***	-0.01***	-0.01***	0.01***	0.01***
Place of residence	-0.01	-0.11***	0.40**	0.32	3.18***	-2.41***	-3.57***	2.20***
Children aged 7 years or younger	-0.02	0.13	-0.06	-0.04	-0.1	-0.73***	0.18	0.64***
Children aged 8 to 12 years	0.01	0.05	0.06	0.02	-0.4	1.19***	0.33*	-1.26***
Consensual union	0.08	0.35	0.57	0.29	-5.16***	0.07	4.51***	-0.7
Married	0.01	0.46	0.24	-0.07	-1.29	0.65	1.03	-1.03
Divorced	1.83	0.92	0.83	0.52	-5.31***	-3.85	2.65	2.41
Separated	-0.04	1.97	0.81	1.75	-3.27**	-1.43	2.51	-2.29
Single	0.13	-0.26	-0.27	-0.54	1.07	0.92	-0.94	-0.13
Low-growth state	-0.11	-0.06	-0.25*	-0.25**	-1.92***	-0.05	2.27***	0.36
Average-growth state	0.08	0.19*	-0.1	0.03	-3.66***	1.14***	3.69***	-1.37***

Source: estimates computed on the basis of information from the National Occupation and Employment Survey and from the National Institute of Statistics and Geography (INEGI).

Note: p*** < 0.01; p** < 0.05; p* < 0.10.

who do not have a partner are more likely to participate in the labour market. For men, these variables were not statistically significant in most cases, as was to be expected (see tables 6 and 7).

(c) Macroeconomic environment

Finally, the economic environment in which these activities take place —which is represented in the model by GDP growth in the states where these activities are located— has a positive marginal effect on the probability of women heads of household engaging in home-based employment in the manufacturing sector in the slow-growth states and a lesser one on this probability in states with average growth rates. This suggests that, to some extent, home-based employment constitutes a refuge for people who are unable to find other types of work. If we were dealing with outsourcing, there would be no reason for it to be confined to states where the pace of economic growth is slow —in fact, just the opposite would be expected.

In the case of services, this factor was significant for women in states with average growth rates, although the marginal effect was weaker than it was for the manufacturing sector. These patterns were not in evidence for men, however, for whom a negative marginal effect was associated with the probability of working in the services industry from home in low-growth states; this suggests that much of this type of employment is found in high-growth states and that it may take the form of outsourcing or of home offices. For women, the probability of working outside the home is greater in slow-growth states than in average-growth ones. Just the opposite occurs in the case of men, where the probability of working outside the home was negative in slow-growth states in both of the years under study, while it was negative in average-growth states in 2005 but was positive in 2010. Finally, the probability of being unemployed is higher in high-growth states for women and lower in those states for men.

These results tell us something about the effect that adverse economic conditions can have. One possible explanation is that, in a negative macroeconomic environment, it becomes more necessary for women to find employment in order to supplement their households' incomes, either because job opportunities are in scarce supply or because their husbands and/or children have migrated to the United States.[12] On the other hand, the results for male employment suggest that economic growth boosts outsourcing and the demand for consultancies and that home-based work does not necessarily serve as a refuge from a shortfall of job opportunities.

[12] Six of the 12 low-growth states belong to the group of states which have the highest migration rates.

V
Final considerations

While forms of employment that date back to the industrial revolution still exist, including the exploitative sweatshops discussed by Marx in *Das Kapital*, the fact remains that workplaces and work environments are undergoing major changes as remote work, home offices and other virtual options become more and more common. This study has shown how complex a form of employment home-based work is and how many different factors are involved. The reasons for its expansion are not simply the existence of a growing demand for flexible, lower-cost, time- and space-saving forms of labour or the development of information technologies that make it easier to monitor home-based work. Another factor —especially in relation to women— that must be considered has to do with patriarchal gender relations that limit women's ability to take part in the labour market on an equal footing with men.

This study's findings show that there are major gender-based differences in the factors underlying the decision to work from home, to work outside the home or to remain outside the workforce. In other words, it provides further evidence that the labour market is not gender-neutral, since there are informal cultural norms that result in gender segregation in certain sectors of the economy and certain types of employment, in addition to the vertical segregation discussed in the feminist economic literature.

The differentials between male and female heads of household stand out clearly, as was to be expected, and can be attributed to the presence of children, which increases the probability that women will work from

home, either in the manufacturing sector or in the services industry, and decreases the probability that they will work outside the home. Another way of wording this is to say that home-based employment is functional in the presence of children and hinders women's participation in the non-home-based labour market. This points up the shortage of schools and childcare facilities that keep hours that would allow women to have a wider range of employment options. Furthermore, it had been expected that, with the increase in the female labour-force participation rate seen over the past two decades, marriage would cease to be an obstacle to women's employment; however, this study's findings regarding the negative correlation existing between marriage or involvement in a consensual union and employment in or outside the home suggest that this is still far from being the case. Single, separated or divorced women are the ones who are highly likely to be part of the workforce.

This confirms Kantor's (2000) assertion that home-based employment is a way for women to work and earn an income without challenging the patriarchal ideology of today's society. By contrast, these variables have no significant influence on men's decisions. Working from home gives women an opportunity to participate in the labour market under flexible conditions in terms of working hours and location, while enables them to combine their employment with domestic tasks. In men's case, there are other more important factors underlying their employment decisions. These findings confirm the conclusions reached by Rani and Unni (2009) and Edwards and Field-Hendrey (2002).

With regard to the gender-based segmentation of the spatial distribution of home-based work in the manufacturing sector, the high probabilities that such employment is concentrated in less urbanized and rural areas (only in the case of women) suggests, in addition, that a larger percentage of these female workers are engaged in the production of indigenous craftwork. This subject also calls for further research. It is noteworthy that the probability of being employed outside the home in highly urbanized areas was negative in 2010 for men, which indicates that the job crisis had a greater impact on men in urban areas.

The study also corroborates the finding that women's reservation wage for home-based work is quite low in both the manufacturing and services sectors and that the probability that they will engage in home-based employment is greater when they have not completed their secondary education. This is also true of men working in the manufacturing sector, but not in the services industry. In the latter sector, the probability of male employment is high among men having professional and/or postgraduate degrees. It cannot be determined whether this is a reflection of the tendency of health professionals to work out of their homes, as they traditionally have done, or whether it is because there are more professionals who became unemployed and have started up businesses in their homes or because more professionals are taking advantage of new ways of working made possible by information technologies. This question raises another: Why do women professionals overwhelmingly tend to take part in the non-home-based workforce? This remains an open line of research.

Finally, if GDP growth can be taken as an acceptable indicator of economic conditions, then the results show that both men and women are more likely to engage in home-based employment in states with an average economic growth rate. One surprising result, however, was that women are more likely to participate in the labour market in any capacity in states where economic growth is low, whereas just the opposite is true of men. This may be attributable to the fact that women are in greater need of going out to work in order to supplement their households' incomes because job opportunities are lacking and/or because their husbands or children have migrated to the United States. On the other hand, the results for men suggest that economic growth spurs outsourcing and the demand for consultancies and that home-based work is a supplementary mechanism rather than a palliative measure for dealing with a tight job market.

The results obtained regarding non-home-based employment point up the difficulties faced by married women with children in working outside the home and underscore the fact that the public policy measures now in place have not succeeded in counteracting those difficulties.

The study indicates that the crisis had a stronger impact on the working population and particularly on home-based employment in the manufacturing sector, which fell off sharply. This may have been partially attributable to a shrinking demand for outsourced products such as furniture, clothing and metal products. This downturn was especially notable in the case of heads of household, many of whom moved into home-based employment in the services industry.

As for other factors that may help to account for decisions by male and female heads of household to work from home, the tendency for home-based employment participation rates to increase in older age groups suggests that the crisis-driven increase in unemployment drove many people into self-employment.

The responsibilities associated with being in an intimate relationship continued to be an obstacle to employment. However, our findings indicate that they were less of an impediment in 2010, which indicates that the impact of the crisis on employment and on income levels prompted women to consider joining the workforce. The results also point up the difficulty that heads of household had in finding work in urban areas in 2010.

It is clear that home-based work has the advantage of serving as a means of earning an income. However, our results also show that wage levels for this form of employment are low. This corroborates the position taken by Atasü Topçuoglu (2005) and Hartmann (1979) regarding women's position within the labour market. These authors assert that the low level of women's wages obliges them to be dependent on their husbands, which means, in turn, that they are in charge of the housework. By the same token, their household duties weaken their position in the labour market, which translates into lower wages for them than for men. As also pointed out by Kabeer, Mahmud and Tasneem (2011), these wage levels are not necessarily high enough to empower women. One promising line for future research would be an examination of this issue in relation to home-based work in Mexico.

The findings of this study indicate that home-based work will continue to be an important form of employment for women and, increasingly, for men as well. Hence the need to explore possible legislative means of recognizing the rights of informal-sector workers and social policy options that would improve home-based working conditions by providing access to health care, social security coverage and training programmes. Thought could also be given to revamping social housing policies that have not taken the requirements of home-based employment into consideration.

ANNEX

TABLE A.1

Results of the regressions: women

	2005 No. of observations: 78 279 Pseudo R^2 9.3%, Prob. Wald 0.00			2010 No. of observations: 75 950 Pseudo R^2 9.3%, Prob. Wald 0.00		
	Home-based work		Work outside home	Home-based work		Work outside home
	Manufacturing	Services		Manufacturing	Services	
Primary	-0.013	-0.104**	-0.170***	-0.001	0.053	-0.174***
	(0.055)	(0.047)	(0.020)	(0.059)	(0.050)	(0.021)
Upper-secondary	-0.243**	0.060	0.403***	-0.210***	0.021	0.384***
	(0.114)	(0.076)	(0.030)	(0.102)	(0.078)	(0.027)
University and postgraduate	-0.481***	0.063	0.947***	-0.471***	-0.123***	0.784***
	(0.095)	(0.060)	(0.023)	(0.096)	(0.067)	(0.023)
Age	0.138***	0.149***	0.184***	0.155***	0.158***	0.184***
	(0.014)	(0.012)	(0.006)	(0.015)	(0.013)	(0.006)
Age^2	-0.002***	-0.002***	-0.002***	-0.002***	-0.002***	-0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Place of residence	-0.706***	0.152***	0.162***	-0.639***	0.224**	0.303***
	(0.053)	(0.042)	(0.018)	(0.055)	(0.045)	(0.017)
Children aged 7 years or younger	-0.058	-0.072**	-0.240***	0.074	-0.067	-0.269***
	(0.039)	(0.031)	(0.013)	(0.071)	(0.063)	(0.022)
Children aged 8 to 12 years	0.120***	0.037	-0.024**	0.215***	0.103*	0.022**
	(0.033)	(0.028)	(0.012)	(0.058)	(0.050)	(0.019)
Consensual union	-0.532**	-0.628***	-0.777***	-0.541*	-0.602***	-0.766***
	(0.125)	(0.105)	(0.046)	(0.136)	(0.110)	(0.046)
Married	-0.657***	-0.690***	-0.957***	-0.451***	-0.651***	-0.914***
	(0.105)	(0.088)	(0.041)	(0.115)	(0.093)	(0.041)
Divorced	0.468	0.502***	0.577***	-0.022	0.181	0.364***
	(0.202)	(0.150)	(0.071)	(0.244)	(0.163)	(0.068)***
Separated	0.473	0.665***	0.551***	0.402	0.317	0.452
	(0.140)	(0.110)	(0.055)	(0.153)	(0.120)	(0.054)
Single	0.433	0.570**	0.702***	0.467	0.314	0.647***
	(0.171)	(0.130)	(0.063)	(0.169)	(0.136)	(0.059)
	(0.095)	(0.060)	(0.023)	(0.096)	(0.067)	(0.023)
Low-growth state	0.193**	0.028	0.096***	0.289***	0.134	0.138***
	(0.080)	(0.057)	(0.022)	(0.078)	(0.059)	(0.021)
Average-growth state	0.838***	0.521***	0.108***	0.847***	0.458***	0.099**
	(0.073)	(0.052)	(0.022)	(0.073)	(0.056)	(0.021)
Constant	-5.632	-5.391	-3.183	-6.351	-5.967	-3.169
	(0.331)	(0.271)	(0.127)	(0.358)	(0.304)	(0.124)

Source: estimates computed on the basis of information from the National Occupation and Employment Survey and from the National Institute of Statistics and Geography (INEGI).

Note: p*** < 0.01; p** < 0.05.

TABLE A.2

Results of the regressions: men

	2005 No. of observations: 64 116 Pseudo R2 9.3%, Prob. Wald 0.00			2010 No. of observations: 59 342 Pseudo R2 9.3%, Prob. Wald 0.00		
	Home-based work		Work outside home	Home-based work		Work outside home
	Manufacturing	Services		Manufacturing	Services	
Primary	0.118	-0.088	-0.145***	-0.065	-0.247	-0.116***
	(0.078)	(0.102)	(0.031)	(0.094)	(0.096)	(0.034)
Upper-secondary	-0.358**	0.002*	-0.169***	-0.121**	0.187*	0.148***
	(0.123)	(0.140)	(0.039)	(0.135)	(0.124)	(0.050)
University and postgraduate	-1.174***	0.536***	-0.399***	-1.145***	0.373***	0.104***
	(0.131)	(0.101)	(0.035)	(0.156)	(0.100)	(0.039)
Age	0.066***	0.042***	0.030***	0.113***	0.139***	0.065***
	(0.016)	(0.018)	(0.007)	(0.023)	(0.02)	(0.008)
Age^2	-0.001***	0.000**	-0.001***	-0.002*	-0.002***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Place of residence	0.036	0.403**	0.324***	-0.328	0.003	-0.253***
	(0.071)	(0.087)	(0.027)	(0.0845)	(0.082)	(0.029)
Children aged 7 years or younger	-0.020	-0.056	-0.011	0.061	-0.092	-0.074***
	(0.051)	(0.065)	(0.017)	(0.066)	(0.063)	(0.027)
Children aged 8 to 12 years	0.007	0.052	-0.040	0.180	0.143***	0.143***
	(0.046)	(0.052)	(0.017)	(0.064)	(0.060)	(0.026)
Consensual union	0.013	0.390	-0.607***	0.402	0.283	0.073
	(0.276)	(0.306)	(0.137)	(0.356)	(0.272)	(0.081)
Married	0.000	0.209	-0.127	0.541	0.054	0.113
	(0.258)	(0.288)	(0.132)	(0.341)	(0.259)	(0.072)
Divorced	0.862	0.536	-0.670***	0.413	0.094	-0.266
	(0.486)	(0.581)	(0.322)	(0.679)	(0.506)	(0.182)
Separated	-0.063	0.525	-0.372**	1.331	1.086	0.250
	(0.459)	(0.464)	(0.207)	(0.453)	(0.359)	(0.152)
Single	0.111	-0.232	0.106	-0.268	-0.477	0.023
	(0.565)	(0.756)***	(0.211)	(1.072)	(0.764)	(0.224)
Low-growth state	-0.113	-0.253*	-0.197**	-0.096	-0.223**	-0.038
	(0.090)	(0.094)	(0.030)	(0.110)	(0.095)	(0.035)
Average-growth state	0.018	-0.137	-0.369***	0.324*	0.165	0.155***
	(0.087)	(0.091)	(0.031)	(0.106)	(0.091)	(0.035)
Constant	-5.348	-5.926	-1.289	-4.053	-4.405	2.307
	(0.476)	(0.546)	(0.195)	(0.651)	(0.576)	(0.218)

Source: estimates computed on the basis of information from the National Occupation and Employment Survey and from the National Institute of Statistics and Geography (INEGI).

Note: p*** < 0.01; p** < 0.05; p* < 0.10.

Bibliography

Anderson, P.M. and P.B. Levine (1999), "Child care and mothers' employment decisions", *JCPR Working Papers*, No. 64, Chicago, Northwestern University/University of Chicago Joint Center for Poverty Research.

Aroche, F. and M.E. Cardero (2007), "Cambio estructural comandado por apertura comercial. El caso de la economía mexicana", *Estudios Económicos*, vol. 23, No. 2, Mexico City, Centro de Estudios Económicos, El Colegio de México.

Atasü Topçuoglu, R. (2005), "Home-based Work and Informal Sector in the Period of Globalisation: An Analysis Through Capitalism and Patriachy. The Case of Turkey", thesis, Ankara, The Graduate School of Social Sciences, Middle East Technical University.

Benería, L. (1981), "Gender and the dynamics of subcontracting in Mexico City", *Gender in the Work Place*, C. Brown and J.A. Pechman (eds.), Washington, D.C., The Brookings Institution.

Benería, L. and M. Roldan (1992), *Las encrucijadas de clase y género. Trabajo a domicilio, subcontratación y dinámica de la unidad doméstica en la Ciudad de México*, Mexico City, El Colegio de México.

_____ (1987), *The Crossroads of Class and Gender: Industrial Homework, Subcontracting, and Household Dynamics in Mexico City*, Chicago, The University of Chicago Press.

Benería, L. and others (2000), "Globalization and gender", *Feminist Economics*, vol. 6, No. 3, Taylor & Francis.

Bover, O. and M. Arellano (1995), "Female labour force participation in the 1980s: the case of Spain", *Investigaciones Económicas*, vol. 19, No. 2, Madrid, SEPI Foundation.

Çağatay, N. (2005), "Gender inequalities and international trade: a theoretical reconsideration", *Seminarios y Talleres series*, No. 136, Montevideo, Centro Interdisciplinary Centre for Development Studies.

Cardero, M.E. and G. Espinosa (2013), "Empleo, empleo informal de hombres y mujeres e indicadores de pobreza", *México, mujeres y economía*, Mexico City, Faculty of Economics, National Autonomous University of Mexico (UNAM).

Carr, M., A.M. Chen and J. Tate (2000), "Globalization and home-based workers", *Feminist Economics*, vol. 6, No. 3, Taylor & Francis.

Cerda, M. (2011), "El 'home office' gana terreno en México", CNN Expansión [online] http://www.cnnexpansion.com/opinion/2011/07/25/el-home-office-gana-terreno-en-mexico.

De Oliveira, O. and M. Eternod (2000), "La fuerza de trabajo en México: Un siglo de cambios", *Cien años de demografía en México*, J. Gómez de León and C. Rabell (eds.), Mexico City, Fondo de Cultura Económica.

Dedeoglu, S. (2010), "Visible hands - invisible women: garment production in Turkey", *Feminist Economics*, vol. 16, No. 4, Taylor & Francis.

Edwards, L. and E. Field-Hendrey (2002), "Home-based work and women's labor force decisions", *Journal of Labor Eoconomics*, vol. 20, No. 1, Chicago, University of Chicago Press.

Elson, D. (1999), "Labor markets as gendered institutions: equality, efficiency and empowerment issues", *World Development*, vol. 27, No. 3, Amsterdam, Elsevier.

García, B. (2001), "Reestructuración económica y feminización del mercado de trabajo en México", *Papeles de Población*, vol. 7, No. 27, Toluca, Autonomous University of the State of Mexico.

García, B. and E. Pacheco (2000), "Esposa, hijos e hijas en el mercado de trabajo de la Ciudad de México en 1995", *Estudios Demográficos y Urbanos*, vol. 15, No. 1, Mexico City, Center for Demographic, Urban and Environmental Studies, El Colegio de México.

García, B. and O. De Oliveira (1994), *Trabajo femenino y vida familiar en México*, Mexico City, El Colegio de México.

Gereffi, G., J. Humphrey and T. Sturgeon (2005), "The governance of global value chains", *Review of International Political Economy*, vol. 12, No. 1, Taylor & Francis.

Hartmann, H. (1979), "The unhappy marriage of Marxism and feminism: towards a more progressive union", *Capital and Class*, vol. 3, No. 2, Sage.

Huber, P.J. (1967), "The behavior of maximum likelihood estimates under nonstandard conditions", *Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability*, Berkeley, University of California Press.

ILO (International Labour Office) (2005), "Economía informal en las Américas: Situación actual, prioridades de políticas y buenas prácticas", "Principios y derechos en el trabajo en el contexto de la XIII Conferencia Interamericana de Ministros de Trabajo de la OEA" project, Lima.

Juárez, H. (2004), *Allá donde viven los más pobres. Cadenas globales y regiones productoras en la industria del vestido*, Mexico City, Universidad Obrera de México.

Kabeer, N., S. Mahmud and S. Tasneem (2011), "Does paid work provide a pathway to women´s empowerment? Empirical findings from Bangladesh", *IDS Working Paper*, vol. 2011, No. 375, Brighton, Institute of Development Studies.

Kantor, P. (2003), "Women´s empowerment through home-based work: evidence from India", *Development and Change*, vol. 34, No. 3, Wiley.

_____ (2000), *Gender Differentials in Microenterprise Success for Homebased Garment Makers in Ahmedabad*, Chapel Hill, University of North Carolina.

Knaul, F. and S.W. Parker (1997), "Estrategias de empleo y cuidado de los niños entre mujeres mexicanas con hijos pequeños", paper presented at the II Seminario de investigación laboral: Participación de la mujer en el mercado laboral, Mexico City, Secretariat of Labour and Social Security.

Langlois, R. (1995), "The vanishing hand: the changing dynamics of industrial capitalism", *Industrial and Corporate Change*, vol. 12, No. 2, Oxford, Oxford University Press.

López, E.S. (2005), "Trabajo a domicilio, pequeños talleres y precariedad laboral en Piedra Negras y Torreón", Mexico City, Instituto de Estudios del Trabajo.

Louw, E. and P. De Vries (2002), "Working at home: the Dutch property dimension", *Planning Practice and Research*, vol. 17, No. 1, Taylor & Francis.

Maldonado, V. and T. Rendón (2004), "Vínculos entre trabajo doméstico, segregación ocupacional y diferencias de ingreso por sexo en el México actual", Mexico City, Instituto de Estudios del Trabajo.

Marx, Karl (1967), *Capital*, Mexico City, Fondo de Cultura Económica.

Millán, León Beatriz (2010), "Factores asociados a la participación laboral de los adultos mayores mexiquenses", *Papeles de Población*, vol. 16, No. 64, Toluca, Autonomous University of the State of Mexico.

Ocampo, J.A. and J. Ros (2011), "Raul Prebisch y la agenda del desarrollo en los albores del siglo XXI", paper presented at the Seminar "La teoría del desarrollo en los albores del siglo XXI", Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC).

Pearson, R. (2004), "Towards the re-politicization of feminist analysis of the global economy", *International Feminist Journal of Politics*, vol. 6, No. 4, Taylor & Francis.

Piore, M.J. and C.F. Sabel (1984), *The Second Industrial Divide*, New York, Basic Books.

Rani Uma and Jeemol Unni (2009), "Do economic reforms influence home-based work? Evidence from India", *Feminist Economics*, vol. 15, No. 3, Taylor & Francis.

Rendón, G.T. and C. Salas (2000), *Segregación y diferencias salariales por género. Hipótesis y evaluación empírica*, Mexico City, Secretariat of Labour and Social Security.

Thompson, E.P. (1963), *The Making of the English Working Class*, London, V. Gollancz.

Tokman, V.E. (2008), "Flexiguridad con informalidad: Opciones y restricciones", *Macroeconomía del Desarrollo series*, No. 70 (LC/L.2973-P), Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC). United Nations publication, Sales No. S.08.II.G.83.

White, H. (1982), "Maximum likelihood estimation of misspecified models", *Econometrica*, vol. 50, No. 1, New York, The Econometric Society.

The structural heterogeneity of family farming in Brazil

José Eustáquio Ribeiro Vieira Filho

ABSTRACT

Regional and productive inequality may stem from the agricultural modernization process, in which some agents are able to incorporate and absorb technological content, while others are excluded, not only from the innovative organizational environment, but also from learning processes and the dissemination of new production techniques and knowledge. This paper analyses family farming, by making comparisons in regional terms and by groups of producers using high, medium and low technology. It also calculates the productive inequality index (Gini coefficient of gross income) of the north, north-east, centre-west, south-east and south regions. In view of the regional differentiation, the size of enterprises and the various levels of technological growth, public policies should focus on reducing the disparities that hamper the dissemination of new knowledge and productivity growth among economic agents, leading to greater productive inclusion.

JEL CLASSIFICATION Q16, O3, O4

KEYWORDS Agriculture, small farms, family, productivity, measurement, evaluation, agricultural development, Brazil

AUTHOR José Eustáquio Ribeiro Vieira Filho is a research officer at the Institute of Applied Economic Research (IPEA). jose.vieira@ipea.gov.br

I
Introduction

The agricultural modernization process can lead to regional and productive inequality, because some economic agents are able to incorporate and absorb technological content, while others remain excluded from the innovative organizational environment, and from learning processes and the dissemination of new techniques and productive knowledge.

Incorrect public policies distort relative prices and hinder access to technology and credit, thereby discouraging the entry of producers who have fallen behind in the technology race. Because climatic and regional factors cause productive differences in various types of crop, less innovative producers become more vulnerable to exogenous fluctuations in production and to factors that are specific to their location.

As noted by Vieira Filho and Silveira (2011), producers adopt technological inputs for the purpose of increasing productivity and reducing relative production costs. Nonetheless, in some situations farmers have no incentive to adopt new techniques and knowledge, since the higher cost involved in incorporating a new technology is not offset by the expected yield. In most cases, farmers who are lagging behind in technological content are in a poverty situation, so they need other sources of nonfarm income to survive.

Apart from the economic issues involved in deciding what to produce and what resources to use, the producer's investment decision has two basic functions: the first refers to the generation of technological innovation and the second to the expansion of capacity to absorb new knowledge and technologies (Evenson and Kislev, 1973; Cohen and Levinthal, 1989; Vieira Filho and Silveira, 2011). Importantly, the better the organizational environment in which production takes place —which can stimulate the technological diffusion process— the greater the cumulative knowledge among economic agents and the better the absorption of external technology.

The empirical analysis of family farming in Brazil's southern region will verify that point. Traditionally, this is the country's most dynamic region and reports the best economic development indicators —an achievement that both requires and also reflects the adequate institutional and technological base that has been developed over time. The same productive environment that fosters innovation does not exist in the north-east. A better understanding of the structural heterogeneity of family farming is needed, with a view to proposing inclusive production solutions that can benefit the regions that are least advanced in this process.

The limited nature of technical assistance and rural extension services compromises the organizational environment, which in turn impairs the exchange of experiences between economic agents and consequently slows down the technology-transfer process. The more structured the productive chain, the more easily knowledge can be disseminated and absorbed by productive agents. In more developed regions, available resources are used more efficiently, and this generates higher land or labour productivity thanks to lower production costs.

Some agricultural crops are integrated into modern value chains that encompass the private sector and public research organizations (universities and rural extension services). Others, though, are excluded from investments in research and development (R&D), so their participation in production lines is limited and they have little incentive for technological development.

According to ECLAC (2010), the discussion of structural heterogeneity reveals development disparities in Latin America with respect to the central countries, especially in terms of regional, sectoral and intra-sectoral labour productivity. In the case of agriculture, Pinto (1970) estimates that labour productivity in crop farming included in the "modern" sector is about 14 times higher than that prevailing in the "primitive" sector, noting also that both modern and outdated production arrangements coexist.

Following the methodology presented by Vieira Filho, Santos and Fornazier (2012), this study analyzes the structural heterogeneity of family farming in Brazil, classifying farms in technology groups and according to productive concentration.[1] The aim is to investigate whether the process of technological innovation in

☐ The author is grateful for suggestions made by the anonymous referee, and also thanks colleagues who participated in the ECLAC/IPEA project "Structural heterogeneity in the Brazilian economy" and contributed to the development of this research. Nonetheless, they are not responsible for any errors or omissions contained in this document.

[1] This study complements the analyses made in Buainain (2007) by updating the data on family farming reported by the 2006 agricultural census, which was published in only 2009.

family farming, in conjunction with regional specifics, contributes to greater productive inequality, which, when it is structural, makes it unviable to include farmers that are on the margins of the technological dynamic. According to the basic hypothesis, technological innovations driven by institutional changes, in conjunction with regional and productive specifics, contribute to greater inequality in agricultural production and growth, favouring dynamic and innovative organizational zones, while regions that are excluded from modern production stagnate.

This article is divided into three sections, following this brief introduction. Section II discusses the analytical method, defining the subdivision of technological groups and presenting the calculation of the productive inequality index (PII). Section III discusses the empirical results; and section IV sets forth the final considerations.

II
Methodology

1. Family farming

The aim of this study is to investigate the smallest family-run farms or enterprises, which account for the vast majority of rural producers (84% of all establishments). This group is also considered the most vulnerable in terms of access to technology, although this is not always true, as will be seen in the analyses. While the term "family farming" is not entirely appropriate, the analysis was restricted to this group because there is a legal criterion for the distinction which defines public policies to promote the sector.

Pursuant to the legal guidelines for agriculture policy-making in Brazil (Brasil, 2006), a rural family entrepreneur is defined as someone who engages in activities in the rural area and also satisfies the following requirements: (i) does not legally own a land area larger than four fiscal modules; (ii) predominantly uses family labour in the economic activities of the establishment; (iii) has a family income that originates mainly in economic activities linked to the establishment or enterprise, and (iv) operates the establishment or enterprise with his/her family.

Size, measured in terms of fiscal modules, is obtained by dividing the total area of the rural property by the fiscal module for each municipality, which is defined in hectares (ha) and takes the following into account: (i) the type of farm operation prevalent in the municipality; (ii) income earned from the operation in question; and (iii) the other operations in the municipality which, though not predominant, are considered on the basis of income or the area used and the concept of family property. It is calculated to determine the size of rural properties and classify them as smallholdings, or as small, medium, and large properties for public-policy purposes. In some cases there are farmers who own more than 100 hectares of land, which, for international comparison purposes, are classified as large rural producers. In other cases, as there is enormous heterogeneity, technology access is highly differentiated. Accordingly, the standardization of public policies could create distortions in the allocation of scarce and limited resources.

The methodology adopted in this paper seeks to classify family farms in groups according to their technological efficiency and the organization of the institutional environment in which production takes place; and to verify how productive concentration occurs in the farms in that classification. There is no doubt that massive dissemination of technology can help eliminate rural poverty, increase productivity and deconcentrate income. For that purpose, the study uses data from the 2006 Agricultural Census conducted by the Brazilian Institute of Geography and Statistics (IBGE).

2. Methodological taxonomy

To gain a better understanding of the structural heterogeneity of production in Brazilian agriculture, Vieira Filho and Santos (2011) constructed a taxonomy of high, medium and low technological and institutional efficiency, based on both economic and qualitative criteria. The economic criteria are linked to total factor productivity (TFP), while the qualitative refer to the level of technology and institutional organization of the economic agents (high and low technological and institutional content: HT and LT, respectively).

Under the economic criterion, TFP was calculated because it can be interpreted as the value of gross income generated by each monetary unit of cost (Alves Souza and Oliveira, 2006). Both the production function

chosen and the input mix affect this measure. Total factor productivity can be measured by dividing gross income by total production cost; and net income is gross income minus total cost. Thus, a TFP of less than 1 means that gross income is less than total cost, which therefore represents a negative net income. The reverse is also true: when the TFP is greater than 1, net income is positive.

The analysis of TFP cannot be decoupled from a temporal analysis, since annual fluctuations in production can be caused by exogenous shocks such as climate changes, crop failures, the emergence of new pests or changes in international price levels. As the analysis only covered the year 2006, however, qualitative criteria were added to the study.

For this purpose, Vieira Filho and Santos (2011) formulated 22 yes/no questions on the use of different technologies and the agents' degree of institutional organization, such as whether the establishment makes use of fertilizers, products to chemically correct the soil, pesticides, tractors, technical assistance, financing, cooperativism, the National Register of Legal Entities, pest control and storage units, among others. To divide the properties into high and low technological and institutional content, the proportion of establishments was graphed according to the frequency with which they responded "yes" to the questions posed —for example, establishments that responded in the affirmative once; those responded "yes" twice, and so on up to the 22nd question. Values that exceed the average of the distribution were classified as HT and values below average as LT.

By blending the economic and qualitative criteria, a taxonomy was defined for the technological efficiency of productive establishments. Table 1 shows the resulting technological-efficiency groupings. It is worth noting that the taxonomy serves only to schematize the groups of establishments, and several derived variables will need to be calculated to compare the different groups. Data are available to quantify gross income, total cost, investment (capital, labour and technologies), the value of capital, net income and labour productivity.

To gain a better understanding of the importance of technology in agriculture, Vieira Filho, Campos and Ferreira (2005) use a Leontief production function with fixed proportions of two types of capital. The output of agricultural activity in period i is equal to the minimum ratio between capital employed (fixed capital Kf_{it}; or variable capital Kv_{it}) and their technical coefficients α and β. Then: $Kf_{it} = \alpha.Q_{it}$ and $Kv_{it} = \beta.Q_{it}$. So production Q_{it} is limited to the maximum given by the minimum combination of those two factors. If $Kf_{it}/\alpha < Kv_{it}/\beta$, there will be a surplus of the second factor. If the opposite occurs, $Kf_{it}/\alpha > Kv_{it}/\beta$, there will be surplus of fixed capital. Thus, the production function is defined as follows:

$$Q_{it} = \min\left\{\frac{Kf_{it}}{\alpha}; \frac{Kv_{it}}{\beta}\right\} \quad (1)$$

The relations between fixed capital and variable capital is given by a constant, with $Kv_{it}/Kf_{it} = z_{it}$. Moreover $(Kv_{it}/\beta) / (Kf_{it}/\alpha) = n$; so $(Kv_{it}/\beta).(\alpha/Kf_{it}) = n$. Thus, making the substitution, the result is $n.(\beta/\alpha) = z_{it}$. The parameters ($\alpha$ and β) are determined at the outset, with n a constant defining proportionality between the different types of capital. In the initial state of the system, z_{it} is given. Thus $\alpha = 1/Af_{it}$ and $\beta = 1/Av_{it}$, where Af_{it} is the productivity of fixed capital (represented by labour-saving technologies), and Av_{it} is the productivity of variable capital (represented by land -saving technologies).

Agricultural growth depends on capital growth. To reconcile the combination of land-saving and labour-saving technologies, fixed capital growth is restricted to the growth of variable capital, and vice versa. To quantify the land-saving technologies (linked to variable capital), a proxy variable was formed from the sum of expenditures on seeds and seedlings, products to correct soil chemistry, fertilizers, agrochemicals, animal feed and

TABLE 1

Taxonomy by technological-efficiency group

Economic criterion – economic efficiency	TFP > 1		TFP < 1	
Qualitative criterion – technological/institutional content	HT	LT	HT	LT
Technological groups	1st group	2nd group	3rd group	4th group
Taxonomy – technological efficiency	High	Medium		Low

Source: prepared by the author.

TFP: total factor productivity.
HT: high technological and institutional content.
LT: low technological and institutional content.

veterinary medicines. Labour-saving technologies (related to fixed capital) were represented by an estimate of the value of vehicles, tractors, machinery and implements (with a depreciation of 6% and an average lifespan of 15 years), plus machinery rental. This makes clear the importance of quantifying technologies in agricultural activities where different productive inputs are combined.

3. Productive inequality index (PII)

Labour productivity, measured by dividing value added by persons employed in each productive establishment, is the reference variable that quantifies structural heterogeneity in ECLAC studies.[2] The greater the dispersion of labour productivity, the greater the diversity of production and probably also the greater the structural inequalities. In order to visualize the system's productive inequalities, the minimum wage equivalent (MWE) was specified as gross production value (GPV) per month, divided by the monthly minimum wage. Thus, an attempt was made to stratify gross income (value of production, including consumption) in four income brackets defined by MWE:

(1) $0 < \text{MWE} <= 2$ times the minimum wage or "extreme poverty";
(2) $2 < \text{MWE} <= 10$ minimum monthly wages or "low income";
(3) $10 < \text{MWE} <= 200$ minimum monthly wages or "middle income", and
(4) MWE > 200 times the minimum wage or "high income".

Steps were then taken to calculate the Gini coefficient[3] of gross income for each group in the farm taxonomy based on technological efficiency, and to compare Brazil's different agricultural regions. As productive inequality is calculated between farms, it was decided to call this the Gini productive inequality index (PII), as noted by Vieira Filho, Santos and Fornazier (2012). Moreover, the PII was calculated for a discrete data sample.

Lastly, a comparison is made between the PII and labour productivity measured as the value added per person employed (VA/PE), both being indicators standardized (by subtracting the mean and dividing by the standard deviation). In this comparison four categories are identified, as shown in the quadrants of figure 1:

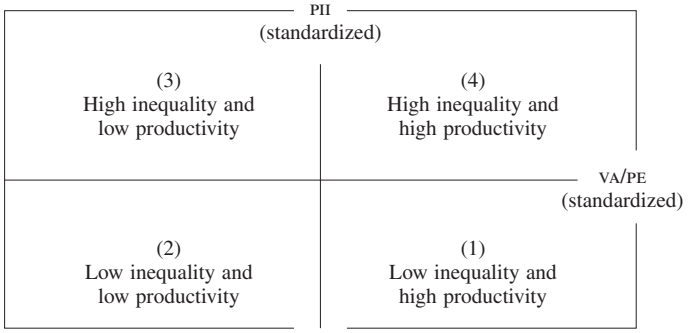
(1) High productivity with low inequality (best-case scenario, or homogenization of wealth);
(2) Low inequality and low productivity (worst-case scenario, or socialization of poverty);
(3) High inequality and low productivity (heterogeneity in poverty), and
(4) High inequality and high productivity (heterogeneity in wealth).

[2] For comparison, see Pinto (1970); Nohlen and Sturm (1982); Sunkel and Infante (2009), and ECLAC (2010). Moreover, with the publication of the study by the Institute of Applied Economic Research (IPEA, 2011) a technical cooperation agreement was established between IPEA and ECLAC, in the framework of the inclusive development project. A line of research was created in IPEA to study the structural heterogeneity of the Brazilian economy. Thus, attempts were made to expand and enhance the debate and discussion on policies, tools, and strategies for inclusive development in Brazil, in particular analysing labour productivity in the various sectors of economic activity.

[3] Hoffmann (1998) contains a methodological explanation of inequality measures and the calculation of the Gini coefficient for a discrete data sample.

FIGURE 1

Productive inequality compared to labour productivity



Source: prepared by the author.

PII: productive inequality index.
VA/PE: value added per population employed.

III
Analysis of results

This section will discuss the findings in relation to the structure of family farming. The various studies undertaken previously by Vieira Filho and Santos (2011); Fornazier and Vieira Filho (2012), Vieira Filho, Santos and Fornazier (2012), and IPEA (2011) show that the technological taxonomy, as described in the methodology, displays a high degree of heterogeneity in both family farming and non-family (commercial) farming. As there are groups of high technological efficiency in both types of farming, the subdivision defined by Law No. 11.326 (Brasil, 2006), which sets guidelines for formulating national policy on family farming, is inappropriate for separating groups of producers that require differentiated public policies. If the level of heterogeneity in the family farming is very high, standardized policies cannot be adopted for different levels;[4] each group of producers with similar production systems needs to make specific demands. The aim of the empirical analysis is to test and evaluate the structural heterogeneity that exists in family farming, in terms of income inequality and technological patterns.

Even when the Brazilian agricultural sector is considered more generally, one can clearly discern the existence of several structural flaws that promote sectoral and regional heterogeneity. According to the 2009 National Household Survey, the agriculture sector employed 11% of the 82.6 million employed persons in Brazil who declared a positive income. Nonetheless, according to Hoffmann (2011), when unpaid workers are included, which is a typical situation among small-scale farmers, its share of all employed persons rises to 17%.

Table 2 presents data from the National Household Survey on the employed population by sector and region,[5] and shows that the agriculture sector in general tends to employ older people with a lower education level than is the case in industry and services. Also, agricultural income is more unequally distributed than in industry, according to the Gini coefficient, although similarly to the service sector. Average income in the agricultural sector is equivalent to 53% of the level in the services sector. In regional terms, the average income in the centre-west region is more than three times that recorded in the north-east —a region that encompasses nearly half (43.2%) of the population employed in agriculture sector with the lowest level of schooling (almost half of this in São Paulo). The average age of agricultural workers is higher than in the industrial and service sectors in all regions of the country, although the average age is highest in the south. In terms of income distribution, the centre-west and south regions are more unequal than in the north, north-east and south-east, São Paulo being the state with the lowest rate of income inequality.

Figure 2 makes a broad comparison between family farming and commercial agriculture, through production-related indicators. The figures show that 84% of establishments are classified as family farms, and these generate just 34% of gross income. This disparity could be explained by the low level of spending on technological resources and essentially because GPV is concentrated in a small number of properties and crops (such as soybeans, maize, sugarcane and cotton).[6] Farms engaging in commercial agriculture account for 16% of the population, and are those that invest most in capital, labour and technology (both land- and labour-saving). Commercial agriculture generates 66% of gross income and uses 76% of available land. In terms of labour productivity, 74% of the population engaged in agriculture work on family farms, which produce only 34% of gross income. Although family farms are labour-intensive, a more in-depth empirical analysis reveals low labour productivity, which is related to the problem of structural heterogeneity, albeit differentiated between regions.

[4] Instead of facilitating it, the homogenization underlying the expression "family farming" seriously restricts government action by hindering the formulation of policies to promote small-scale market production. See Navarro and Pedroso (2011) for a critical and sociological evaluation of the concept of family farming in Brazil.

[5] It should be noted that the area of agricultural enterprise in the National Household Survey is defined differently from the area of agricultural establishment used in the agricultural census. As this is a household survey, the area in question could be formed by discontinuous land plots, possibly located in different regions. It is also hard for research to capture rural properties owned by legal entities. Accordingly, given the methodological differences, any direct comparison between the National household survey and the agricultural census needs to be interpreted with care.

[6] Production is highly concentrated in Brazil, especially in the case of specific crops. Alves and Rocha (2010) provide an idea of that concentration in the cases of milk and cereal production.

TABLE 2

Brazil: income distribution,[a] schooling and age of persons employed, by economic activity sectors and region, 2009

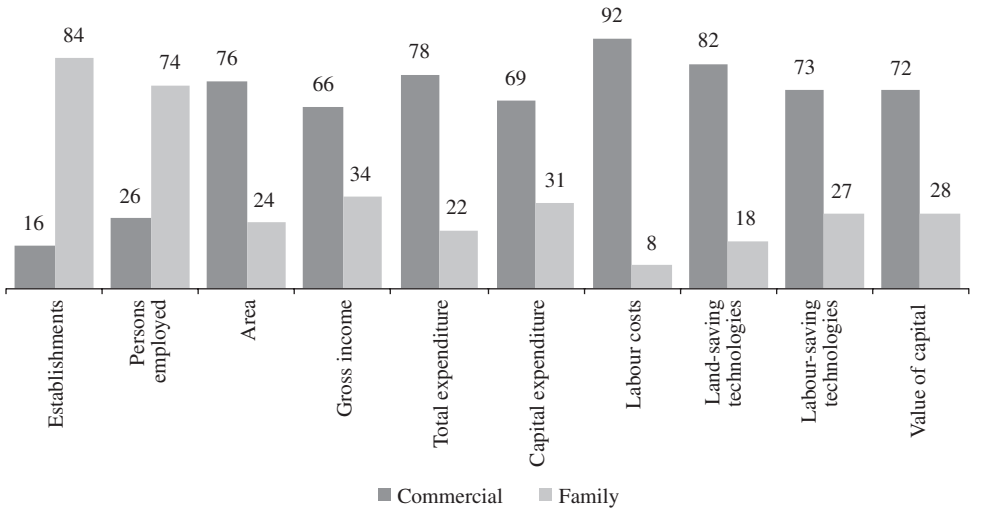
Selected variables		Population *(percentage)*	Average income *(reais)*	Median income *(reais)*	Gini coefficient	Average schooling	Average age
Sectors	Agriculture	11.0	637.4	450.0	0.529	4.0	41.7
	Industry	23.9	1 041.1	700.0	0.454	8.0	36.8
	Services	64.9	1 211.6	690.0	0.526	9.7	36.8
	Total	100.0	1 105.7	630.0	0.518	8.6	37.3
Regions	North	8.7	636.5	450	0.479	3.5	40.6
	North-east	43.2	344.1	248	0.470	3.0	41.0
	MG+ES+RJ	16.5	664.1	465	0.444	4.4	42.3
	São Paulo	8.8	886.5	600	0.423	5.9	40.8
	South	14.9	1 048.4	600	0.515	5.2	43.9
	Centre-west	7.9	1 137.5	635	0.537	5.1	42.2
	Brazil	100.0	637.4	450	0.529	4.0	41.7

Source: 2009 National Household Survey on the basis of R. Hoffmann, "Distribuição da renda agrícola e sua contribuição para a desigualdade de renda no Brasil", *Revista de Política Agrícola*, year XX, No. 2, Brasilia, Secretariat of Agricultural Policy, 2011, pages 9 and 10.

[a] Positive labour income.
MG: Minas Gerais. ES: Espírito Santo. RJ: Rio de Janeiro.

FIGURE 2

Brazil: share of commercial and family farming by selected indicators, 2006
(Percentages)



Source: prepared by the author on the basis of Brazilian Geographical and Statistical Institute (IBGE), 2006 Census of Agriculture.

