N° 115
APRIL • 2015

CEPAL REVIEW

ECONOMIC COMMISSION FOR LATIN AMERICA AND THE CARIBBEAN

UNITED NATIONS

ECLAC

ISSN 0251-2920

CEPAL

REVIEW

ECONOMIC
COMMISSION FOR
LATIN AMERICA AND
THE CARIBBEAN

UNITED NATIONS

ECLAC

Nº 115
APRIL • 2015

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.

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).

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: 978-92-1-121892-3
e-ISBN: 978-92-1-057220-0
LC/G.2636-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.

Stylized features of the investment-growth connection in Latin America, 1980-2012

Sandra Manuelito and Luis Felipe Jiménez

ABSTRACT

Estimates of investment and its components in Latin America over the past 30 years are used to review stylized facts relating to investment and explore factors that explain its connection with economic growth. In particular, the low level of investment, the reduction in public spending in the 1980s and its partial recovery along with private investment between 2003 and 2010 are explored. It is found that the increase in national income —on the back of rising terms of trade— made it possible to increase national saving and its contribution to financing investment between 2004 and 2008. The analysis of causality between the investment ratio and growth in gross domestic product (GDP) suggest that —for a considerable number of Latin American countries— changes in the growth rate have preceded changes in the investment ration in the period under study.

KEYWORDS

Investments, public investment, capital, capital formation, national income, savings, economic growth, Latin America

JEL CLASSIFICATION

E01, E21, E22

AUTHORS

Sandra Manuelito is an Economic Affairs Officer in the Economic Development Division of the Economic Commission for Latin America and the Caribbean (ECLAC). sandra.manuelito@cepal.org

Luis Felipe Jiménez is an expert with the Economic Development Division of the Economic Commission for Latin America and the Caribbean (ECLAC). lfjimenez1953@gmail.com

I
Introduction

One of the difficulties involved in analysing growth and macroeconomic performance in Latin America has been the lack of statistical information on the evolution of certain variables compiled in the countries' national accounts. In particular, more disaggregated information is needed on levels of investment by institutional agent and destination sector, and on investment financing, i.e. on saving and its components. This article aims to fill some of those statistical gaps and describe the main stylized features of investment and saving in the period 1980-2012. In addition, the statistical information compiled is used as the basis for an empirical exploration of the nexus between investment and growth.

On the basis of official statistics from the national accounts of the countries of the region, estimates were prepared for gross fixed capital formation (GFCF) and its components, both by institutional sector (public and private investment) and by type of investment (in construction and in machinery and equipment). To this end, annual national accounts data reported by statistical institutes or central banks in the Latin American countries were compiled and systematized along with statistical datasets prepared and published by the Economic Commission for Latin America and the Caribbean (ECLAC), as well as data taken from different sources (national statistical yearbooks, ministerial reports, national statistical bulletins) and in different formats (electronic files and printed documents), which had not been previously grouped or systematized. Where statistical information was not available, the systematization was performed for those years for which it was possible to interpolate either growth rates or ratios. When this was not possible, no data were obtained. In all the other cases, the methodology ensures the consistency and coherence of the investment data series estimated using official information from the national accounts published by the countries.

Estimates were also performed for total savings series, both external and national, the latter broken down into public and private saving. The limited availability of institutional accounts prepared by the countries precluded advancing towards a regional estimate of non-financial private sector saving and household saving.

The statistical series corresponding to these estimates are available for consultation.[1] They have a broad range of possible theoretical and applied uses, and are highly relevant to study of investment trends in the period 1980-2010 in Latin America.

The article is structured as follows. Following this introduction, section II discusses the main stylized facts relating to investment, its evolution and the factors underlying its increase in the period 1980-2012. Section III presents An empirical approach to the relation beteen growth and investment in latina America. Lastly, section IV offers a summary and sets forth the more significant conclusions.

☐ The authors would like to express their thanks to Manuel Marfán, Juan Alberto Fuentes, Luis Felipe Céspedes, Osvaldo Kacef and Luis Eduardo Escobar for their comments on preliminary versions of this article, to Michael Seitz for his involvement in processing the statistical data, and to two anonymous reviewers for their comments.