Table 3 classifies family farming establishments in four income levels: extreme poverty, and low, middle and high income. At the upper end of the population distribution, represented by middle- and high-income groups, the figures show that 5.2% of farms generated 63.5% of GPV. At the lower end, consisting only of the extreme poverty group, 66.4% of farms contributed around 10% of GPV. Thus, there is a strong pattern of income concentration and a heavy weight of extreme poverty in family farming; and a small number of

TABLE 3

Brazil: stratification of income from family farming by number of establishments and production, 2006

Income groups by minimum wage equivalent	Minimum wage equivalent (MWE) [a]	Share of family farms *(percentages)*	Share of family farm production *(percentages)*	Number of family farms	Percentage	Annual GPV of family farming *(billions of reais)*	Percentage
	Not reported	86.3	…	461 000	10.6	…	…
Extreme poverty	(0 to 2]	89.5	87.3	2.9 million	66.4	5.7	10.2
Low income	(2 to 10]	81.0	79.4	778 000	17.8	14.7	26.2
Middle income	(10 to 200]	53.8	41.3	224 000	5.1	24.7	44.1
High income	>200	15.7	13.3	4 000	0.1	10.9	19.4
Total - Brazil		84.4	33.6	4.4 million	100.0	56.1	100.0

Source: prepared by the author on the basis of Brazilian Geographical and Statistical Institute (IBGE), 2006 Census of Agriculture.

[a] Minimum wage equivalent = gross production value (GPV) per month/ monthly minimum wage.

establishments (which encompass the wealth of family farming) produce more than half of GPV.

The extreme poverty group, consisting of about 2.9 million establishments, is on the fringes of agricultural production and excluded from any economic sector, since it lacks efficient productive organizational structures (microeconomic and market). In the economy as a whole, family farms account for 89.5% of extreme poverty, with the north-east region in particular accounting for 61%[7] of the extremely poor in Brazilian family farming. As previously noted by Vieira Filho, Santos and Fornazier (2012), resolving this distortion is extremely complex and requires comprehensive structural policies, such as an in-depth reform of education, improvements in the health sector, and the provision of basic market infrastructure. Alves and Rocha (2010) claim that population groups that work on the land are more likely to migrate to urban centres. Thus, notwithstanding the formulation of long-term structural policies, short-term measures are also required, including policies to support disadvantaged groups and income transfer.

The government should assist the low-income group through development policies and measures to reinvigorate small-scale production, which is normally family-based. The producers in question operate with low levels of technology and have little capacity to absorb external knowledge, compounded by shortcomings in the management and microeconomic areas. Access to credit needs to be improved and the use of new technologies encouraged. It is the government's responsibility to create technical assistance that reaches the grassroots level, and to undertake research in the public domain when the market fails to provide this. In family farming, this group consists of 778,000 farms, most of which are located in the southern region (about 41%),[8] which contains almost twice the number of family farms generating low incomes, compared with the south-east and north-east which have 21% of such establishments each.

Lastly, the country's agricultural wealth also includes middle- and high-income groups. The south has the largest absolute number of medium- and high-income family farms, consisting of around 100,000 establishments, or 44% of the national total. In contrast, the centre-west region has the fewest (11,600), representing 5% of establishments in the family farming universe. For this group, while technology absorption capacity is a secondary problem, a macroeconomic environment conducive to sales growth is essential. Public policies should be designed on the basis of issues that extrapolate productive microeconomic side, with a focus on stimulating market competitiveness, export promotion and agricultural insurance, while also improving the logistical distribution of products and thus reduce costs.

In a general analysis of the economic viability of family farms, figure 3 displays the TFP economic criterion. According to Gasques and others (2010), from 1970 to 2006 most agricultural output growth was driven by TFP growth. While agricultural production grew by 243%

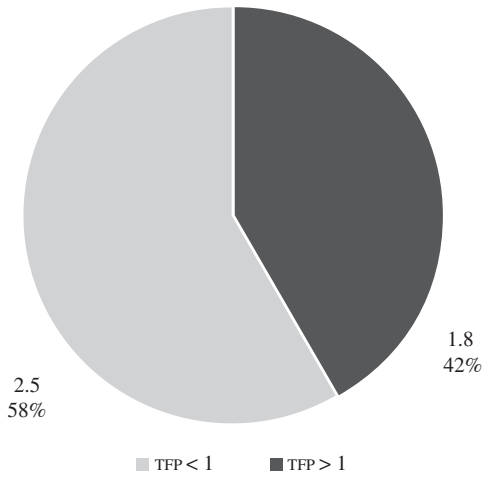
[7] This share is calculated by dividing the total number of establishments in the (0-2) income bracket in Brazil as a whole (2 900.1) by the total number of establishments in the same income bracket in the north-east region (1 767.9).

[8] Analogously to note 7, the percentage is calculated by dividing the total number of establishments in income bracket (2-10] in Brazil as a whole (777.5) by the total number of establishments of the equivalent income bracket in the southern region (317.1).

between 1970 and 2006, input use expanded by just 53% in that period. This proves that the overall growth of Brazilian agriculture was based primarily on productivity increases or technological upgrading. Of the 4.4 million family farms in the Brazilian agriculture sector in 2006, about 42% had a gross income exceeding total costs, which represented a TFP greater than 1. Interestingly, the majority of establishments (58%) faced financial difficulties and had a TFP below 1, or negative net income.

FIGURE 3

Brazil: classification of family farms under the TFP economic criterion, 2006
(Millions and percentages)



Source: prepared by the author on the basis of Brazilian Geographical and Statistical Institute (IBGE), 2006 Census of Agriculture.

TFP: total factor productivity.

Understanding the economic viability of family farms in the Brazilian economy required an analysis of the producers' technological efficiency rating. The joint classification of the economic and qualitative criteria is shown in table 4, which summarizes the family-farm sector classified in technology groups and by selected economic indicators. In the case of gross income, family farmers on average earned less than half the national average income for the entire agricultural sector, including commercial agriculture. In the case of family farming, establishments with a TFP greater than 1 and high technological content have a gross income that exceeds the Brazilian average. Nonetheless, there are also highly productive establishments in family farming; and this simple finding is important because it shows public-sector managers that productive development policies need to be contextually differentiated, and merely distinguishing between family and commercial farming to separate groups of farmers with similar demands is insufficient.

In terms of the average area per farm, those with negative net income had areas that were larger than average for family farming, which shows that it is not always the owner with the largest area that earns highest gross income. When studying technology in agriculture, land is a factor used in the production process. While land is clearly highly relevant to this process, higher technology can generate savings on land use and increase production. If technology has this capacity, the land (since it is a given) becomes secondary resource. While bringing more land into use may increase final output, productivity grows only by incorporating more technology. The fact that agents with a high technological intensity have a smaller average farm area than their low-intensity counterparts, shows that technology is more important than land area for obtaining a higher income (or to combine the efficient use of resources to increase production).[9]

In terms of technologies (whether land - or labour-saving), family firms of high technological content have costs that are lower than the country average; nonetheless, their expenses are higher than the average for family farming. As those establishments use technological inputs above the average level, expenditure on technologies exceeds the average results reported for family farming generally. If future increases in production fail to compensate for the increase in investment in technological inputs, production costs rise and the establishments face financial difficulties, as is the case of the group defined by medium technological efficiency and negative net income, in other words 20% of all establishments. At the other extreme —low cost and high productivity— establishments benefit from a positive net income, a situation pertaining to 19% of total establishments, represented by low technological content and a TFP above 1.

In general, family farms invest less in technology than other sectors of the economy and so generate less

[9] Analysing wealth creation by only considering the land endowment is a mistake. Those who claim that family farming is needed more than employe-based farming, analyse the problem by focusing only on the issue of land. According to Brasil (2006) in the classification of family farming compared to employment based (or non-family) farming, the land factor was considered as a criterion of exclusion. The division takes account of the size of the land area and not economic criteria (sales value, TFP and net income, among others). The results reported here testify to the high level of productive heterogeneity in Brazilian agriculture. Tehchnology is a key issue for discussing this problem.

TABLE 4

Brazil: comparison of family farming by technological-intensity group and selected economic indicators, 2006

Economic and qualitative criteria			Family				Total family	Brazil
			TFP > 1		TFP < 1			
			HT	LT	HT	LT		
Taxonomy – technological intensity			High	Medium		Low		
Indicators by establishments	Thousands of reais	Gross income (GI)	39.7	13.6	6.6	1.7	12.8	32.2
		Total cost (TC)	11.8	2.5	14.9	5.7	8.3	32.5
		Capital expenditure (CE)	1.0	0.1	1.2	0.2	0.6	1.6
		Labour cost (LC)	0.6	0.1	0.9	0.3	0.5	4.5
		Expenditure on land saving technologies	3.8	0.3	4.3	0.5	2.0	9.5
		Expenditure on labour-saving technologies	0.6	0.0	0.8	0.1	0.4	1.1
		Value of capital (VC)	99.0	24.0	132.9	65.8	78.3	239.7
		Net income (NI)	27.9	11.1	-8.3	-4.0	4.5	-0.3
	No	Population employed (PE)	3.2	2.9	2.9	2.5	2.8	3.2
	ha	Area (hectares)	15.5	12.6	19.1	23.1	18.3	64.5
Derived variables		TFP	3.4	5.5	0.4	0.3	1.5	1.0
		Productivity of land (gross income per ha) *(reais)*	2 571.7	1 077	343.1	73.4	699.8	499.4
		Productivity of capital (GI/CE)	39.5	130.2	5.4	6.9	21.9	20.4
		Productivity of labour (GI/LC)	63.9	107.4	7.6	5.6	28.1	7.1
		Share of land-saving and labour-saving technologies in total cost (*percentages*)	37	14	34	11	28	33
		Capital-labour ratio	1.6	0.8	1.4	0.8	1.3	0.3
		Rate of return on capital (NO/VC)	0.3	0.5	-0.1	-0.1	0.1	0.0
		Productivity of labour (VA/PE) *(thousands of reais)*	8.9	3.9	-2.3	-1.0	2.0	2.1
Establishments *(thousands)*			837	993	1 022	1 515	4 366	5 176
Share of establishments *(percentages)*			16	19	20	29	84	100

Source: prepared by the author on the basis of Brazilian Geographical and Statistical Institute (IBGE), 2006 Census of Agriculture.

Note: monetary amounts expressed in reais at 2006 prices.
TFP: total factor productivity.
HT: high technological/institutional content.
LT: low technological/institutional content.
VA/PE: value added per population employed.
GI/GC: gross income/capital expenditure.
NI/VP: net income/value of capital.

value added per worker. Firstly, labour productivity in family farming is 2,000 reais per person, compared to an estimated 2,100 reais for the Brazilian agriculture sector as a whole. Nonetheless, family farming with positive net income is extremely efficient from the TFP standpoint, and represents 35% of total establishments. Family farms that are profitable and have low technological content have the highest TFP, owing to the relatively high productivity of the land compared to establishments that have low technology costs. Family production reporting positive net income obtained productivity indices above the national average.

With regard to the taxonomy, the low technological-efficiency group consists of unproductive establishments. The weak performance of this group is partly due to greater use of land, usually associated with a smaller share in gross income. Public actions should firstly focus on technology promotion policies, which encourage the efficient use of resources. Then, through a carrot-and-stick mechanism, the government would create policies setting higher regional productivity targets, in order to monitor the opportunistic behaviour of producers of weak productivity performance, prioritizing agents with the greatest potential for dynamic market integration and

greater fulfilment of the productivity growth targets. Lastly, it is worth noting that lack of dynamism is linked to poor technological absorption capacity and also, to some extent, to rural poverty. This group should be assisted mainly through structural policies (improvements in education, health and infrastructure, combined with actions for disadvantaged groups and income transfer), although the solution to the problem would hardly be immediate.

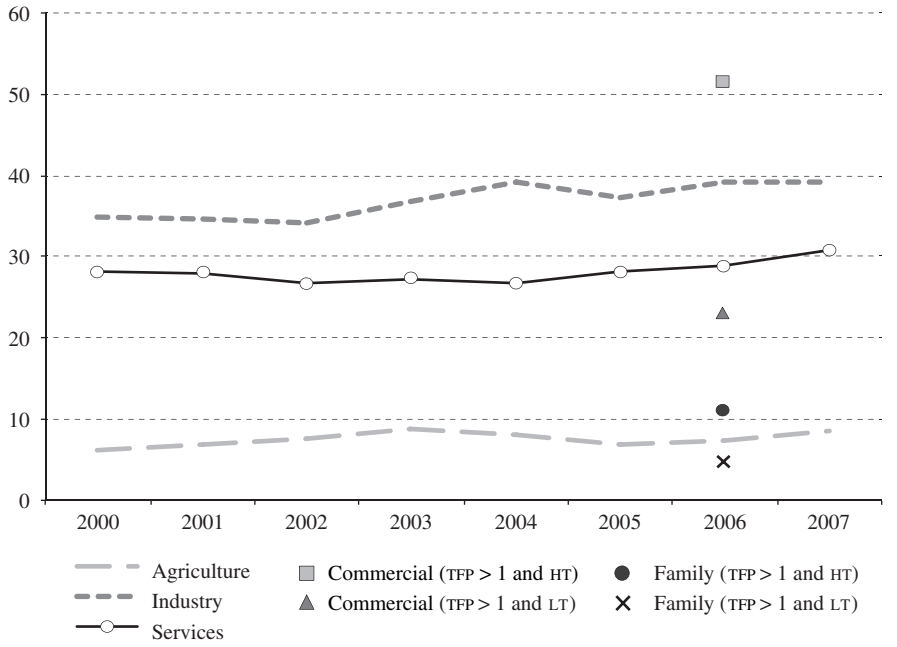
Figure 4 compares labour productivity in the agriculture sector with that in other sectors of the economy using IBGE national accounts data for value added per person employed between 2000 and 2007. By stratifying technology groups in agriculture, only in the case of establishments with positive net income (commercial and family) was it possible to compare heterogeneity in the Brazilian agricultural sector, although only for 2006 (the Agriculture Census reference year).

Global data show that Brazilian agriculture is less productive than the industry and service sectors. However, technological stratification reveals a high degree of variability in labour productivity across productive establishments. This variability may be due to the specific nature of the technological path followed by agriculture. Productive agents have different abilities to absorb technological knowledge. The most productive farmers have a labour productivity nearly seven times the national average, in some cases surpassing the industrial and service sectors. Nonetheless, labour productivity in family farming varies much less than in the commercial agriculture, although this does not mean that structural heterogeneity is less in family farming. In particular, family farming is homogeneous in terms of the "socialization of poverty," which needs to be studied to more effectively plan the development of that type of productive organization.

According to Matteo (2011), labour productivity varies considerably across sectors and regions. In sector terms, labour productivity in industry was around 1.2 times that of services, but close to 4.5 times

FIGURE 4

Brazil: labour productivity by economic activity sector, 2000-2007
(Thousands of reais)



Source: prepared by the author on the basis of Brazilian Geographical and Statistical Institute (IBGE), 2006 Census of Agriculture.

Note: amounts corrected on the basis of the Extended National Consumer Price Index (IPCA), at December 2010 prices.
TFP: total factor productivity.
HT: high technological/institutional content.
LT: low technological/institutional content.

labour productivity in the agriculture sector as a whole (family and commercial), indicating greater productive heterogeneity in the latter comparison. In regional terms, the industry/agriculture labour productivity ratio was 6.5 in the north-east and 1.2 in the centre-west region. According to the author, the highly productive centre-west farming region (extensive soybean and livestock breeding), where few workers are employed, stands in stark contrast to farming in the north-east, which is what is often at subsistence level.

Table 5 makes a regional comparison of family farming by technological-intensity group. The PII is calculated to verify regional patterns of production; and it is interesting to note that there are different patterns of behavior. In the north-east, family farming is more varied and accounts for much of the poverty in the region, although both modern and backward sectors coexist. In contrast, in the south, the production pattern is more uniform and concentrated in the highest income brackets, more than the national average. The south is considered the most dynamic region for family farming, with the lowest rate of rural poverty (around 47.4% of farms) and the lowest PII among all regions studied (0.73). In the centre-west region, the high- and medium-technological-intensity groups display a better distribution of gross income in the highest income brackets. Nonetheless, compared to the other regions analyzed, the low technology intensity group displays a high level of inequality.

Focusing attention on the north-east region, high technological-intensity agriculture generates greater inequality than the region as a whole, which shows that there is a high degree of heterogeneity, even in the most advanced segments. Another finding is that, in the north-east (the most backward region), the higher the level of technological and institutional intensity, the higher the PII. As noted by Vieira Filho, Santos and Fornazier (2012), a pattern of dual convergence can be seen in other regions, which tend to concentrate the most dynamic and modern productions. The high and low technological-intensity groups recorded much lower PIIs than the regional totals, thereby suggesting homogeneous patterns at the extremes of the taxonomy. In the most dynamic region at least, the taxonomy serves to distinguish the more organized economic agents and those with a high level of technology compared to those of more backward production.

It should be noted that the "socialization of poverty" coexists with a "heterogeneity of wealth". In the latter case, in the centre-west region, 0.1% of the establishments that generate income of more than 200 times the monthly minimum wage produce 23.2% of GPV. It is curious to note that in the north-east, 0.1% of establishments in the same income group produced more than 25% of production. The gross value produced by the high-income bracket in the north-east was 3,400 million reais, while the centre-west region produced 726.4 million reais. In other words, GPV in the north-east was 4.7 times higher than that of the center-west region for the income level in question. This comparison shows how unequal family farming is in the north-east, since this region accounts for much of the country's rural poverty. It can also be seen that, in the high technological-efficiency group in the north-east, 0.2% of establishments in the high-income bracket (which generated income of more than 200 times the monthly minimum wage) produce roughly 38% of GPV.

In terms of the "socialization of poverty", especially in the north-east, productive inequality measured by the respective index in low technological-intensity family farming was the lowest in the nation as a whole. Nonetheless, 98.3% of establishments in this technological

TABLE 5

Brazil: comparison of family farming by technological-intensity group, MWE income bracket and PII, 2006

Taxonomy		Establishments *(thousand)* and GPV *(millions of reais)*	MWE income brackets				Total	Percentages				PII
			(0 to 2)	(2 to 10)	(10 to 200)	>200		(0 to 2)	(2 to 10)	(10 to 200)	>200	
TFP > 1 AT	High	No.	11.2	12.2	3.1	0.1	26.6	42.3	45.8	11.6	0.2	0.71
		GPV	50.2	202.2	343.3	114.1	709.8	7.1	28.5	48.4	16.1	
TFP > 1 BT	Medium	No.	104.6	46.0	15.2	0.5	166.3	62.9	27.7	9.2	0.3	0.79
		GPV	302.0	750.3	1 736.7	788.1	3 577.2	8.4	21.0	48.6	22.0	
TFP < 1 AT		No.	28.1	2.8	0.2	0.0	31.1	90.4	9.0	0.6	0.0	0.40
		GPV	71.9	38.8	16.0	0.0	126.7	56.7	30.6	12.6	0.0	
TFP < 1 BT	Low	No.	113.7	19.4	0.9	0.0	133.9	84.9	14.5	0.7	0.0	0.48
		GPV	293.6	306.3	53.5	1.8	655.3	44.8	46.8	8.2	0.3	

Table 5 (*concluded*)

Taxonomy		Establishments *(thousand)* and GPV *(millions of reais)*	MWE income brackets (0 to 2)	(2 to 10)	(10 to 200)	>200	Total	Percentages (0 to 2)	(2 to 10)	(10 to 200)	>200	PII
North		No.	257.6	80.4	19.4	0.6	357.9	72.0	22.5	5.4	0.2	0.76
		GPV	717.7	1 297.6	2 149.5	904.0	5 069.0	14.2	25.6	42.4	17.8	
TFP > 1 AT	High	No.	207.5	69.2	19.6	0.7	297.0	69.9	23.3	6.6	0.2	0.82
		GPV	628.5	1 170.2	2 166.1	2 445.7	6 410.5	9.8	18.3	33.8	38.2	
TFP > 1 BT	Medium	No.	596.2	74.5	24.4	0.4	695.4	85.7	10.7	3.5	0.1	0.78
		GPV	986.4	1 290.5	2 449.7	936.8	5 663.3	17.4	22.8	43.3	16.5	
TFP < 1 AT		No.	306.7	11.5	0.4	0.0	318.6	96.3	3.6	0.1	0.0	0.29
		GPV	453.4	159.6	35.3	0.0	648.4	69.9	24.6	5.4	0.0	
TFP < 1 BT	Low	No.	657.5	11.1	0.4	0.0	669.0	98.3	1.7	0.1	0.0	0.27
		GPV	490.9	163.7	23.8	0.9	679.2	72.3	24.1	3.5	0.1	
North-east		No.	1 767.9	166.3	44.8	1.1	1 980.0	89.3	8.4	2.3	0.1	0.78
		GPV	2 559.2	2 784.0	4 674.9	3 383.4	13 401.4	19.1	20.8	34.9	25.2	
TFP > 1 AT	High	No.	42.8	78.1	34.4	0.7	156.0	27.5	50.1	22.0	0.4	0.72
		GPV	189.2	1 548.9	3 811.3	2 319.1	7 868.5	2.4	19.7	48.4	29.5	
TFP > 1 BT	Medium	No.	42.0	20.2	7.5	0.1	69.9	60.1	28.9	10.8	0.2	0.79
		GPV	113.8	378.1	771.1	366.3	1 629.1	7.0	23.2	47.3	22.5	
TFP < 1 AT		No.	164.2	47.4	6.4	0.0	218.0	75.3	21.7	2.9	0.0	0.63
		GPV	428.6	803.1	479.8	8.4	1 720.0	24.9	46.7	27.9	0.5	
TFP < 1 BT	Low	No.	137.4	17.3	1.2	0.0	155.9	88.2	11.1	0.7	0.0	0.60
		GPV	184.7	296.3	70.8	0.0	551.7	33.5	53.7	12.8	0.0	
South-east		No.	386.4	163.0	49.5	0.8	599.8	64.4	27.2	8.3	0.1	0.79
		GPV	916.3	3 026.4	5 133.0	2 693.8	11 769.3	7.8	25.7	43.6	22.9	
TFP > 1 AT	High	No.	58.5	196.0	79.1	1.0	334.6	17.5	58.6	23.6	0.3	0.64
		GPV	289.2	4 091.5	9 093.0	2 866.5	16 340.2	1.8	25.0	55.6	17.5	
TFP > 1 BT	Medium	No.	23.4	9.3	3.3	0.1	36.0	64.9	25.8	9.1	0.2	0.79
		GPV	67.8	174.1	374.1	168.4	784.4	8.6	22.2	47.7	21.5	
TFP < 1 AT		No.	211.5	105.1	16.1	0.0	332.8	63.6	31.6	4.8	0.0	0.63
		GPV	660.2	1 879.5	1 185.5	15.9	3 741.0	17.6	50.2	31.7	0.4	
TFP < 1 BT	Low	No.	82.3	6.7	0.3	0.0	89.2	92.2	7.5	0.3	0.0	0.50
		GPV	109.6	104.8	22.4	0.0	236.9	46.3	44.2	9.5	0.0	
South		No.	375.7	317.1	98.8	1.1	792.6	47.4	40.0	12.5	0.1	0.73
		GPV	1 126.8	6 249.9	10 675.0	3 050.8	21 102.5	5.3	29.6	50.6	14.5	
TFP > 1 AT	High	No.	5.4	12.3	4.7	0.1	22.6	23.8	54.7	20.9	0.5	0.74
		GPV	28.3	227.2	607.8	442.5	1 305.8	2.2	17.4	46.5	33.9	
TFP > 1 BT	Medium	No.	9.1	11.6	4.1	0.0	24.9	36.6	46.8	16.4	0.2	0.73
		GPV	34.7	233.8	383.5	265.9	917.9	3.8	25.5	41.8	29.0	
TFP < 1 AT		No.	37.7	9.5	1.5	0.0	48.7	77.5	19.5	3.1	0.0	0.65
		GPV	109.5	150.2	139.5	17.9	417.2	26.3	36.0	33.4	4.3	
TFP < 1 BT	Low	No.	60.3	17.2	1.1	0.0	78.7	76.7	21.9	1.4	0.0	0.59
		GPV	132.0	292.6	68.9	0.0	493.4	26.7	59.3	14.0	0.0	
Centre-west		No.	112.5	50.7	11.4	0.2	174.8	64.4	29.0	6.5	0.1	0.77
		GPV	304.5	903.8	1 199.7	726.4	3 134.4	9.7	28.8	38.3	23.2	
TFP > 1 AT	High	No.	325.5	367.9	140.9	2.5	836.7	38.9	44.0	16.8	0.3	0.74
		GPV	1 185.4	7 239.9	16 021.5	8 187.9	32 634.8	3.6	22.2	49.1	25.1	
TFP > 1 BT	Medium	No.	775.2	161.7	54.5	1.1	992.5	78.1	16.3	5.5	0.1	0.81
		GPV	1 504.7	2 826.7	5 715.1	2 525.5	12 571.9	12.0	22.5	45.5	20.1	
TFP < 1 AT		No.	748.3	176.2	24.7	0.0	949.2	78.8	18.6	2.6	0.0	0.64
		GPV	1 723.6	3 031.3	1 856.1	42.2	6 653.2	25.9	45.6	27.9	0.6	
TFP < 1 BT	Low	No.	1 051.1	71.7	3.8	0.0	1 126.6	93.3	6.4	0.3	0.0	0.51
		GPV	1 210.7	1 163.7	239.4	2.7	2 616.5	46.3	44.5	9.1	0.1	
Brazil		No.	2 900.1	777.5	223.9	3.6	3 905.1	74.3	19.9	5.7	0.1	0.80
		GPV	5 624.4	14 261.6	23 832.1	10 758.3	54 476.4	10.3	26.2	43.7	19.7	

Source: prepared by the author on the basis of Brazilian Geographical and Statistical Institute (IBGE). 2006 Census of Agriculture.

TFP: total factor productivity.
HT: high technological/institutional content.
LT: low technological/institutional content.
GPV: gross production value.
PII: productive inequality index.
MWE: minimum wage equivalent.

group generate income in the range of zero to two times the monthly minimum wage, so many of them are extremely poor. The percentage of establishments compared to GPV shows that in the more modern regions there is a larger number of producers in the higher income strata. In general, however, establishments in the most backward regions are mostly concentrated in the lower income strata. The PII of the average technological-intensity group displays greater inequality, which shows that the diversity of such establishments is much more complex.

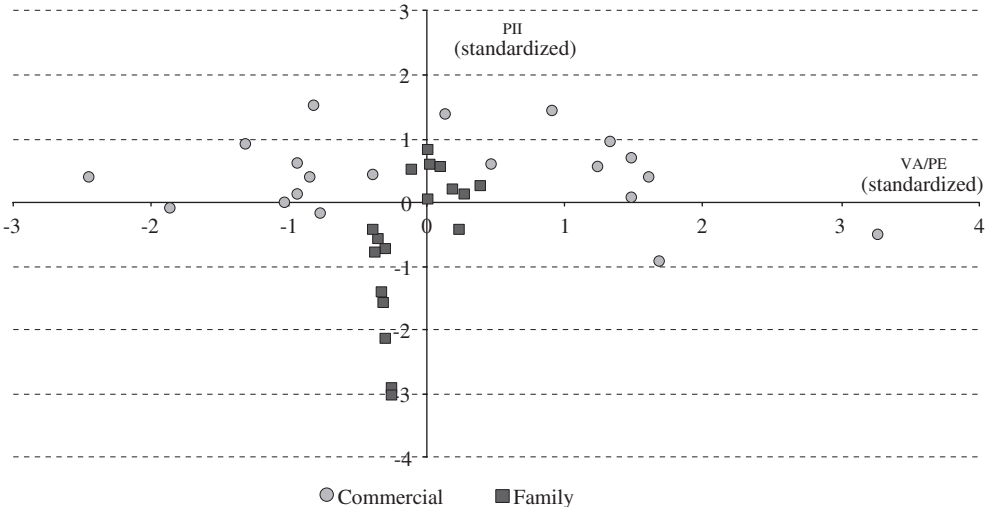
The analytical methodology was used to compare the PII with labour productivity, measured in both cases using standardized indicators. In this comparison, as shown in figure 5, the labour productivity data for commercial agriculture are more dispersed, whereas the corresponding figures for family farming are more concentrated and more static. The quadrant that identifies low productive inequality combined with high productivity ("homogenization of wealth") contains three observations, two of them commercial farming and one family farming.

The quadrant representing high inequality combined with low productivity predominantly consists of commercial farming. In that group, which requires specific policies to raise productivity, inequality levels are high, because production is more dynamic and can be affected by seasonal fluctuations and other shocks external to the market. With regard to the "heterogeneity of wealth" (represented by the upper right-hand quadrant), commercial and family farms alternate, and the latter are concentrated more in the interior figure 5. The lower left-hand quadrant (typical of the "socialization of poverty") is essentially populated by family farming. As noted above, there are many establishments with low productivity and low levels of inequality, because they share a very similar low production characteristic.

An analysis of figure 6, which focuses on family farming alone, shows that high and medium technological-intensity farms are concentrated on the right-hand side of figure 6, which represents higher labour productivity. The left-hand portion distinguishes low and medium technology-intensity establishments. The results show that structural heterogeneity is present in all regions, but in varying degrees in each case (as shown by the size of the standard deviation of labour productivity and the PII). Although the data reflect what would normally be expected in the typical pattern of Brazilian agriculture, they qualify analyses of the productive and technological concentration process. In the low-inequality/high-productivity quadrant ("homogenization of wealth"), the south region includes establishments

FIGURE 5

Brazil: PII compared to labour [a] productivity by type of farming (commercial or family), 2006



Source: prepared by the author on the basis of Brazilian Geographical and Statistical Institute (IBGE), 2006 Census of Agriculture.

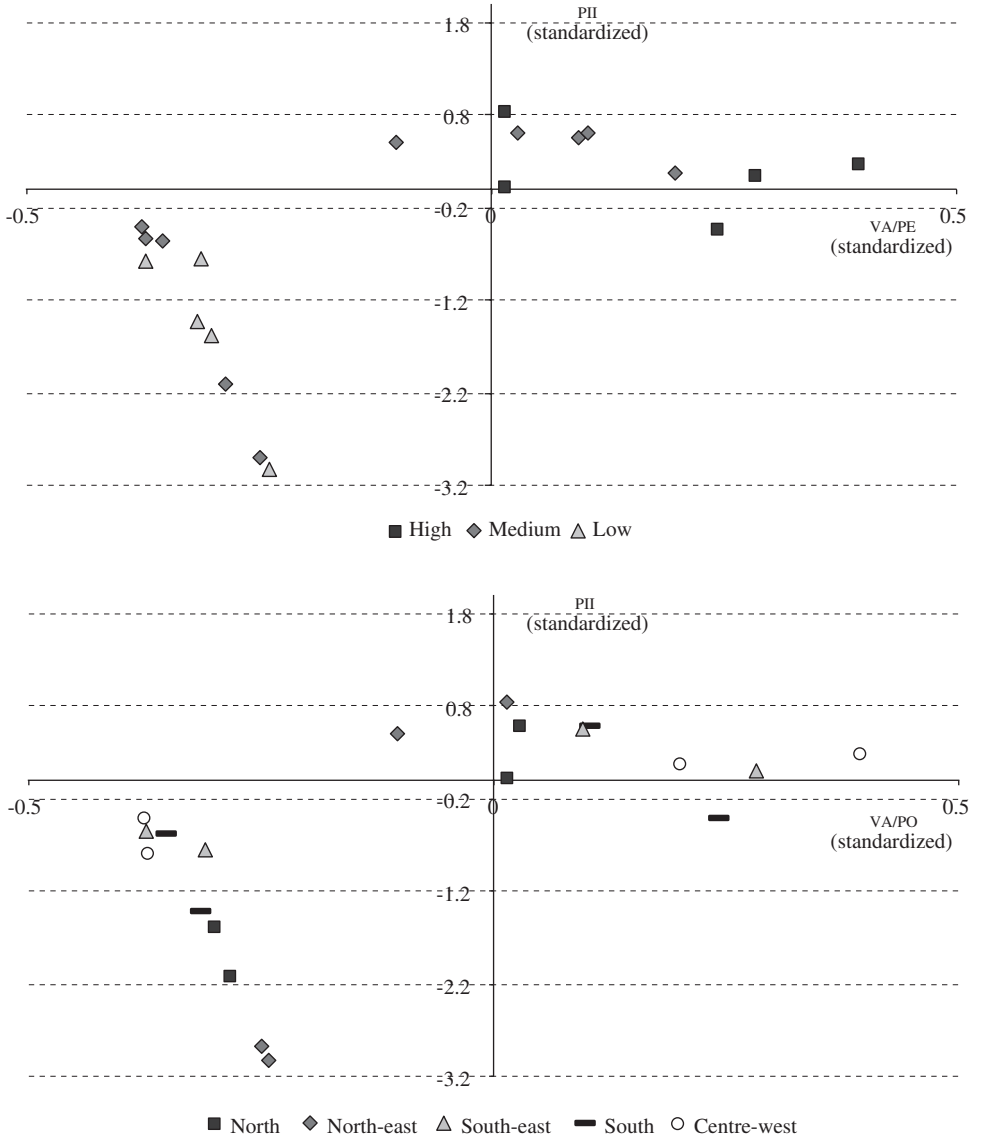
[a] Standardized indicators.
PII: productive inequality index.
VA/PE: value added per population employed.

of high technological intensity, which makes clear that family farming can combine high technology, high labour productivity, and low productive inequality, provided there is an institutional environment that encourages growth and technological innovations.

The medium technological-intensity group needs to be studied in greater depth in this context, because it shows dispersion both in productive inequality and in labour productivity, without displaying a well-defined pattern. The category of low productive inequality combined with low productivity ("socialization of poverty") is clearly dominated by family farming, and the situation is particularly critical in the north east and north regions. As a stylized facts of the analysis of figure 6, it can be

FIGURE 6

Brazil: PII compared to labour productivity[a] by family farming technological-efficiency group and by region, 2006



Source: prepared by the author on the basis of Brazilian Geographical and Statistical Institute (IBGE), 2006 Census of Agriculture.

[a] Standardized indicators.
PII: productive inequality index.
VA/PE: value added per population employed.

seen that the most dynamic regions for family farming are shown more to the right of that figure (centre-west, south and south-east), whereas the more static regions are shown more to the left and normally low down in figure 6, which indicates patterns reflecting the homogeneity of poverty (north and north-east regions). The standard deviation rises or falls according to regional production and development patterns.

IV
Final thoughts

In recent decades, the Brazilian agricultural sector has undergone many changes, prompting an intensive modernization process, greater technological progress and high productivity. Nonetheless, there are still producers who combine low technological content with low productivity. Agriculture cannot simply be divided into modern and backward producers. There are structural problems that create inefficiency in the management of technological resources and the use of productive factors, resulting in an environment that is unconducive to innovations in products and processes or the dissemination of new knowledge.

This paper has sought to identify and quantify the structural heterogeneity in family farming, which prevents backward segments from participating in dynamic markets. First, from the standpoint of public policy-making, the study shows that the distinction between family and commercial farming can be ignored, because the results reveal the coexistence of modern productive agents and backward ones within the same group. The internal diversity of family farming therefore requires specific actions to promote production and reallocate resources to the different segments. Secondly, regional specifics loom very large, so regional planning and development need to be targeted.

The comparison between Brazil's different regions and between technology groups found significant productive and technological heterogeneity in family farming, which seems to verify the initial hypothesis that technological innovations driven by institutional changes serve to increase the heterogeneity of the system and benefit the most innovative participants.

The empirical evidence shows that about 5% of the wealthiest family farms accounted for 64% of GPV, while the poorest 66% generated roughly 10% of total output. Furthermore, family farms account for an estimated 90% of the lowest income group, defined as from zero to two times the minimum wage. There is thus a strong pattern of gross income concentration, on the one hand, and a heavy burden of extreme poverty in family farming, on the other. In analyzing the economic viability of the 4.4 million family farms in 2006, 42% had a gross income that exceeded total costs, or a positive net income. At the other end of the spectrum, however, more than half of the establishments were in an unfavourable financial situation.

In terms of labour productivity, it was possible to compare the agriculture sector with other sectors of economic activity in Brazil. While global data suggest that Brazilian agriculture is less productive than other sectors (industry and services), technological stratification reveals a high level of heterogeneity in labour productivity between productive establishments. The most productive agriculture has labour productivity that is almost seven times the national average for the sector; but family farms have low levels of labour productivity with less variability.

A comparison of labour productivity with the PII, reveals two patterns: (i) "heterogeneity of wealth"; and (ii) "socialization of poverty." In establishments of higher technological content, according to the taxonomy, the higher indicators of inequality and labour productivity obtained varied somewhat between the regions studied. In the most backward regions (specifically in the north-east), family farming is more unequal and accounts for a large proportion of rural poverty, although dual development can be observed (coexistence of modern and backward sectors in the same economic space). In the south there was a more homogeneous pattern of production, and income levels are above average. The south is also considered the most dynamic region for family farming, with the lowest rural poverty rate (47% of productive establishments in the regional total) and the lowest inequality index (0.73) among all regions studied.

In the group combining medium technological intensity and TFP less than 1, policies (including short-term ones) are needed to reverse the situation of negative net income, to increase productive efficiency. This result may be partly blamed on seasonal fluctuations, but another part clearly stems from technological inefficiency; and the low technological-intensity group contains numerous

unproductive establishments. Firstly, structural policies are needed to increase capacity for technology absorption, rural extension and education; and secondly, short-term measures are needed, such as policies for disadvantaged groups and income transfer.

In the high technological-intensity group, although net income is positive, partly because of spending on land-saving and labour saving technologies, TFP did not attain its highest value. Except in the case of seasonal problems, this group of establishments can use its resources more efficiently to increase capacity to absorb external knowledge, which can be stimulated by management training policies specific to the crop and the region in question. Usually targeted on the high technological-efficiency group, horizontal policies to improve competitiveness help reduce production costs, which can at the same time help in terms of increasing and appropriating income.

A more comprehensive study that includes crop-specific analyses will help define public policies, taking regional and productive specifics into account. Nonetheless, the country also needs a clear policy for increasing technology absorption capacity, which entails making progress in rural extension and education. This requires policies that are more closely integrated across the federal, state and municipal levels, to reach the grassroots of the system, spreading the new techniques and knowledge in a way that reaches the producer. Transforming market-based family farming will be the main challenge for agricultural planning and policy in Brazil over the next few years. It should also be noted that the proposed methodology provides a basis for comparison, for example with other Latin American countries, since the region as a whole has characteristics and challenges that are relatively similar to those of Brazil.

Bibliography

Alves, E. and D. Rocha (2010), "Ganhar tempo é possivel", *A agricultura brasileira: desempenho, desafios e perspectivas*, J.G. Gasques, J.E.R. Vieira Filho and Z. Navarro (orgs.), Institute of Applied Economic Research (IPEA).

Alves, E., G.S. Souza and C.A.V. Oliveira (2006), "Desempenho de estabelecimentos do Pronaf", *Migração rural-urbana, agricultura familiar e novas tecnologias: coletânea de artigos revistos*, E. Alves (ed.), Brasilia, Embrapa Informação Tecnológica.

Brasil (2006), "Lei N° 11.326", 24 July.

Buainain, A.M. (ed.) (2007), *Agricultura familiar e inovação tecnológica no Brasil: características, desafios e obstáculos*, Campinas, State University at Campinas.

Cohen, W.M. and D.A. Levinthal (1989), "Innovation and learning: the two faces of R&D", *The Economic Journal*, vol. 99, No. 397, Wiley.

ECLAC (Economic Commission for Latin America and the Caribbean) (2010), *Time for equality: closing gaps, opening trails* (LC/G.2432(SES.33/3)), Santiago, Chile.

Evenson, R.E. and Y. Kislev (1973), "Research and productivity in wheat and maize", *Journal of Political Economy*, vol. 81, No. 6, Chicago, The University of Chicago Press.

Fornazier, A. and J.E.R. Vieira Filho (2012), "Heterogeneidade estrutural no setor agropecuário brasileiro: evidências a partir do censo agropecuário de 2006", *Texto para discusión*, No. 1708, Rio de Janeiro, Institute of Applied Economic Research (IPEA).

Gasques, J.G. and others (2010), "Produtividade total dos fatores e transformações da agricultura brasileira: analise dos dados dos censos agropecuários", *A agricultura brasileira: desempenho, desafios e perspectivas*, J.G. Gasques, J.E.R. Vieira Filho and Z. Navarro (orgs.), Institute of Applied Economic Research.

Hoffmann, R. (2011), "Distribuição da renda agrícola e sua contribuição para a desigualdade de renda no Brasil", *Revista de Política Agrícola*, year XX, No. 2, Brasilia, Secretariat of Agricultural Policy.

_____ (1998), *Distribuição de renda: medidas de desigualdade e pobreza*, São Paulo, Editora da Universidade de São Paulo.

IPEA (Institute of Applied Economic Research) (2011), *Radar: Tecnologia, Produção e Comercio Exterior*, No. 14, Brasilia.

Matteo, M. (2011), "Heterogeneidade regional", *Radar: Tecnologia, Produção e Comercio Exterior*, No. 14, Brasilia, Institute of Applied Economic Research (IPEA).

Navarro, Z. and M.T.M. Pedroso (2011), "Agricultura familiar: é preciso mudar para avançar", *Texto para discusión*, No. 42, Brazilian Agricultural Research Corporation (Embrapa).

Nohlen, D. and R. Sturm (1982), "La heterogeneidad estructural como concepto básico en la teoría de desarrollo", *Revista de Estudios Políticos*, No. 28, Madrid, Centro de Estudios Políticos y Constitucionales.

Pinto, A. (1970), "Naturaleza e implicaciones de la heterogeneidad estructural", *El trimestre económico*, vol. 37, No. 1, Mexico City, Fondo de Cultura Económica.

Sunkel, O. and R. Infante (eds.) (2009), *Hacia un desarrollo inclusivo: El caso de Chile* (LC/L.3126), Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC).

Vieira Filho, J.E.R. (2010), "Trajetória tecnológica e aprendizado no setor agropecuário", *A agricultura brasileira: desempenho, desafios e perspectivas*, J.G. Gasques, J.E.R. Vieira Filho and Z. Navarro (orgs.), Institute of Applied Economic Research (IPEA).

_____ (2009), "Inovação tecnológica e aprendizado agrícola: uma abordagem Schumpeteriana", Ph.D. thesis, Campinas, State University at Campinas.

Vieira Filho, J.E.R., A.C. Campos and C.M.C. Ferreira (2005), "Abordagem alternativa do crescimento agrícola: um modelo de dinâmica evolucionária", *Revista Brasileira de Inovação*, vol. 4, No. 2, Campinas, State University at Campinas.

Vieira Filho, J.E.R. and G.R. Santos (2011), "Heterogeneidade no setor agropecuário brasileiro: contraste tecnológico", *Radar: Tecnologia, Produção e Comercio Exterior*, No. 14, Brasilia, Institute of Applied Economic Research (IPEA).

Vieira Filho, J.E.R., G.R. Santos and A. Fornazier (2012), "Distribuição produtiva e tecnológica da agricultura brasileira e sua heterogeneidade estrutural", Brasilia, Institute of Applied Economic Research (IPEA).

Vieira Filho, J.E.R. and J.M.F. Silveira (2011), "Modelo evolucionário de aprendizado agrícola", *Revista Brasileira de Inovação*, vol. 10, No. 2, Campinas, State University at Campinas.

Chile: Port congestion and efficient rationing in cargo transfer operations

Claudio A. Agostini and Eduardo H. Saavedra

ABSTRACT

No pricing system is likely to be able to do away with congestion in port cargo transfer operations at peak times, since port use is determined not so much by seasonal factors as, first and foremost, by the simultaneous arrival of vessels, which results in rationing. This article shows that rationing, to be efficient, needs to go by the value of the cargo transferred rather than following a first-come-first-served rule. It demonstrates that efficient rationing gives priority to containerized cargo, followed by break bulk cargo, with bulk cargo in last place. These findings are applied to cargo transfer at the San Antonio Terminal Internacional franchised port in Chile.

KEYWORDS

Ports, maritime transport, goods transport, port charges, port administration, commercial efficiency, mathematical modelling, case studies, Chile

JEL CLASSIFICATION

D22, D45, L23, L90

AUTHORS

Claudio A. Agostini is a professor at the School of Government of Universidad Adolfo Ibáñez, Chile. claudio.agostini@uai.cl

Eduardo H. Saavedra is an associate professor at the Latin American Institute of Social Theory and Social Studies (ILADES), Universidad Alberto Hurtado, Chile. saavedra@uahurtado.cl

I
Introduction

The scale and long payback times of the investment that port cargo handling infrastructure requires mean that this infrastructure can be characterized as an essential input, one that presents severe capacity constraints at times of peak or high demand. Economic theory generally states that congestion should be eliminated or reduced efficiently by means of the pricing system. Unfortunately, this mechanism cannot be applied to ports in the way it can to electricity or drinking water consumption, since port infrastructure usage is driven not so much by seasonal factors as by the almost simultaneous arrival of too many ships. This implies that port use necessarily has to be rationed and thus that some ships have to wait.

The question of how best to ration is disputed, however. Although the first-come-first-served system is the best known, the economic literature has shown it to be highly inefficient, since the willingness to pay of shippers subjected to rationing varies greatly with the value of the cargo they are carrying (Strandenes and Wolfstetter, 2005; Button, 1979), besides which it increases port operating costs (Imai, Nagaiwa and Chan, 1997).

In conformity with the literature, this article shows theoretically and empirically that it is socially desirable to impose all rationing on the activities with the lowest value added. This value is measured in theory as the drop in the value of transported cargo when it is subjected to rationing. The result holds even when the model includes compensation for firms subjected to rationing or if there are effects on the cargo handling capacity of the port that depend on the type of service being rationed. The rationing criterion used in this paper is cargo value, with containerized cargo being distinguished from bulk cargo. The two cargo types present marked differences in value and in their cost to the port operator, chiefly in terms of operating times and port infrastructure use.

This study was motivated by a dispute submitted to the Competition Tribunal (TDLC) in Chile in 2007. A company called Terquim S.A. accused San Antonio Terminal Internacional (STI) and Empresa Portuaria San Antonio (EPSA) of abusing their dominant position by following a priority criterion for serving ships in the port rather than doing it on a first-come-first-served basis. Consistently with the findings of the present study, the TDLC rejected the argument put forward by Terquim and dismissed the charge in January 2010. Its ruling was upheld by the Supreme Court in September that same year,[1] and with it the use of priority criteria rather than first-come-first-served for processing ships in the port.

Looking beyond this specific antitrust dispute, however, the economic arguments for rationing port infrastructure in a particular period of time are applicable to any port, as is the methodology proposed in this article.

The rest of this paper is organized as follows. Section II describes the institutional framework for public-private port ownership in Chile, the features of the port of San Antonio, the two companies operating there (STI and EPSA) and the main bulk cargo handled by STI (sulphuric acid). Section III reviews the literature on port rationing and explains why port infrastructure can be regarded as an essential facility. Section IV presents an economic model that shows why it is more efficient to ration by cargo value than on a first-come-first-served basis. Section V provides comparative estimates for the two methods at the port of San Antonio, using STI information for 2007. Lastly, section VI offers conclusions.

[1] For further details, see Agostini and Saavedra (2008), TDLC ruling 96/2010 and the Supreme Court judgement with the reference Rol 1933/2010. See [online] www.tdlc.cl.

II
Description of the market and institutional framework

1. Public-private port partnerships in Chile

During the 1980s and 1990s, the Chilean Port Enterprise (EMPORCHI) operated the 10 State-owned ports under a multi-operator system. Under this system, the State enterprise administered the port infrastructure and a number of private-sector firms carried out loading and unloading of ships at the ports. One of the great drawbacks of this system was that it divided cargo up among a number of firms at the same port, seriously limiting incentives to invest in cargo handling equipment and preventing port infrastructure from being used efficiently.

As international trade grew strongly in Chile, port management began to turn into a bottleneck, and in the late 1990s the Government took the decision to modernize the State port sector. The key goals of the reform were to stimulate and dynamize investment in port infrastructure, technology and management. To this end it was proposed that the multi-operator system should be replaced by a single operator system in which a single firm took responsibility for operating and maintaining a port terminal. This would make it possible to promote competition both between ports and at the tendering stage when selecting the future single operator. A reform was accordingly proposed to break up EMPORCHI, involve private-sector firms in State port development via the concession mechanism and modernize labour practices at ports.

The reform approved in 1998 created 10 autonomous State port enterprises, each owning a single port, with the explicit objective of administering, operating, developing and preserving their respective ports and terminals. The law also gave each of these enterprises the mission of promoting competition between ports and within their own port and of involving the private sector to increase efficiency and investment. For this, the port enterprises may tender the concession of contracts for private-sector firms to operate and invest in each of the port terminals owned by them. Under the concession system, each State port enterprise continues to own the infrastructure and oversees the concession contract, being paid a minimum annual rent by the concession holder plus a percentage of its revenues.

In 1999, the concessions for Chile's three main port terminals, San Antonio, Valparaíso and San Vicente (Talcahuano), accounting between them for about 50% of all cargo handled by EMPORCHI, were put out to tender. Two criteria were followed in awarding the concessions: (i) a tariff index calculated from the dues for ship wharfage, cargo wharfage, container transfer and break bulk cargo transfer, and (ii) an annual fee or payment to the State.

This article will now focus on cargo activity at the port of San Antonio, the largest in Chile for total cargo handled and the second-largest for containerized cargo, according to figures for 2011 from the Infrastructure Services Unit of ECLAC.

2. Public- and private-sector port enterprises at San Antonio

The State firm EPSA has four berthing facilities with a total of nine berths and a total surface area of 495 hectares, 353 hectares of this being sea and 142 land. The basin has a surface area of 75 hectares and the four terminals are the Molo Sur (berths 1, 2 and 3), the Espigón (berths 4, 5, 6 and 7), the Terminal Norte (berth 8 specializing in dry bulk cargoes) and berth 9, specializing in wet bulk cargoes.

The tendering process for the port of San Antonio covered the Molo Sur and Terminal Norte concessions. The Molo Sur, with the largest-capacity berths, was awarded to San Antonio Terminal Internacional (STI), with a tariff index of US$ 7.05 a ton, an upfront payment of US$ 10 million, an annual fee that came to US$ 11,050,606 in 2007 given the tonnage handled that year, and an additional payment of US$ 121,252,062 split into six equal annual instalments in the first six years of the concession. The Terminal Norte was awarded to Puerto Panul and the other five berths are operated by EPSA. Thus, STI holds the concession to operate and administer the Molo Sur terminal, specializing in containers. For this purpose it had 769 metres of continuous wharf with 12 metres draught right

along its docking area at the time of the concession,[2] 31 hectares of dockside area (25 being used for storing containers and bulk cargoes), 6 gantry cranes, 9 forklifts, 41 tractor trucks for handling containers and cargo within the terminal, an area for container consolidation and deconsolidation, 6,000 square metres of roofed cargo storage, 2,000 connections for reefers, railway access to the dockside and container loading areas, and a weighbridge for weighing trucks with bulk or containerized cargo.

The concession contract with STI stipulates loading and unloading speeds and waiting times that must be kept to, failing which the concession holder is fined. It also includes stipulations for a progressive improvement in the service provided by the concession holder over the life of the contract. This provides an incentive for the concession holder to invest as necessary to maintain and improve the standard of service without the need to stipulate specific investments or investment amounts. Basic tariffs are set in the concession contract; however, the concession holder can charge special tariffs for additional services provided at users' request. This encourages the concession holder to invest in accordance with developments both in the technical progress of port operations and demand from its various types of customers, who require different levels of service.

Because container use has substantially reduced cargo handling costs, thereby increasing national and international short sea shipping (Clark, Dollar and Micco, 2004; Blonigen and Wilson, 2008), one of the goals of the tendering process was precisely that there should be investment in increased containerized cargo transfer capacity and efficiency. This trend can also be observed at the port of San Antonio, both in the evolution of the number of dockings at each terminal by vessel type (see figure 1) and in the total amount of cargo transferred by vessel type (see figure 2) and performance by type of cargo transferred (see figure 3).

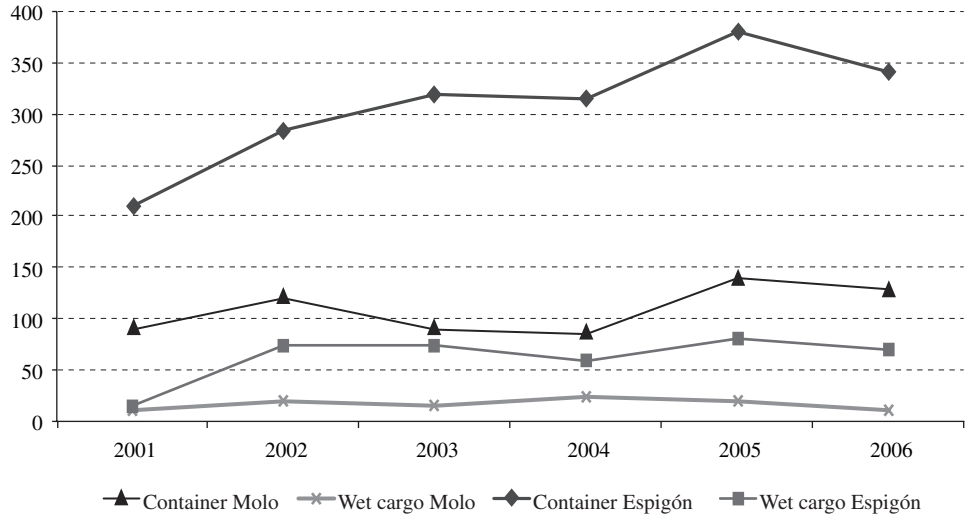
The evolution of cargo in recent years, as reflected in figures 1, 2 and 3, shows not only the tendency towards greater containerization but also the increase in port efficiency brought by containerization. Consequently, having docking facilities that specialize in containerized cargo yields efficiency gains over facilities that mix bulk and containerized cargoes. This is important, as trade volumes can fall off considerably at inefficient ports and the impact can be still greater in small and developing countries (Blonigen and Wilson, 2008).

Berths are a public good, and this implies non-discriminatory public tariffs and an obligation to accept ships and handle cargo. Accordingly, all the landlord

[2] There are currently 380 metres with an authorized draught of 13.5 metres and 389 metres with an authorized draught of 11.34 metres.

FIGURE 1

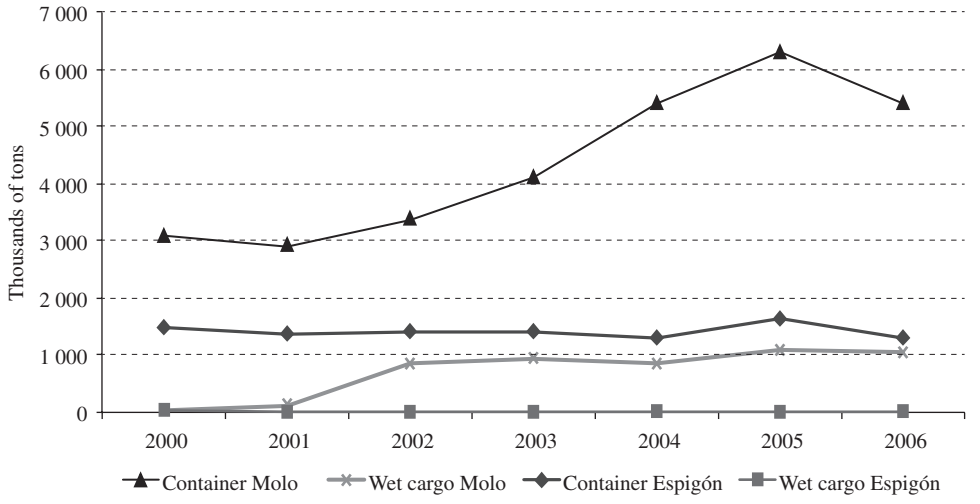
STI: number of dockings by vessel type, 2001-2006



Source: prepared by the authors on the basis of information from San Antonio Terminal Internacional (STI), Chile.

FIGURE 2

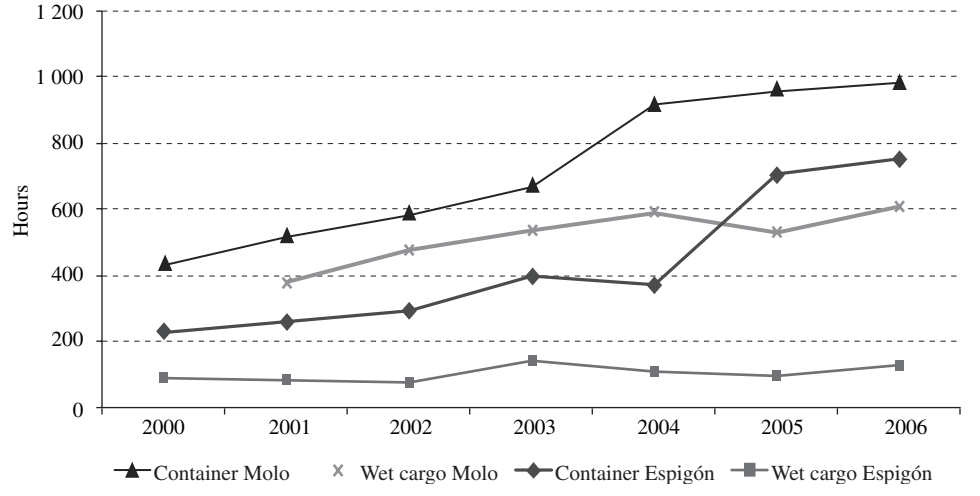
STI: tonnage transferred by cargo type, 2000-2006



Source: prepared by the authors on the basis of information from San Antonio Terminal Internacional (STI), Chile.

FIGURE 3

STI: performance by type of cargo transferred, 2000-2006
(Tons/hour)



Source: prepared by the authors on the basis of information from San Antonio Terminal Internacional (STI), Chile.

ports have internal regulations on the use of docking facilities that are designed to ensure efficient usage of port infrastructure and freedom of choice for users. The service manual lays down docking priority rules and procedures, establishing that dockings must be scheduled on the basis of an objective technical priority rule. Table 1 shows the priorities established for the three berths operated by STI. These priorities reflect preferences for cargo types with faster transfer speeds and port services that operate vessels regularly.

TABLE 1

Chile: STI berthing priorities

	Berth 1	Berth 2	Berth 3
1	Scheduled container ships	Scheduled container ships	Container ships
2	Scheduled break bulk cargo ships	Scheduled ships loading over 10 000 tons of homogeneous cargo	Ships loading over 10 000 tons of homogeneous cargo
3	Bulk cargo ships	Scheduled break bulk cargo ships	Scheduled break bulk cargo ships
4	Other ships	Bulk cargo ships	Bulk cargo ships
5		Other ships	Other ships

Source: San Antonio Terminal Internacional (STI), Chile.

3. The sulphuric acid storage contract and loading protocol

Transportation of sulphuric acid from the El Teniente mine operated by the Chilean National Copper Corporation (CODELCO) to the port of San Antonio is carried out in three sequential stages: trucks, railway and, once in San Antonio, storage in tanks and loading. This last stage is carried out by Terquim, with 97% of all the cargo transferred by Terquim being sulphuric acid. The firm also has the concession to operate at the Molo Sur, i.e., at the terminals awarded to STI.

While STI does not follow a berth reservation policy and thus does not promise to prioritize particular ships over others beyond what is stipulated in its service manual, the contract between STI and CODELCO makes STI responsible for any environmental problems caused by an overflow at the Terquim terminals due to berth unavailability. The aim of this contractual provision is to minimize the time ships carrying sulphuric acid for CODELCO have to wait out at sea, to which end it limits the time the concession holder can keep these ships waiting before they are unloaded, with the clock running from the time the vessel reaches the pilot station until docking manoeuvres begin. The fine prescribed in the contract as applicable in 2007 was US$ 20,000 a day (calculated pro rata for shorter waiting times). In addition, the cost of taking the ship out to an anchorage has to be met by STI (tugs, time, etc.) if it decides to do this. CODELCO, in turn, pays a fixed tariff per ton of acid, this being US$ 1.05 as of April 2008.

The contract specifies three levels of sulphuric acid in the tanks and maximum waiting times before STI has to service ships, depending on the volume accumulated. The volumes and maximum waiting times are: green level, less than 26,000 tons with a maximum wait of 48 hours; yellow level, between 26,000 and 33,000 tons with a maximum wait of 24 hours; and red level, over 33,000 tons with a maximum wait of 6 hours.

In principle, this contract is an efficient economic solution because it is consistent with the literature on port rationing, as shown in section III, and with the theoretical prediction of an economic model of efficient rationing developed in section IV. On the one hand, this rationing criterion gives CODELCO certain guarantees that the sulphuric acid tanks will not fill up completely but will always have the capacity to store acid produced by its smelter. On the other, there is an opportunity cost to STI when it uses a berth for a container vessel and has to pay to keep an acid ship waiting for longer than stipulated in the contract. The economic effect of this contract is precisely to create the right signals so that the use of a docking facility with limited capacity is rationed efficiently.

III

The economic literature on rationing

The literature on rationing the use of a good, and port infrastructure in particular, will now be reviewed. The section will end with a brief discussion of essential inputs, given the special characteristics of the good subject to congestion in this case.

1. Rationing and the economic rationale

The need to ration the use of a good arises when it is costly to modify prices (waiting time in restaurants), when rationing signals quality (medical care or luxury goods) or when there are temporary increases in demand and consumers face switching costs. As a result, there are markets where excess demand leads not to price increases but to rationing for consumers. This happens in markets as diverse as restaurants, electronic components, semiconductors, personal computers, metals, titanium dioxide, polypropylene, petrochemicals, compact discs and children's toys (MacKinnon and Olewiler, 1980; Ghemawat, 1986; Basu, 1987; Carlton, 1991; Slade, 1991; Ungem-Sternberg, 1991; Haddock and McChesney, 1994; De Graba, 1995).

Going by this evidence in different markets, the economic literature has focused on trying to explain the existence of time rationing as an equilibrium situation, and also on determining the optimal rationing mechanisms when it is not possible or desirable to adjust by raising prices.

In one of the seminal articles of this literature, Barzel (1974) established the economic rationale behind first-come-first-served rationing, noting that the waiting time simply created an extra cost for consumers of a good. When a good is available in limited quantities, the time-price mix plays the same role as the monetary price when there is no restriction on quantity; nonetheless, there is a loss of efficiency relative to the unrationed equilibrium. In the event that there are no constraints on the availability of the good but there is price rigidity, the logic is equivalent to Barzel's and waiting time simply serves the purpose of reducing excess demand until it is in balance with the supply of the good (Alderman, 1987).

Even if there are no price rigidities, however, it can still be optimal for a firm to ration rather than raising prices. Bose (1996) shows that when there are users who differ in their willingness to pay and this characteristic is unknown to the supplier, waiting times become an effective mechanism for discriminating between them, insofar as demand and thus willingness to pay are greater among those who wait. As a result, there is an equilibrium with rationing whereby it is more profitable for the supplier to ration consumers than to charge higher prices to achieve market equilibrium.

Looking past the different theoretical explanations given in the literature to account for the existence of rationing as an equilibrium situation in a market, what is relevant in this case is to consider how optimal the different rationing mechanisms are. An early contribution was made by Greenberger (1966), who noted that the optimal system of priorities depended on the objective, as there is a conflict between minimizing the average waiting time and its variance. Thus, a rule giving priority to consumers who need to be served more quickly can be used to minimize the mean waiting time and the number of consumers waiting, but at the cost of increasing variance. Conversely, a first-come-first-served rule serves to control variance in waiting times.

Both rationing criteria assume that the cost of waiting is the same for all consumers. If it is not, there are more efficient options for setting priorities in accordance with how important or urgent the service is for different types of consumers. Thus, Pestalozzi (1964) and Likens (1976) show that a priority index is more efficient than a first-come-first-served system in airport operations. In particular, Pestalozzi's work shows that if the goal is to minimize the average cost of delay, the optimal approach is to introduce priorities by aircraft type, applying the rule that landings have priority over take-offs. It is important to stress that the first-come-first-served rule is never optimal in any of the cases simulated.

Greenberger (1966) considers different rules for computer time-sharing and establishes that the optimal method is to prioritize users by the waiting cost of each, attending first to those for whom the cost is highest. This is similar to the earlier finding of Cox and Smith (1961), who showed that when service delay costs were heterogeneous, the average cost of delay for consumers was minimized by working down the priority list, defined as the waiting cost per unit of time divided by the expected service requirement.

Subsequently, Naor (1969) showed that the first-come-first-served rule, when applied to a homogeneous population of consumers, led to a degree of congestion in excess of what was socially optimal, making it necessary to raise the price to a level that reduced congestion or charge an extra tariff for the same purpose. This finding was subsequently extended by Balachandran and Schaefer (1979) for a situation in which there were heterogeneous consumers.

The paper by Sherman and Visscher (1982) considers the optimal pricing strategy along with rationing mechanisms when demand for a service is stochastic. Their findings show that a rationing mechanism based on priority for consumers with a greater willingness to pay entails an optimal price that is the same for all consumers. Conversely, a rationing mechanism that prioritizes consumers who value the service less entails discriminatory optimal pricing whereby higher prices are charged to consumers who are more willing to pay.

These findings are relevant to the rationing of port infrastructure use, as they show that when it is not possible to charge different prices for different types of consumer and it is mandatory to charge a single non-discriminatory price, the optimum is to ration excess demand in descending order of willingness to pay.

2. Rationing in port infrastructure use

The great majority of studies in the port rationing literature agree that the first-come-first-served mechanism is inefficient, unless all arriving ships and cargoes are identical. Strandeness and Wolfstetter (2005) state that the first-come-first-served criterion is highly inefficient, as it does not reflect ships' relative waiting costs. Likewise, Imai, Nagaiwa and Chan (1997) conclude that if the aim is to achieve high port productivity, first-come-first-served should never be considered as an option for the optimal allocation of berths.

For reasons of efficiency, then, a port should discriminate by means of tolls (extra tariffs) or other mechanisms. Jansson and Ryden (1979) suggested using a two-part tariff, divided into a charge reflecting the opportunity cost of using the port facility and another charge per ton that would be differentiated on the basis of demand elasticity. Similarly, Button (1979) evaluates the design of an economic pricing system in which one criterion is that users of a port should pay the marginal social opportunity cost of the resources they use. The outcome is that ports should charge a two-part tariff, consisting of one charge for cargo, based on the marginal social opportunity cost, and a fixed charge for the right to use the port, based on frequency and the amount of time it is used for. Under this system, regular users of the port have priority over infrequent users, since the first-come-first-served system does not reflect each ship's effective demand for port services.

Following this line of argument, Ghosh (2002) shows that it is optimal to give priority to the ships that most value the service and suggests a system of sequential berth auctions for this purpose. Setting out from this idea, and applying the Vickrey-Clarke-Groves mechanism, Strandenes and Wolfstetter (2005) propose a system of berth auctions using a mechanism that ensures that the bids reveal the true value to each ship of docking at the place and time being auctioned.

Looking beyond theoretical considerations and the consensus in the literature regarding the inefficiency of the first-come-first-served system of berth allocation, in practice different prioritization systems have been increasingly employed at different ports all over the world. For example, Imai, Nishimura and Papadimitriou (2004) argue that allocating berths in a way that takes considerations of priority into account is very important for port operators working in a competitive environment, particularly in view of the greater flexibility it gives them in their decisions about infrastructure use.

Consequently, some ports establish ship size or cargo volume as a priority criterion. For example, port authorities in Japan, Singapore and Norway give priority in some ports to the ships with the largest volume of containers (Imai, Nagaiwa and Chan, 1997; Imai, Nishimura and Papadimitriou, 2004; Svendsen, 1967).

3. Ports as an essential facility

Conceptually, an essential facility or essential infrastructure can be understood as the basic input for supplying firms that participate in competitive segments (even if competition is imperfect) of an industry, where this basic input is provided under conditions of monopoly or market power. It is important to stress that market power deriving from ownership or control of the operation of assets deemed essential does not necessarily have to be monopolistic, as it is enough if the operator of these assets is able to set a completely unregulated limit price that yields rents beyond what their operation would normally provide.

The first thing that needs to be properly understood about the essential facility concept is that the industry has to have a vertical structure, i.e., the market serving consumers must necessarily require access to a basic input because alternative inputs do not exist or are

economically unviable.[3] In the case of a port, this essential facility interacts with different shipping companies offering containerized, bulk or break bulk cargo transport services. There are also indirect users of the port, such as producers and final consumers of the goods transported. Other actors likewise participate in the port cargo transportation activity, examples being the shipping authority and the pilot stations before or after a ship arrives at or leaves its berth, plus customs, customs agencies and the Agriculture and Livestock Service before or after a ship's arrival.

The second thing that has to be understood is that not every type of essential facility needs to be regulated. It is possible to find industries with low sunk costs and little market power in which there is competition for essential facilities, with two or more firms opting to build their own essential facility, sometimes even offering access (paid for but freely determined by the market) to their rivals in the market for the final customer. An example of this might be a liberalized health-care industry (Robinson and Casalino, 1996) or the telecommunications industry (Valetti and Cambini, 2005; Mancero and Saavedra, 2006). Alternatively, there are industries with larger sunk costs where two or more competitors share their essential facilities, sometimes as a market outcome upon the entry of a new competitor, possible examples being the liquid fuel industry (Balmaceda and Saavedra, 2007) and the air transport industry (Agostini, 2008 and 2012).

If the decision has been taken to regulate the tariffs and quality of the essential facility, then two points are worth analysing. First, when the auction process for the port privatization or concession is being designed, care needs to be taken with the ex post conditions governing the actual operation of the facilities (Engel, Fischer and Galetovic, 2004), with particular attention being paid to the conditions of ownership of the private-sector operators, the horizontal structure of the industry, tariff regulation and regulation of the quality of the service to be provided. Second, if the choice is made not to separate the industry vertically, the port operator may have commercial interests in the shipping market, enabling it to sabotage rivals by giving them a lower-quality service than it provides to its own ships (Mandy and Sappington, 2007). The Chilean regulations guard against these risks by laying down explicit rules for service priority, waiting times and quality standards that are overseen by the relevant port regulator.

In summary, the concession of port infrastructure operations is economically efficient if the tendering and regulation processes mimic a competitive market, providing the right signals to the operator with respect to pricing, service quality and most particularly investment. Consequently, the matter of whether the right port investments have been made is not in dispute, since congestion at given price levels is something that is bound to arise anyway at some point, and it is precisely then that an efficient way of handling rationing is needed.

[3] Strictly speaking, the port industry does have imperfect substitutes for the essential facility, such as more distant ports in the same country or a State port at the same place. They are imperfect because the cost of access to them is greater (in money or waiting times).

IV

An efficient port rationing model

1. The basic model

Given the decision taken by the State prior to the port tendering process, particularly industry ownership and structure constraints and the setting of prices for the various services, the port operator will be faced with the need to ration use of the essential facility at times of high service demand. Simply put, whatever volume of investment may be needed, the optimal and actual situation is that there will be periods when the port infrastructure will have capacity available to cope with any type of cargo and, optimally, there will be other periods when it will be overwhelmed by excess demand.

It will now be shown that efficient rationing is achieved by assigning all port activity at periods of high demand to the container service, leaving the residual capacity for other services with less value added, such as bulk or break bulk cargo, which will be dealt with once the congestion is over. This is the right thing to do as long as there are no externalities affecting the population as a result of any spillages caused by excessive build-up of hazardous bulk cargoes in the port, an example being sulphuric acid at times when large volumes accumulate.

This cargo handling allocation in favour of containers is generally more efficient for three reasons: greater profits in the form of surpluses for users of port services, greater profits for the port operator and greater port capacity available for services provided at times of high demand.[4]

Assuming that port activity is restricted to just two activities, namely container transfer (C) and bulk cargo transfer (B), only three periods are relevant: the first, in which there is no rationing because total demand for the two activities falls short of installed capacity (K); the second, when the demand for container transfer increases to the point where total demand exceeds installed capacity ($D_1 > K$); and the third, when demand returns to normal and the demand subjected to rationing in the previous period is also dealt with. The prices for these services are regulated exogenously, and are thus equal to p^C and p^B, and costs are respectively c^C and c^B, where $p^C > p^B > c^B > c^C$. This captures the fact that the margin earned by the concession operator on the container service is greater than the margin earned on the bulk cargo service.[5]

Demand for the two services in the second and third periods is equal and is defined as $p^C = a - b \cdot Q^C$ and $p^B = a - b \cdot Q^B$, with bulk demand in the second period being the same and container demand in the second period growing to $p^C = a + \alpha - b \cdot Q^C$. Figure 4 summarizes the structure of the industry for the second and third periods, with the third period resembling the first.

Society's welfare is equal to the sum of the surpluses of service users plus the profits of the port firm. It is important to stress the relevance of incorporating the profits of the port firm into the social benefit because: (i) it uses them to pay for infrastructure investment and (ii) the right to operate the port has been awarded under a concession, which means that the expected rents from the business were captured by the State at the time the port operation was put out to tender with the annual fee and upfront payment required. Nonetheless, as will be shown later, the qualitative results do not change if only the surpluses of port service users are considered.

If we use the terms π_t^C and π_t^B, respectively, for the net surpluses of container and bulk transfer customers ($t = 1, 2, 3$), social welfare is:

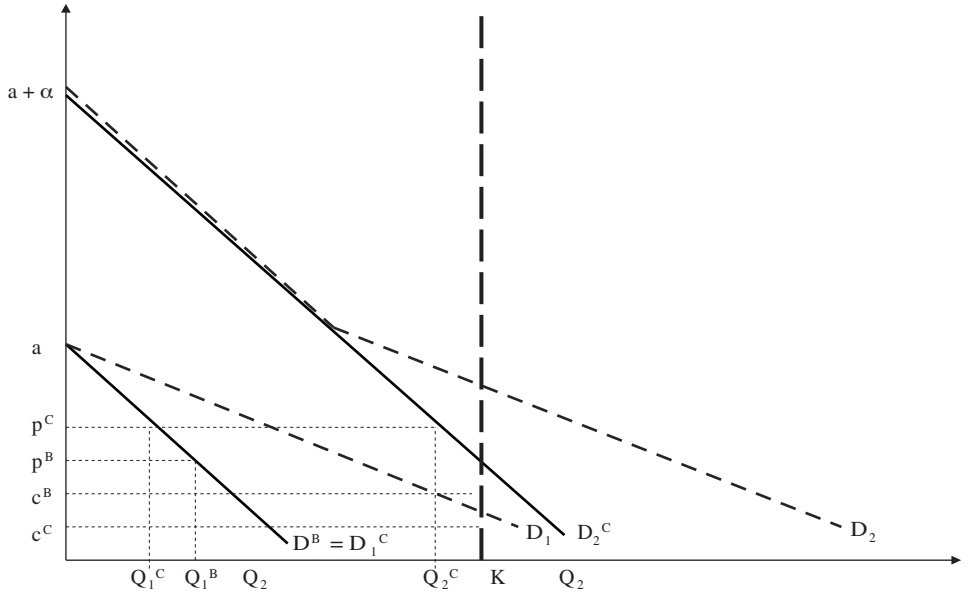
$$W = W_1 + W_2 + W_3 = \sum_{i=1}^{3} \left(U_i^C + U_i^B + \pi_i^C + \pi_i^B \right) \quad (1)$$

[4] By greater port capacity is meant the speed with which ships transporting a given tonnage are loaded or unloaded. Thus, port capacity is higher when a ship is processed more quickly than another, given a constant cargo transfer tonnage.

[5] This is once again subject to there being no risk involved in the build-up of bulk cargoes. If there is, c^B will be greater, and may exceed the price charged for this activity.

FIGURE 4

Containerized and bulk cargo markets in periods of low and high demand

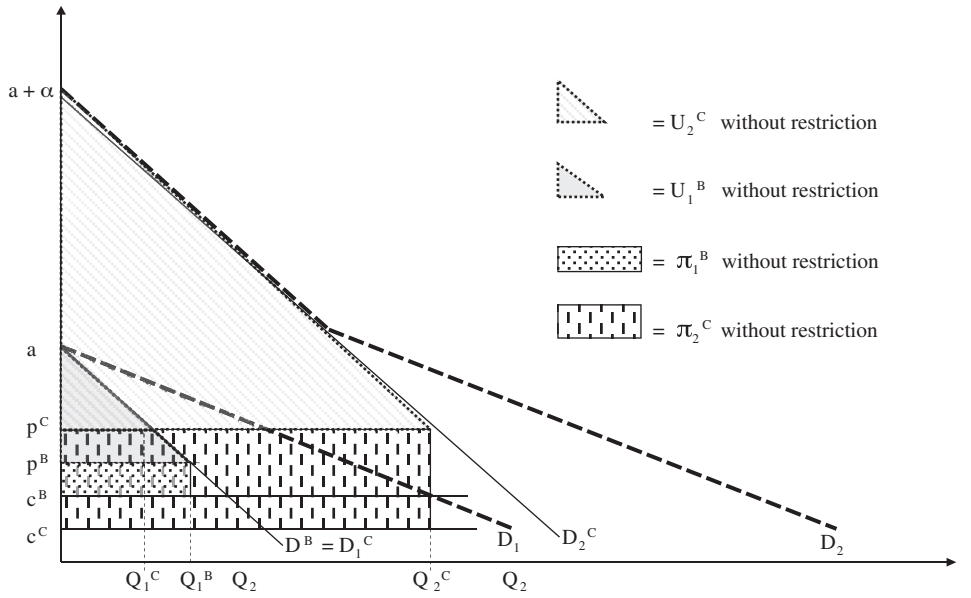


Source: prepared by the authors on the basis of information from San Antonio Terminal Internacional (STI), Chile.

It should be noted that although demand is the same in all three periods, the surpluses of bulk users vary insofar as the service is rationed in the second period and the demand is wholly or partially met in the third period. To give a better understanding of these surpluses that social welfare is comprised of, figure 5 illustrates the four surpluses or profits for the second period. For simplicity, and solely for the purposes of figure 5, it is assumed that there is no capacity constraint.

FIGURE 5

Social welfare in the second period without rationing



Source: prepared by the authors on the basis of information from San Antonio Terminal Internacional (STI), Chile.

To return to the general case, when there is rationing in the second period, it can be assumed that a proportion θ of the rationing is assigned to bulk activities, while $(1 - \theta)$ of this rationing is assigned to container activity. The cargo subjected to rationing is completely processed in the following period, but the user only receives a proportion of the surplus: δ^C and δ^B. Given that in practice container activity is substantially more important to the country's economy and the customers of port services themselves, it is reasonable to assume that it is these who have most to lose by rationing, and this is captured in the model, with the assumption that $0 < \delta^C$ and $\delta^B < 1$. It should be explained that there is no flow discounting between periods, as rationing is assumed to be very short-lived, which means that δ^C and δ^B only represent the opportunity cost of the service not being provided when required. Lastly, it is assumed that the port firm forfeits $(1 - f)$ of its profits by compensating a customer subjected to rationing, which covers fuel, wage and other costs, in addition to any compensation to third parties (like that payable to CODELCO in the case of sulphuric acid). This payment amount does not include any compensation for the shipping companies subjected to rationing; this would only constitute income transfers which would not affect the efficiency of resource allocation.

What will be reviewed first is the case where the installed port capacity required to process ships' cargoes is fixed and independent of the parameter θ. Then consideration will be given to the case where this installed port services capacity in a given period increases as more rationing falls upon bulk activities, i.e.:

$$\frac{\partial K}{\partial \theta} > 0$$

where $K \in \left[\underline{K}, \overline{K}\right]$.

2. Social welfare and rationing with fixed capacity

The surpluses of users and of the port for the three periods are:

$$\begin{aligned} W_1 &= U_1^C + U_1^B + \pi_1^C + \pi_1^B \\ &= \frac{1}{2}(a-p^C)Q_1^C + \frac{1}{2}(a-p^B)Q_1^B + (p^C-c^C)Q_1^C \\ &+(p^B-c^B)Q_1^B = -\frac{1}{2b}\left[(a-p^C)^2+(a-p^B)^2\right] \\ &+\frac{1}{b}\left[(a-c^C)(a-p^C)+(a-c^B)(a-p^B)\right] \end{aligned} \tag{2}$$

$$\begin{aligned} W_2 &= U_2^C + U_2^B + \pi_2^C + \pi_2^B \\ &= \frac{1}{2}(a+\alpha-p^C)Q_2^C - (1-\theta)\frac{b}{2}(Q_2-K)^2 \\ &+\frac{1}{2}(a-p^B)Q_2^B - \theta\frac{b}{2}(Q_2-K)^2 \\ &+(p^C-c^C)Q_2^C - (1-\theta)(p^C-c^C)(Q_2-K) \\ &+(p^B-c^B)Q_2^B - \theta(p^B-c^B)(Q_2-K) \\ &=-\frac{1}{2b}\left[(a+\alpha-p^C)^2+(a-p^B)^2\right] \\ &+\frac{1}{b}\left[(a+\alpha-c^C)(a-p^C)+(a-c^B)(a-p^B)\right] \\ &-\frac{1}{2b}\left(2a+\alpha-(p^C+p^B)-bK\right)^2 \\ &-\frac{1}{b}\left[(p^C-c^C)-\theta\left[(p^C-c^C)-(p^B-c^B)\right]\right] \\ &\left(2a+\alpha-(p^C+p^B)-bK\right) \end{aligned} \tag{3}$$

$$\begin{aligned} W_3 &= U_3^C + U_3^B + \pi_3^C + \pi_3^B \\ &= \frac{1}{2}(a-p^C)Q_3^C - \delta^C(1-\theta)\frac{b}{2}(Q_2-K)^2 \\ &+\frac{1}{2}(a-p^B)Q_3^B + \delta^B\theta\frac{b}{2}(Q_2-K)^2 \\ &+(p^C-c^C)Q_3^C + f(1-\theta)(p^C-c^C)(Q_2-K) \\ &+(p^B-c^B)Q_3^B + f\,\theta(p^B-c^B)(Q_2-K) \\ &= W_1 + \frac{1}{2b}\left(2a+\alpha-(p^C+p^B)-bK\right)^2 \\ &\left[\delta^C+\theta(\delta^B-\delta^C)\right] \\ &+\frac{f}{b}\left[(p^C-c^C)-\theta\left[(p^C-c^C)-(p^B-c^B)\right]\right] \\ &\left(2a+\alpha-(p^C+p^B)-bK\right) \end{aligned} \tag{4}$$

For the purposes of the relevant economic analysis, it is possible to separate social welfare into the portion that does not depend on how rationing is carried out and the portion that does depend on rationing. Thus, if the term $W(a, \alpha, p^C, p^B, c^C, c^B)$ $W(a, \alpha, p^C, p^B, c^C, c^B)$ is used for the portion of social welfare that depends neither on rationing nor on installed capacity, after substituting equations (2), (3) and (4) into (1), total social welfare will be found to be expressed as:

$$\begin{aligned} W &= W(a,\alpha,p^C,p^B,c^C,c^B) \\ &+\frac{1}{2b}\left(1-\left[\delta^C+\theta(\delta^B-\delta^C)\right]\right) \\ &\left(2a+\alpha-(p^C+p^B)-bK\right)^2 \\ &+\frac{1-f}{b}\theta\left[(p^C-c^C)-(p^B-c^B)\right] \\ &\left(2a+\alpha-(p^C+p^B)-bK\right) \end{aligned} \tag{5}$$

Then, the effect of assigning more rationing to bulk cargo services is always socially beneficial, since $0 < \delta^C$ and $\delta^B < 1$, as when equation (5) is derived for q, the derivation is positive:

$$\begin{aligned} \frac{\partial W}{\partial\theta} &= \frac{1}{2b}(\delta^B-\delta^C)\left(2a+\alpha-(p^C+p^B)-bK\right)^2 \\ &+\frac{1-f}{b}\left[(p^C-c^C)-(p^B-c^B)\right] \\ &\left(2a+\alpha-(p^C+p^B)-bK\right) > 0 \end{aligned} \tag{6}$$

The first term of expression (6) shows the change in users' welfare as a consequence of assigning more rationing at the margins to the service with less value added, which is reflected in the fact that $\delta^C < \delta^B$. This is because users of container ships lose significantly more than users of bulk cargo ships when cargo loading or unloading is delayed. The second term is only significant when the port firm pays the costs entailed by the rationing and its profits are thereby reduced ($f < 1$), these costs being lower when efforts are focused on the activity with faster cargo transfer.

In view of this result, given that rationing is allowed because prices do not adjust to demand at a specific point in time when port services are provided, it is efficient to assign all rationing to bulk transfer activities; i.e., it is efficient to set $\theta = 1$.

Although this result applies fairly generally, it is not completely applicable when the population is confronted with negative externalities resulting from the excessive build-up of certain types of cargo, as can potentially occur with sulphuric acid in the case of San Antonio or with other toxic materials at other ports in the country. To capture a situation like this, the model can be modified for periods of sulphuric acid accumulation (something that is known about in advance and is not random), so that the (social) cost of postponing this cargo is rising and convex with the bulk cargo rationed, i.e., a function $S(\theta)$, so that $S'(\theta) > 0$ and $S''(\theta) > 0$. On this assumption, expression (6) would become:

$$\left.\frac{\partial W}{\partial \theta}\right|_{S(\theta)>0} = \left.\frac{\partial W}{\partial \theta}\right|_{S(\theta)=0} - S'(\theta) \gtreqless 0 \qquad (7)$$

If stored cargo is dangerous enough for the externality to generate considerable costs for society, then this effect will dominate so that, in a situation like the one described, it will be advisable to ration containers. The assumption must be that this will not usually be the case and equation (6) will therefore operate.

3. Social welfare and rationing with endogenous capacity

In the previous result concerning the efficiency generated by rationing the loading of bulk or break bulk cargo relative to containerized cargo, port capacity is assumed to be given (fixed and exogenous), which means it is relevant to consider whether this conclusion holds in the event of port capacity being endogenous. This is particularly important not just for the general robustness of a model in relation to its assumptions, but because in this case, as will be shown empirically further on, the evidence is that more time is required to transfer bulk cargo than to deal with a container ship of the same size.

Considering port capacity to be endogenous to the rationing decision implies, in terms of this model, that the capacity of the port increases as rationing is shifted from containers to bulk cargoes or, mathematically, $K = K(\theta)$, with $\frac{\partial K}{\partial \theta} > 0$. It is assumed that $K(0) = \underline{K}$ and $K(1) = \overline{K}$ and ; however, even if all rationing were assigned to bulk activity, there would still be rationing, which means that $Q_2 > \overline{K}$. Taking the results of the previous subsection, the effect of a rise of θ on social welfare is:

$$\begin{aligned}\frac{\partial W}{\partial \theta} &= \frac{1}{2b}\left(\delta^B - \delta^C\right)\left(2a + \alpha - \left(p^C + p^B\right) - bK\right)^2 \\ &+ \frac{1-f}{b}\left[\left(p^C - c^C\right) - \left(p^B - c^B\right)\right]\left(2a + \alpha - \left(p^C + p^B\right) - bK\right) \\ &+ \left(2a + \alpha - \left(p^C + p^B\right) - bK\right)\left(1 - \left[\delta^C + \theta\left(\delta^B - \delta^C\right)\right]\right)\frac{\partial K}{\partial \theta} \\ &+ \left(1-f\right)\left[\left(1-\theta\right)\left(p^C - c^C\right) + \theta\left(p^B - c^B\right)\right]\frac{\partial K}{\partial \theta} > 0\end{aligned} \qquad (8)$$

where the last two terms of (8) are new, i.e., do not appear in expression (6), and capture the impact of lesser rationing insofar as this is assigned to bulk cargo transfer. Consequently, when this prioritization rule is adopted for port activity, both the direct effects of favouring containerized cargo and the indirect effects in the form of greater port capacity increase social welfare.

In the same way, if the social welfare repercussions of rationing bulk cargo, $S'(\theta)$, were large enough, owing for example to the consequences of a higher probability of spillage for a hazardous cargo, then the effect would be the opposite of the one predicted in expression (8). It will be assumed that these cases are governed by protocols or contracts between the port and those generating the cargo, or regulated directly by environmental laws or regulations, so that rationing would be applied to containers in these circumstances.

V

Applying priority criteria at the port of San Antonio in Chile

The theoretical model presented earlier, consistently with the findings of the economic literature, shows that a rationing mechanism based on waiting instead of pricing is efficient and increases welfare in the case of a port with essential facility characteristics. The question is whether or not this model is consistent with the rationing applied in real-world port operations, and whether these predicted efficiencies actually exist. To consider how rationing by cargo type works in practice, we shall now analyse what happened with each of the wet cargo ships that arrived at the port of San Antonio and used STI facilities during 2007. We then estimate the efficiency of rationing that favours containerized cargo (and break bulk cargo) as opposed to using the first-come-first-served criterion to ration available capacity when this falls short of demand.

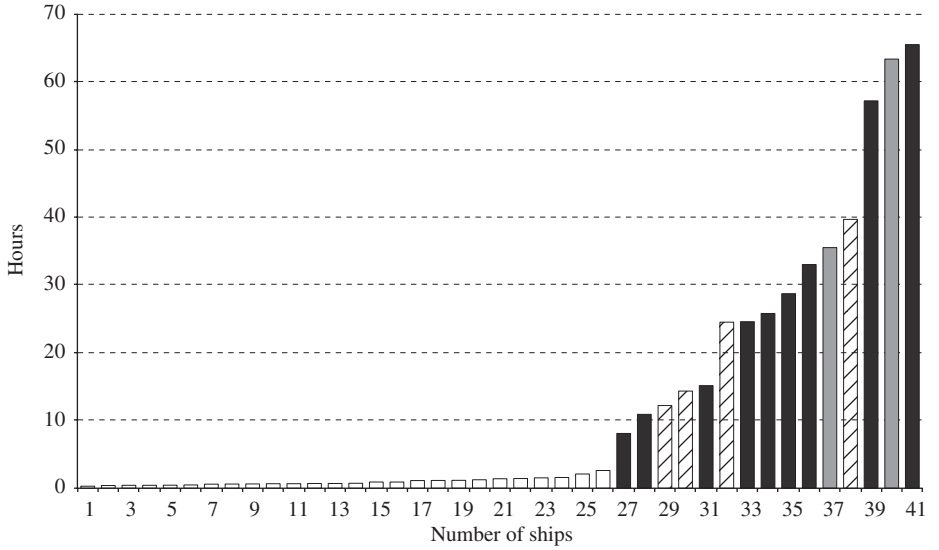
The form this rationing took in 2007 is first characterized. It is then shown that the port is more efficient at transferring containerized cargo than bulk cargo or, consistently with the section IV model, it is shown that $c^C < c^B$. Lastly, it is shown that it is better for society if containerized cargo is prioritized over bulk cargo, i.e., $p^C > p^B$. These port efficiency and welfare estimates are arrived at separately for sulphuric acid and other wet cargoes.