[1] The statistical series used in this study are an updated version of the series published in Manuelito and Jiménez (2013), and are available in electronic format upon request from the authors. Although every effort was made to ensure that these statistical series are compatible with the official statistics published by the countries, as in other ECLAC publications, these estimates do not correspond to official data from the countries, so citation of the source of information should refer to the present article.

II

Main stylized facts in relation to investment in 1980-2012

1. Evolution of investment over the period

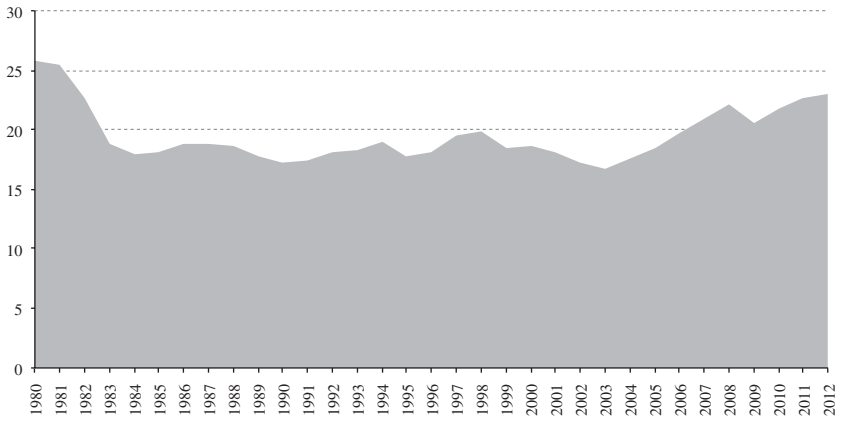
Compared to emerging countries which have managed to sustain high GDP growth rates, the investment rate in the Latin American countries is generally low. Taking 1980 as a starting point, GFCF fell steadily as a percentage of GDP in the first half of the 1980s and remained below 20% until 2007, bottoming out in 2003 at 16.7%. From that point on, the investment rate rose steadily and reached 22.9% in 2012, which nevertheless fell short of the figures for 1980 and 1981 (see figure 1).[2]

This performance contrasts with that of the Asian emerging economies, which have recorded high growth rates over recent decades. Figure 2 compares the investment rate in these economies and in Latin America. China and India stand out among the Asian economies, with high investment rates of around 45% and 35% of GDP, respectively, followed by the Republic of Korea and Thailand, with levels of almost 25% of GDP. Except for the past few years, Latin America's investment rate has been consistently lower than in these countries.

[2] Following investment statistics compilation practices, investment and its components are presented using calculations at constant prices. By contrast, statistics relating to investment financing —i.e. total saving— are presented at current prices. This is because, first, we attempt to be consistent with the statistics published by the countries in the statistical series on which the analysis in this article is based. And, second, methodological differences arise when attempting to define a deflator for savings, on which there is no technical consensus regarding either the most suitable deflator or its economic interpretation. This article takes as a reference the series in local currency at constant prices published by the countries included in the study, maintaining the respective national accounts basis, since the aim here is to compile relatively long series of investment rates as percentages of GDP. Calculating the investment ratio on the basis of absolute values obtained by retropolation would have generated different investment ratios from those the countries publish on the basis of their official figures. In addition, on this occasion statistical information was too limited to calculate or estimate gross fixed capital formation series at current prices. Few countries in the region compile this national accounts aggregate, and the data available become increasingly scant as longer time series are attempted. In addition, there are methodological elements, such as prices implicit in the estimation of gross capital formation at current prices which, for the period under study (1980-2012), create difficulties for economic analysis, owing, in particular, to episodes of high inflation in the region in the late 1980s and early 1990s.

FIGURE 1

Latin America: gross fixed capital formation as a percentage of GDP, 1980-2012
(Dollars at constant 2005 prices)



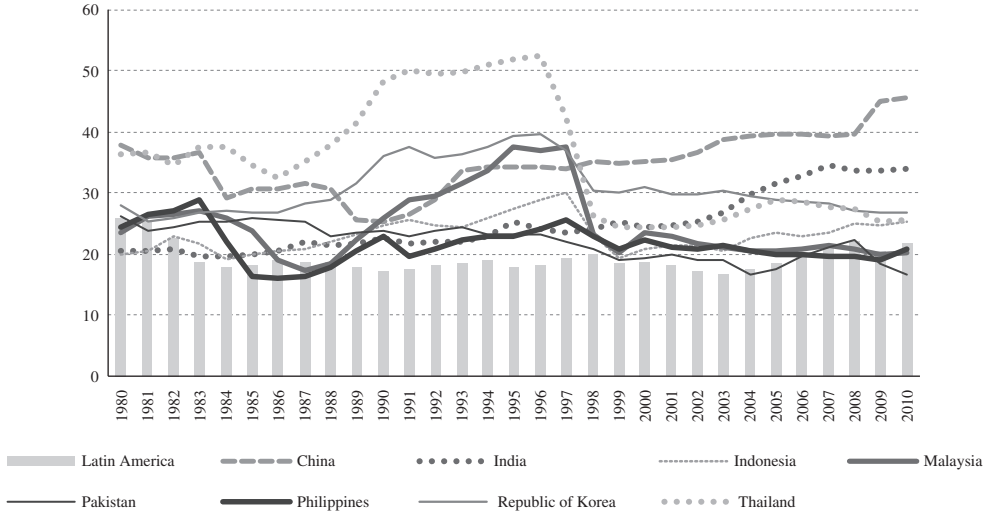
Source: prepared by the authors on the basis of Economic Commission for Latin America and the Caribbean (ECLAC), "América Latina y el Caribe: Series históricas de estadísticas económicas 1950-2008", *Cuadernos Estadísticos de la CEPAL*, No. 37 (LC/G.2415-P), Santiago, Chile, 2009.

GDP: gross domestic product.

FIGURE 2

Latin America and selected Asian countries: gross fixed capital formation as a percentage of GDP, 1980-2010

(Local currency at constant prices and dollars at constant 2005 prices)



Source: prepared by the authors on the basis of Economic Commission for Latin America and the Caribbean (ECLAC), "América Latina y el Caribe: Series históricas de estadísticas económicas 1950-2008", *Cuadernos Estadísticos de la CEPAL*, No. 37 (LC/G.2415-P), Santiago, Chile, 2009, and United Nations, data from *UNdata*.

GDP: gross domestic product.

Tables 1, 2 and 3 show the average investment rate[3] for 19 Latin American countries for which statistics are available for 1980-2010, broken down by institutional sector (public and private investment), and by type of investment (investment in construction and in machinery and equipment). The data are presented by subperiods defined according to the features of regional economic activity. The first subperiod runs from 1980 to 1989 and corresponds to the years of Latin America's external debt crisis. The second is 1990-1998, years of widespread and fairly steady economic growth, except in Argentina and Mexico, which both suffered the effects of Mexico's balance-of-payments crisis in 1994-1995.

The third subperiod is 1999-2002, when many of the region's economies experienced slow growth owing to fallout from the Asian crisis, financial shocks in some Latin American countries and economic slowdown in the United States in 2000-2001. Lastly, the fourth subperiod runs from 2003 to 2010, the recent growth years in the Latin American economies. Although this growth was interrupted in 2009 by the impacts of the global financial crisis, the region's average growth rates in 2010 were similar to those for the period 2003-2008.

Analysis of the results shown in tables 1 and 2 leads to three stylized facts. First, in 8 of the 19 countries included (Argentina, Brazil, Cuba, El Salvador, Guatemala, Paraguay, Plurinational State of Bolivia and Uruguay), GFCF remained below 20% for lengthy periods. Second, public investment as a percentage of GDP was lower in the subperiod 1990-1998 than in the 1980s in 15 of the 19 countries, and in some of them into the subperiod 1999-2002 as well. In 2003, public investment began to rise in relation to GDP in 8 of the 19 countries, but in 13 remained below the 1980s figure.[4] The third stylized fact is that, by contrast with the performance of public investment, in the 1990s private investment rose in 14 of the 19 countries. Private investment has performed unevenly since 2003; in 8 countries it was down on the records for 1999-2002, but in 7 it reached the highest levels for the entire period examined.