1. Characterization of waiting times with efficient rationing

Figure 6 shows the distribution of total waiting times for ships carrying sulphuric acid in 2007, counting from arrival at the pilot station until the first mooring line is attached at a berth. Of 41 ships carrying sulphuric acid, 15 had to wait longer than they would had they been serviced immediately and without interruptions. However, only 9 of these 15 cases can be ascribed to the priority rules (the black bars in figure 6), since according to STI the wait was due on four occasions to the berths being occupied by ships that had arrived first, just as a port would operate if it followed the first-come-first-served rule (striped bars in figure 6), and in two cases CODELCO asked the ship to wait out at sea because there was not enough sulphuric acid to load (grey bars in figure 4). The effect of applying rationing by cargo

FIGURE 6

STI: waiting times and causes for sulphuric acid ships



Source: prepared by the authors on the basis of information from San Antonio Terminal Internacional (STI), Chile.

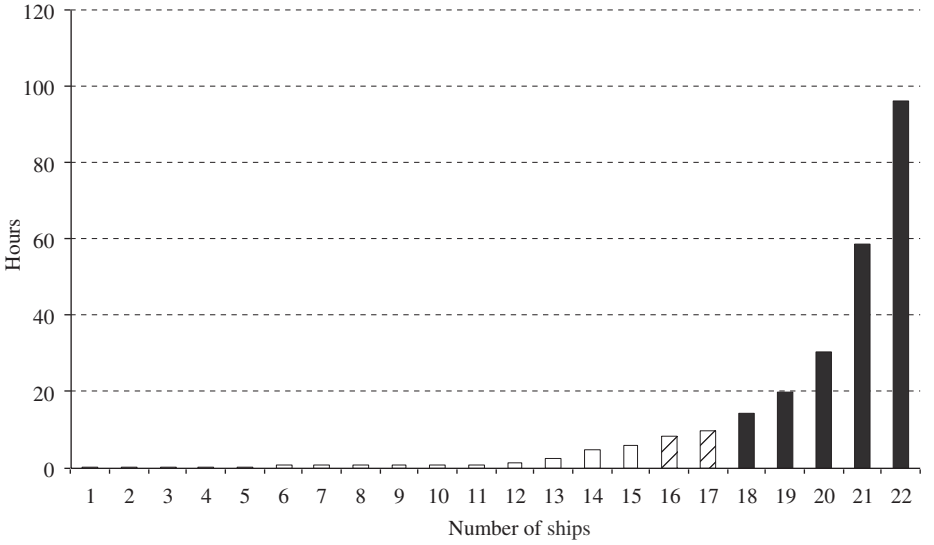
type and sending bulk carriers out to sea was that this happened in 22% of STI sulphuric acid loading operations in 2007.

The situation with wet cargoes other than sulphuric acid was not much different. Figure 7 illustrates the distribution of total waiting times for these wet cargo ships in 2007. It can be seen that 22 such ships came into the port that year, of which just 5, or 22.7%, had to wait because of the STI priority regulations (black bars in figure 7). In addition, two had to wait because the berths were in use by ships that had arrived earlier (striped bars in figure 7).

In summary, the conclusion from analysing information on waiting times at STI in 2007 is that 20% of wet cargo ships were subjected to a wait longer than they would have had under a first-come-first-served system.

FIGURE 7

STI: waiting times and causes for other wet cargo ships



Source: prepared by the authors on the basis of information from San Antonio Terminal Internacional (STI), Chile.

2. The opportunity cost of efficient rationing

Whatever the percentage of times it happens or the percentage of ships affected, it is far more relevant to know the opportunity cost of the efficient rationing policy or, in other words, the estimated value of the containerized and break bulk cargo given priority over sulphuric acid and other wet cargoes. This information can be used to reach some kind of estimate of how much society gains by following the priority rule described instead of adopting a first-come-first-served rule. What is at issue is not social welfare, certainly, since it is not the demand for each product that is being estimated but the value of the cargo at market equilibrium prices.[6]

- Ideal estimates

Bulk cargo (B) has a gross value on a certain date t of $v_t^B = p_t^B \cdot Q_t^B$. Ideally, this information could be obtained more precisely from the FOB value of the cargo transported.[7] In this case, the gross value of a shipload of bulk cargo would simply be $v_t^B = FOB_t^B$. Similarly, containerized (C) and break bulk cargo has a value for each shipload transported that is given by the same product of prices and quantities. Since cargoes on these ships are heterogeneous, the best way of estimating the gross value of the cargo transported in each ship i at each moment of time v_{jt}^B is simply to take its FOB value. Then, if a bulk cargo ship is subjected to rationing to make way for J ships carrying containers or break bulk cargoes or both, the gross value to society

[6] It is also important to bear in mind that the social opportunity cost of rationing sulphuric acid cargoes could be increased by the impact this measure would have on the mining operations that require it as a production input. It is assumed that since delays did not amount to so much as three days, at least in 2007, this impact would not halt mining production (delays in 2007 averaged just under 30 hours).

[7] The FOB value is the value of the merchandise put aboard the ship in the country of origin, excluding insurance and freight.

of prioritizing the ships carrying this type of cargo is $\sum_{j=1}^{J} v_{jt}^{C} = \sum_{j=1}^{J} FOB_{jt}^{C}$.

Since the costs of processing any type of ship are essentially fixed, given that the greatest cost is the opportunity cost of the sunk infrastructure investment in wharves, cranes, manifolds, and so on, it is not enough to know how much space is occupied by each ship in the port, as the time (*hrs*) it takes to load or unload it also has to be established. Consequently, the right comparison is between the value of the cargo of a ship subjected to rationing and the value of the cargo of ships given priority over it:

$$\frac{FOB_{t}^{B}}{hrs_{t}} \gtrless \sum_{j=1}^{J} \frac{FOB_{jt}^{C}}{hrs_{jt}} \left(\frac{Q_{jt}^{C}}{\sum_{j=1}^{J} Q_{jt}^{C}} \right) \qquad (9)$$

In other words, each mean operation is weighted by the relative cargo transfer tonnages for the ship concerned.

Nonetheless, it is of the greatest interest to learn how large this difference was in a particular year, and for this it is enough to calculate the weighted average number of tons per hour for the whole of a given year:

$$\sum_{t=1}^{T} \frac{FOB_{t}^{B}}{hrs_{t}} \left(\frac{Q_{t}^{B}}{\sum_{t=1}^{T} Q_{t}^{B}} \right)$$
$$\gtrless \sum_{t=1}^{T} \left[\sum_{j=1}^{J} \frac{FOB_{jt}^{C}}{hrs_{jt}} \left(\frac{Q_{jt}^{C}}{\sum_{j=1}^{J} Q_{jt}^{C}} \right) \right] \left(\frac{\sum_{j=1}^{J} Q_{jt}^{C}}{\sum_{t=1}^{T} \left[\sum_{j=1}^{J} Q_{jt}^{C} \right]} \right) \qquad (10)$$

In this case, *T* refers to all bulk cargo ships subjected to rationing in a particular year where, as seen in the formula, mean transfers need to be weighted for each case.

- Prioritization and efficiency: sulphuric acid

Unfortunately, there is no publicly available information on FOB values for the loading and unloading operations carried out, which would allow an exact calculation to be made, so market or aggregate variables are used as a proxy for the true values; i.e., the cargo valued at market prices: $p_{t}^{as} \cdot Q_{t}^{as}$. For this purpose, information is available on the tonnage of each sulphuric acid ship subjected to rationing in 2007 (Q_{t}^{as}), and the average price paid for sulphuric acid by Chilean importers is used, the latest CIF value available as of 2008 being the average price for 2006: p_{t}^{as} = US$ 57.1 a ton (COCHILCO, 2007). The rest of the relevant information for shipments of sulphuric acid in 2007 was supplied by STI and the relevant variables for this calculation are presented in table 2.

The data show that it took an average of just under 30 hours to begin cargo transfer operations on ships subjected to rationing from the time they reached the port. This was 2.5 times the average time taken to start loading sulphuric acid on to the 41 ships that came to the port to take on this cargo in 2007, which was 11.76 hours. The rate at which sulphuric acid was loaded on to each ship subjected to rationing at STI that year was 573.5 tons an hour (average weighted by the amount loaded on to each vessel). To sum up, the average value of the sulphuric acid loaded on to these vessels subjected to rationing by the port in 2007 was US$ 32,748 per ton/hour of loading.

Regarding the ships given priority over those subjected to rationing, since the FOB value of each shipment is unknown, as are tonnages and prices, the implicit average price of Chilean exports and imports has been used, going by information from the Central Bank of Chile (FOB value of imports and exports in 2006) and the Maritime and Port Chamber of Chile (total amounts imported and exported that year). Going by these data, the average price estimated for 2006 is p^{co} = US$ 1,251 a ton.[8]

Table 3 provides general information on the number of ships prioritized, tons transferred and the amount of time spent using the port for this, while the last two columns show the calculations for tons per hour and the value of these transfers, in accordance with expression (10).

The main conclusions from the data analysis regarding port efficiency are as follows:

(i) When the efficiency of the port at loading acid is compared with its efficiency at loading prioritized cargo, particularly containerized cargo, the findings are consistent with those predicted by the theoretical model inasmuch as the port is more efficient at transferring containerized and break bulk cargo than at loading sulphuric acid. The amount loaded on to prioritized ships for each hour of port infrastructure use averaged 773.35 tons (weighted) in 2007, while the equivalent average hourly transfer for sulphuric acid ships was 573.62 tons. It can be concluded that the port is more efficient at transferring containerized and break bulk cargo tonnage than at loading acid,

[8] This price represents a lower bound to the actual average price for that year, since this proxy variable incorporates the weighted price of bulk cargo, which is lower than that of containerized and break bulk cargo.

TABLE 2

STI: sulphuric acid ships subjected to rationing in 2007

Arrival	Hours' wait	Hours' loading hrs_t	Tonnage Q_t^{as}	Tons/hour [a]	Value *(per ton/hour)* [b] *(dollars)*
2 January	57.15	44.15	25 020	566.70	32 359
14 January	28.70	48.05	25 023	520.77	29 736
19 February	25.78	20.73	11 766	567.49	32 404
10 March	65.45	47.50	26 018	547.75	31 276
21 March	15.13	44.75	26 025	581.56	33 207
4 May	33.00	39.60	26 018	657.02	37 516
16 August	8.08	22.95	11 925	520.36	29 713
12 October	24.50	43.55	26 019	597.45	34 114
17 December	10.90	26.63	15 030	564.33	32 223
Average	29.86	37.54	21 427	573.52	32 748

Source: prepared by the authors on the basis of information from San Antonio Terminal Internacional (STI), Chile.

[a] The average transfer rate for ships subjected to rationing is weighted by the load of each (a simple average gives an average loading rate of 569.27 tons/hour).

[b] The load-weighted average of the final value for cargo subjected to rationing is equivalent to the expression on the left-hand side of equation (10), while the simple average would give a value of US$ 32,505 per ton/hour.

TABLE 3

STI: ships prioritized over sulphuric acid ships in 2007

Arrival	Number of ships J	Hours' loading $\sum_{j=1}^{J} hrs_{jt}$	Tonnage $\sum_{j=1}^{J} Q_{jt}^{co}$	Tons/hour *(weighted)* [a]	Value *(per ton/hour)* [b] *(dollars)*
2 January	3	41.98	20 131	568.96	711 732
14 January	3	75.42	41 515	684.96	856 832
19 February	2	33.47	28 559	875.24	1 094 857
10 March	6	96.00	84 606	956.45	1 196 443
21 March	2	53.42	24 086	534.39	668 481
4 May	2	43.95	41 964	1 063.72	1 330 628
16 August	2	44.38	28 664	824.46	1 031 333
12 October	3	179.92	76 249	556.84	696 569
17 December	1	20.92	3 234	154.61	193 410
Average	2.67	65.49	38 779	773.35	967 409

Source: prepared by the authors on the basis of information from San Antonio Terminal Internacional (STI), Chile.

[a] The cargo prioritized for each ship subjected to rationing is weighted in accordance with equation (10) as $\sum_{j=1}^{J} \frac{Q_{jt}^{co}}{hrs_{jt}} \left(\frac{Q_{jt}^{co}}{\sum_{j=1}^{J} Q_{jt}^{co}} \right)$. The final average transfer for prioritized ships is weighted in turn by the transfer calculated earlier (a simple average gives an average loading rate of 691.07 tons/hour).

[b] The load-weighted average of the final value of the prioritized cargo is equivalent to the expression on the right-hand side of equation (10), while the simple average would give a value of US$ 864,476 per ton/hour.

since it did the latter only 74.16% as effectively as the prioritized activity (or, to put it another way, the port is 34.84% more efficient on average at loading cargo on to prioritized vessels).

(ii) Looking at the respective efficiency of the two activities from the point of view of how society values their use, which is done by making some reasonable assumptions about the prices of the goods transported, the data reveal that containerized and break bulk cargo loading activities are 29.5 times as valuable as sulphuric acid loading activities. The value of the containerized and break bulk cargo prioritized by STI in 2007 averaged US$ 967,409 an hour, while the value of the sulphuric acid cargo subjected to rationing by STI in 2007 averaged US$ 32,748 an hour. Given the

different orders of magnitude involved, then, there can be no doubt at all that it is socially preferable for port infrastructure use to give priority to containerized cargo.

- Prioritization and efficiency: other wet cargoes

The great heterogeneity of the other wet cargoes transferred means that the average price for these products in 2007 cannot be determined. It is possible, however, to show that in terms of efficiency in tons per hour of port infrastructure usage, a rule giving priority to containerized and break bulk cargo over wet cargoes is the right one. According to the relevant information on transfers of other wet cargoes for 2007 provided by STI and shown in table 4, ships subjected to rationing had to wait an average of almost 44 hours, which was 3.8 times the average wait for a ship of these characteristics, whether subjected to rationing or not, at that port in 2007. The same table shows that the average cargo transfer speed for ships subjected to rationing was 135.4 tons per hour (average weighted by the amount loaded on each ship).

As for the ships given priority, table 5 shows that the prioritization rule set by STI was efficient. The cargo prioritized over other wet cargoes was loaded at an average rate of 821.33 tons per hour, which means that the port was 500% as efficient at moving containerized and break bulk cargo tonnage than at transferring other wet cargoes.

TABLE 4

STI: other wet cargo ships subjected to rationing in 2007

Arrival	Hours' wait	Hours' loading hrs_t	Tonnage Q_t^{other}	Tons/hour [a]
10 March	58.75	8.72	786	90.17
10 March	96.25	17.25	1 420	82.32
30 June	19.97	16.75	3 122	186.39
25 November	14.42	11.00	948	86.18
28 December	30.50	12.25	1 649	134.61
Average	43.98	13.19	1 585	135.44

Source: prepared by the authors on the basis of information from San Antonio Terminal Internacional (STI), Chile.

[a] The average transfer for ships subjected to rationing is weighted by the cargo of each (a simple average would give an average loading rate of 115.93 tons/hour).

TABLE 5

STI: other wet cargo ships prioritized in 2007

Arrival	Number of ships J	Hours' loading $\sum_{j=1}^{J} hrs_{jt}$	Tonnage $\sum_{j=1}^{J} Q_{jt}^{co}$	Tons/hour [a] (*weighted*)	Value [b] *(per ton/hour) (dollars)*
10 March	2	19.08	13 821	733.93	918 086
10 March	5	71.42	57 368	893.76	1 118 027
30 June	1	17.28	17 257	998.46	1 249 002
25 November	1	14.70	2 931	199.42	249 459
28 December	1	30.60	18 043	589.64	737 596
Average	2.67	30.62	21 884	821.33	1 027 428

Source: prepared by the authors on the basis of information from San Antonio Terminal Internacional (STI), Chile.

[a] The cargo prioritized for each ship subjected to rationing is weighted in accordance with equation (10) as $\sum_{j=1}^{J} \frac{Q_{jt}^{co}}{hrs_{jt}} \left(\frac{Q_{jt}^{co}}{\sum_{j=1}^{J} Q_{jt}^{co}} \right)$. The final average transfer rate for prioritized ships is weighted in turn by the transfer rate calculated earlier (a simple average gives an average loading rate of 683.04 tons/hour).

[b] The load-weighted average of the total value of the prioritized cargo is equivalent to the expression on the right-hand side of equation (10), while the simple average would give a value of US$ 854,434 dollars per ton/hour.

VI
Conclusions

The economic literature analysing port congestion has consistently established that the first-come-first-served rule is inefficient in all cases except when all arrivals are identical. From a resource allocation standpoint, it is efficient to use discrimination mechanisms that can ration a scarce resource in an optimal way. In the application presented in this paper, it can be seen that at the landlord port of San Antonio in Chile, as in many other ports around the world, STI follows a priority rule that allows berths to be employed efficiently, with containerized and break bulk cargo being prioritized over bulk cargo.

This paper employs a simple theoretical model which captures the relevant stylized facts for port infrastructure usage. This model allows conclusions to be drawn about the benefits of applying a priority rule in port operations instead of using the first-come-first-served rule. Its results show that, given the inflexibility of the pricing system in port concessions, there needs to be a criterion for rationing efficiently. What has been determined is that it is socially desirable, both for firms using the port and for the concession firm, for all rationing to fall upon the activities with the lowest value added. This lower value added has been conceptually measured by the fall in the value of the cargo being shipped when rationing is applied. This finding still holds if compensation for firms subjected to rationing is incorporated, or if it is assumed that port transfer capacity is affected depending on the type of service being rationed.

The empirical evidence for the berths operated under concession by STI is consistent with the theoretical results. The estimates for the efficiency of STI at transferring sulphuric acid and other wet cargoes, as compared to containers and break bulk cargo, indicate that the port is clearly more efficient at moving containerized and break bulk cargo tonnage per hour of port capacity usage. The estimates in this paper reveal that efficiency is 34.84% higher for container and break bulk cargo operations than for the sulphuric acid loading operations they displace in accordance with the port's priorities manual.

Furthermore, efficiency as measured by performance in the use of port facilities is 500% as great when the comparison is with ships loading other wet cargoes, displaced in accordance with the same priorities manual. Much the same conclusion is reached when the value of the shipped cargo is measured, with sulphuric acid being displaced by cargo worth 26.6 times as much.

It can be inferred from these results that rationing by shipped cargo value is perfectly consistent with economic efficiency, measured as the optimal use of port infrastructure. Furthermore, it is clear that the impact on ships carrying wet cargoes is minor, as just 22% had longer waits than they would have had under the inefficient first-come-first-served system.

Bibliography

Agostini, C. (2012), "El mercado de transporte aéreo: Lecciones de política de una revisión de la literatura", *Journal of Transport Literature*, vol. 6, No. 3, São José dos Campos, Brazilian Transport Planning Society.

_____ (2008), "La organización industrial del transporte aéreo en Chile", *Revista de Análisis Económico*, vol. 23, No. 1, ILADES/ Georgetown University.

Agostini, C. and E. Saavedra (2008), "Racionamiento eficiente en una facilidad esencial: El caso del Puerto de San Antonio" [online] http://www.tdlc.cl/DocumentosMultiples/Informe_Claudio_Agostini_y_Eduardo%20Saavedra_C_136_07.pdf.

Alderman, H. (1987), "Allocation of goods through non-price mechanisms: evidence on distribution by willingness to wait", *Journal of Development Economics*, vol. 25, No. 1, Amsterdam, Elsevier.

Balachandran, K. and E. Schaefer (1979), "Class dominance characteristics at a service facility", *Econometrica*, vol. 47, No. 2, New York, The Econometric Society.

Balmaceda, F. and E. Saavedra (2007), "Vertical integration and shared facilities in unregulated industries", *Journal of Industrial Economics (Notes & Comments)*, vol. 55, No. 4, Wiley, December.

Barzel, Y. (1974), "A theory of rationing by waiting", *Journal of Law and Economics*, vol. 17, No. 1, Chicago, The University of Chicago Press.

Basu, K. (1987), "Monopoly, quality uncertainty and 'status' goods", *International Journal of Industrial Organization*, vol. 5, No. 4, Amsterdam, Elsevier.

Blonigen, B. and W. Wilson (2008), "Port efficiency and trade flows", *Review of International Economics*, vol. 16, No. 1, Wiley Blackwell.

Bose, P. (1996), "Adverse selection, waiting lists and restaurant rationing", *International Journal of Industrial Organization*, vol. 15, No. 3, Amsterdam, Elsevier.

Button, K.J. (1979), "The economics of port pricing", *Journal of Maritime Policy and Management*, vol. 6, No. 3, Taylor & Francis.

Carlton, D. (1991), "The theory of allocation and its implications for marketing and industrial structure: why rationing is efficient", *Journal of Law and Economics*, vol. 34, No. 2, Chicago, The University of Chicago Press.

Clark, X., D. Dollar and A. Micco (2004), "Port efficiency, maritime transport costs, and bilateral trade", *Journal of Development Economics*, vol. 75, No. 2, Amsterdam, Elsevier.

COCHILCO (Chilean Copper Commission) (2007), "El mercado del ácido sulfúrico en Chile proyectado al año 2015" [online] http://www.cochilco.cl/anm/articlefiles/614-INFORMEASULF2006_VersionFINAL.pdf.

Cox, D. and W. Smith (1961), *Queues*, New York, John Wiley.

De Graba, P. (1995), "Buying frenzies and seller-induced excess demand", *The RAND Journal of Economics*, vol. 26, No. 2, Wiley.

Engel, E., R. Fischer and A. Galetovic (2004), "How to auction a bottleneck monopoly when underhand vertical agreements are possible", *Journal of Industrial Economics*, vol. 52, No. 3, Blackwell Publishing.

Ghemawat, P. (1986), "Sustainable advantage", *Harvard Business Review*, Boston, Harvard Business Publishing, September.

Ghosh, M. (2002), "Bidding for a berth: an action based queue management mechanism for ports", *Singapore Maritime & Port Journal*, Singapore, Maritime & Port Authority of Singapore.

Greenberger, M. (1966), "The priority problem and computer time sharing", *Management Science*, vol. 12, No. 11, Institute for Operations Research and the Management Sciences.

Haddock, D. and F. McChesney (1994), "Why do firms contrive shortages? The economics of intentional mispricing", *Economic Inquiry*, vol. 32, No. 4, Wiley.

Imai, A., K. Nagaiwa and W. Chan (1997), "Efficient planning of berth allocation for container terminals in Asia", *Journal of Advanced Transportation*, vol. 31, No. 1, Wiley.

Imai, A., E. Nishimura and S. Papadimitriou (2004), "Berth allocation with service priority", *Transportation Research Part B: Methodological*, vol. 37, No. 5, Amsterdam, Elsevier.

Jansson, J. e I. Ryden (1979), *Swedish Seaports: Economics and Policy*, Stockholm, Stockholm School of Economics, The Economic Research Institute.

Likens, J. (1976), "The welfare cost of nonoptimal airport utilization", *Journal of Public Economics*, vol. 5, No. 1-2, Amsterdam, Elsevier.

MacKinnon, J. and N. Olewiler (1980), "Disequilibrium estimation of the demand for copper", *Bell Journal of Economics*, vol. 11, No. 1, Santa Monica, RAND Corporation.

Mancero, X. and E. Saavedra (2006), "Un modelo de entrada y competencia en telecomunicaciones", *Revista de Análisis Económico*, vol. 21, No. 1, ILADES/Georgetown University.

Mandy, D. and D. Sappington (2007), "Incentives for sabotage in vertically-related industries", *Journal of Regulatory Economics*, vol. 31, No. 3, Springer.

Naor, P. (1969), "The regulation of queue size by levying tolls", *Econometrica*, vol. 37, No. 1, New York, The Econometric Society.

Pestalozzi, G. (1964), "Priority rules for runway", *Operations Research*, vol. 12, No. 6, Institute for Operations Research and the Management Sciences.

Robinson, J. and L. Casalino (1996), "Vertical integration and organizational networks in healthcare", *Health Affairs*, vol. 15, No. 1, Bethesda, Project HOPE — The People-to-People Health Foundation, Inc. .

Sherman, R. and M. Visscher (1982), "Non-price rationing and monopoly price structures when demand is stochastic", *The Bell Journal of Economics*, vol. 13, No. 1, Santa Monica, RAND Corporation.

Slade, M. (1991), "Strategic pricing with customer rationing: the case of primary metals", *Canadian Journal of Economics*, vol. 24, No. 1, Wiley.

Strandenes, P. and E. Wolfstetter (2005), "Efficient (re-)scheduling: an auction approach", *Economics Letters*, vol. 89, No. 2, Amsterdam, Elsevier.

Svendsen, A.S. (1967), *Does the Traditional Set-up of Port Charges Favour Old and Unmodern Ships?*", Bergen, Institute of Shipping Research.

Ungem-Sternberg, T. (1991), "Rationing in restaurants", *International Journal of Industrial Organization*, vol. 9, No. 2, Amsterdam, Elsevier.

Valetti, T. and C. Cambini (2005), "Investments and network competition", *RAND Journal of Economics*, vol. 36, No. 2, Santa Monica, RAND Corporation.

The performance of transnational corporations: Evidence for the manufacturing industry in Chile

Sebastián Vergara M.

ABSTRACT

This article analyses the performance of transnational corporations in Chilean manufacturing industry. The findings show that while the productivity of subsidiaries of foreign-owned firms is higher than that of local firms, the same is not true of productivity growth. They also show that there are no significant differences in market survival rates between transnational corporations and local firms. However, firms under mainly foreign ownership that are small and have low productivity are more likely to exit the market, displaying more footloose behaviour than their local counterparts. This is associated with lower levels of profitability for this group of transnational firms. Lastly, the findings suggest that transnational corporations are not always more profitable than local firms. Furthermore, they seem able to exploit their advantages over the latter only in the higher quantiles of the profitability distribution.

KEYWORDS Transnational corporations, industry, manufactures, productivity, profitability, evaluation, statistical data, Chile

JEL CLASSIFICATION L25, F23, C21

AUTHOR Sebastián Vergara M. is an Economic Affairs Officer at the United Nations Department of Economic and Social Affairs (DESA). vergaras@un.org

I
Introduction

In recent decades, transnational corporations have become important global players in trade, innovation, technology and value chains, and key actors in many countries' development (Cohen, 2007; UNCTAD, 2005; Narula and Lall, 2006). One of the most widely accepted theories about the phenomenon of transnational corporations is that they enjoy advantages of ownership, location and internationalization (Dunning, 2000).[1] The direct implication is that the subsidiaries of transnational corporations should perform better than local firms in the host economies, in terms of productivity and profitability for example, because of their higher levels of technology, capabilities and know-how in international markets.

These considerations need to be treated with caution, however, as foreign ownership does not in itself guarantee a better performance than that of local firms. First, the subsidiaries of transnational corporations, like local firms, constitute a large and heterogeneous array of businesses with differing characteristics and capabilities. Second, there are factors that can negatively affect the performance of transnational corporations, such as lack of experience in the local market and inadequate knowledge of competition patterns. Indeed, this can be a particularly important factor in developing countries that have specific characteristics as regards suppliers, infrastructure, labour markets and informality. Third, it can be seen from the recent literature that the flow of knowledge in a transnational corporation is a complex and demanding process, and it cannot be assumed that knowledge will move freely between the parent firm and its subsidiaries. In other words, the advantages of ownership by transnational corporations could be confined to their more advanced production operations. For example, Hobday and Rush (2007) stress the degree of autonomy subsidiaries have and their integration into corporate strategies that are decentralized from the parent companies as aspects that determine the flow of knowledge between a parent company and its subsidiaries. Marín and Arza (2009) discuss the role played by the latter in terms of their ability to interconnect two knowledge networks, the global one and the national one. These factors call into question the assumption that the subsidiaries of transnational corporations will necessarily have a better production performance than local firms.

In Latin America there is a substantial literature on foreign direct investment (FDI) and transnational corporations, particularly as regards sectors of operation, activity types, modes of entry and corporate strategies that explain their regional positioning (ECLAC, 2012;[2] Gallagher and Chudnovsky, 2009; Moran, Graham and Blomström, 2005). However, there is little information about the production activities of transnational corporations based on performance indicators comparable to those for local firms. Furthermore, such evidence as does exist is usually confined to a small group of large transnational corporations operating in oligopolistic service markets with high levels of concentration, such as energy and telecommunications, where regulation plays a particularly important role in competition patterns and profitability. It is important to look more closely at this aspect, given the role played by these firms in shaping the production mix of the region's countries, something that is also crucial for understanding their potential effects on the host economies. Indeed, there is a huge literature examining the effects the activities of transnational corporations have on host economies, particularly as regards linkages, technology transfers and the creation and enhancement of local capabilities in developing countries. Nonetheless, the evidence is mixed and often contradictory. It seems that the effects depend not only on the characteristics of transnational corporations in terms of corporate strategies, sectors and types of production and service activity, but also on the absorption capacity of economies (Lipsey, 2002; Moran, Graham and Blomström, 2005).[3]

☐ The author is grateful for the comments of Miguel Torres and an anonymous referee.

[1] See Caves (1996) and Markusen (2002) for an overview of the literature on transnational corporations.

[2] See the various editions of *Foreign Direct Investment in Latin America and the Caribbean*, published annually by the Division of Production, Productivity and Management of ECLAC.

[3] The effects of transnational corporations' operations may be direct or indirect. The direct effects are those that do not depend particularly on the interaction between transnational corporations and absorption capacity. Among these, mention may be made of greater access to foreign currency, increased gross fixed capital formation, increased supply (greater production of and access to goods and services and increased employment) and effects associated with higher exports and potential environmental repercussions. The indirect effects, meanwhile, are determined by the absorption capacity of the host country: human capital, the capabilities of the technology base, infrastructure, local

This article analyses the performance of transnational corporations' subsidiaries relative to local firms in the Chilean manufacturing sector, on the basis of three indicators: productivity, market survival and profitability.[4] The study is organized as follows. Section II briefly reviews the literature and section III sets out some general characteristics of the presence of transnational corporations in Chilean manufacturing industry. Then section IV describes the different empirical methodologies and section V discusses the results of the estimations. Lastly, section VI presents the main conclusions.

suppliers, the production mix and the national innovation system. Among these effects, mention may be made of production linkages, technology transfer and the creation and enhancement of local capabilities (ECLAC, 2011, p. 27).

4 A complementary examination of firms' productivity and profitability is justified by the fact that they are used to measure different operational aspects. On the one hand, productivity is more closely associated with technical and production aspects, linking output to a particular level of inputs. Profitability, on the other hand, ties in with economic and financial aspects via revenues and operating costs. The correlation between the two variables shows that productivity increases translate to some degree into higher profitability, but this is not necessarily always the case. Most private firms focus exclusively on maximizing the profitability of their operations.

II
A brief review of the literature

There are a number of studies comparing the performance of transnational corporations with that of local firms, especially in developed countries. In terms of productivity, on which there is a relatively extensive literature, particularly for the manufacturing sector, there is ample evidence that the advantages enjoyed by transnational corporations, whether foreign-owned or domestically owned,[5] make them more productive than local firms. This has been confirmed using different measures, such as indicators of technical efficiency, labour productivity or total factor productivity (TFP). For example, Baldwin, Lipsey and Richards (1998) point out that the subsidiaries of transnational corporations in the United States are more capital-intensive, pay higher wages and have higher labour productivity, even when factors such as size, sector and so on are controlled for. Temouri, Driffield and Higón (2008) analyse TFP in Germany in the 1995-2004 period. Using semiparametric evidence to control for endogeneity problems, the authors show that the fact of being a transnational firm (whether domestically owned or foreign-owned) goes a long way towards explaining productivity differences between firms.

Likewise, Girma, Kneller and Pisu (2005) have shown for the United Kingdom that both the subsidiaries of transnational corporations and British transnationals are more productive than exporting firms, which in turn are more productive than non-exporting firms.[6] Thus, a distinction is made in the literature on developed countries between transnational corporations (foreign or local) and purely domestic firms, largely because many local firms carry out international operations.

In a developing country context, Blomström and Sjöholm (1999) present similar evidence for manufacturing industry in Indonesia, where transnational corporations have higher labour productivity and local firms benefit from productivity spillovers. However, the degree of foreign ownership at the firm level does not seem to affect the results. In Latin America, Blomström (1988) analyses labour productivity in Mexican manufacturing industry. His findings reveal that the subsidiaries of transnational corporations are more productive because of specific advantages in terms of capabilities and know-how, i.e., ownership advantages. In a more recent analysis, Álvarez and Crespi (2007) examine the case of Chilean industry during the 1979-2000 period. Their findings reveal that transnational corporations have higher TFP and, furthermore, are important agents in technology transfer; consequently, their presence is favourable to productivity catch-up at local firms.

In terms of market survival, there are opposing theoretical arguments regarding the performance of transnational corporations. On the one hand, the subsidiaries of transnational corporations might be more likely to exit the market because, in an economic crisis, they can shift or alter operations across different production locations via the transnational corporation's international production system. This may be more clearly the case if the subsidiary has few linkages with the local economy. Thus, in a local economic crisis, the

5 Domestically owned transnational corporations are local firms carrying out operations in international markets.

6 Dimelis and Louri (2002) present efficiency estimates for industry in Greece. Their findings show that firms under majority foreign ownership have the highest productivity.

subsidiaries of transnational corporations may have a greater proclivity to exit the market than local firms. For example, Bandick (2010) studies the survival of transnational corporations in Swedish industry. The findings suggest that these firms really are more likely to exit the market than local firms. However, when firms are differentiated by export activity, transnational corporations have higher survival rates than local firms that do not export, while survival rates for transnational corporations and local exporters are not significantly different. Similarly, Görg and Strobl (2003) and Bernard and Sjöholm (2003) show that transnational corporations are more likely to exit than domestic firms in Ireland and Indonesia, respectively. For Chile, Álvarez and Görg (2009) indicate that domestic market-oriented subsidiaries of transnational corporations were also more likely to exit in the 1990s than their local counterparts.

On the other hand, subsidiaries of transnational corporations may present a lesser likelihood of exit (i.e., higher survival rates) insofar as they have greater sunk costs and operating projects whose returns lie in the medium term. This could be particularly the case if an economic crisis is believed to be temporary. While there are no empirical studies to confirm this, it has been shown that local and transnational firms can behave similarly. In a recent study, Godart, Görg and Hanley (2011) find that firms with different ownership situations in Ireland did not behave heterogeneously in the face of the 2008 economic crisis. In other words, while exit rates increased across the board, transnational corporations were not a cause of particular instability in the economy. Mata and Portugal (2002) note that, after controlling for different variables at the firm and industry level, transnational and local firms in Portuguese industry do not behave very differently in terms of survival.

Lastly, studies on profitability differences between transnational and local firms are scarce and report mixed results. On the one hand, some studies show that the advantages of transnational corporations do in fact translate into higher profitability. For example, Benvignati (1987) shows that transnational corporations in the United States are more profitable on average than domestic firms, and the findings are statistically robust when different measures of foreign ownership are considered. Kumar (1990) analyses the manufacturing sector in India. His findings also suggest that transnational corporations do indeed perform better than local firms, especially in knowledge-intensive sectors. This seems to be related to the fact that these sectors can take advantage of know-how and capabilities accumulated, for example, through past investments in research and development (R&D). Ramstetter (1998) likewise examines the importance of transnational corporations in a number of Asian economies. His findings show, among other characteristics, that transnational corporations have higher levels of profitability, in Singapore for example. Conversely, Barbosa and Louri (2005) study the cases of Portugal and Greece in the 1990s. In the case of Portugal, the results indicate that foreign ownership is not associated with significant differences in profitability. By contrast, in Greece profitability differences between domestic and foreign firms appear only in the upper quintiles of the profitability distribution.

III

Data and stylized facts

In the past few decades, a development model based on market opening and deregulation with a heavy predominance of the private sector in production activities has been implemented in the Chilean economy. In this context, foreign direct investment (FDI) has become a cornerstone of the development strategy, and a legal framework with strong guarantees for foreign capital has been established. Indeed, Chile stands out among Latin American countries as one of the most important destinations for FDI in the last decade, both in absolute terms and in relation to the size of its economy (ECLAC, 2012 and 2001).[7] Transnational corporations have thus come to form a group of agents with a presence in most production and service activities. They have only a relatively small presence in manufacturing, however, by comparison with the primary and service sectors, where

[7] FDI in Chile averaged US$ 5.4 billion a year during 2000-2006 and over US$ 15 billion during 2006-2011. In recent years, the ratio of FDI to gross domestic product (GDP) has been over 8%, one of the highest among the larger economies of Latin America (ECLAC, 2012).

most FDI has gone. Between 2005 and 2010, 92% of FDI went to natural resource and service sectors, with just 7% going to manufacturing (ECLAC, 2012). The inward FDI share of the manufacturing sector in Chile was greater between 1996 and 2005, at about 11% (ECLAC, 2006).

The information source used to analyse the performance of transnational corporations in the Chilean manufacturing sector is the National Institute of Statistics (INE) Annual National Industry Survey (ENIA) for the 2001-2006 period. This survey collects information at the manufacturing plant level on production, value added, sales, employment, ownership, wages, exports, investment and energy use, among other variables. Sectoral deflators provided by INE were used to convert the monetary variables to constant 2003 pesos. For each year, the survey compiles information on some 4,500 manufacturing plants, which are also classified at the sector level using the International Standard Industrial Classification of All Economic Activities (ISIC).

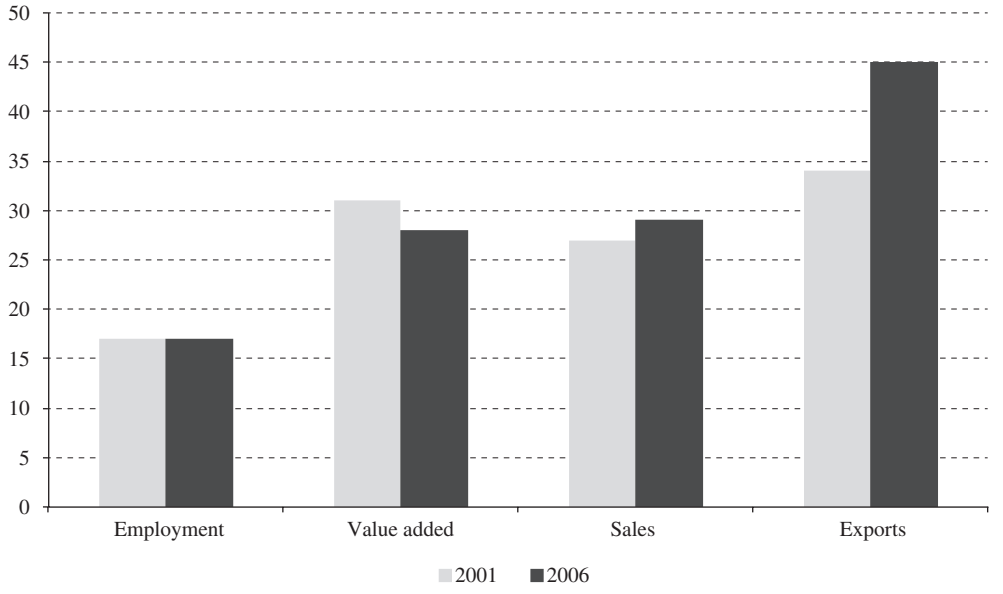
From the ENIA information it can be seen that transnational corporations account for a relatively low share of aggregate employment but a considerably greater share of value added, sales and, especially, exports. In 2006, manufacturing firms under foreign ownership accounted for 30% of value added and 45% of industrial exports, but just 17% of employment (see figure 1). Transnational corporations' shares of employment, value added and sales had held steady or were slightly down on the start of the decade. Their share of exports had risen strongly, however, from 34% in 2001 to 45% in 2006. Thus, as the country has become more integrated into the international economy, transnationals have become more important to exports, probably by exploiting their larger scales of operation, their more advanced technology and their greater knowledge of external markets.[8]

The characteristics of industrial sectors play an important role in the sectoral positioning of transnational firms. Key aspects are capital intensity, sunk costs, optimum plant size and technology patterns in each sector. Thus, the sectors with the greatest presence of transnationals, in terms of value added, are the tobacco, plastics, non-ferrous metals, transport equipment and scientific and professional control equipment industries. In these sectors, foreign-owned firms account for over 50% of sectoral value added. Conversely, there is only a small

[8] Álvarez and López (2008) show that the export activity of transnational corporations in the Chilean manufacturing sector generates major productivity spillovers, both towards suppliers and customers and towards other plants in the same sector.

FIGURE 1

Chile: transnational corporations' share of the industrial sector
(Percentages)



Source: prepared by the author on the basis of the Annual National Industry Survey (ENIA), 2001-2006.

proportion of foreign ownership in more labour-intensive sectors, including in particular the leather, furniture, textile and wearing apparel industries. Transnational corporations' share of sectoral value added is below 10% in these sectors.

At a more disaggregated level, transnational corporations differ from local firms in various respects. Table 1 gives an overview of some differences between the two groups of firms in Chilean manufacturing industry. It can be seen that transnational manufacturing firms are substantially larger than local ones, invest more on average in physical capital and have a slightly higher level of capabilities in their workforces. Transnational corporations are also more oriented towards external markets: in the period of analysis, over 60% of transnational corporations exported at some time or other. Furthermore, while local firms carrying out exports made just 6% of their sales on average in external markets, the figure was 28% for transnational corporations.

With regard to performance, a preliminary exercise is to observe average values for labour productivity (defined as value added over the number of employees), market survival and profitability by firm type. Labour productivity is higher in transnational firms, something that has been amply documented in the literature, as discussed in the previous section. Survival rates are likewise higher for transnational firms than for local ones, which appears to indicate that they are better placed to cope with fluctuations in the business cycle owing, for example, to economies of scale and, probably, better financing conditions. Lastly, transnational corporations appear to have higher levels of profitability. For local firms, the index of earnings before taxes, depreciation and amortization over sales is 24%, while for transnational corporations it is 30% (see table 1).

Thus, the preliminary descriptive analysis tends to confirm a priori expectations about the behaviour of transnational corporations relative to local firms: they are larger, invest more in fixed capital and have higher employee skill levels, while in terms of performance they have greater productivity, survival rates and profitability. Section IV analyses these differences in greater depth.

TABLE 1

Chile: characteristics of manufacturing firms by ownership, 2001-2006

Variable	Local (7 333 different firms) *(n=28 871)*		Transnational (549 different firms) *(n=1 950)*	
	Mean	Standard deviation	Mean	Standard deviation
Size	66.54	144.9	208.77	343.8
Investment	0.07	0.15	0.09	0.14
Skills	0.41	0.31	0.44	0.30
Exports	0.17	0.37	0.61	0.48
Export orientation	0.06	0.20	0.28	0.36
Labour productivity	9.02	1.09	10.37	1.38
Survival	0.89	0.30	0.92	0.26
EBITDA	0.24	0.19	0.30	0.23

Source: prepared by the author on the basis of the Annual National Industry Survey (ENIA), 2001-2006.

Note: explanatory variables: Size: number of employees. Investment: ratio between physical capital investments and capital stock. Skills: ratio between numbers of skilled and unskilled employees. Exports: average dichotomous variable taking the value 1 if the firm exports and 0 otherwise. Export orientation: percentage of sales made abroad. Labour productivity: ratio between value added and number of employees. Survival: likelihood of a firm observed in the market at time t also being there at t+1. EBITDA: earnings before interest, taxes, depreciation and amortization as a percentage of sales.

n = number of firms.