Analysis of table 3 shows that, although the rate of investment in construction was uneven from one

[3] Measured as gross fixed capital formation as a percentage of GDP in local currency at constant prices.

[4] Public investment refers to investment by the central government, i.e. excluding investment by State-owned firms, which are included under private investment.

TABLE 1

Latin America: gross fixed capital formation as a percentage of GDP, 1980-2010[a]

(Local currency at constant prices)

Country	1980-1989	1990-1998	1999-2002	2003-2010
Argentina	19.3	18.4	16.0	20.3
Bolivia (Plurinational State of)	12.1	16.0	16.6	14.8
Brazil	18.5	18.1	15.9	17.3
Chile	17.6	26.4	23.0	24.7
Colombia	16.6	20.0	13.7	21.5
Costa Rica	19.7	20.9	20.9	21.8
Cuba	25.5	14.8	11.8	11.5
Ecuador	18.4	24.9	22.7	27.0
El Salvador	12.5	17.8	19.2	18.1
Guatemala	9.7	10.4	15.6	17.3
Honduras	16.7	21.8	24.9	24.8
Mexico	18.9	17.9	20.0	21.1
Nicaragua	18.4	18.6	25.3	21.7
Panama	18.2	20.9	18.5	20.9
Paraguay	21.9	22.9	16.6	17.9
Peru	20.5	20.6	19.0	22.5
Dominican Republic	18.8	19.0	23.1	19.1
Uruguay	12.7	14.5	13.0	16.8
Venezuela (Bolivarian Republic of)	20.9	17.7	24.4	27.3
Latin America[b]	17.7	19.0	19.0	20.4

Source: Economic Commission for Latin America and the Caribbean (ECLAC), *Statistical Yearbook for Latin America and the Caribbean*, various years.

[a] In tables 1-7 simple averages are used to calculate the aggregate regional investment rate. Giving all the countries equal weight in the regional aggregate enables comparison between them, regardless of the size of their economy, and facilitates comparison of a given country's experience vis-à-vis a typical case in the region. If the weighted average were used, the typical regional case would be represented by the three largest economies. In fact, both practices are used in ECLAC documents, depending on whether the focus of the analysis is the regionwide performance (in which case weighted averages are used) or policy matters (in which case simple averages of the figures for the countries are more suitable).

[b] Simple average for the countries included.

GDP: gross domestic product.

TABLE 2

Latin America: public and private gross fixed capital formation as a percentage of GDP, 1980-2010

(Local currency at constant prices)

Country	Public investment				Private investment			
	1980-1989	1990-1998	1999-2002	2003-2010	1980-1989	1990-1998	1999-2002	2003-2010
Argentina	1.7	1.5	1.2	2.4	17.6	16.9	14.8	17.9
Bolivia (Plurinational State of)	8.0	7.4	5.3	7.4	4.1	8.6	11.4	7.4
Brazil	2.2	2.7	1.7	1.8	16.4	15.4	14.2	15.5
Chile	2.4	2.2	2.5	2.4	15.2	24.2	20.5	22.4
Colombia	7.6	4.7	3.2	3.7	9.0	15.2	10.5	17.8
Costa Rica	6.1	4.6	2.9	1.9	13.6	16.3	18.0	19.9
Cuba	..	7.1	6.8	9.1	...	4.7	5.0	2.4
Ecuador	5.7	4.2	5.1	7.3	12.6	20.7	17.6	19.7
El Salvador	2.0	3.4	3.0	2.3	10.4	14.4	16.3	15.9
Guatemala	3.5	3.0	3.4	2.6	6.1	7.4	12.2	14.7
Honduras	7.7	7.7	5.1	3.9	9.0	14.1	19.8	20.8
Mexico	7.1	3.7	3.3	4.8	11.8	14.2	16.7	16.4
Nicaragua	10.8	7.2	6.1	4.0	7.6	11.4	19.2	17.7
Panama	5.6	3.7	5.0	5.8	12.6	17.3	13.5	15.1
Paraguay	5.2	3.8	2.7	3.0	16.7	19.2	13.9	13.1
Peru	5.4	4.3	3.7	3.9	15.1	16.3	15.3	18.6
Dominican Republic	4.1	3.3	2.3	1.5	14.7	15.6	20.7	17.7
Uruguay	4.6	3.6	3.3	4.0	8.1	10.9	9.8	12.7
Venezuela (Bolivarian Republic of)	11.4	9.6	9.0	15.7	9.5	8.1	15.4	12.0
Latin America[a]	5.6	4.6	4.0	4.6	11.7	14.3	15.0	15.7