IV
Empirical strategy

1. Productivity

Productivity is analysed on the basis of total factor productivity (TFP). TFP is calculated using the methodology proposed by Olley and Pakes (1996) as modified by Levinsohn and Petrin (2003). Thus, a Cobb-Douglas production function is estimated for each sector at the three-digit level of ISIC using the following equation:

$$y_{it} = \beta_0 + \beta_1 K_{it} + \beta_2 L^s_{it} + \beta_3 L^u_{it} + \varepsilon_{it} \qquad (1)$$

where y_{it} is the logarithm of the value added of firm i at time t, K_{it} is the logarithm of the capital stock and L^s_{it} and L^u_{it} are the logarithms of the number of skilled and unskilled workers, respectively. TFP is then defined as:

$$TFP = \exp(y_{it} - \beta_1 K_{it} - \beta_2 L^s_{it} - \beta_3 L^u_{it}) \qquad (2)$$

If the error in equation (1) is not correlated with the explanatory variables, the production function can be estimated directly using ordinary least squares (OLS). However, it is usual to expect the error term ε_{it} to be correlated with the explanatory variables, since productivity is observed by the firm managers, who also take the decisions about the use of inputs in production. According to Olley and Pakes (1996) and Levinsohn and Petrin (2003), the production function is estimated with explicit reference to this problem of endogeneity. For this, it is assumed that $\varepsilon_{it} = \omega_{it} + \eta_{it}$, where ω_{it} reflects the correlation with productivity, and that η_{it} is an error term which is not correlated with production input decisions. It is likewise assumed that $m_{it} = m_{it}(k_{it}, \omega_{it})$, where m_{it} are the intermediate inputs used in the production process. Levinsohn and Petrin (2003) show that this ratio is monotonically increasing in ω_{it}, so that the intermediate inputs function can be inverted to get $\omega_{it} = m_{it}(k_{it}, m_{it})$. Thus, the production function to be estimated is specified as follows:

$$y_{it} = \Phi(K_{it}, m_{it}) + \beta_2 L^s_{it} + \beta_3 L^u_{it} + \eta_{it} \qquad (3)$$

$$\Phi(K_{it}, m_{it}) = \beta_0 \beta_1 K_{it} + m_{it}(K_{it}, m_{it}) \qquad (4)$$

Equation (3) is estimated using electricity consumption as an intermediate input, which means that capital elasticity can be identified, correcting the simultaneity bias. Once TFP has been estimated for each firm and for the different years of the analysis period, a test of means (or of heterogeneous variances between groups of companies) and the Kolmogorov-Smirnov test are carried out to analyse whether the productivity distributions by firm type, in both levels and differences, are similar. Likewise, the following regression model is specified in levels and differences to analyse these hypotheses:

$$TFP_{it} = \theta X_{it} + d_j + d_t + \varepsilon_{ijt} \qquad (5)$$

$$\Delta TFP_{it} = \theta X_{it} + d_j + d_t + \varepsilon_{ijt} \qquad (6)$$

The vector of variables X is composed of different explanatory variables: firm size (number of employees), investments (ratio between fixed capital investments and the capital stock) and labour skills (ratio between numbers of skilled and unskilled employees). Also included are two dichotomous variables that control for the fact of being a transnational corporation and for exporter status.[9] A priori, these variables can affect productivity both in levels and in differences. The variables d_j and d_t, meanwhile, are dichotomous variables that control for specific effects at the sector level (three-digit ISIC) and by year, respectively. The estimation of equations (5) and (6) is implemented using OLS.[10]

2. Survival

To analyse survival patterns, and the influence of foreign ownership in particular, the following Probit model is estimated:

[9] Some studies have shown that the matter of who owns a transnational is also relevant to its operations in other countries. For example, Crespi, Criscuolo and Haskel (2006) analyse the performance of firms in the United Kingdom and show that the ways in which United States multinationals organize work and use information technology make them more flexible and thus more productive than their European counterparts. Unfortunately, information by country on foreign ownership is not available in the Chilean Annual National Industry Survey (ENIA).

[10] Table A.1 presents the correlation matrix for the explanatory variables used in the estimates.

$$\Pr(survival_{ijt}) = f(\alpha + \beta X_{it} + \gamma Z_{jt} + d_j + d_t + \varepsilon_{ijt}) \quad (7)$$

where $\Pr(survival_{ijt})$ is the survival probability of firm *i* operating in sector *j* at time *t*; X_{it} is a vector of variables that control for various firm-level characteristics; and Z_{jt} is a vector of variables that control for characteristics at sectoral level. Similarly, d_j and d_t are dichotomous variables that control for specific effects by sector (three-digit level of ISIC) and by period, respectively. In accordance with the survival literature (Audretsch and Mahmood, 1995; Doms, Dunne and Roberts, 1995; Bernard and Sjöholm, 2003), the vector of variables X includes specific firm-level variables that are expected a priori to affect the survival of a company. Thus, firm size (number of employees), productivity (using the TFP measure), investment (investments in fixed capital formation over capital stock) and labour skills (ratio between numbers of skilled and unskilled employees) are incorporated as explanatory variables.

Also included is a dichotomous variable that controls for foreign ownership of the firm. This variable tests the correlation between foreign ownership and the probability of firm survival. On the one hand, transnational corporations may have advantages associated with greater know-how and technology, and also greater sunk costs, which could make them less likely to exit the market, especially when there is a temporary shock. On the other hand, it may happen that transnational corporations have little knowledge of the local market, while benefiting from international production networks. In this case, such firms can decide to exit the market quickly if difficulties arise and move operations to other locations. Accordingly, transnational corporations may be especially sensitive to short-term returns and behave in a footloose way.[11]

It could also be argued that the mobility of transnational corporations depends on the amount of intangible assets they have invested in their local operation (sunk costs). Thus, survival rates in knowledge-intensive sectors could differ from those in more traditional sectors, such as those based on natural resources or labour. To test the hypothesis that transnational corporations can have different survival rates depending on the type of sector they operate in, the estimates also include dichotomous variables that control for sectors being labour-, natural resource- or knowledge-intensive.[12] The correlation between foreign ownership and firm survival in different operating sectors is calculated by exploiting the non-linearity of the Probit model.

The Z_{jt} vector incorporates three variables that control for market structure at the sector level. Thus, average firm size and the Herfindahl-Hirschman index of market concentration are included as explanatory variables, calculated at a three-digit level of the ISIC classification. In the tradition of industrial dynamics modelling, these variables capture the different entry costs by industrial sector. Lastly, sectoral sales growth is included as a proxy variable for capturing potential demand shocks, likewise at the three-digit level of the ISIC classification. The Probit model is estimated using the maximum likelihood method.

3. Profitability

The profitability analysis is performed on the basis of the following empirical equation:

$$Ebitda_{ijt} = \alpha + \beta X_{it} + \gamma Z_{jt} + d_j + d_t + \varepsilon_{ijt} \quad (8)$$

where $Ebitda_{ijt} = EBITDA_{ijt} - EBITDA_{jt}$, and $EBITDA_{it}$ is earnings before interest, taxes, depreciation and amortization over sales for firm *i* operating in sector *j* at time *t*; and $EBITDA_{jt}$ is the average of this variable for firms operating in sector *j* at time *t*. Thus, the *Ebitda* variable represents the deviation from the sectoral mean of each firm's profitability. There are different reasons for using this variable instead of employing the EBITDA variable directly, such as the need to eliminate different levels of profitability between industries and effects common to all firms, such as the business cycle.[13]

In accordance with the earlier literature, different aspects at both the firm and the sector level are used as explanatory variables in the profitability model. Thus, firm size, the investment to capital ratio, labour skills and exporter status are included as variables. A dichotomous variable is employed to test the effect of ownership, and this takes the value 1 in the event that a firm is foreign-owned. Lastly, sectoral concentration (as measured by the Herfindahl-Hirschman index) and sectoral sales growth (as a proxy for demand shocks) are taken as control variables.

[11] "Footloose" firms are those that have a tendency to relocate their production operations geographically as a strategic response in their international positioning.

[12] The classification of natural resource-, labour- and knowledge-intensive sectors was carried out in the light of the typology discussed in Cimoli and others (2005).

[13] See Cefis and Cicarelli (2005) for a more detailed discussion of this aspect.

Equation (8) is estimated empirically using quantile regressions.[14] In contrast to OLS, quantile regressions estimate the relationship between variables in different quantiles of the distribution of the dependent variable (Koenker, 2005). This methodology has the advantage of being more statistically robust to extreme values and in cases where errors are not normal. Thus, this methodology can be used to adjust regressions for different quantiles of the profitability distribution, something that is particularly relevant in situations of high heterogeneity. In these cases, in fact, considering the conditional mean function, as happens in traditional OLS estimations, can potentially conceal significant aspects of the relationship between the dependent variable and the explanatory variables. Thus, foreign capital can be expected to have heterogeneous effects at different points of the profitability distribution.[15]

[14] In the empirical model, ownership is assumed to be exogenous to profitability. Although profitability might be expected to influence the presence of foreign capital over long periods, this is unlikely over six years. Furthermore, only 2.9% of firms changed owners during the period.

[15] Another study using quantile regressions to analyse the profitability of firms is Love, Roper and Du (2009) for Ireland. Although the article mainly focuses on the effects of innovation on profitability, the results also show that transnationals from the United States and the United Kingdom are more profitable than local firms.

V
Results

1. Productivity

Where productivity is concerned, TFP is analysed in both levels and differences using non-parametric and parametric evidence. The non-parametric evidence is based on a test of means (of heterogeneous variances between groups of firms) and comparison of distributions using the Kolmogorov-Smirnov test (see table 2).[16] The test of means shows that transnational corporations are more profitable than domestic firms, and the difference is statistically significant. This finding is consistent whether the criterion taken is any degree of foreign ownership or over 50% foreign ownership. Accordingly, the Kolmogorov-Smirnov test suggests that the productivity levels of the two groups of firms derive from different sample distributions. In this way, an initial characterization of TFP across firms indicates that foreign ownership is a relevant factor.

The statistical analysis also reveals that there are no significant differences in terms of TFP growth. Consequently, it is not possible to reject the hypothesis that the average TFP growth rate differs between the two groups of firms. Furthermore, the average annual productivity growth rate is higher for domestic firms (1.6%) than for transnational ones (0.7%). This reveals that, while transnationals have higher productivity, productivity is faster-growing in local firms. Nonetheless, it is important to control for other variables to show that these characteristics are maintained when both firm-level and sector-level variables are considered as well.

Table 3 shows the regressions of the productivity equations in levels and differences using OLS.[17] Columns (1) and (2) present estimates of the TFP level. Since column (2) controls for sector-level effects (which could potentially be relevant to the way transnational corporations are distributed in industry), it is the preferred empirical model. The estimation reveals that firm size is positively associated with productivity, illustrating the benefits of economies of scale. Likewise, fixed capital investments are also associated positively with productivity. Skills present a negative and significant coefficient, which a priori is counter-intuitive. Consistently with international evidence (Wagner, 2007) and evidence for Chile (Álvarez and López, 2005), the fact of a firm exporting also correlates significantly with productivity.

The focus of interest, however, is on the variable that controls for foreign capital. The table 3 estimates suggest that transnational corporations do indeed have

[16] Figure A.1 presents the histogram of TFP by type of firm.

[17] The productivity equations could also be estimated using quantile regressions, much like the profitability equations. When they are implemented empirically, however, the results of the quantile estimations show no differences from the OLS estimations. In other words, the estimates in the different quantiles of the productivity distribution are no different from when estimation is carried out using OLS.

TABLE 2

Chile: test for total factor productivity (TFP) across firms

Variable	Kolmogorov-Smirnov test H_0: observations are from the same distribution	Test of means H_0: $TFP_{transnational}=TFP_{local}$ H_1: $TFP_{transnational}>TFP_{local}$
I. Firms with some degree of foreign ownership compared to domestic firms		
Total factor productivity (TFP)	0.380 (0.000)***	28.83 (0.000)***
Δ Total factor productivity (TFP)	0.048 (0.006)**	-0.405 (0.657)
II. Firms that are at least 50% foreign-owned compared to domestic firms		
Total factor productivity (TFP)	0.371 (0.000)***	24.66 (0.000)***
Δ Total factor productivity (TFP)	0.036 (0.142)	0.071 (0.523)

Source: prepared by the author on the basis of the Annual National Industry Survey (ENIA), 2001-2006.

** Significant at 5%. *** Significant at 1%.

TABLE 3

Chile: total factor productivity (TFP) estimations

Variable	Levels (1)	Levels (2)	Differences (3)	Differences (4)
Size	0.249	0.268	-0.010	-0.012
	(25.62)***	(33.16)***	(-2.09)**	(-2.52)**
Investment	0.130	0.165	0.055	0.067
	(4.44)***	(5.87)***	(1.65)*	(2.08)**
Skills	-0.033	-0.039	-0.032	-0.031
	(1.58)	(-1.99)**	(-2.54)**	(-1.95)*
Exports	0.208	0.184	-0.001	0.001
	(10.28)***	(10.10)***	(-0.14)	(0.14)
Transnational	0.382	0.316	0.010	0.031
	(9.36)***	(8.94)***	(0.48)	(1.36)
Sector-specific effects	No	Yes	No	Yes
Year-specific effects	No	Yes	No	Yes
Wald chi^2 test	1 190.1	10 802.3	12.8	150.4
Prob. Wald > chi^2	0.000	0.000	0.03	0.000
No. of firms	7 103	7 103	6 125	6 125
No. of observations	27 869	27 869	20 589	20 589

Source: prepared by the author on the basis of the Annual National Industry Survey (ENIA), 2001-2006.

Note: the dependent variable is calculated by the methodology of Levinsohn and Petrin (2003). Explanatory variables: Size: logarithm of number of employees. Productivity: TFP calculated by the methodology of Levinsohn and Petrin (2003). Investment: ratio between physical capital investments and capital stock. Skills: ratio between numbers of skilled and unskilled employees. Exports: dichotomous variable taking the value 1 if the firm exports and 0 otherwise. Transnational: dichotomous variable taking the value 1 if the firm is foreign-owned and 0 otherwise (any percentage of foreign ownership for columns (1) to (3), over 50% for column (4)).
* Significant at 10%. ** Significant at 5%. *** Significant at 1%.

higher levels of productivity, even controlling for other firm-level and sector-level variables, which confirms the descriptive evidence. In turn, the model in column (4) uses the TFP growth rate. The results show that smaller enterprises are the ones with the highest TFP growth. Again, fixed capital investment is positively linked to productivity growth. This could be because investments in machinery and equipment can raise output and simultaneously bring other improvements, including in other areas such as organization. Consistently with the descriptive evidence, the coefficient related to the transnational variable is not significant. Thus, controlling for other variables, there are no significant differences in productivity growth rates between domestic and transnational firms.

The fact that productivity is higher in transnational corporations but productivity growth is similar across firms suggests that local firms can benefit from productivity spillovers, technology transfers and learning of new practices (Álvarez and Crespi, 2007). Thus, these findings implicitly highlight the potential impact of policies to promote technological spillover effects and the scope that exists for transnational corporations to carry out technological upgrading of their activities.

2. Survival

The results of the Probit model can be seen in table 4. The base estimation model is presented in column (1), and then other control variables are added sequentially in the estimates. Size is positively associated with firms' likelihood of survival and with productivity and physical capital investment. Larger and more productive firms and those with higher investment rates have a greater likelihood of survival. These findings are consistent with other studies of firm survival for both developed and developing countries, and also for the particular case of Chile (Audretsch and Mahmood, 1995; Van Biesebroeck, 2005; Álvarez and Vergara, 2013).

Nonetheless, the main interest lies in comparing behaviour across company ownership types. According to the estimates, there are no significant differences between transnational and local firms, with the coefficients estimated in columns (2) and (3) being non-significant. As a way of testing the robustness of the estimates, however, table 4 presents similar estimates in columns (4), (5) and (6), but with the criterion of firms being at least 50% foreign-owned. The use of this criterion is justified because many administrative and strategic management decisions, such as the decision to remain in a market, to change the production mix or to issue new debt, depend on whether there is 50% ownership or not. Accordingly, it is possible that only firms that are at least 50% foreign-owned are run and behave like transnational corporations.

Consistently with the results of the previous columns, the estimates in columns (4), (5) and (6) of table 4 confirm the findings for the size, TFP and capital investment variables. However, the coefficient associated with the foreign capital variable is positive, albeit significant only at 10%, showing that firms which are at least 50% foreign-owned have, on average and *ceteris paribus*, a 2% greater likelihood of exiting the market than local companies. Even though the effect is modest in scale and only significant at 10%, it suggests that transnational corporations behave in a somewhat footloose way compared to local firms.

Taking advantage of the non-linearity of the Probit model, an analysis is conducted to determine what type of firms' survival is most affected by foreign ownership.[18] Table 5 illustrates the marginal effect of foreign capital by productivity level and firm size. The effect of foreign ownership on companies that are at least 50% foreign-owned is greater for small firms. The marginal effect of foreign ownership by productivity level, meanwhile, is significant only in low- and medium-productivity firms, not high-productivity ones, which are probably exporters.

The last thing to be tested is whether the characteristics of the sectors where transnational corporations operate are relevant to their likelihood of survival. First, the estimates show that all businesses operating in knowledge-intensive sectors seem to have lower survival rates than firms in other sectors (see columns (1) and (3) of table A.2). However, this loses significance when sectoral effects at the three-digit level of ISIC are added in, so that it is not possible to draw consistent conclusions (see columns (2) and (4) of table A.2). As to whether transnational corporations behave differently depending on the sector they operate in, the estimates show this not to be the case (see table A.3). In fact, the marginal effect estimated for transnational corporations (using the two criteria of there being some degree of foreign ownership and more than 50% foreign ownership) is similar across sectors and confirms the results of the previous estimates: only transnational corporations that are over 50% foreign-owned are less likely to survive (at 10% significance), and this finding is homogeneous

[18] In a Probit model, marginal effects are a function of the other explanatory variables. Marginal effects are usually calculated using the average value for these variables. The marginal effect corresponds to the expression: $\partial Pr(y=1)/\partial X_k = \phi(X'\beta)\beta_k$.

TABLE 4

Chile: firm survival, Probit models (marginal effects)

Variable	(1)	(2)	(3)	(4)	(5)	(6)
Size	0.018	0.019	0.019	0.018	0.019	0.019
	(8.48)***	(8.10)***	(8.08)***	(8.48)***	(8.09)***	(8.07)***
Productivity	0.015	0.016	0.016	0.015	0.016	0.015
	(6.89)***	(7.06)***	(7.04)***	(6.89)***	(7.09)***	(7.08)***
Investment	0.039	0.039	0.039	0.039	0.038	0.039
	(3.14)**	(3.13)**	(3.13)**	(3.14)**	(3.13)**	(3.14)**
Skills	-0.005	-0.004	-0.004	-0.005	-0.004	-0.004
	(-0.80)	(-0.70)	(-0.68)	(-0.80)	(-0.68)	(-0.67)
Exports	-0.003	-0.004	-0.003	-0.003	-0.002	-0.003
	(-0.54)	(-0.55)	(-0.55)	(-0.48)	(-0.48)	(-0.49)
Transnational		-0.013	-0.013		-0.019	-0.019
		(-1.41)	(-1.42)		(-1.83)*	(-1.83)*
Concentration			0.098			0.096
			(1.06)			(1.04)
Average firm size			0.029			0.029
			(0.75)			(0.75)
Sectoral growth			0.11			0.122
			(0.88)			(0.91)
Sector-specific effects	Yes	Yes	Yes	Yes	Yes	Yes
Year-specific effects	Yes	Yes	Yes	Yes	Yes	Yes
Wald Chi test (36)	470.7	473.6	474.3	470.7	473.8	474.3
Prob. Wald > Chi^2	0.000	0.000	0.000	0.000	0.000	0.000
No. of observations	23 322	23 322	23 322	23 322	23 222	23 222

Source: prepared by the author on the basis of the Annual National Industry Survey (ENIA), 2001-2006.

Note: the dependent variable is equal to 1 if the firm has operations at t+1 and 0 otherwise. Size: logarithm of number of employees. Productivity: calculated by the methodology of Levinsohn and Petrin (2003). Investments: ratio between physical capital investments and capital stock. Skills: ratio between numbers of skilled and unskilled employees. Exports: dichotomous variable taking the value 1 if the firm exports and 0 otherwise. Transnational: dichotomous variable taking the value 1 if the firm is foreign-owned and 0 otherwise (any percentage of foreign ownership for columns (1) to (3), over 50% for columns (4) to (6)). Concentration: Herfindahl-Hirschman index calculated from gross output value by sector (three-digit ISIC) and year. Average firm size: average number of employees by sector (three-digit ISIC) and year. Sectoral growth: change in gross output value by sector (three-digit ISIC) and year. All estimates include sector- and year-specific effects.
* Significant at 10%. ** Significant at 5%. *** Significant at 1%.

across sectors. This shows that transnational corporations in knowledge-intensive sectors do not behave any differently in terms of survival.

In summary, small, low-productivity firms with majority foreign ownership evince a greater likelihood of exit than their local counterparts, irrespective of the sectors they operate in. This could be because these firms tend to suffer more acutely from the fluctuations of the local business cycle owing to unfamiliarity with the market, lack of linkages and lesser flexibility when it comes to adjusting to conditions of lower demand. This finding is consistent with what was presented by Álvarez and Görg (2009) for manufacturing industry in Chile, but during the 1990s. The authors show that transnational corporations geared to the domestic market are the least likely to survive.

TABLE 5

Chile: marginal effects of foreign ownership on firm survival [a]

By firm size		
Small	Medium	Large
-0.022	-0.012	-0.008
(-1.69)*	(-1.66)*	(-1.62)*
By firm productivity		
Low	Medium	High
-0.033	-0.014	-0.004
(-1.79)*	(-1.67)*	(-1.50)

Source: prepared by the author on the basis of the Annual National Industry Survey (ENIA), 2001-2006.

[a] Marginal effects calculated from the results of column (6) in table 4.
* Significant at 10%.

3. Profitability

The profitability estimations arrived at by using quantile regressions are presented in tables 6 and 7.[19] These estimates are justified in this case because the profitability and residuals estimated from equation (8) using OLS do not have a normal distribution.[20] Tables 6 and 7 differ only in the criterion used to define a transnational: some degree of foreign ownership in the first case and at least 50% in the second. The OLS estimates are also presented for the purposes of comparison.

The estimates present some consistent results, mainly the positive correlation between profitability and the variables that control for size and capital investment. Indeed, there is ample evidence that size is a significant determinant of profitability, since it tends to be associated with benefits arising from economies of scale and better borrowing conditions. The positive correlation with investment may be reflecting a good short-term business outlook. In a number of quantiles, furthermore, it can be seen that exporting firms have higher profitability, which could reflect both greater capabilities within the company and less vulnerability to swings in local demand.

The central goal of this subsection is to analyse the correlation with the variable that controls for a firm being transnational. A preliminary observation is that there is a positive relationship between profitability and foreign ownership in the OLS estimates. However, it is evident that estimating by OLS does not do a good job of calculating an average effect for the sample. In fact, the quantile estimates provide greater information by

[19] Figure A.2 presents the histogram of profitability by firm type.
[20] The test rejects the normal distribution both for profitability and for the residuals estimated from equation (8) with a 1% significance level.

TABLE 6

Quantile regressions of profitability (1)

Variable	OLS	Quantile				
		0.1	0.25	0.5	0.75	0.9
Size	0.009	0.022	0.014	0.008	0.004	-0.001
	(7.93)***	(12.18)***	(11.80)	(7.61)***	(3.03)**	(-0.44)
Investment	0.023	0.017	0.033	0.026	0.023	0.003
	(3.47)**	(1.68)*	(4.72)***	(4.11)***	(2.91)**	(0.29)
Skills	0.010	0.000	0.002	0.006	0.014	0.023
	(2.90)**	(0.03)	(0.75)	(1.78)*	(3.04)**	(3.62)***
Exports	0.009	-0.011	0.004	0.008	0.020	0.035
	(2.76)**	(-2.28)**	(-1.43)	(2.58)*	(4.80)***	(6.05)***
Transnational 1	0.011	-0.030	-0.015	-0.001	0.029	0.058
	(2.10)**	(-4.14)***	(-2.95)**	(-0.25)	(4.88)***	(6.91)***
Concentration	0.060	-0.036	0.016	0.036	0.047	0.144
	(1.17)	(-0.50)	(0.33)	(0.74)	(0.78)	(1.71)*
Sectoral growth	0.013	0.094	-0.011	0.007	0.025	0.039
	(1.42)	(6.23)***	(-1.26)	(0.71)	(2.58)*	(3.29)**
Sector-specific effects	Yes	Yes	Yes	Yes	Yes	Yes
Year-specific effects	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	28 895	28 895	28 895	28 895	28 895	28 895

Source: prepared by the author on the basis of the Annual National Industry Survey (ENIA), 2001-2006.

Note: dependent variable: $Ebitda_{ijt}$ = $EBITDA_{ijt} - EBITDA_{jt}$, where $EBITDA_{ii}$ represents earnings before interest, taxes, depreciation and amortization over sales for firm *i* operating in sector *j* at time *t*, and $EBITDA_{jt}$ is the average of this variable for firms operating in sector *j* at time *t*. Size: logarithm of number of employees. Investment: ratio between physical capital investments and capital stock. Skills: ratio between numbers of skilled and unskilled employees. Exports: dichotomous variable taking the value 1 if the firm exports and 0 otherwise. Transnational 1: dichotomous variable taking the value 1 if the firm has some degree of foreign ownership and 0 otherwise. Concentration: Herfindahl-Hirschman index calculated from gross output value by sector (three-digit ISIC) and year. Sectoral growth: change in gross output value by sector (three-digit ISIC) and year. OLS: ordinary least squares.
* Significant at 10%. ** Significant at 5%. *** Significant at 1%.

TABLE 7

Quantile regressions of profitability (2)

Variable	OLS	Quantile				
		0.1	0.25	0.5	0.75	0.9
Size	0.011	0.021	0.014	0.008	0.004	-0.000
	(10.27)***	(11.33)***	(11.49)***	(7.62)***	(3.24)**	(-0.04)
Investment	0.023	0.015	0.032	0.026	0.024	0.001
	(3.44)**	(1.37)	(4.57)***	(4.13)***	(3.07)**	(0.17)
Skills	0.011	0.000	0.002	0.006	0.014	0.023
	(3.11)**	(0.06)	(0.53)	(1.92)*	(3.14)**	(3.67)***
Exports	0.010	-0.010	-0.005	0.009	0.023	0.039
	(3.15)**	(-2.07)**	(-1.60)	(3.01)**	(5.64)***	(6.94)***
Transnational 2	0.000	-0.026	-0.013	-0.007	0.010	0.023
	(0.04)	(-3.11)**	(-2.35)**	(-1.50)	(1.58)	(2.46)**
Concentration	0.060	-0.060	0.018	0.026	0.025	0.152
	(1.17)	(-0.79)	(0.35)	(0.55)	(2.53)**	(1.82)*
Sectoral growth	0.015	0.099	-0.011	0.006	0.074	0.040
	(1.62)*	(6.27)***	(-1.23)	(0.65)	(5.71)***	(3.47)**
Sector-specific effects	Yes	Yes	Yes	Yes	Yes	Yes
Year-specific effects	Yes	Yes	Yes	Yes	Yes	Yes
No. of observations	28 895	28 895	28 895	28 895	28 895	28 895

Source: prepared by the author on the basis of the Annual National Industry Survey (ENIA), 2001-2006.

Note: dependent variable: $Ebitda_{ijt}$ = $EBITDA_{ijt} - EBITDA_{jt}$, where $EBITDA_{it}$ represents earnings before interest, taxes, depreciation and amortization over sales for firm *i* operating in sector *j* at time *t,* and $EBITDA_{jt}$ is the average of this variable for firms operating in sector *j* at time *t*. Size: logarithm of number of employees. Investment: ratio between physical capital investments and capital stock. Skills: ratio between number of skilled and unskilled employees. Exports: dichotomous variable taking the value 1 if the firm exports and 0 otherwise. Transnational 2: dichotomous variable taking the value 1 if the firm is over 50% foreign-owned and 0 otherwise. Concentration: Herfindahl-Hirschman index calculated from gross output value by sector (three-digit ISIC) and year. Sectoral growth: change in gross output value by sector (three-digit ISIC) and year. OLS: ordinary least squares.
* Significant at 10%. ** Significant at 5%. *** Significant at 1%.

showing a heterogeneous effect at the different points of the profitability distribution. In both estimates, i.e., using both criteria for defining a transnational firm, the coefficient is negative and significant in the first two quantiles of the profitability distribution. This suggests that in situations of relatively low corporate profitability, foreign ownership seems to correlate negatively with firm performance. Thus, transnational corporations are less profitable than local firms. This could be explained by the fact that transnational corporations with low profitability might suffer more acutely than local firms in the same sector from unfamiliarity with the market, lack of productive linkages and lack of flexibility and strategic management when adapting to more competitive conditions and changes in demand patterns. For example, transnational corporations may have determined their product mix by criteria that are not exclusively local. This finding is consistent with what was presented in the previous section, where it was noted that small and less productive transnational corporations were more likely to exit the market. Thus, one important point that could explain this result would be that these transnational corporations are less profitable than local firms.

Similarly, the estimates show that foreign ownership is linked positively and significantly to profitability in the two quantiles above the mean of the profitability distribution. Thus, in situations of relatively high profits, transnational corporations perform better than local companies and can exploit advantages associated with economies of scale, patents, licences and specific technologies, distribution

channels abroad or financing conditions. Strictly speaking, it is not possible to speak of firms with high or low profitability in cases where a quantile regression is implemented on panel data. However, since the standard deviation of intra-firm profitability is half the deviation between firms, it can be broadly assumed that the observations in the high-profitability quintiles are associated with high-profitability firms, while the observations in the low quintiles concern low-profitability firms.[21] Thus, it could be argued that among high-profitability companies, transnational firms perform better than local ones. Conversely, among low-profitability companies, it is local ones that perform better.

[21] Estimates from equation (8) using average variables at the firm level (for both profitability and the explanatory variables) yield similar conclusions.

VI
Conclusions

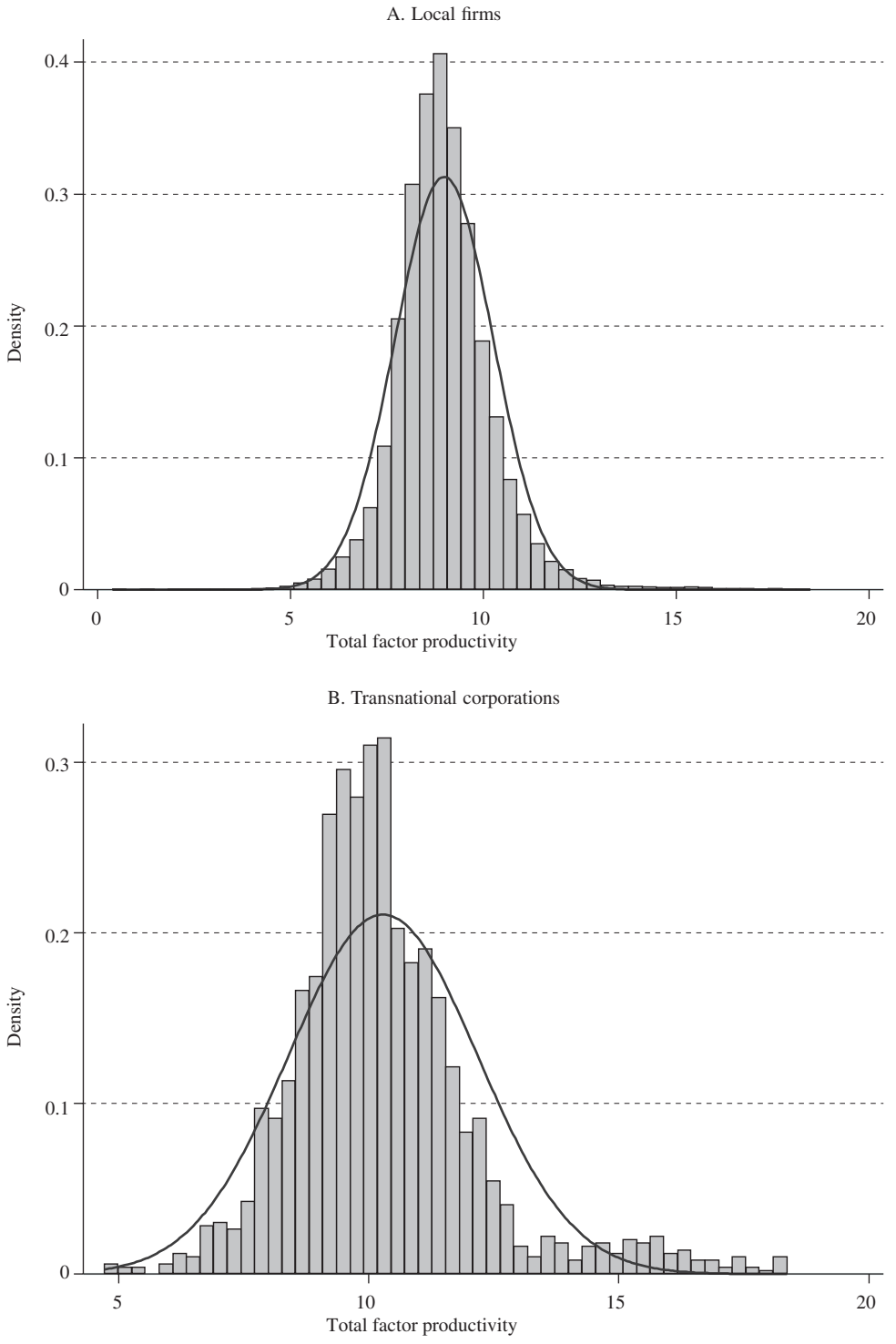
This article analyses the performance of transnational corporations in manufacturing industry in the context of a small open economy like Chile's. First, the results show that subsidiaries of transnational corporations behave differently from domestic firms, and also from one another when their characteristics differ, which highlights the high level of heterogeneity in manufacturing industry. Second, productivity is higher in transnational corporations than in local firms, but not faster-growing. Third, the results suggest that local and transnational firms do not greatly differ in terms of market survival. However, a more detailed analysis also shows that firms which are mainly foreign-owned, and especially small ones with low productivity, are more likely to exit the market than their local counterparts. This is associated with lower profitability in the first distribution quantiles. Low-productivity subsidiaries of transnational companies probably have little market knowledge, fewer linkages and less ability to adjust to swings in domestic demand. Lastly, the results show that there is no linear, unequivocal link between foreign ownership and profitability. For example, transnational corporations seem to be more profitable than local firms only in the upper quantiles of the profitability distribution. In other words, it cannot be assumed that the subsidiaries of transnationals have permanently and robustly higher rates of profit than local firms.

In summary, this article discusses some of the peculiarities characterizing the operations of transnational corporations in the highly heterogeneous context of the Chilean manufacturing sector. These results obviously cannot be extended to other production sectors, such as natural resources or services, where patterns of competition and the characteristics of the subsidiaries of transnational corporations are significantly different from those in the manufacturing sector. It is important to consider these performance patterns of transnational corporations at a time like the present, when foreign investment flows into the region are surging, and especially when production and technology policies designed to enhance the benefits of these to host economies are under discussion.

ANNEX

FIGURE A.1

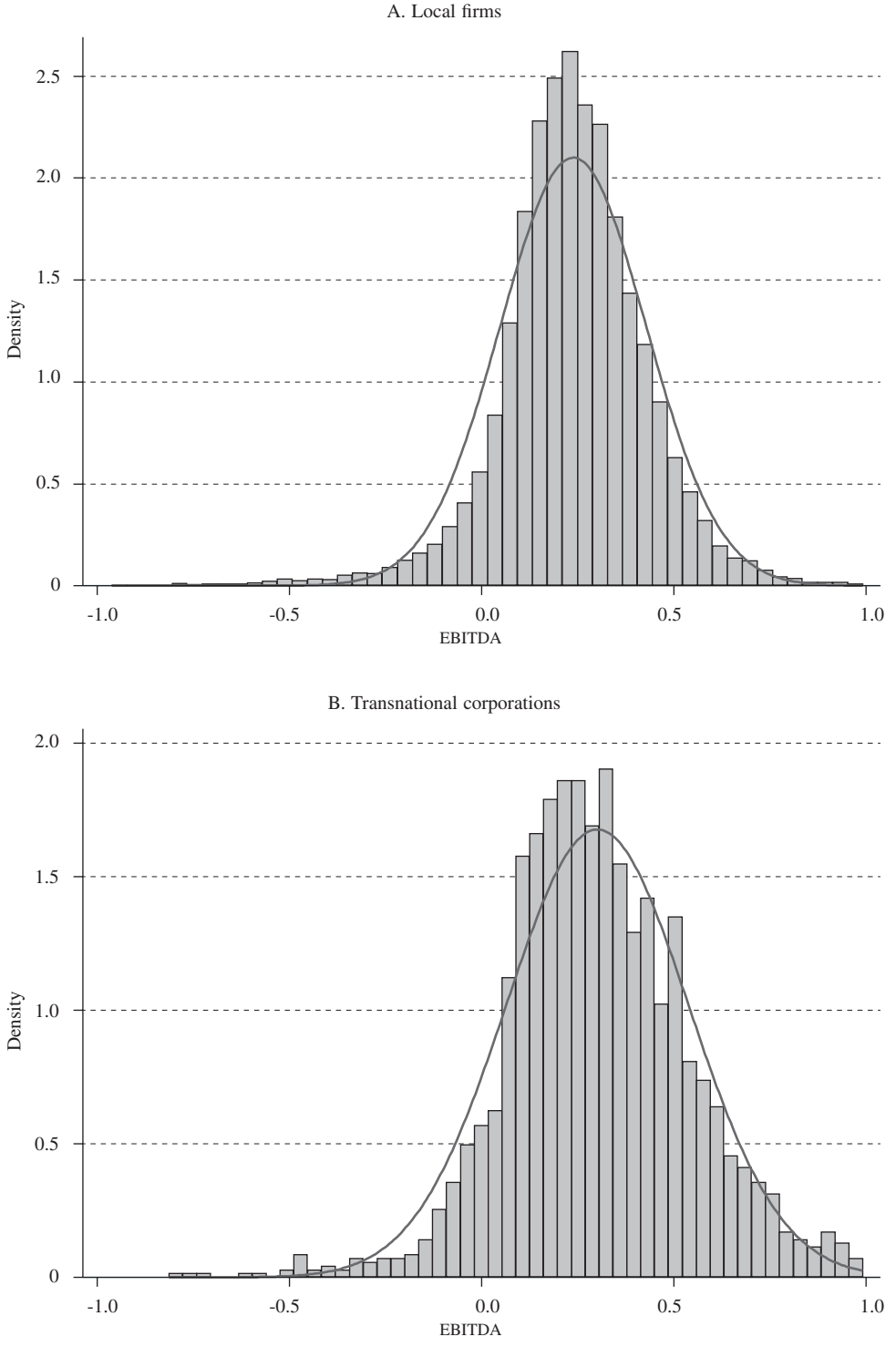
Histogram of total factor productivity (TFP)



Source: prepared by the author on the basis of the Annual National Industry Survey (ENIA), 2001-2006.

FIGURE A.2

Histogram of profitability



Source: prepared by the author on the basis of the Annual National Industry Survey (ENIA), 2001-2006.

EBITDA: earnings before interest, taxes, depreciation and amortization over sales.

TABLE A.1

Correlation matrix

	EBITDA	Productivity	Survival	Size	Investment	Transnational 1	Exports	Transnational 2	Average firm size	Concentration	Sectoral growth
EBITDA	1										
Productivity	0.401	1									
Survival	0.051	0.084	1								
Size	0.076	0.443	0.096	1							
Investment	0.029	0.096	0.034	0.112	1						
Exports	0.055	0.319	0.046	0.506	0.054	1					
Transnational 1	0.036	0.232	0.018	0.229	0.024	0.262	1				
Transnational 2	0.016	0.205	0.013	0.200	0.026	0.245	0.884	1			
Average firm size	0.019	0.390	0.018	0.220	0.034	0.224	0.182	0.172	1		
Concentration	0.012	-0.068	-0.010	-0.004	-0.030	-0.006	0.026	0.026	-0.040	1	
Sectoral growth	-0.002	0.001	0.002	0.002	-0.003	0.013	0.016	0.027	0.020	0.032	1

Source: prepared by the author on the basis of the Annual National Industry Survey (ENIA), 2001-2006.

Note: $Ebitda_{ijt}$ = $EBITDA_{ijt} - EBITDA_{jt}$, where $EBITDA_{it}$ represents earnings before interest, taxes, depreciation and amortization over sales for firm *i* operating in sector *j* at time *t*, and $EBITDA_{jt}$ is the average of this variable for firms operating in sector *j* at time *t*. Productivity: calculated by the methodology of Levinson and Petrin (2003). Survival: variable taking the value 1 if the firm has operations at *t*+1 and 0 otherwise. Size: logarithm of number of employees. Investment: ratio between physical capital investments and capital stock. Skills: ratio between numbers of skilled and unskilled employees. Exports: dichotomous variable taking the value 1 if the firm exports and 0 otherwise. Transnational 1: dichotomous variable taking the value 1 if the firm has some degree of foreign ownership and 0 otherwise. Transnational 2: dichotomous variable taking the value 1 if the firm is at least 50% foreign-owned and 0 otherwise. Concentration: Herfindahl-Hirschman index calculated from gross output value by sector (three-digit ISIC) and year. Average firm size: average number of employees by sector (three-digit ISIC) and year. Sectoral growth: change in gross output value by sector (three-digit ISIC) and year.

TABLE A.2

Firm survival, Probit models (marginal effects)

Variable	(1)	(2)	(3)	(4)
Size	0.019	0.019	0.019	0.019
	(8.11)***	(7.91)***	(8.10)***	(7.90)***
Productivity	0.015	0.015	0.015	0.015
	(7.79)***	(6.96)***	(7.84)***	(7.00)***
Investment	0.040	0.039	0.040	0.039
	(3.24)**	(3.13)**	(3.24)**	(3.13)**
Skills	-0.004	-0.004	-0.004	-0.004
	(0.67)	(0.66)	(0.65)	(0.64)
Exports	-0.002	-0.003	-0.002	-0.003
	(0.44)	(0.65)	(0.40)	(0.59)
Transnational	-0.009	-0.012	-0.014	-0.018
	(1.07)	(1.33)	(1.46)	(1.79)*
Concentration	-0.008	0.099	-0.008	0.097
	(0.35)	(1.07)	(0.34)	(1.05)
Average firm size	-0.017	0.029	-0.016	0.029
	(1.92)**	(0.75)	(1.88)*	(0.76)
Sectoral growth	0.118	0.114	0.121	0.119
	(0.86)	(0.87)	(0.88)	(0.89)
Natural resource dummy	0.001	-0.020	0.002	-0.021
	(0.42)	(0.97)	(0.46)	(0.97)
Knowledge dummy	-0.016	-0.011	-0.015	-0.010
	(2.75)**	(0.39)	(2.72)**	0.35)
Sector-specific effects	No	Yes	No	Yes
Year-specific effects	Yes	Yes	Yes	Yes
Wald Chi test (36)	436.98	471.29	436.94	471.18
Prob. Wald > Chi^2	0.000	0.000	0.000	0.000
No. of observations	23 322	23 322	23 322	23 322

Source: prepared by the author on the basis of the Annual National Industry Survey (ENIA), 2001-2006.

Note: the dependent variable is equal to 1 if the firm has operations at t+1 and 0 otherwise. Size: logarithm of number of employees. Productivity: calculated by the methodology of Levinsohn and Petrin (2003). Investment: ratio between physical capital investments and capital stock. Skills: ratio between numbers of skilled and unskilled employees. Exports: average of a dichotomous variable taking the value 1 if the firm exports and 0 otherwise. Transnational: dichotomous variable taking the value 1 if the firm is foreign-owned and 0 otherwise (any percentage of foreign ownership for columns (1) and (2), over 50% for columns (3) and (4)). Concentration: Herfindahl-Hirschman index calculated from gross output value by sector (three-digit ISIC) and year. Average firm size: average number of employees by sector sector (three-digit ISIC) and year. Sectoral growth: change in gross output value by sector (three-digit ISIC) and year. Knowledge dummy: variable taking the value 1 if the firm operates in knowledge-intensive sectors and 0 otherwise. Natural resource dummy: variable taking the value 1 if the firm operates in natural resource-intensive sectors and 0 otherwise. All the estimates include sector- and year-specific effects.
* Significant at 10%. ** Significant at 5%. *** Significant at 1%.

TABLE A.3

Marginal effects of foreign ownership on firm survival[a]

Degree of foreign ownership	Knowledge-intensive sectors	Other sectors
Transnational 1	-0.012	-0.013
(some degree of foreign ownership)	(1.27)	(1.26)
Transnational 2	-0.019	-0.018
(al least 50% foreign ownership)	(1.65)*	(1.67)*

Source: prepared by the author on the basis of the Annual National Industry Survey (ENIA), 2001-2006.

[a] Marginal effects calculated from the results of columns (2) and (4) of table A.2.
* Significant at 10%.

Bibliography

Álvarez, R. and G. Crespi (2007), "Multinational firms and productivity catching-up: the case of Chilean manufacturing", *International Journal of Technological Learning, Innovation and Development*, vol. 1, No. 2, Inderscience Enterprises Ltd., January.

Álvarez, R. and H. Görg (2009), "Multinationals and plant exit: evidence from Chile", *International Review of Economics and Finance*, vol. 18, No. 1, Amsterdam, Elsevier.

Álvarez, R. and R. López (2008), "Is exporting a source of productivity spillovers?", *Review of World Economics*, vol. 144, No. 4, Springer, December.

_____ (2005), "Exporting and performance: evidence from Chilean plants", *Canadian Journal of Economics*, vol. 38, No. 4, Quebec, Canadian Economics Association.

Álvarez, R. and S. Vergara (2013), "Trade exposure, survival and growth of small and medium-size firms", *International Review of Economics & Finance*, vol. 25(C), Amsterdam, Elsevier.

Audretsch, D. and T. Mahmood (1995), "New firm survival: new results using a hazard function", *The Review of Economics and Statistics*, vol. 77, No. 3, Cambridge, Massachusetts, The MIT Press, August.

Baldwin, R., R. Lipsey and J. Richards (1998), *Geography and Ownership as Bases for Economic Accounting*, Chicago, The University of Chicago Press.

Bandick, R. (2010), "Multinationals and plant survival", *Review of World Economics,* vol. 146, No. 4, Springer.

Barbosa, N. and H. Louri (2005), "Corporate performance: does ownership matter? A comparison of foreign- and domestic-owned firms in Greece and Portugal", *Review of Industrial Organization*, vol. 27, No. 1, Springer.

Benvignati, A. (1987), "Domestic profit advantages of multinational firms", *The Journal of Business*, vol. 60, No. 3, Chicago, The University of Chicago Press, July.

Bernard, A. and F. Sjoholm (2003), "Foreign owners and plant survival", *NBER Working Papers,* No. 10039, Cambridge, Massachusetts, National Bureau of Economic Research.

Blomström, M. (1988), "Labor productivity differences between foreign and domestic firms in Mexico", *World Development*, vol. 16, No. 11, Amsterdam, Elsevier, November.

Blomström, M. and F. Sjöholm (1999), "Technology, transfer and spillovers: does local participation with multinationals matter?", *European Economic Review*, vol. 43, No. 4-6, Amsterdam, Elsevier.

Caves, R.E. (1996), *Multinational Enterprise and Economic Analysis*, Cambridge, Cambridge University Press.

Cefis, E. and M. Ciccarelli (2005), "Profit differentials and innovation", *Economics of Innovation and New Technologies*, vol. 14, No. 1–2, Taylor & Francis.

Cimoli, M. and others (2005), "Cambio estructural, heterogeneidad productiva y tecnología en América Latina", *Heterogeneidad estructural, asimetrías tecnológicas y crecimiento en América Latina*, M. Cimoli (ed.), Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC)/Inter-American Development Bank (IDB).

Cohen, S.D. (2007), *Multinational Corporations and Foreign Direct Investment: Avoiding Simplicity, Embracing Complexity*, New York, Oxford University Press.

Crespi, G., C. Criscuolo and J. Haskel (2006), "Information technology, organizational change, and productivity growth", *Working Papers*, No. 558, London, Queen Mary University of London.

Dimelis, S. and H. Louri (2002), "Foreign ownership and production efficiency: a quantile regression analysis", *Oxford Economic Papers*, vol. 54, No. 3, Oxford, Oxford University Press.

Doms, M., T. Dunne and M. Roberts (1995), "The role of technology use in the survival and growth of manufacturing plants", *International Journal of Industrial Organization*, vol. 13, No. 4, Amsterdam, Elsevier, December.

Dunning, J.H. (2000) "The eclectic paradigm as an envelope for economic and business theories of MNE activity", *International Business Review*, vol. 9, No. 2, Amsterdam, Elsevier.

ECLAC (Economic Commission for Latin America and the Caribbean) (2012), *Foreign Direct Investment in Latin America and the Caribbean, 2011* (LC/G.2538-P), Santiago, Chile, June. United Nations publication, Sales No. E.12.II.G.4.

_____ (2011), *Foreign Direct Investment in Latin America and the Caribbean, 2010* (LC/G.2494-P), Santiago, Chile, May. United Nations publication, Sales No. E.11.II.G.4.

_____ (2006), *Foreign Investment in Latin America and the Caribbean, 2005* (LC/G.2309-P), Santiago, Chile, May. United Nations publication, Sales No. E.06.II.G.44.

_____ (2001), *Foreign Investment in Latin America and the Caribbean, 2000* (LC/G.2125-P), Santiago, Chile, April. United Nations publication, Sales No. E.01.II.G.12.

Gallagher, K. and D. Chudnovsky (2009), *Rethinking Foreign Investment for Sustainable Development. Lessons from Latin America*, London, Anthem Press.

Girma, S., R. Kneller and M. Pisu (2005), "Export versus FDI: an empirical test", *Review of World Economics*, vol. 141, No. 2, Springer.

Godart, O., H. Görg and A. Hanley (2011), "Surviving the crisis: foreign multinationals vs domestic firms in Ireland", *IZA Discussion Paper Series*, No. 5882, Institute for the Study of Labour, Bonn, July.

Görg, H. and E. Strobl (2003), "Footloose' multinationals?", *The Manchester School*, vol. 71, No. 1, John Wiley & Sons, January.

Hobday, M. and H. Rush (2007), "Upgrading the technological capabilities of foreign transnational subsidiaries in developing countries: the case of electronics in Thailand", *Research Policy*, vol. 36, No. 9, Amsterdam, Elsevier.

Koenker, R. (2005), *Quantile Regression*, New York, Cambridge University Press.

Kumar, N. (1990), "Mobility barriers and profitability of multinational and local enterprises in Indian manufacturing", *The Journal of Industrial Economics*, vol. 38, No. 4, Wiley, June.

Levinsohn, J. and A. Petrin (2003), "On the micro-foundations of productivity growth", November, unpublished.

Lipsey, R. (2002), "Home and host country effects of FDI", *NBER Working Paper*, No. 9293, Cambridge, Massachusetts, National Bureau of Economic Research, October.

Love, J.H., S. Roper and J. Du (2009), "Innovation, ownership and profitability", *International Journal of Industrial Organization*, vol. 27, No. 3, Amsterdam, Elsevier.

Marín, A. and V. Arza (2009), "The role of multinational corporations in innovation systems of developing countries. From technology diffusion to international involvement", *Handbook of Innovation Systems and Developing Countries. Building Domestic Capabilities in a Global Context*, B. Lundvall and others (eds.), Cheltenham, Edward Elgar.

Markusen, J.R. (2002), *Multinational Firms and the Theory of International Trade*, Cambridge, Massachusetts, The MIT Press.

Mata, J. and P. Portugal (2002), "The survival of new domestic and foreign-owned firms", *Strategic Management Journal*, vol. 23, No. 4, John Wiley & Sons, April.

Moran, T., M. Graham and M. Blomström (2005), *Does Foreign Direct Investment Promote Development?*, Washington, D.C., Peterson Institute for International Economics.

Narula, R. and S. Lall (eds.) (2006), *Understanding FDI-Assisted Economic Development*, New York, Routledge.

Olley, S. and A. Pakes (1996), "The dynamics of productivity in the telecommunications industry", *Econometrica*, vol. 64, No. 6, New York, The Econometric Society.

Ramstetter, E. (1998), "Comparisons of foreign multinationals and local firms in Asian manufacturing over time", *Working Papers Series*, vol. 98-18, Kitakyushu, The International Centre for the Study of East Asian Development.

Temouri, Y., N.L. Driffield and D. Higón (2008), "Analysis of productivity differences among foreign and domestic firms: evidence from Germany", *Review of World Economics*, vol. 144, No. 1, Springer.

UNCTAD (United Nations Conference on Trade and Development) (2005), *World Investment Report 2005: Transnational Corporations and the Internationalization of R&D* (UNCTAD/WIR/2005), Geneva, United Nations. United Nations publication, Sales No. E.05.II.D.10.

Van Biesebroeck, J. (2005), "Firm size matters: Growth and productivity growth in African manufacturing", *Economic Development and Cultural Change*, vol. 53, No. 3, Chicago, University of Chicago Press.

Wagner, J. (2007), "Exports and productivity: a survey of the evidence from firm-level data", *The World Economy*, vol. 30, No. 1, Wiley Blackwell.

An assessment of the dynamics between the permanent and transitory components of Mexico's output and unemployment

Alejandro Islas C. and Willy W. Cortez

ABSTRACT

Previous studies about the relationship between the cyclical components of Mexico's output and unemployment suggest that it closely resembles that found in the economy of the United States of America. This would indicate that the dynamics between output and labour markets in the two economies are rather similar. However, these estimates are puzzling for they do not correspond to a characterization made to Mexico's labour market. Using a methodology first proposed by Clark (1989), we find that the correlation between the transitory components of output and unemployment is much lower than previously thought.

KEYWORDS

Labour market, unemployment, output, mathematical models, Mexico

JEL CLASSIFICATION

C32, E23, E24, E32

AUTHORS

Alejandro Islas C., Professor Numerario III C, Department of Statistics, Autonomous Technological Institute of Mexico (ITAM). aislas@itam.mx

Willy W. Cortez, Professor-Researcher C, Department of Quantitative Methods, University Center for Economic and Administrative Sciences (CUCEA), University of Guadalajara, Jalisco, Mexico. wcortez@cucea.udg.mx

I
Introduction

Between 1987 and 2008, open unemployment rates in Mexico showed wide fluctuations, ranging from 5.2% in the first quarter of 1987 to 2.6 in the second quarter of 1991 and 8.2 in the third quarter of 1995, when it reached its maximum level. Subsequently, it declined to 2.3% in the fourth quarter of 2000 and has trended upward since then. These changes in the mean value of unemployment were accompanied by changes in the unemployment volatility, indicating changes in Mexico's labour market dynamics. Between the first quarter of 1987 (1987:Q1) and the fourth quarter of 1994 (1994:Q4), standard deviation in unemployment was about 0.176, while between 1995:Q1 and 2000:Q4, it increased to about 0.394. It later declined to 0.148 in 2001:Q1 and 2007:Q1.

These fluctuations in unemployment have coincided with output movements in the opposite direction; that is, when unemployment was below its long-term trend, output was above its long-term trend; whereas when unemployment was above, output was below its respective long-term trend. Chavarín (2001) and Loria and Ramos (2007), for instance, have estimated that a 1-percentage-point change in unemployment was associated with a negative output growth between 2.3% and 2.7%. The empirical regularity between changes in unemployment and changes in output, also known as Okun's law, is an important building block in Keynesian macroeconomics for it relates output and labour markets.[1]

The usefulness of Okun's law as a policy instrument has been stressed in a number of papers; Knotek (2007), for instance, argues that it can be used as a simple rule of thumb to determine how much unemployment would induce "x" output growth. It can also help to forecast the unemployment rate. Balakrishnan, Das and Kannan (2010), for their part, use Okun's law as an organizing framework to explain unemployment dynamics for a group of advanced countries during the last recession.

Within this literature, one of the main issues in which economists have been interested has been whether Okun's estimates are stable. A quick review of several studies done for the United States of America, as well as for other developed countries indicates that the coefficient varies significantly across countries and across time periods. There is also evidence that Okun's coefficient is sensitive to the time horizon used to measure the unemployment-output relationship, that is, contemporaneous, short run and long run (Weber, 1995).

The variability of the coefficient across countries can be explained by several factors. Blanchard and Quah (1989), for example, argue that Okun's coefficient is a mongrel coefficient because it depends on the type of disturbances that affect the economy, that is, supply or demand shocks.[2] International studies provide overwhelming evidence that the coefficient does not remain constant. Schnabel (2002) found evidence that during 1990-2000, the coefficient changed significantly in a sample of industrialized countries. The changes, however, were not homogeneous across countries: some countries exhibited higher sensitivity of output growth to unemployment change than others. Cazes, Verick and Al Hussami (2011) and Balakrishnan, Das and Kannan (2010), in turn, present evidence that the 2008 economic crisis has had a different impact on labour markets in countries of the Organisation for Economic Cooperation and Development (OECD); namely, there are countries that have endured a higher change in unemployment rates —like Spain and the United States— while others have had a lower change in unemployment rates, like Germany, Japan and Italy. Recent studies also provide further evidence that Okun's coefficient is not symmetrical; that is, it takes different values in booms and in recessions (Jardin and Gaétan, 2011).

Our knowledge of the dynamics between output and unemployment in the Mexican economy is rather limited. The existing literature maintains that Mexico's Okun's

☐ Professor Numerario III C refers to the appointment that Alejandro Islas C. holds at the Autonomous Technological Institute of Mexico. He is a full-time, category IIIC, tenured professor and researcher.

Professor-Researcher C refers to the appointment that Willy W. Cortez holds at the University of Guadalajara. He is a full-time, category "C", tenured professor and researcher.

☐ The authors are grateful for the useful comments made by staff members of the ECLAC subregional headquarters in Mexico and by participants at the Seminario Aleatorio of the Autonomous Technological Institute of Mexico. Alejandro Islas is grateful to the Asociación Mexicana de Cultura, A.C. for providing support to carry out this work.

[1] Prachowny (1993) notes that the aggregate supply curve is derived from the Phillips curve with the help of Okun's law.

[2] They found that Okun's coefficient is much smaller when the shock comes from the demand side than when it comes from the supply side of the economy.

coefficient is close to Okun's original calculations for the United States economy (Chavarín, 2001; Loria and Ramos, 2007). However, those estimates are puzzling for they would indicate that Mexico's labour market is as flexible as the United States'. Yet, when looking at different measures of flexibility, Mexico's labour market is one of the most rigid among OECD and Latin American countries.[3]

In a study of 13 Latin American economies, González-Anaya (2002) found that Mexico's Okun coefficient was among the lowest coefficients for Latin American countries. According to his estimates, it was closer to the ones found for Europe and Japan. He argued that this was attributable in part to the greater real-wage flexibility in Mexico.

Two other issues arise in connection with the studies by Chavarín (2001) and Loria and Ramos (2007). First, from a statistical point of view they both use the two-step methodology to estimate Okun's coefficient, which might result in biased and inefficient estimates (Sinclair, 2009). Second, neither of these studies provides an explanation of how the size of the coefficient may be influenced by Mexico's output and unemployment interrelated dynamics, or by the functioning of the Mexican labour market.

As shall be clear later on, there are a number of issues involved in the estimation of Okun's coefficient. Our task in this study is rather limited in the sense that we are interested in providing a point estimate that is unbiased and efficient. We depart from the conventional two-step procedure by following a methodology first proposed by Clark (1989). In addition, we relate the size of the estimated coefficient to Mexico's labour market conditions and provide a proper explanation of why the estimates are reasonable or acceptable.

This paper is divided into six sections, including this Introduction. Section II outlines some of the studies done to estimate Okun's coefficient, while, in section III, we discuss briefly the nature of the Mexican labour market and the insight provided by Clark's estimation technique. In section IV, we describe the econometric model used to estimate the relationship between output and unemployment. Section V discusses the main results while the last section, section VI, presents some concluding remarks.

[3] For instance, according to OECD, Mexico's Employment Protection Strictness Index during the 1990s and 2000s has been 3.1, compared with 0.21 for the United States economy.

II
Okun's Law

Okun's purpose for his 1962 paper was to provide an estimate of the cost of unemployment in terms of potential output. Over time, this research agenda has evolved into a fertile ground for discussing the dynamics of output and unemployment and how they are related over the business cycles.

In his seminal paper, Okun (1962) estimated that a 1-percentage-point increase in unemployment would induce a decline in output growth of about 3.3%. Although it has not been noted by many researchers, the underlying assumption for getting a measure of the impact of unemployment on potential output was that the unemployment rate summarizes, —or is correlated to—, the behaviour of other variables such as: average hours worked, participation rates and labour productivity. In other words, unemployment "…can be viewed as a proxy variable for all the ways in which output is affected by idle resources…" (p. 2). This assumption is very important for obtaining and predicting a fixed coefficient between unemployment change and output growth; otherwise, one should not expect this coefficient to be fixed. Furthermore, technical change, changes in labour market institutions, variations in participation rates and demographic shifts, among other things, would induce changes in the coefficient.

An important conclusion derived from the existing literature is that the relationship between the cyclical components of output and unemployment is rather complex and unstable for it depends on a number of variables and as such we should not expect it to be identical across countries.[4] To explain the latter, let us define unemployment as the difference between labour supply and labour demand for a given wage rate, then changes in unemployment are induced by changes in

[4] Lee (2000), in a study for OECD countries, found that Okun's estimates are also sensitive to the choice of models (including the first difference and the gap specifications).

either labour supply or demand or both. Labour supply, on the one hand, depends on demographic variables and labour market institutions.[5] Labour demand, on the other hand, depends on technical progress and on the conditions prevailing in the goods market. In the short run, actual employment would also depend on firms' capacity to adjust the number of hours put in by workers and their work force's productivity. Thus, it is not clear whether a change in output demand would automatically induce a change in employment hence, in unemployment. For instance, if we assume that there is an increase in aggregate demand and if the higher demand is met with an increase in the number of hours worked and/or higher labour productivity, then employment (unemployment) would not necessarily increase (decrease). A priori, we cannot say how fast those variables would adjust across countries and over time. But we know that they will not adjust uniformly across countries.

It is customary to present Okun's law in terms of the impact that a one-percentage-point change in unemployment would have on the output growth rate. However, from a Keynesian perspective, unemployment depends on goods market conditions. In other words, unemployment is the dependent variable while output is the independent one.[6] In the past, economists would run unemployment on output and then assume that Okun's coefficient was the inverse of the estimated parameter. We now know that this procedure is incorrect because, as we argued above, not only is the relationship between them non-linear but it is also probable that they measure different things. Barreto and Howland (1993) were among the first to notice this. They maintained that one should seriously consider the direction of the regression. They indicated that Okun erroneously assumed that it was possible to track the relationship in both ways. Specifically, $\Delta u = f(\Delta y)$ may be related to demand and/or supply shocks, while $\Delta y = g(\Delta u)$ may be associated to supply and demographic shocks. Thus, from a theoretical point of view, there is no reason for us to expect that the two coefficients have any arithmetic or algebraic relationship. It should be noted that this is independent of the feedback effect that emerges between them.

Within Okun's literature, we identify three techniques of estimation: (i) Estimation of Okun's coefficient using the conventional two-step procedure; (ii) the estimation of Okun's coefficient as part of a bivariate model where the cyclical component is estimated jointly with the trend component, (iii) estimation of Okun's coefficient assuming that it varies over time.

The conventional estimation of Okun's coefficient involves a two-step procedure. The first step consists in removing the permanent component of the series and the second step in estimating the correlation between the transitory components of output and unemployment. The permanent component of the series is usually obtained through the use of different techniques, which range from estimating the trend component by ordinary least squares (OLS), to using the Hodrick-Prescott filter. In some cases, the unobserved permanent component has been simply eliminated by taking the first differences of the series[7]. Once the (unobserved) permanent component has been estimated, the transitory component is obtained by subtracting the permanent component from the observed series. The second step involves estimating Okun's coefficient by OLS.

Sinclair (2009) maintains that this methodology provides a biased and inefficient coefficient for two reasons. First, since the permanent and the transitory components of the two series are correlated, it is more efficient to jointly estimate their cyclical components. Second, to the extent that the measurement error of the independent variable is correlated with the measurement error of the dependent variable, OLS estimates are biased and inconsistent. Thus, a better approach would be to use the estimate of the correlation rather than the correlation of the estimates.

Bivariate models that estimate jointly the permanent and transitory elements of unemployment and output began as a reaction to Nelson and Plosser's (1982) methodology to remove non-stationarity by first differencing, making the trend a random walk with drift rather than a straight line. Clark (1987) points out that two shortcomings of this approach are, first, tests for non-stationarity in trend have very little power against plausible alternatives; second, the analysis is based on the strong assumption that the auto-covariance function for the first difference of output is exactly zero after lag one.

Clark (1987) proposed a new analysis of United States output by decomposing the series into its two unobserved independent components: the non-stationary trend and the stationary cyclical components. The framework for his analysis is the state space model, which allows for a more general specification of the trend component.

[5] Demographic variables are, for example, population growth, women's participation in the labour market, while labour market institutions include factors that affect workers' preferences about work-leisure trade-off, employment protection legislation, habits and work effort among others.

[6] In Keynes' view, labour demand is a derived demand.

[7] When one of the series is stationary, i. e., I(0), then the first step might be redundant.

Clark (1989), on the other hand, uses the Kalman filter and maximum likelihood to estimate the non-stationary permanent and stationary cyclical components of output growth and unemployment for six developed economies.[8] He finds strong evidence that the estimated output's stationary component is closely related to unemployment's cyclical component. Evans (1989), for his part, uses a bivariate vector autoregressive (VAR) model to describe output-unemployment dynamics, to estimate the degree of persistence in output innovations, and to decompose output into trend and cycle. He concludes that a bivariate analysis indicates the existence of feedback between unemployment and output growth as well as a negative contemporaneous correlation between output growth and unemployment innovations.

The discussion about the relationship between the transitory and permanent components of real gross domestic product (GDP) is important because it allows us to determine whether the observed GDP variability is the result of the variability of the permanent or transitory components. Furthermore, it can also help us estimate the cross series relationships between the permanent component and the transitory components.

The third technique of estimation is related to the fact that the coefficient has not remained constant over time. Since the mid-1990s, an increasing number of studies have investigated whether Okun's coefficient is unstable or not. Prachowny (1993), for example, argues that the 3:1 ratio of output to unemployment holds only because other factors like weekly hours, induced labour supply and productivity tend to rise as well. An important conclusion of Prachowny's paper is that if any of these other factors change then, other things being equal, the coefficient linking output to unemployment should change as well.

Knotek (2007) and Balakrishnan, Das and Kannan (2010), among others, present evidence that, contrary to the findings of previous studies, the relationship between output and unemployment has not remained stable. In a study on the United States economy during 1960-2007, Knotek found that Okun's coefficient has fluctuated between -0.067 in 1975 to about -0.088 in 1995 to -0.04 in 2007; that is, the coefficient has significantly increased during the 2000s.

Balakrishnan, Das and Kannan (2010) investigated unemployment dynamics for a number of industrialized countries between 1980 and 2008. They found that Okun's coefficient changed significantly among OECD countries. In particular, they observed that for Sweden and the United Kingdom of Great Britain and Northern Ireland the coefficient steadily increased (in absolute values), while for Germany and the United States it fluctuated with no clear pattern. They argue that institutional changes in labour markets and technological as well as demographic changes induced the changes that the coefficient shows for this group of developed countries. A recent study by Cazes, Verick and Al Hussami (2011) presents evidence that the impact on unemployment of the financial crisis of 2008 has been different between the United States and the European countries. These differentiated effects are due to the different evolution of Okun's coefficient in these countries.

An additional conclusion of their studies is that the impact of output fluctuations on unemployment is asymmetrical; that is, the coefficient behaves differently during recession than during recoveries. Crespo (2003) found that for the United States economy the contemporaneous effect of growth on unemployment is significantly higher in recessions than in expansions. He also found that shocks to unemployment tend to be more persistent in the expansionary regime. Jardin and Gaétan (2011), in turn, in a study for 16 European countries found evidence that unemployment responds more strongly to output growth when the economy is contracting than when it is expanding.

In the next section, we discuss some of the main characteristics of Mexico's labour market and present the two contrasting views about its nature. This section is important for it will help us understand the empirical results.

[8] These economies were Canada, France, Germany, Japan, United Kingdom of Great Britain and Northern Ireland and United States.

III

How flexible is Mexico's labour market?

Common sense suggests that the magnitude of Okun's coefficient is a reflection of the labour market dynamics imposed by the country's institutional framework and technical change. We can classify the studies on the nature of Mexico's labour market into two types according to the view on which they are based. On the one hand, there is the view that Mexico's labour market is heavily regulated by laws that impede employment creation. In this case, output growth would not necessarily translate into large unemployment variations but rather into real wage changes (Heckman and Pagés, 2000, and Gill, Montenegro and Dömeland, 2001). In times of recession and because of the rigidity of the federal labour law and unions, it would be extremely difficult for firms to lay-off workers.[9] It is also argued that job security provisions (which include severance payments) increase dismissal costs to the firms. These costs discourage firms from firing workers whenever there is a negative shock and from increasing job creation in expansions. Heckman and Pagés (2000) found that Mexico exhibits one of the highest indices of job security within Latin American countries, which implies that it has one of the most regulated labour markets in the region.[10] Assuming that these rigidities operate during expansions as well as during recessions, one would expect a low correlation between the transitory components of output and unemployment; that is, one would expect a low Okun's coefficient.

A contrasting view is that since the mid-1980s, when Mexico began its new development strategy based on trade and economic liberalization, an increasing number of firms have adopted new mechanisms that enable them to adjust better to economic fluctuations (De la Garza, 2005). Among these schemes there is the increased use of short term contracts and outsourcing as a means of reducing labour costs that result from job stability. This is particularly true for the maquila[11] and service sectors, the fastest growing sectors within the Mexican economy since the late 1980s (Marshall, 2004). This view therefore, would suggest that Okun's coefficient is large enough so that variations in output growth would induce significant variations in unemployment rates.

Implicit in this debate is the recognition of the existence of a large informal sector which provides employment to about half of Mexican employed workers (Loayza and Sugawara, 2009). Even though informality is an unobservable variable, the size of the informal labour market has been estimated by indirect means.[12]

Calderon (2000) found that there is a close integration between Mexico's formal and informal labour markets. More recent studies by Alcaraz, Chiquiar and Ramos-Francia (2008) and Alcaraz (2009) corroborate the idea of a close interaction between the two markets. These authors found evidence that the transition rate between formal and informal employment is higher than the one between manufacturing and service sectors. They point out that this higher mobility between formal and informal sectors would indicate the existence of institutional labour market rigidities in Mexico's formal sector.

In section II, we provided an explanation of why under certain circumstances changes in output would not translate into changes in unemployment (and vice versa). The existence of a large informal labour market closely interrelated to the formal one means that there is an additional channel through which output fluctuations would not necessarily translate into fluctuations in open unemployment, or vice versa. In other words, the existence of a large informal labour market would modify the expected relationship between the cyclical components of output and unemployment. Instead, we may observe that a given change in output would induce higher labour mobility between the formal and informal sectors while the unemployment rate remains constant. Consider, for example, decomposing employment rate into formal employment rate (e_f) and informal employment rate (e_{inf}), then the following should be true:

$$u = 1 - e_f - e_{inf}$$
$$\Delta u = - \Delta e_f - \Delta e_{inf}$$

[9] On December 2012, the Mexican Congress approved new labour legislation that provides much more flexibility to firms to hire and fire workers.

[10] OECD also found evidence that among OECD members, Mexico has the highest employment protection index for both types of contract (permanent and temporary).

[11] The maquila sector is composed of assembly plants whose output is intended mainly for export.

[12] For a brief description of some of these methods, see Loayza and Sugawara (2009).

If formal employment is heavily regulated, then variations in unemployment would be mostly absorbed by variations in informal employment. Furthermore, given that Mexico's official labour statistics do consider informal employment as employment, the correlation between variations in output and unemployment would be fairly low, unless the informal sector is not flexible enough.[13] This is true even in the light of the institutional rigidities mentioned by Heckman and Pagés (2000). Okun himself noted that the value of the coefficient depended on a set of strong assumptions about the behaviour of labour productivity, average hours worked and participation rates.[14]

Having discussed the relationship between the transitory components of unemployment and output, there remains the question of what to expect about the relationship between the permanent components of both series. We expect that the long-run equilibrium relationship is measured by the correlation between the permanent components of both series. In this sense, Okun's coefficient will be smaller because in the long run a number of variables would not remain fixed as in the case of the capital utilization, technology and participation rates and labour productivity.

[13] Or the relative importance of the informal sector is rather small.

[14] So, if any of these variables change, then the coefficient should not be expected to remain constant but rather to change over time.

IV

A model for the output and unemployment rate

In this section, we follow the permanent-transitory components model for output and unemployment rates developed by Clark (1989) and Sinclair (2009):

$$y_t = \tau_{y_t} + c_{y_t}, \tag{1}$$

$$\tau_{y_t} = \mu_y + \tau_{y_{t-1}} + \eta_{y_t}, \tag{2}$$

$$u_t = \tau_{u_t} + c_{u_t}, \tag{3}$$

$$\tau_{u_t} = \mu_u + \tau_{u_{t-1}} + \eta_{u_t} \tag{4}$$

In this model, the output (y_t) and the unemployment rate (u_t) are the sum of two components. The first component ($\tau_{i_t}, i = y, u$) is the permanent component which is the steady-state level after removing all temporary movements. The second component ($c_{i_t}, i = y, u$) is the transitory component that expresses all temporary movements and is assumed to be stationary. Each of the trend components is assumed to be a random walk to allow for permanent movements in the series. The transitory component $\left\{\left(c_{y_t}, c_{u_t}\right)\right\}$, on the other hand, is a stationary bi-variate stochastic process.

To complete the characterization of output and unemployment rates, we assume that the transitory deviations from the equilibrium values are driven by a stationary VAR(p) process,

$$\Phi(L)\underline{c_t} = \underline{\varepsilon_t} \tag{5}$$

where $c_t = \begin{pmatrix} c_{y_t} \\ c_{u_t} \end{pmatrix}$,

$$\underline{\varepsilon_t} = \begin{pmatrix} \varepsilon_{y_t} \\ \varepsilon_{u_t} \end{pmatrix} \overset{i.i.d}{\sim} \left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma^2_{\varepsilon_y} & \rho_y \sigma_{\varepsilon_y} \sigma_{\varepsilon_u} \\ \rho_u \sigma_{\varepsilon_y} \sigma_{\varepsilon_u} & \sigma^2_{\varepsilon_u} \end{pmatrix} \right)$$

and $\Phi(L)$ is a two-dimensional lag polinomial of order p.

1. An autoregressive (AR(2)) transient dynamics

Following a tradition in the unobserved components literature the cyclical component is modelled as an autoregressive (AR(2)) process, since it facilitates the constraint that the roots of the AR polynomial stay outside the unit circle during the maximum likelihood estimation (see for instance, Morley, Nelson, and Zivot, 2003; Clark, 1987 and 1989; and Watson, 1986).[15] The AR(2) model is obtained from (5) by setting

[15] A theoretical justification for the AR(2) cycle for unemployment follows from Alogoskoufis and Manning (1988), who argue that the unemployment rate for all countries should be modelled by an AR(2).

$\phi_y(L) = 1 - \phi_{1y}L - \phi_{2y}L^2$, $\phi_u(L) = 1 - \phi_{1u}L - \phi_{1u}L^2$. We assume the innovations (η_{yt}, η_{ut}, ε_{yt}, and ε_{ut}) are normally distributed random variables with mean zero and general covariance matrix —allowing possible correlation between any of the components.

The unobserved component model can be estimated by using state space techniques to find the likelihood function of the sample. If the error terms are assumed to be normally distributed, then the parameters of the model can be estimated employing maximum likelihood techniques. For instance, parameter estimates in the above system can be obtained by starting with an initial guess for the state vector and its covariance matrix. Given the initial estimated parameters, the Kalman filter recursively generates the prediction equations. Ultimately, the Kalman filter generates both unobserved components $(\tau_{i_t}, i = y, u)$ and $(c_{i_t}, i = y, u)$. A special feature of the state-space system is that the transition matrix has two unit roots —corresponding to the two stochastic trends. Therefore the covariance matrix of the initial value of the state vector will be unbounded. Hence, care has to be taken with regards to the initialization of the state vector. We deal with this problem through the initialization method developed by Koopman (1997) and refined in Durbin and Koopman (2001).[16]

It may not be immediately obvious that the unobserved component model is identified. However, through a reduced form representation of the model, in a number of papers (see for instance, Schleicher, 2003; Morley, Nelson and Zivot, 2003; Morley, 2007), it is shown that an unobserved component model with correlated innovations is identified, provided that it has sufficiently rich dynamics. Schleicher (2003) presents a general discussion of a number of technical issues involved in the identification and estimation of a multivariate, correlated, unobserved components model. He shows that, in general, the requirement for identification of a structural unobserved component model with non-common trends and non-common cycles, where the transitory components are modelled as AR(p) cycles, is: $p \geq 1 + \frac{1}{n}$. Therefore, for a multivariate case, AR(2) cycles will result in an implicit over-identification restriction. It should be noted that, even though the correlated unobserved component model is identified, weak identification could still be an issue. Weak identification is a problem because it can lead to distorted inferences using estimated standard errors. Nelson and Startz (2007) show that the true variance goes to infinity in the limit of non-identification, but that the sample variance remains finite. They suggest using likelihood ratio statistics instead of Wald statistics for hypothesis testing when identification is a potential problem.

The random-walk-AR(2) model implies the following moments:

$$Var\left(c_{y_t}\right) = \frac{\left(1 - \phi_{2y}\right)\sigma^2_{\varepsilon_y}}{\left(1 + \phi_{2y}\right)\left[\left(1 - \phi_{2y}\right)^2 - \phi^2_{1y}\right]} \quad (6)$$

$$Var\left(c_{u_t}\right) = \frac{\left(1 - \phi_{2u}\right)\sigma^2_{\varepsilon_u}}{\left(1 + \phi_{2u}\right)\left[\left(1 - \phi_{2u}\right)^2 - \phi^2_{1u}\right]} \quad (7)$$

and

$$Cov\left(c_{y_t}, c_{u_t}\right) = \frac{\left(1 - \phi_{2y}\phi_{2u}\right)\sigma_{\varepsilon_y\varepsilon_u}}{1 - \phi_{1y}\phi_{1u}\left(1 + \phi_{2y}\phi_{2u}\right) - \phi_{2y}\left(\phi^2_{1y} + 2\phi_{2y}\right) - \phi_{2y}\phi^2_{1u} + \phi^2_{2y}\phi^2_{2u}} \quad (8)$$

Let us look at these issues in the context of Okun's law. Okun suggested that there was a strong link between the output gap and the unemployment gap. Since the relationship is indigenously bidirectional, researchers have been juggling the equations and have regressed both, output on unemployment (e.g. Freeman, 2001) and vice versa (e.g., Sögner and Stiassny, 2000). Yet, the interpretation of the results frequently misguided the authors and Okun himself, which leads to spurious results.

As argued, the relationship between real output and the unemployment rate is not necessarily linear. Separate regressions should therefore be run: output on unemployment and unemployment on output; thus,

$$y_t - y^*_t = \lambda(u_t - u^*_t) + \vartheta_t \quad (9)$$

or

$$u_t - u^*_t = \theta(y_t - y^*_t) + \zeta_t \quad (10)$$

where $(y_t - y^*_t)$ and $(u_t - u^*_t)$ are the transitory components of output and unemployment rate, respectively, and ϑ_t, ζ_t represent the random errors. The best linear predictor of the unemployment rate given output can be found by regressing unemployment on gross national product (GDP) (see equation 10), while any attempt to predict output given unemployment requires that GDP be regressed on unemployment (see equation 9).

[16] For the unobserved component model, the diffuse initial state vector can be defined as $\alpha_{1|0} = \begin{bmatrix} \delta_{kx1} \\ 0_{2kx1} \end{bmatrix} + \upsilon_0$ where $\delta \sim N(0, kI_2), k \to \infty$. The covariance matrix of the initial state vector, $P_{1/0}$ can be split into an unbounded component kP_∞ pertaining to the stochastic trends and a bounded component associated with the stationary component P_*.

It is customary to use λ to represent Okun's coefficient. As already pointed out, the conventional estimation of Okun's law has two consequences. First, OLS estimates are biased and inconsistent, and since λ is negative, λ will tend to overestimate λ. Second, since the two components are correlated, it is more efficient to estimate both cyclical components jointly. In our model λ and θ are obtained as

$$\lambda = \frac{Cov\left(c_{y_t}, c_{u_t}\right)}{Var\left(c_{u_t}\right)} \tag{11}$$

and

$$\theta = \frac{Cov\left(c_{y_t}, c_{u_t}\right)}{Var\left(c_{y_t}\right)} \tag{12}$$

respectively.

V
Empirical results

1. The data

The key variables are unemployment and production. The figures for Mexico's gross domestic product were obtained from the National Institute of Statistics and Geography (INEGI),[17] and are calculated on a quarterly basis in real pesos (base year = 2003). The unemployment series was obtained from the National Survey on Urban Employment (ENEU) and the National Survey on Occupation and Employment, (ENOE), conducted by INEGI.[18] The data are representative of the urban areas in Mexico, which account for about a third of the population.[19] All data are quarterly, seasonally adjusted and cover the period 1987: QI to 2008: Q4.

Figure 1 shows the behaviour of the variables used in the analysis. High unemployment rates in the late 1980s and mid-2000s were accompanied by relatively low and slowly growing production levels. The Mexican financial crisis of 1994 and the global crisis of 2008 dramatically raised unemployment and slashed output levels. The average rate of unemployment for the period 1987-2008 is about 4.99% with minimum and maximum values of 3.06% and 9.03%, respectively. During the early 1990s, the unemployment rate showed a slight upward trend and reached its highest value by the end of 1995. In 1996, it started to decline rapidly, so that by the end of 2000, it had reached its lowest level. This decline in the unemployment rate was short-lived for in the next year unemployment began a new upward trend; this last upward trend in the Mexican unemployment rate could be related to the slowdown in the United States economy in 2001, which worsened after the September 11 terrorist attacks, and hit Mexico's economy hard. Real GDP growth dropped from 6.6% in 2000 to 0.2% in 2001.

We now turn to the estimation of our econometric model.

2. Unit root test

Before estimating the permanent and transitory components of each time series employing the unobserved component model, we need to check if the series are stationary or not. Given that the period of analysis includes the 1994 Mexican financial crisis and the recovery during the second half of the Zedillo administration as well as the 2001 Mexican recession and the fall in growth rates during the Fox administration, we use the endogenous Lee and Strazicich (2003) minimum Lagrange multiplier unit root test with two structural breaks. The data used are the log of real GDP multiplied by 100 (y_t) and the unemployment rate (u_t). Results of the unit root test using level data are shown in table 1. We fail to reject the null hypotheses that there exists a unit root for each series. This implies that each time series then follows a unit root process and therefore they are not stationary in levels. This is the desired condition, so the proposed unobserved component model can be implemented.

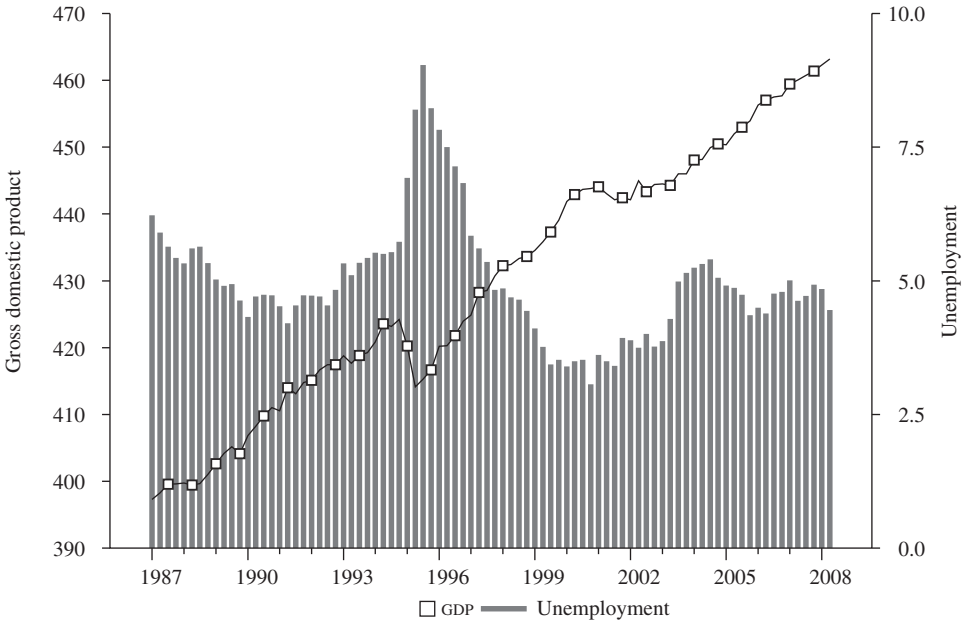
[17] INEGI performs statistical work comparable to that done in the United States by the Census Bureau, Bureau of Labor Statistics, and Bureau of Economic Analysis.

[18] Unemployment data from 1987-I to 2004-4 are from ENEU, standardized by ENOE criteria.

[19] Approximately 70% of the Mexican population lives in urban areas. Moreover demographic and labour market conditions are very different across the urban and rural sectors so the results of this paper must be considered with this in mind.

FIGURE 1

Mexico: real GDP and unemployment, first quarter 1987 - fourth quarter 2008



Source: National Institute of Statistics and Geography (INEGI) of Mexico.

TABLE 1

The endogenous two-break Lagrange multiplier unit root test

Log (GDP). Model C: K=1, T_{B_1} = 1994: 4, T_{B_2} = 2000: 1, N = 88, $\lambda_1 \cong 0.3$, $\lambda_2 \cong 0.6$ Critical values 5% (-5.74)$t_{\emptyset}$ = -3.5403						
Parameter	μ	d_1	d_{t_1}	d_2	d_{t_2}	ϕ
Estimator	0.758	-4.123	-0.596	1.177	1.782	-0.2739
T-statistics	3.5403*	-3.2122*	-1.4205**	0.930	3.305*	-3.5403
Unemployment model C: K = 1, T_{B_1} = 1995: 1, T_{B_2} = 1999: 4, N = 88, $\lambda_1 \cong 0.4$, $\lambda_2 \cong 0.6$ Critical values 5% (-5.67) $t_{\emptyset}$=-2.865						
Parameter	μ	d_1	d_{t_1}	d_2	d_{t_2}	ϕ
Estimator	-0.252	1.555	0.023	0.249	0.393	-0.188
T-statistics	-2.302*	4.997*	0.184	0.783	4.120*	-2.865

Source: prepared by the author.

*, ** denotes significance at 5% and 10% respectively.
Null: $y_t = \mu_0 + d_1 B_{1t} + d_{t1} D_{1t} + d_2 B_{2t} + d_{t2} D_{2t} + y_{t-1} + v_{1t}$
Alternative: $y_t = \mu_1 + \Upsilon t + d_1 D_{1t} + d_{t1} DT_{1t} + d_2 D_{2t} + d_{t2} DT_{2t} + v_{2t}$
Where D_{jt} = 1 for $t \geq T_{Bj} + 1$, j = 1, 2 and 0 otherwise; $DT_{jt} = t - T_{Bj}$ for $t \geq T_{Bj} + 1$, j = 1, 2 and 0 otherwise; B_{jt} = 1 for $t = T_{Bj} + 1$, j = 1, 2, and 0 otherwise T_{Bj} denotes a time period when a break occurs.

3. Maximum likelihood estimates

Using the Kalman Filter, we estimate the unobserved-component model for output and unemployment rate by maximum likelihood. Table 2 reports the estimates and asymptotic standard errors, while figures 2 and 3 plot the estimated temporary components of the logs of real GDP and the unemployment rate respectively, along with their unobserved permanent components. They are produced using the Kalman smoother, which uses all information available in the sample, thus providing a better "*in sample*" fit compared with the basic Kalman filter, which only uses information available at time t. The drift (μ_y) in the permanent component of output was significant while the drift in unemployment rates was not so and is not included in the report. We included a structural break in the drift term in the fourth quarter of 1994 for the log of real GDP. Some results are worth mentioning.

First, innovations to the permanent component of output have considerable impact and are stronger than similar shocks on the permanent component of unemployment. Both supply and demand side shocks seem to have important effects on output performance. Open unemployment, owing to the existence of a rigid labour law and a large informal labour market, is less sensitive to external shocks.

Second, innovations to the permanent components are significant and negatively correlated with innovations to the transitory components in both real GDP and unemployment rates. Also, the estimates of the autoregressive parameters are relatively small, suggesting that most of the persistence of both series is captured in the permanent component. As we can observe in table 2, most of the movements for real GDP and the unemployment rate appear to stem from permanent shocks.

Third, unlike output, the volatilities of the permanent and temporary components of unemployment are rather equal. This would suggest that external shocks to the labour market affect equally both its temporary and permanent components. However, these impacts are much lower than the ones that affect output.

TABLE 2

Maximum likelihood estimates of the trend AR(2) model [a]

Parameter	Estimated	Parameter	Estimated	Parameter	Estimated
Real GDP		Unemployment rate		Cross-series correlation	
σ_{η_y}	1.8487	σ_{η_u}	0.5141	$\rho_{\eta_y\eta_u}$	-0.7977
	(0.3067)		(0.1067)		(0.0670)
σ_{ε_y}	0.8311	σ_{ε_u}	0.5105	$\rho_{\eta_y\varepsilon_u}$	0.7207
	(0.2676)		(0.1209)		(0.0816)
$\rho_{\eta_y\varepsilon_y}$	-0.8151	$\rho_{\eta_u\varepsilon_u}$	-0.9929	$\rho_{\eta_u\varepsilon_y}$	0.9995
	(0.1166)		(0.0054)		(0.0054)
$\mu_{y_{1987\text{-}1994}}$	0.7232	ϕ_{1_u}	0.3267	$\rho_{\varepsilon_y\varepsilon_u}$	-0.9890
	(0.1212)		(0.1915)		(0.0338)
$\mu_{y_{1995\text{-}2010}}$	0.7982	ϕ_{2_u}	-0.0668		
	(0.1903)		(0.0967)		
ϕ_{1y}	0.4479				
	(0.1673)				
ϕ_{2y}	-0.4000				
	(0.1098)				

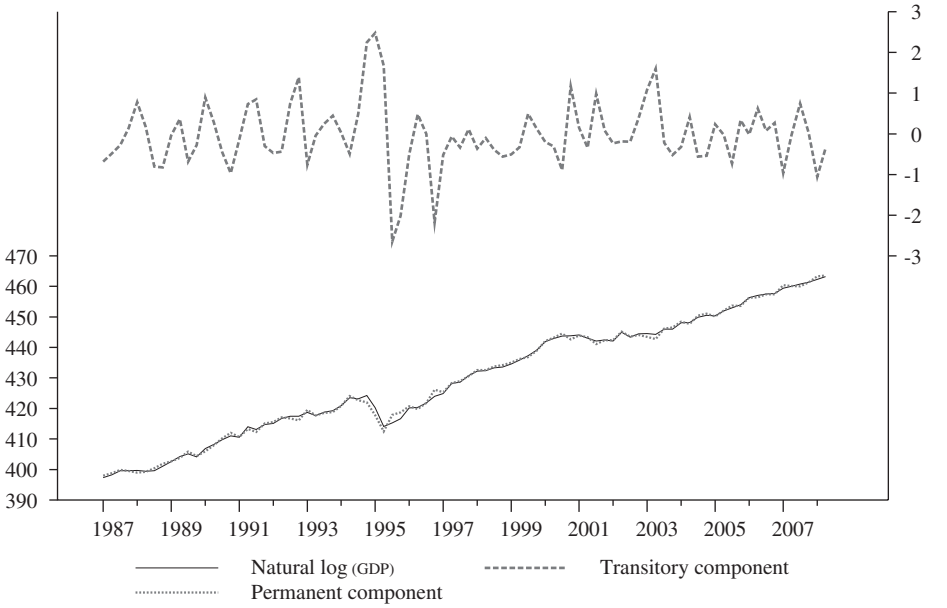
Log likelihood = -158.2011

Source: prepared by the author.