Source: prepared by the authors, on the basis of official figures of the countries and S. Manuelito and L.F. Jiménez, "La inversión y el ahorro en América Latina: Nuevos rasgos estilizados, requerimientos para el crecimiento y elementos para una estrategia para fortalecer su financiamiento", *Macroeconomía del Desarrollo series*, No. 129 (LC/L.3603), Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC), 2013.

[a] Simple average for the countries included.

GDP: gross domestic product.

TABLE 3

Latin America: public and private gross fixed capital formation in construction and in machinery and equipment as a percentage of GDP, 1980-2010
(Local currency at constant prices)

Country	Investment in construction				Investment in machinery and equipment			
	1980-1989	1990-1998	1999-2002	2003-2010	1980-1989	1990-1998	1999-2002	2003-2010
Argentina	12.5	11.1	10.0	12.2	6.7	7.4	6.0	8.1
Bolivia (Plurinational State of)	6.2	8.1	8.6	8.0	5.9	7.9	8.1	6.8
Brazil	12.6	12.7	10.6	10.2	5.9	5.5	5.3	7.1
Chile	9.9	13.2	14.0	13.4	7.7	13.2	9.1	11.3
Colombia	8.7	11.5	8.2	12.3	7.9	8.4	5.4	8.3
Costa Rica	9.3	8.7	8.8	10.1	10.4	12.2	12.1	11.8
Cuba	...	10.9	9.6	8.4	...	3.9	2.3	3.1
Ecuador	9.8	12.3	13.4	15.5	8.6	12.7	9.2	11.6
El Salvador	6.3	8.5	8.5	7.3	6.2	9.3	10.7	10.9
Guatemala	4.7	4.5	6.5	7.3	5.0	5.9	9.1	10.0
Honduras	10.6	11.5	10.1	7.4	6.1	10.4	14.8	17.3
Mexico	11.5	9.5	9.1	13.1	7.4	8.4	10.8	7.9
Nicaragua	5.8	8.3	11.3	8.9	12.6	10.3	14.0	12.8
Panama	12.0	10.3	8.9	10.8	6.1	10.6	9.6	10.1
Paraguay	13.5	11.3	9.5	9.1	8.4	11.6	7.2	8.8
Peru	12.7	12.0	11.0	12.2	7.8	8.5	7.9	10.4
Dominican Republic	14.2	14.0	17.1	14.9	4.6	4.9	6.0	4.3
Uruguay	8.4	7.8	7.5	8.9	4.3	6.7	5.5	7.5
Venezuela (Bolivarian Republic of)	11.5	10.8	13.0	12.3	9.5	6.7	10.3	13.8
Latin America[a]	10.0	10.4	10.3	10.6	7.3	8.7	8.6	9.6

Source: prepared by the authors, on the basis of official figures of the countries and S. Manuelito and L.F. Jiménez, "La inversión y el ahorro en América Latina: Nuevos rasgos estilizados, requerimientos para el crecimiento y elementos para una estrategia para fortalecer su financiamiento", *Macroeconomía del Desarrollo series*, No. 129 (LC/L.3603), Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC), 2013.