[a] Where σ_{η_i}; $i = y, u$ is the standard deviation of permanent innovation. σ_{ε_i}; $i = y, u$ is the standard deviation of temporary innovation. $\rho_{\eta_i}\varepsilon_i$; $i = y, u$ is the correlation between innovations. $\rho_{\eta_y\eta_u}$ is the correlation between permanent unemployment and permanent GDP. $\rho_{\eta_y\varepsilon_u}$ is the correlation between permanent GDP and transitory unemployment. $\rho_{\eta_u\varepsilon_y}$ is the correlation between permanent unemployment and transitory GDP. $\rho_{\varepsilon_y\varepsilon_u}$ is the correlation between transitory GDP and transitory unemployment. ϕ_{ji}; $i = y, u$; $j = 1,2$ are the AR(2) model parameters.

FIGURE 2

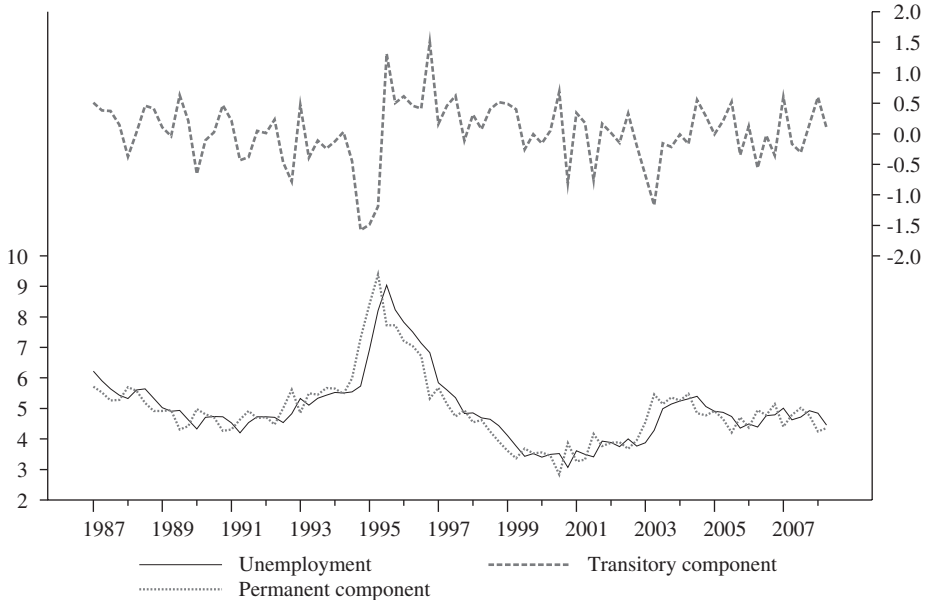
Mexico: real GDP and the estimated components, first quarter 1987 - fourth quarter 2008



Source: prepared by the author.

FIGURE 3

Mexico: unemployment rate and estimated components, first quarter 1987 - fourth quarter 2008



Source: prepared by the author.

A closer examination of figure 3 would indicate that at the beginning of the 1994 Mexican financial crisis, the unemployment rate started to rise, but our estimates suggest that the permanent level of the unemployment rate rose faster in anticipation of future increases in the unemployment rate. We observe the same behaviour at the beginning of 2001 when the permanent component of unemployment rose faster, anticipating the negative effect of the United States recession on the Mexican economy.

Fourth, as Okun's law suggests, the transitory components of output and the unemployment rate are negatively correlated. Even though our results suggest that most of the fluctuations in both real GDP and the unemployment rate are due to movements in the permanent components, it is still important to consider the relationship between their transitory components.

Equation (9) is relevant for answering the following question: Given a certain level of unemployment, what level of GDP should one expect under the economic conditions prevailing during the sample period? To answer this question, we estimate Okun's coefficient through equation (11) to obtain:

$$\lambda = -1.657 \text{ (standard deviation: 0.842)}$$

which implies that a 1-percentage-point decrease in transitory unemployment corresponds to a 1.6 percentage-point increase in transitory real GDP. Our estimates of Okun's coefficient (λ) is, therefore, much lower than previous ones.

Several possible phenomena could explain this lower coefficient. First of all, the estimation assumes that the number of working hours and labour productivity move at the same pace as unemployment. However, if any of these variables change at a different rate, then one should expect the coefficient to be lower. Unfortunately, we do not have reliable data on either variable to control for these changes. Second, as already reported by Heckman and Pagés (2000) and Gill, Montenegro and Dömeland (2001), among others, México's Federal labour law and labour unions are factors underlying the low responsiveness of employment to output fluctuations. Moreover, given that the Mexican labour market is characterized by the existence of a large informal sector, [20] output fluctuations would induce labour mobility between the formal and informal employment without affecting open unemployment. All these elements —that is, changes in hours worked, labour productivity, heavy labour regulation and a large informal sector— operate in the same direction of lowering Okun's coefficient.

Third, to the extent that employment in the informal sector is characterized by low productivity, its contribution to overall GDP would be low indeed. Thus, the impact of a, say, reduction in unemployment on output would be significantly reduced.

Fourth, underreported revenues might bias the GDP estimates. Loayza and Sugawara (2009) showed that the size of the informal Mexican economy is about 30% of GDP, while the International Labour Organization (ILO, 1999), Schneider (2002) and Vuletin (2008) estimated that the size of the Mexican informal economy during the 1990s ranged from 30% to 40% of GDP and employed more or less the same percentage of the labour force.

From a strictly Keynesian point of view, the relevant equation should be equation (10), where unemployment is the dependent variable and output is the independent one. Hence, the relevant coefficient is θ (see equation 12).

$$\theta = -0.5226 \text{ (standard deviation: -0.039)}$$

As expected, the value of θ is not related to the value of λ. It measures the impact of a 1-percentage-point change in output growth on unemployment change. Obviously, much of the discussion about Mexico's labour market applies in this case. Another element that could explain the low correlation between the temporary components of output and unemployment is labour migration. To the extent that a large number of unemployed workers decide to migrate to the United States rather than stay at home, a given change in output would have a lower impact on registered unemployment rates for they will not show up in the unemployment statistics.

We now turn to the analysis of the correlation between the permanent components of output and unemployment. The relationship between the permanent innovations of output and unemployment rate can be examined in a way similar to traditional Okun's coefficient. Therefore, let be Okun's coefficient for permanent movements, we find that

$$\gamma = \frac{\rho_{\eta_y \eta_u} \sigma_{\eta_y}}{\sigma_{\eta_u}} = -2.868 \text{ (standard deviation: 0.952)}$$

The resulting coefficient of the relationship between the permanent components of output and unemployment is also negative but higher than the one found for

[20] It should be noted, however, that informal sector is not the same as informal employment. The informal sector is the unregulated sector whereas informal employment is the employment that does not have employment benefits, such as social security, health care, vacations, etc. A worker may have an informal job in a formal enterprise.

their transitory components. To the extent that this coefficient incorporates all short-run adjustments, we expect it to be larger than the conventional (short-run) Okun's coefficient. It seems that the unemployment rigidity caused by the existence of labour market rigidities and the informal labour sector present in the short-run is less binding over longer periods of time.

VI
Conclusions

The purpose of this essay was twofold: first, to estimate Okun's coefficient for the Mexican economy using a bivariate model that jointly estimates the permanent and temporary components of output and unemployment because this method provides unbiased and efficient estimates; and, second, to provide an economic interpretation of the parameters found. We have presented the two contrasting views of the nature of Mexico's labour market and argued that they are important in providing a proper explanation of the size of Okun's coefficient.

The methodology used allowed us to estimate two types of Okun's coefficient: a short-run coefficient which relates to the temporary component of output and unemployment, and a long-run coefficient which emerges when we correlate the permanent components of output and unemployment. Our results indicate that Okun's coefficient is much lower than previously estimated. We argue that this is to be expected, partly because of the existence of labour market rigidities and a large informal labour market, which reduces the impact of output growth on open unemployment rates. Another factor underlying this low coefficient is that labour unions severely restrain job creation during expansions and avoid job reductions during recessions. In the long run, a few other factors intervene in Mexico's labour market so that the size of the correlation between the permanent components of output and unemployment is larger than the short-run coefficient: namely, changes in capacity utilization, technical progress, the changing nature of the labour contracts, international migration and demographic changes. All of these elements seem to induce a higher coefficient. All of these issues remain open for future research.

In this study we have provided an estimate of Okun's coefficient at a given point in time; however, given the mounting evidence about the changing nature of Mexico's labour market, in particular, the increasing number of short term contracts and outsourcing arrangements, it is very likely that the coefficient has not remained constant. We suspect that the dynamic relationships of both the permanent and cyclical components have changed over time. This is particularly important because since the mid-1980s Mexico adopted a different economic strategy which has involved not only price and trade liberalization but also changes in labour-market institutions, among other things. Furthermore, there is the question of whether or not Okun's coefficient is symmetric, that is, whether or not we expect the impact of output growth on unemployment to be equal during expansions and recessions.

Bibliography

Alcaraz, C. (2009), "Informal and formal labour fexibility in Mexico", *Desarrollo y Sociedad*, No. 63, Bogota, Centre for Economic Development Studies (CEDE).

Alcaraz, C., D. Chiquiar and M. Ramos-Francia (2008), "Diferenciales salariales intersectoriales y el cambio en la composición del empleo urbano de la economía mexicana en 2001-2004", *Documentos de Investigación*, No. 2008-06, Mexico City, Banco de México.

Alogoskoufis, G. and A. Manning (1988), "Wage setting and unemployment persistence in Europe, Japan and the USA", *European Economic Review*, vol. 32, No. 3, Amsterdam, Elsevier.

Balakrishnan, R., M. Das and P. Kannan (2010), "La dinámica del desempleo durante las recesiones y las recuperaciones: La Ley de Okun como punto de partida", *Perspectivas de la economía mundial*, Washington, D.C., International Monetary Fund.

Barreto, H. and F. Howland (1993), "There are two Okun's law relationships between output and unemployment", Crawfordsville, Wabash College.

Blanchard, O. and D. Quah (1989), "The dynamic effects of aggregate demand and supply disturbances", *American Economic Review*, vol. 79, No. 4, Nashville, Tennessee, American Economic Association.

Calderón, A. (2000), "Job stability and labor mobility in Urban Mexico: a study based on duration models and transition analysis", *Research Department Publications*, No. 3117, Washington, D.C., Inter-American Development Bank.

Cazes, S., S. Verick and F. Al Hussami (2011), "Diverging trends in unemployment in the United States and Europe: evidence from Okun's law and the global financial crisis", *Employment Working Paper*, No. 106, Geneva, International Labour Office.

Chavarín, R. (2001), "El costo del desempleo medido en producto. Una revisión empírica de la ley de Okun para México", *El Trimestre Económico*, vol. 68, No. 270, Mexico City, Fondo de Cultura Económica.

Clark, P. (1989), "Trend reversion in real output and unemployment", *Journal of Econometrics*", vol. 40, No. 1, Amsterdam, Elsevier.

_____ (1987), "The cyclical component of U.S. economic activity", *Quarterly Journal of Economics*, vol. 102, No. 4, Cambridge, Massachusetts, The MIT Press, November.

Crespo, J. (2003), "Okun's law revisited", *Oxford Bulletin of Economics and Statistics*, vol. 65, No. 4, Wiley.

De la Garza, E. (2005), "La flexibilidad del trabajo en México" [online] http://docencia.izt.uam.mx/egt/publicaciones/articulos/flexibilidad.pdf.

Durbin, J. and S. Koopman (2001), *Time Series Analysis by State Space Methods*, New York, Oxford University Press.

Evans, G.W. (1989), "Output and unemployment dynamics in the United States: 1950-1985", *Journal of Applied Econometrics*, vol. 4, No. 3, John Wiley & Sons, Ltd.

Freeman, D.G. (2001), "Panel test of Okun's law for ten industrial countries", *Economic Inquiry*, vol. 39, No. 4, Wiley.

Gill, I., C. Montenegro and D. Dömeland (eds.) (2001), "Crafting Labor Policy: Techniques and Lessons Learned from Latin America", Washington, D.C., World Bank.

González Anaya, J. (2002), "Labor Market Flexibility in Thirteen Latin American Countries and the United States: Revisiting and Expanding Okun Coefficients", SCID *Working Paper*, No. 136, Stanford University, June.

Heckman, J. and C. Pagés (2000), "The Cost of Job Security Regulation: Evidence From Latin American Labor Markets", NBER *Working Paper,* No. 7773, Cambridge, Massachusetts, National Bureau of Economic Research.

Hwa, K., E. Zivot and D. Creal (2006), "The relationship between the Beveridge-Nelson decomposition and unobserved components models with correlated shocks", *Working Papers*, No. UWEC-2006-16-FC, Seattle, University of Washington.

ILO (International Labour Organization) (1999), *Panorama laboral 1999,* Lima.

Jardin, M. and S. Gaétan (2011), "How Okun's law is non-linear in Europe: a semi-parametric approach", Rennes, University of Rennes 1 – CREM, May.

Knotek, E.S. (2007), "How useful is Okuns's law?", *Economic Review,* Kansas, Federal Reserve Bank of Kansas City.

Koopman, S. (1997), "Exact initial Kalman filtering and smoothing for non-stationary time series models", *Journal of the American Statistical Association*, vol. 92, No. 440, Taylor & Francis.

Lee, J. (2000), "The robustness of Okun's law: evidence from OECD countries", *Journal of Macroeconomics*, vol. 22, No. 2, Amsterdam, Elsevier.

Lee, J. and M. Strazicich (2003), "Minimum Lagrange multiplier unit root test with two structural breaks", *The Review of Economics and Statistics*, vol. 85, No. 4, Cambridge, Massachusetts, The MIT Press.

Loayza, N. and N. Sugawara (2009), "El sector informal en México: Hechos y explicaciones fundamentales", *El Trimestre Económico*, vol. 76, No. 4, Mexico City, Fondo de Cultura Económica.

Loria, E. and M. Ramos (2007), "La ley de Okun: Una relectura para México, 1970-2004", *Estudios Económicos*, vol. 22, No. 1, Mexico City, El Colegio de México.

Marshall, A. (2004), "Labour market policies and regulations in Argentina, Brazil and Mexico: programmes and impacts", Buenos Aires, National Council of Scientific and Technical Research/ Institute of Economic and Social Development.

Morley, J.C. (2007), "The slow adjustment of aggregate consumption to permanent income", *Journal of Money, Credit, and Banking*, vol. 39, No. 2-3, Blackwell Publishing.

Morley, J.C., C.R. Nelson and E. Zivot (2003), "Why are the Beveridge-Nelson and unobserved components decompositions of GDP so different?", *Review of Economics and Statistics*, vol. 85, No. 2, Cambridge, Massachusetts, The MIT Press.

Nelson, C.R. and C.I. Plosser (1982), "Trends and random walks in macroeconomic time series: some evidence and implications", *Journal of Monetary Economics*, vol. 10, No. 2, Amsterdam, Elsevier.

Nelson, C.R. and R. Startz (2007), "The zero-information-limit condition and spurious inference in weakly identified models", *Journal of Econometrics*, vol. 138, No. 1, Amsterdam, Elsevier.

Okun, A.M. (1962), "Potential GNP: its measurement and significance", *Proceedings of the Business and Economic Statistics Section,* Washington, D.C., American Statistical Association.

Prachowny, M. (1993), "Okun's law: theoretical foundations and revised estimates", *Review of Economics and Statistics*, vol. 75, No. 2, Cambridge, Massachusetts, The MIT Press, May.

Schleicher, Ch. (2003), "Structural time-series models with common trends and common cycles", University of British Columbia.

Schnabel, Gert (2002), "Output trends and Okun's law", *BIS Working Papers*, No. 111, Basel, Bank for International Settlements, April.

Schneider, F. (2002), "Size and measurement of the informal economy in 110 countries around the world", Washington, D.C., World Bank.

Sinclair, T. (2009), "The relationships between permanent and transitory movements in U.S. output and the unemployment rate", *Journal of Money Credit and Banking*, vol. 41, No. 2-3, Blackwell Publishing, March-April.

Sögner, L. and A. Stiassny (2000), "A cross-country study on Okun's law", *Working Paper Series*, No. 13, Vienna, Vienna University of Economics and Business.

Vuletin, G. (2008), "Measuring the informal economy in Latin America and the Caribbean", *IMF Working Paper*, No. 08/102, Washington, D.C., International Monetary Fund.

Watson, M.W. (1986), "Univariate detrending methods with stochastic trends", *Journal of Monetary Economics*, vol. 18, No. 1, Amsterdam, Elsevier.

Weber, C. (1995), "Cyclical output, cyclical unemployment and Okun's coefficient: a new approach", *Journal of Applied Econometrics*, vol. 10, No. 4, John Wiley & Sons, Ltd.

An empirical analysis of technology absorption capacity of the Brazilian industry

Pablo Felipe Bittencourt and Ricardo Giglio

ABSTRACT

This article presents and discusses empirical evidence on external technology absorption facilitated by activities performed inside firms. Indicators of internal and external learning are developed and applied in statistical causality models, to distinguish possible ways in which technology can be absorbed. Industrial activity sectors at the three-digit level of the National Classification of Economic Activities (NACE) are the basic reference units of the research, which uses the information generated by Brazil's Survey of Technological Innovation (PINTEC). The results show that in-house research and development (R&D) is the main source of technology absorption, followed by the knowledge generated from the "learning by doing" and "training practices".

KEYWORDS: Industry, industrial firms, innovations, absorption capacity, technology, research and development, Brazil

JEL CLASSIFICATION: O32, O33, O38

AUTHORS: Pablo Felipe Bittencourt is a Professor in the Postgraduate Economics Programme at the Federal University of Santa Catarina. pablofelipe.bittencourt@gmail.com

Ricardo Giglio is a PhD student in economics at the University of Kiel. rgiglio@gmail.com

I
Introduction

Capacity to develop innovations that have an impact on domestic and international markets is crucial for strengthening competitiveness in a context of increasingly globalized competition. Innovations of higher impact usually require a substantial and complex set of knowledge, which can only partly be found inside the firm. Given the increasing the volume and complexity of potentially useful knowledge, the task of absorbing it is ever less simple. Adapting to that reality tends to involve changes in routines to increase internal capacities, which also makes it possible to improve conditions for recognizing opportunities that exist outside the firm. The learning process in which firms participate with a view to adapting to those conditions can be viewed as an expansion of their absorption capacities. Cohen and Levinthal (1990) define absorption capacity in terms of the firm's ability to recognize the value of external information, assimilate it, and then apply it for commercial purposes. Basically, that skill can involve knowledge generated in formal R&D departments, in the firm's productive environment, or simply derived from the individuals who form part of it.

Empirical research has focused on the influence of internal and external forms of learning in generating innovations, as exemplified by the work of Vega-Jurado and others (2008); Veugelers (1997); Nieto and Quevedo (2005); Tsai and Wang (2009); Jensen and others (2007); Caloghirou, Kastelli and Tsakanikas (2004), and Cassiman and Veugelers (2006).[1] Nonetheless, these analyses generally include evidence that can be classified as "byproducts" of the results of the primary focus of the studies in question and, therefore, cannot be considered as empirical evidence of the phenomenon that is effectively supported.[2]

Thanks to the aforementioned studies, recent research has focused on the absorption capacity of firms, examples being Arora and Gambardella (1994); Stock, Greis and Fischer (2001); Schmidt (2005); Murovec and Prodan (2009), and Tsai (2009). In these studies, the use of an external knowledge source is usually seen as an indication that the firm has some capacity to absorb it. Assuming this, the aim is to improve understanding of the internal activities of the firm that have capacity to absorb external knowledge. The results show that in-house R&D complements a broader set of activities.[3]

In the research reported below, additional quantitative evidence is provided on the role of in-house R&D, training and "learning by doing" in the absorption of technological knowledge generated outside the firm, which has the capacity to generate product innovations of high impact. The analysis targets the sector-learning patterns defined in Bittencourt (2012). The sector-level focus is useful because it makes it possible to define groups of sectors according to the characteristics of their learning. Such an approach has been crucial, at least since Pavitt (1984) noted similarities and differences between sectors for sectoral processes of technological change.[4]

The statistical causality method also proved apt, by making it possible to test the hypothesis of the dual effect of R&D activities, training and "learning by doing" in generating high-impact innovations.

Following this introduction and a presentation of the theoretical framework in section II, this article contains four further sections. Section III describes learning patterns, section IV sets out the methodological reference framework, section V discusses the empirical results, and section VI presents the main conclusions.

[1] In many studies, the results are actually based on the assumption that in-house R&D activities are important for absorption capacity.

[2] The majority of recent results are based on indirect measures, which casts doubt on their validity.

[3] The dual nature or two phases of R&D investments refer to: (i) the capacity to generate new knowledge that is directly applicable to the products and processes developed by the firms; and (ii) the expansion of capacity to absorb external knowledge (Cohen and Levinthal, 1989). This article recognizes that those same characteristics can be seen in two other innovation activities, defined as "learning by doing", and "learning through training".

[4] This does not imply acceptance of the Pavitt (1984) classification as the best way to analyse the Brazilian case in the period in question, because, while the relevance of that paper and many of its derivations is undeniable, the authors consider that its conclusions are confined to the specific history and geography it was proposed to investigate.

II
Theoretical and analytical framework

This section is divided into five subsections. The first introduces and discusses the concept of absorption capacity and provides some empirical evidence. The next three subsections discuss increase in absorption capacity, linked respectively to in-house R&D, training and learning arising from production routines —a concept referred to as "learning by doing". This section closes with a brief theoretical discussion of the concepts of absorption capacity and technology absorption, to encourage the reader to conduct further theoretical research.

1. Absorption capacity: concept and empirical evidence

Innovations are generated by combining new knowledge, which Dosi (1988) characterized as reflecting the search for a solution to problems that sometimes require knowledge derived from past experiences, and sometimes require formalized knowledge (such as that generated by the natural sciences).[5] The learning processes that emanate from that search are based on the use of one or more sources of information and knowledge, which may be internal or external to the firms.[6] Owing to the costs involved, firms will only participate in innovation search if they perceive profit opportunities that have not yet been exploited.[7]

Nonetheless, being in a position to perceive and exploit technological opportunities depends to some extent on the accumulation of relevant knowledge. Research has focuses particularly on R&D, since Cohen and Levinthal (1989) emphasized its dual effect in generating knowledge that is directly applicable to products and processes and also increases the ability to understand and absorb knowledge generated by potential external technology partners, such as universities, research centres, suppliers and customers.

Since then a number of empirical studies have focused exclusively on how to expand absorption capacity; and the present authors have published notes relating to the diversity of ways used to absorb knowledge generated outside the firm's perimeter. Moreover, in the introduction to their classic 1990 article on absorption capacity, Cohen and Levinthal (1990) stressed the characteristics of the labour force employed, the firm's manufacturing routines and experience derived from productive activities, as other factors affecting this capacity.

Each firm's absorption capacity is built on a process that depends on past decisions (path dependence) and can involve several stages, which certainly requires considerable work. In other words, it is not possible to increase that capacity solely through learning by doing, as emphasized in Arrow (1962). Indeed, Mowery, Oxley and Silverman (1996) argue that absorption capacity consists of a comprehensive set of skills to deal with the tacit component of the knowledge to be transferred from external sources, together with the ability to modify it. The complexity of tacit knowledge transfer reinforces the idea that knowledge acquisition requires an ongoing effort to understand the relevant events that are occurring beyond the firm's boundaries.

Zahra and George (2002) recognize the complexity of the concept and make theoretical progress by subdividing it into four dimensions: (i) acquisition as such, related to the ability to acquire external knowledge that is critical to the firm's operations, in which the intensity, direction and the speed with which activities are undertaken are the critical elements; (ii) assimilation, linked to the stages of analysis, understanding and interpretation of the external knowledge obtained; (iii) transformation, which refers to the firm's ability to develop and improve its routines, so that the new knowledge is combined effectively with existing knowledge; and (iv) exploitation of that knowledge by integrating it into structured routines, to enable the firm to sustain the benefits of the new knowledge it has assimilated and transformed, over long periods.

[5] For Dosi (1988), processes of searching for and adopting new products and processes are defined by the complex combination of various elements, such as training and the stimulus generated inside each firm and in each industry, the science situation in different sectors, the characteristics of the consumption pattern, the pattern of competition of the industry, the financial structure, macroeconomic trends and public policies, among others. Without denying the relevance of those factors, it would be impossible to consider all of them in an analysis such as that made in this article.

[6] The most widely researched include suppliers, customers, competitors, universities and research centres.

[7] The concept of innovation as an interactive process arising from internal and external learning is widely accepted. Various lines of research develop from that concept, although with significantly different approaches, including innovative media (Maillat, 1996) and innovation systems, whether national (Lundvall, 1992; Nelson, 1993; Freeman, 1987), sectoral (Breschi and Malerba, 1997; Malerba, 2002), regional (Cooke and Morgan, 1998) or local (Cassiolato and Lastres, 2003).

In general, the concept of absorption capacity refers to the complementarity[8] of internal and external knowledge in the innovation process, which is expressed in the firm's continuous ability to learn from the external environment and hence develop its own experiences which are accumulated in its production and innovation routines. For Mowery, Oxley and Silverman (1996), its importance can be summarized as an understanding that effective participation in interactions may depend on absorption capacity.

The development of skills in a specific area would give the firm an advantage in absorbing new knowledge in this area —a privilege that could be decisive in the climate of uncertainty that characterizes capitalist competition, since it determines the firm's ability to assess the commercial potential of potential production and technological decisions.

As the concept is broad and complex, it is hard to measure quantitatively; and this may explain the small number of empirical studies that have been published. As noted in the introduction, a large proportion of the analyses on the subject of secondary and others, such as Stock, Greis and Fischer (2001), have a predilection for in-house R&D.

More recently, successive endeavours to diversify ways of quantifying the phenomenon have made significant contributions to studies of the economics of innovation. Variables relating to the quality of the workforce, training activities and entrepreneurial attitudes have sometimes proven as important as the widely-emphasized use of in-house R&D, or even more so (Murovec and Prodan, 2009; Schmidt, 2005; Arbussa and Coenders, 2007; Tsai, 2009).

In Brazil, the study by De Negri (2006) remains the key reference. Based on Schmidt (2005), the author emphasizes the use of external information sources as evidence of technology absorption, and investigates how external information relates to R&D activities and to the characteristics of the labor force employed in Brazilian firms. The analysis divides external information sources into two categories, namely business and academic. The results highlight the profile of the workforce and R&D activities directly related to absorption capacity, and stress that the effectiveness of the firm's training initiatives depends on its ability to hold on to the employees trained.

2. Absorption capacity and the generation of new knowledge from in-house R&D

Cohen and Levinthal (1990) offer a key perspective for evaluating R&D absorption capacity, by noting that the firm's ability to exploit external knowledge is often a byproduct of its in-house R&D activities. These stimulate the firm's core technological capacities, enabling it to better understand the tacit knowledge embedded in processes and products, and enhance its ability to access and absorb external knowledge. The notion that high levels of R&D extend the firm's "connectivity" with external knowledge sources is widespread in several studies (see, for example, Freeman, 1991; Chesbrough and Teece, 1996; Arora and Gambardella, 1994; Jensen and others, 2007). Obviously, this does not diminish the importance of investment in R&D for generating knowledge applied directly to new products and processes, as recognized to a greater or lesser extent in all studies of the economics of innovation.

3. Absorption capacity and knowledge generation through training

Education and training are recognized as important elements in the innovation capacity of a region or country (Lundvall et al, 2002). At the firm level, training activities should be viewed as initiatives to transfer abstract knowledge from a person that has specialized know-how to someone who, having not developed a specific routine, does not have this knowledge. This is merely an initiative to transmit tacit knowledge. The benefit arises from the increase in the firm's capacity to discover and solve the problems that arise in production routines, because a larger group of individuals will be equipped to do this.

Quantification of this element frequently demonstrates the importance attributed to the existence of qualified personnel within the firm. Nonetheless, as Murovec and Prodan (2009) point out, training expenses are much more closely linked to the specific needs identified by firms. Technology absorption may be one of those needs, and it is precisely this characteristic that the "learning through training" indicator, described below, aims to capture.

[8] See Caloghirou, Kastelli and Tsakanikas (2004). There also findings such as those reported by Laurensen and Salter (2006), which suggest a substitution effect between the search for new external knowledge and in-house R&D activities. When considering the cost of search outside the firm, emphasis is placed on the fact that, at a certain level of expenditure, the increase in expenses can have a negative effect on innovative performance. This admits the theoretical potential benefits of the variety of knowledge related to the diversity of sources, but stresses that the degree of openness must be weighed against the related costs of such openness.

4. Capacity for absorption through "learning by doing"

Arrow (1962) was the first to discuss the ability to generate new knowledge from learning acquired in production routines. Basically, the author emphasized repetitive activities leading to the development of productive skills that could increase productivity through improved manufacturing techniques. Apart from the ability to generate new knowledge that is directly applicable to new production processes, this form of learning can expand the capacity for understanding techniques that are generated and used outside the firm. Cohen and Levinthal (1990) point out the following:

> "(…) absorption capacity may also be developed as a byproduct of a firm's manufacturing operations. Abernathy (1978) and Rosenberg (1982) have noted that through direct involvement in manufacturing, a firm is better able to recognize and exploit new information relevant to a particular product market. Production experience provides the firm with the background necessary both to recognize the value of and implement methods to reorganize or automate particular manufacturing processes." (Cohen and Levinthal, 1990, p. 2).

Pisano (1996) extends this concept by noting that the "practical" aspect can be observed in computer solutions, laboratory analyses, prototype testing and other experiments not necessarily directly related to manufacturing.

Zahra and George (2002) suggest an interpretation of the complementarity that exists between the three forms of internal learning in the complex process of technology absorption. It is understood that learning through R&D would be more closely related to phases (i) acquisition and (ii) assimilation of the external knowledge crucial to innovations of major impact on the domestic market, and would entail full-time work by individuals devoted to the understanding and analysis of various types of information and external knowledge. The new information or knowledge —understood and used in R&D laboratories— requires mobilizing knowledge generated in the production plant, together with knowledge that is spread through training practices, both for (iii) transforming the new project or prototype, while respecting the specifics of the firm's production processes; and for (iv) improving the ability to explore new the knowledge absorbed.[9]

5. Note on the conceptual similarity between absorption capacity and technological capacity

The research reported in this article has used the terms "absorption capacity" and "technological capacity" to refer to the same phenomenon. This subsection presents and briefly discusses the observed conceptual similarities, albeit neither definitively nor even exhaustively. The aim is to encourage new academic ventures capable of increasing analytical rigour in the use of the terms.

Firstly there is a similarity in the internal aspects of the firm that make it possible to incorporate external knowledge. From the standpoint of "absorption capacity", the internal aspects will be revealed not only in (i) organizational and management routines or (ii) expansion of the tacit skills of individuals, but also in (iii) new the products, services and processes that are generated. In contrast, "technological capabilities" would appear in (i) organizational systems; (ii) the knowledge and technical skills of the firm's employees, and (iii) technical-physical systems such as machinery, equipment, software, plants, manufacturing and products and services (Figueiredo, 2004). The similarities between (i), (ii) and (iii) are complemented by the fact that, in the manifestations of both capacities, these aspects are configured as cumulative training, dependent on past decisions. This means that a specific learning path would give each firm specific capabilities to absorb knowledge.

A second similarity is the acceptance of the diversity of internal sources of knowledge that can expand such capacity. In both views, the idea of "learning by doing" (Arrow, 1962) is insufficient to explain the absorption of external knowledge. Another feature relates to labor force skills and the relevance of in-house R&D: "[...] when more novel elements of technology are incorporated into investment projects along established technology, the necessary capabilities may requires more sophisticated engineering and R&D." (Bell and Pavitt, 1995, p. 85).[10]

Another similarity between the two concepts is the recognition that internal and external knowledge (training) is combined through a complex process involving efforts at various stages, even between those that have no similarity. While the concept of absorption capacity recognizes that the initial stage involves acquiring and assimilating external knowledge (Zahra and George, 2002), in the concept of technological

[9] The greater intensity suggested of one of the forms of learning in each phase of the absorption process does not preclude the possibility of feedback in relation to the initial phases of the process, including new considerations on the object of technological absorption, as well as an exchange of information between the "phases".

[10] Subsections 2, 3 and 4 describe those elements in Cohen and Levinthal (1990).

capability, the initial phase relates to the need for efforts (investment) in the stages of adapting and implementing the new technology to the specific situations in which it will operate.

A subsequent phase of absorption capacity involves the firm's capacity to "transform" its routines, so that the new knowledge (embedded in the technology) can be effectively combined with existing knowledge. Normally, the knowledge combination stage would occur when new prospects arise and new opportunities are recognized (Zahra and George, 2002) and, thus, other changes and improvements in technology take place. In the case of technological capacity, that phase involves the generation of a series of incremental innovations stemming from the acquisition of the new productive process. Those innovations would be implemented to maintain and expand the firm's capacity through time, and both stem from and depend on the technological capacity differentials accumulated in each firm.

Lastly, a more liberal view of absorption capacity and technological capacity is the recognition of similarity in relation to the territorial space in which firms operate, since in both concepts, the skill to assimilate external knowledge, particularly tacit knowledge, stems from the specific characteristics of the learning process in which the firm participates. For example, when analysing the potential benefits of interactions with suppliers, Bell and Pavitt (1995) note that the users of specific materials or components, who have skills to transform them (innovate), could actively encourage their suppliers to develop those inputs if the latter have a certain level of technological capacity. In that case, participating in a peripheral national innovation system —where production could include suppliers and users who do not have the same technical capacity as mature ones involved in the development of the technology located in the innovation system— could pose a significant constraint on technological dissemination, and on expanding absorption capacity.

III

Sectoral learning patterns and indicators of learning and innovation

This section is divided into two subsections. The first describes the sectoral learning patterns identified in Bittencourt (2012) and the learning indicators they defined. The second considers the importance of working with innovations that have a major effect (for the domestic market), and presents the indicator used to track them.

1. Sectoral learning patterns

The use of sectoral learning patterns as a sectoral reference is justified not only because it is a construction that matches the characteristics of Brazil's National Innovation System, but also because the indicators used are suitable for the purpose of this article.

Table 1 lists the learning indicators developed in Bittencourt (2012). Forms of learning are defined on the basis of Malerba (1992); Hedberg (1981) and Kim and Nelson (2005), taking into account the quantification limitations imposed by the Brazilian Survey of Technological Innovation (PINTEC), conducted by the Brazilian Institute of Geography and Statistics (IBGE). The indicators can combine information sources used in innovation processes with relevant data on expenditure on innovation activities, as reported by the firms. The combinations were designed to take account of the probable innovative activity associated with the use of a particular information source, as a source of ideas for innovation.[11] In other words, it is highly likely that the perspective that arises in the R&D department (information source), for example, will be linked to R&D expenditures, according to the relationship presented in Indicator 1, "learning through in-house R&D," which is derived from "learning through research".

The possible responses by innovative firms to the questions posed by PINTEC, which were used to establish qualitative indicators, are always qualitative: high, medium, low or irrelevant. Those qualitative attributes were then transformed into quantitative attributes to make it possible to use the statistical technique, by replacing

[11] Nonetheless, there is no assumption of an absolute correspondence between the sources of ideas and expenditure on innovation activities. In fact, the ideas arising in the R&D departments (learning through research) could be executed through R&D expenses externally (learning through high-level science and technology). Nonetheless, the indicators suggest that there is a greater likelihood of expenses being incurred in the R&D departments of the firm itself, in that case.

TABLE 1

Brazil: learning indicators - related features

PINTEC variables used to define the indicators		Indicators of learning							
		1. In-house R&D	2. Learning by doing	3. Training	4. Advanced science and technology	5. Suppliers	6. Customers	7. Other sources of interaction	8. Imitation
	Sources	Internal sources of R&D	Other internal sources	Training centres	Universities	Suppliers	Customers	Conferences, meetings and publications	Competitors
		…	…	…	Research institutes or technology centres	…	…	Trade fairs and exhibitions	Licences, patents and specialized knowledge
		…	…	…	…	…	…	Consulting firms	…
		…	…	…	…	…	…	Competitors	…
	Amount of expenditure	Formal in-house R&D	Industrial projects and other technical preparations	Training	Acquisition of other external knowledge	Acquisition of machinery and equipment	Introduction of the innovation on the market	…	Acquisition of other external knowledge

Characteristics of the indicators									
Location of knowledge source	Inside the firm			Outside the firm					
Main characteristic of the knowledge in question	Codified	Tacit	Tacit	Codified	Tacit	Tacit	Tacit	Codified and tacit	

Source: P.F. Bittencourt, "Padrões setoriais de aprendizagem da indústria brasileira: uma análise exploratória", *Revista Brasileira de Inovação*, vol. 11, No. 1, Campinas, 2012.

PINTEC: Brazilian Survey of Technological Innovation.

the qualitative indicators "high", "medium" and "low or irrelevant" by "1", "0.66" and "0.167" respectively.[12] Thus, indicators are formed using a weighted average of the importance attached by the set of innovative firms in each sector to the variables chosen to compose those indicators. Thus the cluster technique of multivariate statistical analysis was applied to the sectors (defined at the 3-digit level of the National Classification of Economic Activities (NACE)), to identify the sector learning patterns shown in table 2 (Bittencourt, 2012).

[12] The value assigned to the qualitative specifications "low or irrelevant" follows the sequential valuation of information of high- and medium relevance. The value 0.176 is the average between 0.33 and 0.00, which other values attributed to "low" and "irrelevant", respectively.

TABLE 2

Brazil: sectors that comprise the sector learning patterns

Pattern 1 Sectors intensive in learning in the productive domain	Pattern 2 Sectors intensive in learning in the early stages	Pattern 3 Sectors intensive in multiple forms of learning	Pattern 4 Sectors intensive in internal learning and later stages
Meat and fish	Extraction of rock, gravel, and clay	Pharmaceutical products	Inorganic chemicals
Vegetable and animal oils	Extraction of other minerals	Agricultural pesticides	Resins, elastomers, fibres, artificial and synthetic lints
Dairy products	Milling, manufacture of starch products and animal feed	Information technology and office machinery and equipment	Paints, varnishes, enamels, lacquers, and similar products

Table 2 (*concluded*)

Pattern 1 Sectors intensive in learning in the productive domain	Pattern 2 Sectors intensive in learning in the early stages	Pattern 3 Sectors intensive in multiple forms of learning	Pattern 4 Sectors intensive in internal learning and later stages
Sugar	Food products	Insulated electrical wires, cables and conductors	Miscellaneous chemical products and preparations
Coffee	Natural textile fibres	Electrical batteries and accumulators	Cutlery and blacksmith articles, and hand tools
Beverages	Finished goods in yarns and fabrics	Telephone and radio telephone apparatus and equipment, and television and radio transmitters	Motors, pumps, compressors, and transmission equipment
Yarn	Fabric products and other textiles	Measurement, testing and control apparatus and instruments	Machinery and equipment of general use
Cellulose	Knitted fabrics	Optical, photographic and cinematographic apparatus, instruments and materials	Machinery and equipment for use in mineral extraction and construction
Alcohol	Garment manufacture and accessories	Automobiles, trucks, and utility vehicles	Other machinery and equipment for use in mineral extraction
Cement	Professional safety garments	Trucks and buses	Electrical material for vehicles
Cast iron and iron alloys	Travel articles and a leather products	Tobacco products	Manufacture and repair of electrical machines, apparatus and materials
Tubes	Footwear		Basic electronic material
Non-ferrous metal metallurgy	Woodcuts and pieces		Other transport equipment
Miscellaneous metal products	Wood products and twisted material		Petroleum products
Tractors, machines, and equipment for agriculture	Paper or corrugated cardboard packaging		Weapons, ammunition and military equipment
Machines-tools	Paper, corrugated cardboard, card and capable		Construction and repair of boats and railway vehicles
Electrical equipment	Publishing, printing and reproduction		Construction, assembly and repair of aircraft
Autoparts	Organic chemical products Rather articles Plastic products Glass and glass products Articles made from concrete, cement, and similar materials Ceramic products Stone polishing and the manufacture of line, among others Smelting Metallic structures and heady boiler works Tanks, boilers, metallic deposits Powder metallurgy and treatment of metals Maintenance and repair of machinery and equipment Manufacture of lamps and lighting equipment Cabins, chassis, and restoration of engines Furniture articles Miscellaneous products Recycling		

Source: P.F. Bittencourt, "Padrões setoriais de aprendizagem da indústria brasileira: uma análise exploratória", *Revista Brasileira de Inovação*, vol. 11, No. 1, Campinas, 2012.

2. Innovations for the domestic market

PINTEC defines two levels of innovation for the firm and for the domestic market. As shown in table 3, higher-level innovations are rare and their share has decreased since the first survey. Their low frequency is due to factors that characterize the precarious historical development of Brazil's national innovation system (Albuquerque, 2000; Viotti, 2002).

The focus of this article is restricted to innovations for the domestic market which: (i) have a major impact on the dynamics of economic development, and (ii) require a more extensive knowledge set for implementation than innovations for the firm.

The indicator used to measure high-impact innovations across sectors of economic activity was the percentage of such innovations in the total number of innovations registered for the sector in each period. It was only possible to calculate correlations between this indicator and the learning indicators because they are measures of intensity.

TABLE 3

Brazil: innovations for the firm and for the domestic market

Year	Number of innovating firms	Rate of innovation	Percentage of product innovations		Percentage of process innovations	
			Firm	National market	Firm	National market
2000	22 698	31.52	32.28	9.27	52.22	6.23
2003	28 036	33.27	37.62	5.67	54.18	2.53
2005	30 377	33.56	35.42	6.90	54.15	3.52

Source: PINTEC I, II and III.

IV
Methodology

The methodology is broken down as follows: subsection 1 describes the statistical treatment applied to the data, in other words the simple and partial correlations and causal statistical models that guide the analysis. Subsection 2 interprets these models, while subsection 3 focuses on the object of the research. Lastly, subsection 4 lists statistical conditions needed for the case study.

1. Models of statistical causality using Pearson correlation

Pearson correlation coefficients "*r*" are widely applied in economics as measures of linear dependence between two variables. They range from -1 (perfect negative correlation) and 1 (perfect positive correlation). Formally, the coefficient is defined as:

$$\rho = \frac{\sum_{i=1}^{n}\left(x_i-\bar{x}\right)\left(y_i-\bar{y}\right)}{\sqrt{\sum_{i=1}^{n}\left(x_i-\bar{x}\right)^2}\cdot\sqrt{\sum_{i=1}^{n}\left(y_i-\bar{y}\right)^2}} = \frac{cov\left(X,Y\right)}{\sqrt{var\left(X\right)\cdot var\left(Y\right)}}$$

where :

$$\bar{x} = \frac{1}{n}\cdot\sum_{i=1}^{n} x_i \text{ and } \bar{y} = \frac{1}{n}\cdot\sum_{i=1}^{n} y_i$$

are the arithmetic means of the variables.

The partial correlation coefficients serve to measure the intensity of the correlation between two specific indicators —"B" and "C" — if another indicator, say "A", hypothetically influences both "B" and "C", and to measure the strength of the correlation between "B" and "C" after controlling for the effects of "A".

In this article, "A" refers to indicators of internal learning, "B" to learning through customers and "C" the indicator of the intensity of product innovations for the domestic market (see table 4).

This methodology is suitable for defining different causal relations between A, B and C through the simple partial correlation coefficients (Legendre and Legendre, 1998). Both in that article and in the statistics, causality implies the hypothesis that changes in one indicator (variable) have an effect on changes in other indicator (variable).

TABLE 4

Indicators of learning and innovation corresponding to the causal models

Variables of the causal models	A	B	C
	Internal learning. Internal sources of knowledge generation	External learning. External sources of technology absorption	Performance. Proportion of innovations for the domestic market
Indicators of internal, external learning and innovative performance	- In-house R&D - Training - Learning by doing	- Universities - Suppliers - Customers - Conferences, meetings and publications - Competitors	Product

Source: prepared by the authors.