[a] Simple average for the countries included.
GDP: gross domestic product.

country to another throughout the period 1980-2010, in several it behaved similarly to public investment. On average, however, investment in construction held relatively steady at around 10% of GDP between 1980 and 2010. Investment in machinery and equipment behaved similarly to private investment, rising over the preceding subperiod in 1990-1998 (in 15 of the 19 countries) and 2003-2010 (in 14 of 19 countries). The regional average for that type of investment was considerably higher, in the subperiod 2003-2010 than in the 1980s (9.6% of GDP compared with 7.3% of GDP).

2. Factors influencing the rise in investment in 1990-1998 and 2003-2010

Although the purpose of this article is not to build an econometric model to establish the contribution or impact of different factors to the variation of the investment rate in the period under consideration, the ongoing analyses conducted by ECLAC reveal a number of elements that help to explain the phenomenon.[5] Thus, the greater availability of foreign-exchange financing —and the consequent easing of the external constraint on growth— was one of the factors contributing to a modest rise in the investment rate in 1990-1998 and 2003-2010. This was also a factor in the rise in investment in machinery and equipment.

Most of the Latin American economies became increasingly open in the period 1990-1998 (some had already embarked upon this strategy in the second half of the 1980s). This opened up certain sectors to foreign direct investment (FDI) and led to the privatization of utilities and banking services, which boosted investment flows into the region. Foreign trade was also opened up and trade integration processes gained ground, including the

[5] This discussion is supported by the analysis and evidence presented in the editions of the *Economic Survey for Latin America and the Caribbean* published each year by ECLAC.

North American Free Trade Area (NAFTA), the Southern Common Market (MERCOSUR), and the establishment of maquila industries in Central America. These processes all attracted increasing amounts of investment and boosted goods exports, mainly through the expansion of export volumes.[6]

Together with the increase in exports, in 1990-1998 international prices came down for manufactures but rose for some raw materials, at least until the Asian crisis of 1997.[7] As a result, the region saw the purchasing power of its exports[8] rise, especially in Mexico, thanks to NAFTA, and in the Central American countries, owing to maquila-related investments.[9] Despite the larger inflows of foreign exchange, however, the structure of the region's investment financing remained unchanged. As will be discussed later, in 1990-1998 investment financing became even more reliant on external saving, partly as a result of more ready access, to the detriment of national-savings-based financing (see table 7).

There was a second factor facilitating the rise in investment, and especially investment in machinery and equipment. The flow of foreign exchange into the economies of the region, as a result of increased exports and the incipient development of a financial market in several of the countries, contributed to exchange-rate appreciations which cheapened local-currency costs of imported goods. This is important, given the large share of imported capital goods in machinery and equipment investment in the countries of the region. In four countries (Argentina, Brazil, Ecuador and Mexico), real exchange-rate appreciation was sharper still, owing to schemes to counter inflation that used the exchange rate as a nominal anchor.

All this combined with a downtrend in international prices for capital goods,[10] which had begun in the 1980s and sharpened in the 1990s. International prices for capital goods fell by 23% between 1980 and 1990 and by a further 42% between 1990 and 2000, based on the unit value index of capital goods imports from the United States, prepared by the Bureau of Economic Analysis (see figure 3).[11]

The cycle of investment expansion was broken in 1997-1998 by the onset of the Asian crisis. Between 1990 and 1998, in several countries burgeoning domestic demand had generated current-account disequilibria which were unsustainable when the external financing constraint hit. As a result, several countries were forced to adjust domestic demand, which accounts for the fall in investment rates, especially in machinery and equipment, between 1999 and 2002.

The second subperiod in which investment rates rose, 2003 to 2010, showed a significant shift in relation to the trends for 1998-2002. Disposable gross national income began to climb strongly in several countries starting in the second half of 2003 and swelled national saving, public and private alike, owing chiefly to large terms-of-trade gains as a result of the sudden rise in international commodity prices (see table 4).

Analysis of private and public national saving presents certain difficulties of comparison between the countries, because some calculate net saving (i.e. net of fixed capital consumption), while others estimate gross saving. The comparison of the two definitions is inexact, yet over time sheds light on macroeconomic aspects of investment financing (see tables 5 and 6).

Although data availability is uneven over time, in both subperiods in which public saving rose, it rose both with respect to the preceding subperiod and by comparison with the period 1980-1989. Public saving rose more during the subperiod 2003-2010, especially in the countries in which natural resources account for a large percentage of fiscal income[12] —Argentina, Bolivarian Republic of Venezuela, Chile, Ecuador, Peru and the Plurinational State of Bolivia— with the exception of Mexico.

[6] The maquila industry also brought a considerable increase in goods imports, so that the rise in goods exports had a limited impact in terms of improving the trade balances of the Latin American countries.

[7] In particular, international prices for beef, coffee, soybeans and wheat. Prices for metals and minerals were more volatile, although form 1993 to 1995 international prices for aluminium, copper and nickel rose by over 50% in cumulative terms. Later, when the Asian crisis broke out, raw materials prices fell across the board and remained low until 2003.

[8] The purchasing power of exports may be defined as the value of goods exports measured in terms of their purchasing power of goods imports. In other words, it corresponds to the volume of exports multiplied by the terms of trade, as given in the following expression:

$$PCE = Qx * \left(\frac{Px}{Pm}\right)$$

where
Qx = the volume index of goods exports,
Px = the price index of goods exports, and
Pm = the price index of goods imports.

[9] It must be recalled, however, that goods exports have quite a large imported component in both cases, so that the greater exports produced only a very limited rise in national income.

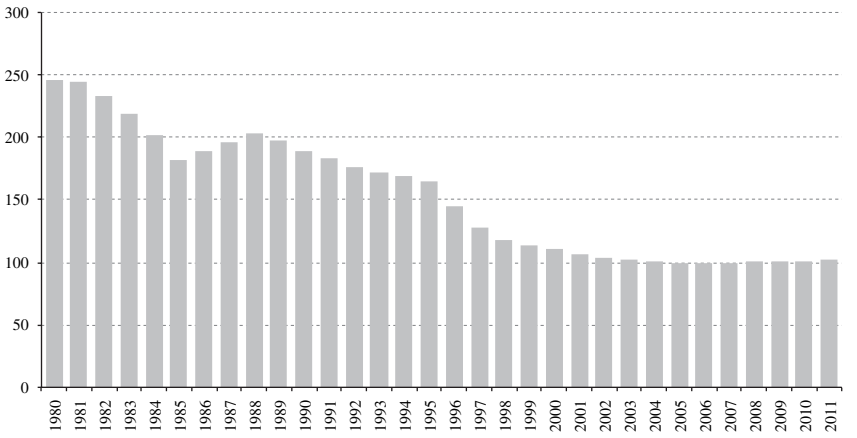
[10] Refers to the index for capital goods excluding automobiles.

[11] This index is used here as a reference only for international capital goods prices that are relevant for the region, because the structure of capital goods imports in the United States does not necessarily coincide with that of the Latin American countries.

[12] See ECLAC (2011, table I.2) which shows the increasing weight of income from primary goods in fiscal revenues in several countries.

FIGURE 3

Index of capital goods import prices, excluding automobiles, 1980-2011
(Index: 2005=100)



Source: prepared by the authors, on the basis of figures from the Bureau of Economic Analysis of the United States Department of Commerce.

TABLE 4

Latin America: national saving as a percentage of GDP, 1980-2010
(Local currency at constant prices)

Country	1980-1989	1990-1998	1999-2002	2003-2010
Argentina	17.9	15.8	15.4	24.1
Bolivia (Plurinational State of)	16.4	9.8	10.7	22.2
Brazil	20.1	17.2	13.6	17.7
Chile	11.8	22.3	20.7	22.9
Colombia	18.5	20.6	15.2	19.6
Costa Rica	16.1	14.5	13.3	16.8
Cuba	...	...	...	10.9
Ecuador	...	17.3	22.2	22.1
El Salvador	...	14.9	14.3	11.6
Guatemala	9.5	11.0	12.5	14.1
Honduras	4.5	18.3	17.2	20.0
Mexico	21.7	19.1	19.4	24.0
Nicaragua	3.6	2.0	10.3	13.1
Panama	24.7	24.7	18.4	20.0
Paraguay	19.8	21.0	17.5	17.3
Peru	21.3	15.5	17.3	21.4
Dominican Republic	15.7	16.5	18.9	15.0
Uruguay	11.7	13.8	11.9	16.5
Venezuela (Bolivarian Republic of)	22.7	23.1	30.6	34.3
Latin America[a]	16.0	16.5	16.6	19.2