R&D: research and development.

One potential disadvantage of estimating confidence intervals for Pearson's correlation "*r*" is the assumption of a bivariate normal distribution between X and Y. This problem is avoided by estimating the confidence intervals using the bootstrap technique with 5,000 new random samples. The use of this technique does not change the results of the calculations of the Pearson coefficients, but in confidence intervals, which makes it unnecessary to assume the binormality typical of the traditional hypothesis test (Efron and Tibshirani, 1993). The results of the technique are reported in Bittencourt (2010).[13]

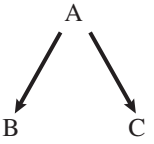
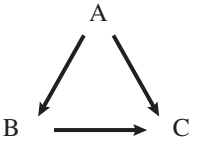
The causal models and the conditions to be fulfilled by the simple and partial correlation coefficients between variables "A", "B" and "C" are shown in figure 1. Model 1 is referred to as the "indirect effect model"; model 2 as the "dual cause model"; and model 3 as the "multiple causality model." These are discussed successively below.

Model 1. Identifies the presence of an indirect causal effect from A to C, mediated by B. In the cases explained in this model, the knowledge generated in A (internal learning) makes it possible to absorb knowledge present in B (external learning), which generates C (innovations). The innovations are based largely on absorption capacity.

[13] Each Pearson correlation matrix contains a lower band and an upper band of possibilities, representing the parameters that make it possible to reject or not reject the null hypothesis, that the correlation is different from zero. Only the positive correlations are important for the present study. For these, a negative lower band does not make it possible to reject the hypothesis that the Pearson correlation is statistically different from zero.

FIGURE 1

Statistical causality models

Model	1	2	3
Causality			
Conditions	*r*ab, *r*bc, *r*ab.c and *r*bc.a ≠ 0 *r*ac.b not significant |*r*ab|> |*r*ac| |*r*bc|>|*r*ac| |*r*ab.c|< |*r*ab| |*r*bc.a|<|*r*bc|	*r*ab, *r*ac, *r*ab.c, *r*ac.b ≠ 0 *r*bc.a not significant |*r*ab|> |*r*bc| |*r*ac|>|*r*bc| |*r*ab.c|< |*r*ab| |*r*ac.b|<|*r*ac|	*r*ab, *r*bc, *r*ac ≠ 0 *r*ab.c, *r*bc.a, *r*ac.b ≠ 0

Source : prepared by the authors on the basis of P. Legendre and L. Legendre, *Numerical Ecology*, Amsterdam, Elsevier, 1998.

Model 2. Indicates that both the technology absorption effect from A to B, and the effect of generating new knowledge from A to C, are present (dual effect), but technology absorption is only effective in the presence of A. This is because, without the influence of A, the partial correlation *r*bc.a. is not significantly different from zero. The simple correlation *r*.bc depends on the existence of A. In other words, the absorption of external knowledge depends largely on the form of internal learning being analysed.

Model 3. The cases represented by this model also include the dual effect of internal forms of learning. Nonetheless, unlike model 2, the correlation *r*bc.a is significantly different from zero, which means that a large proportion of the external knowledge absorbed is independent of the form of internal learning, A, being analysed. In other words, even in the absence of A, the knowledge generated in B is absorbed to generate C. Compare to model 2, in this case external knowledge absorption depends less on the form of internal learning.

2. Focus of the research: technology absorption in sectoral patterns

As noted above, the indicator that measures the intensity of innovations for the domestic market is their percentage share of total innovations registered in the sector in each period.

Considering the possible relations between knowledge internal to the firm, A, knowledge external to the firm, B, and product innovations for the national market, C, in the four sector learning patterns, it was found that over 50 possibilities could be investigated.[14] The following procedure made it possible to reduce the number of applications:

Based on the theoretical notion that access to external information is the first indicator that firms are absorbing knowledge (Schmidt, 2005; De Negri, 2006), the research excluded correlations between the intensity of product innovations for the national market (C) and forms of external learning (B) that were not positive and significantly different from zero. The only correlations that fulfil the condition were those that involve the use of customers, and only between the sectors of patterns 1, 2 and 3. The simple correlations were, respectively, $r = 0.40$, $r = 0.44$ and $r = 0.33$.[15]

That procedure gave rise to nine possibilities for investigating the increase in absorption capacity derived from internal efforts, as summarized in table 5.

[14] Strictly speaking, there would be 60 possibilities, as a result of multiplying 4x3x5, which corresponds, respectively, to the number of learning patterns (4), internal forms of learning (3) and external forms of learning (5).

[15] In the pattern 4 sectors, the method used fails to identify technological absorption owing to the absence of a positive simple correlation that is significantly different from zero between any form of external learning and the innovations analysed. It should be added that the suppliers and advanced science and technology sources reported significant correlations with process innovations for the national market. Moreover, the use of "imitation" sources, and external sources in the form of suppliers and customers, was correlated significantly with the firm's innovations, in both products and processes.

TABLE 5

Focus of the investigation of technology absorption with respect to product innovations for the national market, between sector learning patterns

Pattern	Focus of the investigation of absorption capacity	Technology absorption with respect to product innovation for the domestic market	
		Internal learning	External learning
Pattern 1 Sectors intensive in learning in the productive sphere	Investigation 1	In-house R&D	Customers
	Investigation 2	Learning by doing	Customers
	Investigation 3	Training	Customers
Pattern 2 Sectors intensive in learning in the early stages	Investigation 4	In-house R&D	Customers
	Investigation 5	Learning by doing	Customers
	Investigation 6	Training	Customers
Pattern 3 Sectors intensive in multiple forms of learning	Investigation 7	In-house R&D	Customers
	Investigation 8	Learning by doing	Customers
	Investigation 9	Training	Customers

Source: prepared by the authors.

R&D: research and development.

Generally speaking, customers absorb knowledge through practices that adapt products to demand, which involves an interaction between the producer and the user that is capable of increasing the former's understanding of the latter's needs. Personal contacts occur particularly at the end of the innovation process, sometimes even at the production plant when technical adaptation is needed. These contacts may include market tests and adaptations of the product to different markets.

The absorption of knowledge from customers to produce product innovations stems from (i) in-house R&D activities; (ii) employee training, and (iii) learning by doing. Points to be noted include: (i) since they depend on customer knowledge, the experimental nature of certain R&D activities may explain the relationship; (ii) knowledge obtained through learning by doing may include interaction with customers when the trials, tests, formulation of technical specifications, and improvement of operational characteristics of the products (not included in R&D routines) prove necessary or relevant; and (iii) training practices, by disseminating knowledge within the firm to combine with the knowledge that individuals already possess, expand possibilities for discovering potentials and improving new products.

3. Statistical conditions needed for the analysis of selected cases

Apart from the basic condition requiring a positive correlation that is significantly different from zero between (b) and (c), other conditions were imposed to confine the investigation to the cases actually relevant for the purpose of study. These are:

(i) The correlation between A and B (*r*a.b) should be positive and significantly different from zero. This correlation indicates that knowledge absorbed from an external source B is linked to a particular form of internal learning A. A negative correlations indicates that the use of internal sources (R&D, training and learning by doing) correlates inversely with one of the forms of external learning (customers and suppliers, among others). Such relationships are not considered in the scope of this study.

(ii) The correlation between A and C (*r*ac) should be positive, but need not be significantly different from zero, because the indirect causal relations between A and C can be revealed. Nonetheless, negative correlations indicate inverse relationships between A and C, which it is not intended to explain.

(iii) The partial correlation between B and C, excluding the influence of A (*r*bc.a), must be weaker than the correlation between B and C. This means that A is a determinant of the *r*bc correlation. When A is present, the rbc correlation is stronger, which means that knowledge generated in A serves the purpose of absorption from B and also generation of C. This indicator, linked to conditions 1 and 2 mentioned above, is sufficient to confirm the hypothesis that internal learning generated in A influences the absorption of external knowledge B for the generation of a type of innovation C.

V

Results and discussion

This section discusses the results obtained from applying the methodology. The focus on sectoral learning patterns shows what forms of internal learning best explain technology absorption in each sectoral learning pattern in Brazil.

1. Product innovations for the domestic market and absorption capacity

The results obtained from applying the methodology are summarized in table 6 below. In addition to the research focus by sectoral learning pattern, shown above in table 5, table 6 shows the values of the statistical correlations needed for the research (conditions) and result of this. The last column reveals that only six of the nine research focuses were confirmed.

Research focus 2 (I-2) was not confirmed, because the correlation between learning by doing (a) and the use of customers (b) *r*ab = 0.06 was not significantly different from zero. Focus (I-3) was not confirmed, because the simple correlation between training (a) and product innovation (c) *r*ac = - 0.14 was negative. Focus (I-9) was not confirmed, because in addition to a very low rac correlation of 0.04, the influence of

TABLE 6

Results of the hypotheses: technology absorption for product innovation

Pattern	Research focus	Product innovation for the national market (C)		Conditions				Result of the research
		Internal learning (A)	External learning (B)	*r*ab	*r*ac	*r*bc	*r*bc.a	
P - 1	I - 1	In-house R&D	Customers	0.39	0.23	0.40	0.35	Confirmed: M[a] - 3
	I - 2	Doing	Customers	0.06	0.26	0.40	0.39	Not confirmed: *r*ab not significant
	I - 3	Training	Customers	(0.06)	(0.14)	0.40	0.39	Not confirmed: *r*ac negative
P - 2	I - 4	In-house R&D	Customers	0.46	0.48	0.44	0.29	Confirmed: M - 3
	I - 5	Doing	Customers	0.19	0.21	0.44	0.42	Confirmed: M - 3
	I - 6	Training	Customers	0.22	0.12	0.44	0.33	Confirmed: M - 1
P - 3	I - 7	In-house R&D	Customers	0.58	0.52	0.33	0.03	Confirmed: M - 2
	I - 8	Doing	Customers	0.58	0.21	0.33	0.25	Confirmed: M - 1
	I - 9	Training	Customers	0.44	0.04	0.33	0.34	Not confirmed: *r*bc.a > *r*bc

Source: prepared by the authors.

[a] M - Model.
R&D: research and development.

learning through training (a) on the *r*bc correlation was negative.

In model 3 research focus 1 (I-1) was confirmed, and the presence of the dual effect of in-house R&D (Cohen and Levinthal, 1989) is suggested. The value of the correlations *r*ab = 0.39 combined with *r*bc.a = 0.35 suggests, however, a relatively limited influence of R&D in the absorption of knowledge from customers, B, generators of innovation C (*r*bc = 0.40). In other words, the relevant customer knowledge would be transferred to firms even in the absence of R&D.

In the analysis of the sectors of sectoral pattern 2, the three research focuses were confirmed:[16]

I-4 through model 3, the dual effect of in-house R&D is highlighted. Again, the fact that the partial correlation *r*bc.a = 0.29 is considerably smaller than *r*bc = 0.44, suggests that other forms of internal learning may influence absorption capacity.

This was revealed in the confirmation of both I-5 and I- 6, by model 3 and model 1 respectively. The analysis of I-5 suggest a smaller effect of learning by doing than in-house R&D activities, both in terms of its potential for expanding absorption capacity, and in the direct application of innovation-generating knowledge. This is based, respectively, on the *r*bc.a correlation = 0.42, indicating a very limited influence of A on *r*bc = 0.44, and the correlation *r*ab = 0.19, which was considerably lower than that obtained for in-house R&D: *r*ab = 0.46.

I-6 was confirmed by model 1, which suggests only indirect effects of training on the generation of innovations. A more detailed analysis suggests that training activities have a small, though non-negligible, influence in expanding the absorption of knowledge from customers. This interpretation arises from the following set of results: *r*ac = 0.12, is not significantly different from zero, which excludes a direct link between training and innovation generation; *r*ab = 0.22, is significantly different zero, suggesting that the absorption of customer knowledge derived from learning by training is non-negligible, and *r*bc = 0.44 in combination with *r*bc.a = 0.33 suggesting weak influence of learning through training on the absorption of knowledge from customers.

I-7, which was confirmed by model 2, reveals that among the sectors of highly dynamic learning (pattern 3), the absorption of knowledge from customers depends largely on the performance of in-house R&D. This possibly stems from the level of demand and complexity of knowledge involved in the sales of these sectors, closely linked to the activities of the current technological paradigm. This interpretation is obtained from the fact that in-house R&D is a powerful factor that confuses the correlation between the absorption of knowledge from customers and the generation of product innovations (*r*bc = 0.33), as shown in the partial correlation *r*bc.a = 0.03.

[16] Combining the results of (I-1, I-2 and I-3) provides the first evidence of the need to expand studies on technological absorption —specifically, by investigating more of the firm's internal behaviour variables that can quantify its capacity to absorb external knowledge.

Even pattern 3, I-8 —which is associated with learning by doing— was confirmed through model 1, suggesting an exclusively indirect relationship of major effect between learning by doing and product innovations. In that case, the influence of (a) in the *r*bc correlation decreased, from *r*bc = 0.33 to *r*bc.a = 0.25. The results of I-7 suggest that, apart from R&D, there would be no more space for influence by any other form of internal learning in the rbc correlation, since it would have become virtually zero. Nonetheless, the intensity of in-house R&D does not preclude intensive "learning by doing", since the PINTEC interviews make it possible to register more than one internal learning source as relevant for the innovation process. Thus sectors that are intensive in in-house R&D can also be intensive in "learning by doing". Thus, the joint analysis of I-7 and I-8 suggests complementarity between the knowledge generated by the two forms of learning and absorbing knowledge from customers to generate innovations that impact the domestic market.

The results show that in the process of acquiring, assimilating and transforming external information, it is crucial to know "who" has useful knowledge that can be transformed into innovations of major impact, at least among sectors included in patterns 1, 2 and 3. Nonetheless, the body of knowledge developed internally that makes such absorption feasible differed across sectoral learning patterns.

Among the sectors defined by the intensity of use of sources from the productive sphere (pattern 1), in-house R&D was the main inducer of the capacity to absorb knowledge from customers that is useful for generating innovations of major effect.

Among the areas of pattern 2, defined by early-stage learning, not only in-house R&D, but also knowledge acquired through training and "learning by doing" are related to the absorption of knowledge from customers. Sectors that are most intensive in the three forms of learning are differentiated, therefore, by their capacity to access knowledge from their customers and generate high-impact product innovations.

Among the sectors defined by multiple forms of learning (pattern 3), the absorption of knowledge from customers, which is a determinant of innovation for the domestic market, involves complementary knowledge gained through in-house R&D and learning obtained through internal manufacturing routines ("learning by doing").

VI
Conclusions

Before presenting the final reflections, some of the shortcomings of this study should be noted. Firstly, the use of sectors as the reference of the analyses means assuming homogeneous behaviour among firms, which, clearly, is not theoretically rigorous and only makes it possible to provide statistical "evidence" of technology absorption or any other phenomenon. It also meant working with a small number of observations, which is a statistical constraint, since it restricts the degrees of freedom in terms of the quantitative research. This could explain, for example, why the simple correlations between the use of advanced science and technology sources and product innovations for the domestic market proved unexpectedly non-significant.[17]

Moreover, the main results showed that the indicators used are inadequate for drawing conclusions on absorption capacity. A recommended line of research in this regard would be to explore the characteristics of the firm's labour force.

Nonetheless, a brief comparative reflection on the role of the three forms of learning quantified by the indicators reported in this study, points in relevant directions: learning through in-house R&D plays a greater role than the absorption of external information and knowledge capable of generating innovations with an impact on the national market, compared to "learning by doing" and "learning through training", in any of the cases (patterns) studied. Knowledge generated directly

[17] Such expectations are based on the sector composition of the learning patterns, specifically in their linkage with the Pavitt (1984) taxonomy. Thus, one would expect to find evidence of an increase in the absorption of knowledge from customers through "learning by doing" between the sectors of pattern 4, which has a similar sector composition to "specialized suppliers" (Pavitt, 1984).

by R&D applied to innovations (dual effect) is relevant in all cases analysed.

The fact that "learning by doing" has proven important for technology absorption, whether between technologically more dynamic sectors (pattern 3) or between those that are less dynamic (pattern 2), shows that knowledge obtained through manufacturing routines enables firms to access external information and knowledge with different levels of complexity.

Training-based learning, which was important only in model 1 (indirect causality), expands the assimilation of external knowledge that is useful for high-impact product innovations; but it does not seem to have a direct impact on generating innovations.

Two points to emerge from the results should be emphasized. Firstly, the fact of "knowing who" has the information and knowledge, and "knowing how" to gain access to it, is decisive for the development of innovations. Such knowledge can be found both outside and inside the firm; and R&D activities are not the only way to access it, even in the case of innovations of major impact. Accordingly, technology policies cannot be restricted merely to stimulating R&D activities in firms.

Bibliography

Albuquerque, E. (2000), "Domestic patents and developing countries: arguments for their study and data from Brazil (1980-1995)", *Research Policy*, vol. 29, No. 9, Amsterdam, Elsevier.

Arbussa, A. and G. Coenders (2007), "Innovation activities, use of appropriation instruments and absorptive capacity: evidence from Spanish firms", *Research Policy*, vol. 36, No. 10, Amsterdam, Elsevier.

Arora, A. and A. Gambardella (1994), "Evaluating technological information and utilizing it: scientific knowledge, technological capability and external linkages in biotechnology", *Journal of Economic Behavior and Organization*, vol. 24, No. 1, Amsterdam, Elsevier.

Arrow, K.J. (1962), "The economic implications of learning by doing", *Review of Economic Studies*, vol. 29, No. 3, Oxford, Oxford University Press.

Bell, M. and K. Pavitt (1995), "The development of technological capabilities", *Trade, Technology and International Competitiveness*, I.U. Haque and others (eds.), Washington, D.C., World Bank.

_____ (1993), "Technological accumulation and industrial growth: contrast between developed and developing countries", *Industrial and Corporate Change*, vol. 2, No. 2, Oxford, Oxford University Press.

Bittencourt, P.F. (2012), "Padrões setoriais de aprendizagem da indústria brasileira: uma análise exploratória", *Revista Brasileira de Inovação,* vol. 11, No. 1, Campinas.

_____ (2010), "Aprendizagem e absorção tecnológica na indústria brasileira: três ensaios sobre fatores da inovação na indústria brasileira", Ph.D. thesis, Rio de Janeiro, Fluminense Federal University.

Breschi, S. and F. Malerba (1997), "Sectoral innovation systems, technological regimes, Schumpeterian dynamics and spatial boundaries", *Systems of Innovation: Technologies, Institutions and Organization*, C. Edquist (eds.), London, Pinter.

Caloghirou, Y., I. Kastelli and A. Tsakanikas (2004), "Internal capabilities and external knowledge sources: complements or substitutes for innovative performance?", *Technovation*, vol. 24, Amsterdam, Elsevier.

Cassiman, B. and R. Veugelers (2006), "In search of complementarity in innovation strategy: internal R&D and external knowledge acquisition", *Management Science*, vol. 52, No. 1, Institute for Operations Research and the Management Sciences.

Cassiolato, J.E. and H.M.M. Lastres (2003), "O foco em arranjos produtivos e inovativos locais de micro e pequenas empresas", *Pequena empresa: cooperação e desenvolvimento local*, H.M.M. Lastres, J.E. Cassiolato and M.L. Maciel, Rio de Janeiro, Relume Dumará.

Chesbrough, H.W. and D.J. Teece (1996), "When is virtual virtuous? Organizing for innovation", *Harvard Business Review*, vol. 74, No. 1, Boston, Harvard Business Publishing.

Cohen, W.M., and D.A. Levinthal (1990), "Absorptive capacity: a new perspective of learning and innovation", *Administrative Science Quarterly*, vol. 35, No. 1, Sage Publications.

_____ (1989), "Innovation and learning: the two faces of R&D", *The Economic Journal*, vol. 99, No. 397, St. Andrews, Royal Economic Society.

Cooke, P. and K. Morgan (1998), *The Associational Economy: Firms, Regions, and Innovation*, New York, Oxford University Press.

De Negri, F. (2006), "Determinantes da inovação e da capacidade de absorção nas firmas brasileiras: qual o perfil da mão de obra?", paper presented at the Encounter of the National Association of Postgraduate Centers of Economics (ANPEC).

Dosi, G. (1988), "The nature of innovative process", *Technical Change an Economic Theory*, G. Dosi and others (eds.), London, Pinter.

Edquist, C. (2001), "The system of innovation approach and innovation policy: an account of the state of the art", Aalborg, Danish Research Unit for Industrial Dynamics, June.

Efron, B. and R. Tibshirani (1993), *An Introduction to the Bootstrap*, Boca Raton, Florida, Chapman & Hall.

Figueiredo, P.N. (2004), "Aprendizagem tecnológica e inovação industrial em economias emergentes: uma breve contribuição para o desenho e implementação de estudos empíricos e estratégias no Brasil", *Revista Brasileira de Inovação*, vol. 3, No. 2, Campinas, July/December.

Freeman, C. (1991), "Networks of innovators: a synthesis of research issues", *Research Policy*, vol. 20, No. 5, Amsterdam, Elsevier.

_____ (1987), *Technology, Policy and Economic Performance: Lessons from Japan*, London, Printer.

Hedberg, B. (1981), "How organizational learn and unlearn?", *Handbook of Organization Design*, P.C. Nystrom and W.H. Starbuck (eds.), London, Oxford University Press.

Jensen, M.B. and others (2007), "Forms of knowledge and modes of innovation", *Research Policy*, vol. 36, No. 5, Amsterdam, Elsevier.

Kim, L.y R. Nelson (2005), "Introdução", *Tecnologia, aprendizado e inovação: as experiências das economias de industrialização recente*, Campinas, Editora Unicamp.

Laurensen, K. and A. Salter (2006), "Open for innovation: the role of openness in explaining innovative performance among UK manufacturing firms", *Strategic Management Journal*, vol. 27.

Legendre, P. and L. Legendre (1998), *Numerical Ecology,* Amsterdam, Elsevier.

Lundvall, B-Å. (2002), "The university in the learning economy", *DRUID Working Paper*, No. 02-06, Aalborg, DRUID.

_____ (org.) (1992), *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, London, Pinter.

Lundvall, B-Å and others (2002), "National systems of production, innovation and competence building", *Research Policy*, vol. 31, No. 2, Amsterdam, Elsevier.

Maillat, D. (1996), "Regional productive systems and innovative milieux", *Network of Enterprises and Local Development*, Paris, Organization for Economic Cooperation and Development (OECD).

Malerba, F. (2002), "Sectoral systems of innovation and production", *Research Policy*, vol. 31, No. 2, Amsterdam, Elsevier.

_____ (1992), "Learning by firms and incremental technical change", *The Economic Journal*, vol. 102, No. 403, St. Andrews, Royal Economic Society.

Mowery, D.C., J.E. Oxley and B.S. Silverman (1996), "Strategic alliances and interfirm knowledge transfer", *Strategic Management Journal*, vol. 17.

Murovec, N. and I. Prodan (2009), "Absorptive capacity, its determinants, and influence on innovation output: cross-cultural validation of the structural model", *Technovation*, vol. 29, No. 12, Amsterdam, Elsevier.

Nelson, R.R. (1993), *National Innovation Systems: a Comparative Analysis*, New York, Oxford University Press.

Nieto, M. and P. Quevedo (2005), "Absorptive capacity, technological opportunity, knowledge spillovers, and innovative effort", *Technovation*, vol. 25, No. 10, Amsterdam, Elsevier.

Pavitt, K. (1984), "Sectoral patterns of technical change: towards a taxonomy and a theory", *Research Policy*, vol. 13, No. 6, Amsterdam, Elsevier.

Pisano, G. (1996), "Learning-before-doing in the development of new process technology", *Research Policy*, vol. 25, No. 7, Amsterdam, Elsevier.

Schmidt, T. (2005), "What determines absorptive capacity", paper presented at the DRUID Summer Conference 2005 on Dynamics of Industry and Innovation: Organizations, Networks and Systems, Copenhagen.

Stock, G.N., N. Greis and W.A. Fischer (2001), "Absorptive capacity and new product development", *Journal of High Technology, Management Research*, vol. 12, No. 1, Amsterdam, Elsevier.

Tsai, K.H. (2009), "Collaborative networks and product innovation performance: toward a contingency perspective", *Research Policy*, vol. 38, No. 5, Amsterdam, Elsevier.

Tsai, K.H. and J. Wang (2009), "External technology sourcing and innovation performance in LMT sectors: an analysis based on the Taiwanese technological innovation survey", *Research Policy*, vol. 38, No. 3, Amsterdam, Elsevier.

Vega-Jurado, J.V. and others (2008), "The effect of external and internal factors on firms' product innovation", *Research Policy*, vol. 37, No. 4, Amsterdam, Elsevier.

Veugelers, R. (1997), "Internal R&D expenditures and external technology sourcing", *Research Policy,* vol. 26, No. 3, Amsterdam, Elsevier.

Viotti, E.B. (2002), "National learning systems – A new approach on technological change in late industrializing economies and evidences from the cases of Brazil and South Korea", *Technological Forecasting and Social Change*, vol. 69, No. 7, Amsterdam, Elsevier.

Zahra, S. and G. George (2002), "Absorptive capacity: a review, reconceptualization and extension", *Academy of Management Review*, vol. 27, No. 2, Briarcliff Manor, Academy of Management.

CEPAL Review referees 2012 and January-August 2013

During this period, the following academics and researchers acted as referees for the *CEPAL Review*:

Jorge Abrahão
Manuel Agosin
José Eduardo Alatorre
Dillon Alleyne
Roberto Alvarez
Adriana Amado
Verónica Amarante
Rodrigo Astorga
Reynaldo Bajraj
Renato Baumann
Omar Bello
Néstor Bercovich
Janine Berg
Luis Bértola
Ricardo Bielschovsky
Javiera Blanco
Bineswaree Bolaky
José Borello
Marisa Bucheli
Rudolf Buitelaar
Fernando Cantú
Marco Capasso
Rodrigo Caputo
Pablo Carvallo
Simone Cecchini
Gustavo Crespi
Renato da Fonseca
Gaaitzen de Vries
Robert Devlin
Armando Di Filippo
Eliseo Díaz
Fernando Dougnac
Alvaro Erazo
Hubert Escaith
Ernesto Espíndola
Juan Federico
Fernando Ferrari
Carlo Ferraro
Helder Ferreira de Mendonça
Adolfo Figueroa
Carlos Fortin
Guillermo Fuentes
Sebastián Gallegos
Humberto García
Ivonne González
Pablo González
Camila Gramkow
Gunther Held
Niels Hermes
Sebastián Herreros
María Eugenia Ibarrarán
Gonzalo Iberti
Rhys Jenkins
Luis Felipe Jiménez
Juan Jimeno
Roberto Jovel
Bernado Kosacoff
Guillermo Larraín
Javier Lewkowicz
Carlos Ludena
Oscar Mac-Clure
Xavier Mancero
Sandra Manuelito
Salvador Marconi
Gustavo Marcos
Jorge Mario Martínez
Ricardo Martner
Andrés Mideros
Alejandra Mizala
César Morales
André Nassif
Lucas Navarro
Cecilia Oreiro
Ramón Padilla
Michael Pedersen
Mauricio Pereira
Esteban Pérez
Miguel Pérez
Marcela Perticará
Pierre-Alain Pionnier
Gabriel Porcile
Fernando Porta
Pedro Quaresma de Araujo
Benjamín Rae
Guilherme Resende
Luis Riffo
Juan Carlos Rivas
Mônica Rodrigues
Adrián Rodríguez
Corina Rodríguez
Luis Raúl Romero
Indira Romero
Jaime Ros
Osvaldo Rosales
Gert Rosenthal
Cecilia Rossel
Renzo Rossini
Patricio Rozas
Clemente Ruiz Durán
Jaime Ruiz-Tagle
Jesús Sánchez
Diego Saravia
Claudia Schatan
Lucía Scuro
Daniel Sotelsek
Humberto Soto
Giovanni Stumpo
Guillermo Sunkel
Raquel Szalachman
Joanilio R. Teixeira
Mario Tello
Ian Thomson
Edelberto Torres
Varinia Tromben
Carlos Urzúa
Juan Pablo Valenzuela
Marco Vega
Sebastián Vergara
Andrea Vigorito
Francisco Villarreal
Pablo Villatoro
Robert Vos
Jürgen Weller
Alicia Williner

CEPAL Review is grateful for their invaluable assistance.

Guidelines for contributors to the *CEPAL Review*

In order to facilitate the submission, consideration and publication of articles, the editorial board of the *CEPAL Review* has prepared the following information and suggestions to serve as a guide for future contributors.

The submission of an article implies an undertaking by the author not to submit it simultaneously to other publications. The copyright to all articles published in the *Review* shall be owned by the United Nations.

Each article will be reviewed by the editorial board, which may decide to submit it to external referees.

Papers should be submitted in the original language (English, French, Portuguese or Spanish). They will be translated into the appropriate language by the relevant ECLAC services.

Each article must be accompanied by a summary, no more than 150 words in length, giving a brief description of its subject matter and main conclusions.

Each article must also carry three JEL (Journal of Economic Literature) classification codes. The JEL Classification Codes Guide is available online at www.aeaweb.org/jel/jel_class_system.php.

Papers should be no longer than 10,000 words, including the summary, notes and bibliography. Shorter papers will also be considered.

Articles should be sent by e-mail to *revista@cepal.org* in Word format. Papers in PDF format will not be accepted.

Style guide:

Titles should not be excessively long.

Footnotes

— It is recommended that footnotes be kept to a minimum.

— It is recommended that footnotes not be used to cite bibliographical references; such references should preferably be incorporated into the text.

— Footnotes should be numbered consecutively using superscript Arabic numerals.

Tables, figures and equations

— It is recommended that tables and figures be kept to a minimum, avoiding any redundancy with the text.

— Equations should be written using the Office equation editor "MathType"; they should not be inserted as "pictures".

— Tables, figures and other elements should be inserted at the end of the text in the format in which they were designed; they should not be inserted as "pictures". Figures in Excel should include the corresponding worksheets.

— The location of tables and figures in the body of the article should be indicated in the appropriate place as follows:

Insert figure 1
Insert table 1

— Tables and figures should include an explicit and complete reference to their sources.

— Tables should indicate the period covered at the end of the title, and should indicate the units in which the data are expressed in a subtitle (in italics and between brackets).

— The symbols referred to in the "Explanatory notes" which appear on the page preceding the table of contents should be taken into account in the preparation of tables and figures.

— Footnotes to tables and figures should be ordered consecutively using superscript lower-case letters.

— Figures should be prepared bearing in mind that they will be printed in black and white.

Acronyms and abbreviations

— Acronyms and abbreviations should not be used unless absolutely necessary, in which case the full name should be written out the first time it occurs in the article.

Bibliography

— Bibliographical references should be directly related to the content of the article and should not be excessively long.

— At the end of the article, under the title "Bibliography", all the necessary information should be included accurately and in alphabetical order by author: name of author(s), year of publication, full name of article (if any) and publication (including any subtitle), city of publication, publisher and, in the case of a periodical, month of publication.

The editorial board of the *Review* reserves the right to make any necessary editorial changes in the articles, including their titles.

Authors will receive a one-year courtesy subscription to the *Review*, plus 30 offprints of their article in Spanish and 30 in English, at the time of publication in each language.

NACIONES UNIDAS
UNITED NATIONS

CEPAL
ECLAC

Publicaciones recientes de la CEPAL / *ECLAC recent publications*

Comisión Económica para América Latina y el Caribe / *Economic Commission for Latin America and the Caribbean*
Casilla 179-D, Santiago de Chile.

Véalas en: www.cepal.org/publicaciones
Publications may be accessed at: www.eclac.org

Contacto / Contact: publications@cepal.org

Informes periódicos / *Annual reports*

También disponibles para años anteriores / *Issues for previous years also available*

- *Balance Preliminar de las Economías de América Latina y el Caribe 2013,* 94 p.
  ***Preliminary Overview of the Economies of Latin America and the Caribbean 2013,* 92 p.**
- *Estudio Económico de América Latina y el Caribe 2013,* 222 p.
  ***Economic Survey of Latin America and the Caribbean 2013,* 212 p.**
- *Panorama de la Inserción Internacional de América Latina y el Caribe 2013,* 130 p.
  ***Latin America and the Caribbean in the World Economy 2013,* 122 p.**
- *Panorama Social de América Latina, 2013*, 228 p.
  ***Social Panorama of Latin America, 2013,* 228 p.**
- *La Inversión Extranjera Directa en América Latina y el Caribe 2013*, 154 p.
  ***Foreign Direct Investment in Latin America and the Caribbean 2012,* 142 p.**
- *Anuario Estadístico de América Latina y el Caribe 2013 /* ***Statistical Yearbook for Latin America and the Caribbean 2013,*** 228 p.

Libros y documentos institucionales / *Institutional books and documents*

Prospectiva y desarrollo: el clima de la igualdad en América Latina y el Caribe a 2020, 2013, 72 p.
Comercio internacional y desarrollo inclusivo: construyendo sinergias, 2013, 210 p.
El Estado frente a la autonomía de las mujeres, 2012, 238 p.
Eslabones de la desigualdad: heterogeneidad estructural, empleo y protección social, 2012, 266 p.
Cambio estructural para la igualdad: una visión integrada del desarrollo, 2012, 330 p.
***Structural Change for Equality: an integrated approach to development,* 2012, 308 p.**
La hora de la igualdad: brechas por cerrar, caminos por abrir, 2010, 290 p.
***Time for Equality: closing gaps, opening trails,* 2010, 270 p.**
***A Hora da Igualdade: Brechas por fechar, caminhos por abrir*, 2010, 268 p.**

Libros de la CEPAL / *ECLAC books*

120 *Broadband in Latin America: beyond connectivity*, Valeria Jordán, Hernán Galperin and Wilson Peres (editors), 2013, 348 p.
119 *La montaña rusa del financiamiento externo: el acceso de América Latina y el Caribe a los mercados internacionales de bonos desde la crisis de la deuda, 1982-2012*, Inés Bustillo y Helvia Velloso, 2013, 150 p.
119 *Debt financing rollercoaster: Latin American and Caribbean access to international bond markets since the debt crisis, 1982-2012*, Inés Bustillo and Helvia Velloso, 2013, 135 p.
118 *Sistemas de innovación en Centroamérica. Fortalecimiento a través de la integración regional*, Ramón Padilla Pérez (ed.), 2013, 222 p.
117 *Envejecimiento, solidaridad y protección social en América Latina y el Caribe. La hora de avanzar hacia la igualdad*, Sandra Huenchuan, 2013. 190 p.
***117 Ageing, solidarity and social protection in Latin America and the Caribbean Time for progress towards equality,* Sandra Huenchuan, 2013, 176 p.**
116 Los *fundamentos de la planificación del desarrollo en América Latina y el Caribe. Textos seleccionados del ILPES (1962-1972)*, Ricardo Martner y Jorge Máttar (comps.), 2012, 196 p.

115 ***The changing nature of Asian-Latin American economic relations,*** **German King, José Carlos Mattos, Nanno Mulder and Osvaldo Rosales (eds.), 2012, 196 p.**

114 *China y América Latina y el Caribe. Hacia una relación económica y comercial estratégica*, Osvaldo Rosales y Mikio Kuwayama, 2012, 258 p.

114 **China *and Latin America and the Caribbean Building a strategic economic and trade relationship*, Osvaldo Rosales y Mikio Kuwayama, 2012, 244 p.**

113 *Competitividad, sostenibilidad e inclusión social en la agricultura: Nuevas direcciones en el diseño de políticas en América Latina y el Caribe*, Octavio Sotomayor, Adrián Rodríguez y Mônica Rodrigues, 2012, 352 p.

Copublicaciones / *Co-publications*

Decentralization and Reform In Latin America. Improving Intergovernmental Relations, **Giorgio Brosio and Juan P. Jiménez (eds.), ECLAC/Edward Elgar Publishing, United Kingdom, 2012.**

Sentido de pertenencia en sociedades fragmentadas. América Latina desde una perspectiva global, Martín Hopenhayn y Ana Sojo (comps.), CEPAL/Siglo Veintiuno, Argentina, 2011.

Las clases medias en América Latina. Retrospectiva y nuevas tendencias, Rolando Franco, Martín Hopenhayn y Arturo León (eds.), CEPAL/Siglo XXI, México, 2010.

Innovation and Economic Development. The Impact of Information and Communication Technologies in Latin America, **Mario Cimoli, André Hofman and Nanno Mulder, ECLAC/Edward Elgar Publishing, United Kingdom, 2010.**

Sesenta años de la CEPAL. Textos seleccionados del decenio 1998-2008, Ricardo Bielschowsky (comp.)*,* CEPAL/Siglo Veintiuno, Argentina, 2010.

El nuevo escenario laboral latinoamericano. Regulación, protección y políticas activas en los mercados de trabajo, Jürgen Weller (ed.)*,* CEPAL/Siglo Veintiuno, Argentina, 2010.

Internacionalización y expansión de las empresas eléctricas españolas en América Latina, Patricio Rozas, CEPAL/Lom, Chile, 2009.

Coediciones / *Co-editions*

Perspectivas económicas de América Latina 2014: logística y competitividad para el desarrollo, CEPAL/OCDE, 2013.

Latin American Economic Outlook 2014: Logistics and Competitiveness for Development, **ECLAC/OECD, 2013**

Juventud y bono demográfico en Iberoamérica, Paulo Saad, Tim Miller, Ciro Martínez y Mauricio Holz, CEPAL/OIJ/UNFPA, 2012.

Perspectivas económicas de América Latina 2013. Políticas de Pymes para el Cambio Estructural, OCDE/CEPAL, 2012.

Latin American Economic Outlook 2013. SME Policies for Structural Change, **OECD/ECLAC, 2012.**

Perspectivas de la agricultura y del desarrollo rural en las Américas: una mirada hacia América Latina y el Caribe 2013, CEPAL/FAO/IICA, 2012.

Reforma fiscal en América Latina. ¿Qué fiscalidad para qué desarrollo?, Alicia Bárcena y Narcís Serra (eds.), CEPAL/SEGIB/CIDOB, 2012.

La sostenibilidad del desarrollo a 20 años de la Cumbre para la Tierra. Avances, brechas y lineamientos estratégicos para América Latina y el Caribe, CEPAL/ONU, 2012.

Sustainable development 20 years on from the Earth Summit. Progress, gaps and strategic guidelines for Latin America and the Caribbean, **ECLAC/UN, 2012.**

Perspectivas económicas de América Latina 2012.Transformación del Estado para el desarrollo, CEPAL/OCDE, 2011.

Latin America Outlook 2012. Transforming the State for Development, **ECLAC/OECD, 2011.**

Perspectives économiques de l'Amérique latine 2012. Transformation de l'État et Développement, **CEPALC/OCDE, 2012.**

Breeding Latin American Tigers. Operational principles for rehabilitating industrial policies, **Robert Devlin and Graciela Moguillansky, ECLAC/World Bank, 2011.**

Cuadernos de la CEPAL

101 *Redistribuir el cuidado: el desafío de las políticas*, Coral Calderón Magaña (coord.), 2013, 460 p.

101 *Redistributing care: the policy challenge*, Coral Calderón Magaña (coord.), 2013, 420 p.

100 *Construyendo autonomía. Compromiso e indicadores de género*, Karina Batthyáni Dighiero, 2012, 338 p.

99 *Si no se cuenta, no cuenta*, Diane Alméras y Coral Calderón Magaña (coords.), 2012, 394 p.

98 ***Macroeconomic cooperation for uncertain times: The REDIMA experience*, Rodrigo Cárcamo-Díaz, 2012,164 p.**

97 *El financiamiento de la infraestructura: Propuestas para el desarrollo sostenible de una política sectorial*, Patricio Rozas Balbontín, José Luis Bonifaz y Gustavo Guerra-García, 2012, 414 p.

96 *Una mirada a la crisis desde los márgenes*, Sonia Montaño (coord.), 2011, 102 p.

Cuadernos estadísticos de la CEPAL

41 Los *cuadros de oferta y utilización, las matrices de insumo-producto y las matrices de empleo.* Solo disponible en CD, 2013.

40 *América Latina y el Caribe: Índices de precios al consumidor. Serie enero de 1995 a junio de 2012.* Solo disponible en CD, 2012.

39 *América Latina y el Caribe: indicadores macroeconómicos del turismo.* Solo disponible en CD, 2010.

38 *Indicadores ambientales de América Latina y el Caribe, 2009.* Solo disponible en CD, 2010.

37 *América Latina y el Caribe: Series históricas de estadísticas económicas 1950-2008*. Solo disponible en CD, 2009.

Documentos de proyecto / *Project documents*

La economía del cambio climático en la Argentina: primera aproximación, 2014, 240 p.
La economía del cambio climático en el Ecuador 2012, 2012, 206 p.
Economía digital para el cambio estructural y la igualdad, 2013, 130 p
***The digital economy for structural change and equality*, 2014, 128 p.**
Desarrollo de la telesalud en América Latina: aspectos conceptuales y estado actual, Alaneir de Fátima dos Santos y Andrés Fernández (editores), 2013, 614 p.
La integración de las tecnologías digitales en las escuelas de América Latina y el Caribe. Una mirada multidimensional, Guillermo Sunkel, Daniela Trucco, Andrés Espejo, 2013, 166 p.

Series de la CEPAL / *ECLAC Series*

Asuntos de Género / Comercio Internacional / *Desarrollo Productivo* / *Desarrollo Territorial* / *Estudios Estadísticos* / *Estudios y Perspectivas* (Bogotá, Brasilia, Buenos Aires, México, Montevideo) / ***Studies and Perspectives*** (The Caribbean, Washington) / *Financiamiento del Desarrollo* / *Gestión Pública* / *Informes y Estudios Especiales* / *Macroeconomía del Desarrollo* / *Manuales* / *Medio Ambiente y Desarrollo* / *Población y Desarrollo* / *Política Fiscal* / *Políticas Sociales* / *Recursos Naturales e Infraestructura* / *Reformas Económicas* / *Seminarios y Conferencias*.
Véase el listado completo en: www.cepal.org/publicaciones / *A complete listing is available at*: www.eclac.org/publications

Revista CEPAL / *CEPAL Review*

La Revista CEPAL se inició en 1976 como parte del Programa de Publicaciones de la Comisión Económica para América Latina y el Caribe, con el propósito de contribuir al examen de los problemas del desarrollo socioeconómico de la región. Las opiniones expresadas en los artículos firmados, incluidas las colaboraciones de los funcionarios de la Secretaría, son las de los autores y, por lo tanto, no reflejan necesariamente los puntos de vista de la Organización. La *Revista* CEPAL se publica en español e inglés tres veces por año.
CEPAL Review first appeared in 1976 as part of the Publications Programme of the Economic Commission for Latin America and the Caribbean, its aim being to make a contribution to the study of the economic and social development problems of the region. The views expressed in signed articles, including those by Secretariat staff members, are those of the authors and therefore do not necessarily reflect the point of view of the Organization. CEPAL Review is published in Spanish and English versions three times a year.

Observatorio demográfico / *Demographic Observatory*

Edición bilingüe (español e inglés) que proporciona información estadística actualizada, referente a estimaciones y proyecciones de población de los países de América Latina y el Caribe. Incluye también indicadores demográficos de interés, tales como tasas de natalidad, mortalidad, esperanza de vida al nacer, distribución de la población, etc. Desde 2013 el Observatorio aparece una vez al año.
Bilingual publication (Spanish and English) proving up-to-date estimates and projections of the populations of the Latin American and Caribbean countries. Also includes various demographic indicators of interest such as fertility and mortality rates, life expectancy, measures of population distribution, etc. Since 2013, the Observatory appears once a year.

Notas de población

Revista especializada que publica artículos e informes acerca de las investigaciones más recientes sobre la dinámica demográfica en la región, en español, con resúmenes en español e inglés. También incluye información sobre actividades científicas y profesionales en el campo de población.

La revista se publica desde 1973 y aparece dos veces al año, en junio y diciembre.

Specialized journal which publishes articles and reports on recent studies of demographic dynamics in the region, in Spanish with abstracts in Spanish and English. Also includes information on scientific and professional activities in the field of population.

Published since 1973, the journal appears twice a year in June and December.

Las publicaciones de las Naciones Unidas y de la Comisión Económica para América Latina y el Caribe (CEPAL) se pueden adquirir a través de:

Publicaciones de las Naciones Unidas
PO Box 960
Herndon VA 20172
Estados Unidos

Tel. 1-703-661-1571
Fax 1-703-996-1010
Contacto: publications@un.org
Pedidos: order@un.org

Publications of the United Nations and the Economic Commission for Latin America and the Caribbean (ECLAC) can be ordered through:

United Nations Publications
PO Box 960
Herndon VA 20172
USA

Tel. 1-703-661-1571
Fax 1-703-996-1010
Contact: publications@un.org
Orders: order@un.org

www.un.org/publications

ECONOMIC COMMISSION FOR LATIN AMERICA AND THE CARIBBEAN

ECLAC

United Nations Publication • E1300623 • December 2013 • ISSN 0251-2920 • e-ISBN 978-92-1-056022-1