Source: prepared by the authors, on the basis of official figures from the countries and S. Manuelito and L.F. Jiménez, "La inversión y el ahorro en América Latina: Nuevos rasgos estilizados, requerimientos para el crecimiento y elementos para una estrategia para fortalecer su financiamiento", *Macroeconomía del Desarrollo series*, No. 129 (LC/L.3603), Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC), 2013.

[a] Simple average for the countries included.
GDP: gross domestic product.

TABLE 5

Latin America: public saving as a percentage of GDP, 1980-2010

(Local currency at constant prices)

Country	1980-1989	1990-1998	1999-2002	2003-2010
I. Countries which report gross public saving				
Argentina	...	-0.2	-1.5	2.4
Bolivia (Plurinational State of)	-3.8	2.6	-1.7	4.7
Brazil	...	1.7	1.3	0.5
Colombia	2.5	3.6	-1.6	1.0
Cuba	...	...	...	2.2
El Salvador	...	1.3	0.2	0.0
Guatemala	...	1.8	2.3	2.4
Nicaragua	...	2.3	0.3	1.1
Dominican Republic	...	3.7	3.4	2.1
Uruguay	-0.2	3.3	-2.3	-0.5
Average[a]	-0.5	2.2	0.0	1.6
II. Countries which report net public saving				
Chile	...	4.4	0.8	5.5
Costa Rica	3.2	2.4	2.6	3.7
Ecuador	...	4.9	3.5	7.9
Honduras	...	1.0	2.6	0.0
Mexico	...	4.1	1.6	2.0
Panama	-2.8	3.0	0.7	1.2
Paraguay	1.2	2.6	1.4	5.2
Peru	-1.7	0.6	-0.3	2.5
Venezuela (Bolivarian Republic of)	...	9.2	1.4	4.9
Average[a]	0.0	3.6	1.6	3.7

Source: prepared by the authors, on the basis of official figures from the countries and S. Manuelito and L.F. Jiménez, "La inversión y el ahorro en América Latina: Nuevos rasgos estilizados, requerimientos para el crecimiento y elementos para una estrategia para fortalecer su financiamiento", *Macroeconomía del Desarrollo series*, No. 129 (LC/L.3603), Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC), 2013.

[a] Simple average for the countries included.

GDP: gross domestic product.

TABLE 6

Latin America: private saving as a percentage of GDP, 1980-2010

(Local currency at constant prices)

Country	1980-1989	1990-1998	1999-2002	2003-2010
I. Countries which report gross public saving				
Argentina	...	16.8	16.9	21.6
Bolivia (Plurinational State of)	20.2	7.2	12.5	17.9
Brazil	...	11.6	12.3	17.2
Colombia	16.1	17.0	16.9	18.8
Cuba	...	...	...	...
El Salvador	...	13.6	14.1	11.7
Guatemala	...	9.2	10.2	11.8
Nicaragua	...	0.8	10.0	12.0
Dominican Republic	...	12.7	15.6	12.9
Uruguay	11.9	10.5	14.1	15.6
Average[a]	16.1	11.1	13.6	15.5
II. Countries which report net public saving				
Chile	...	7.3	6.7	5.8
Costa Rica	9.6	6.8	4.9	7.9
Ecuador	-3.1	11.6	16.8	14.0
Honduras	...	17.3	14.7	15.5
Mexico	..	5.2	8.1	12.9
Panama	20.6	14.7	9.6	11.7
Paraguay	8.2	13.9	11.9	12.6
Peru	17.2	8.4	10.4	12.1
Venezuela (Bolivarian Republic of)	..	7.2	23.1	23.8
Average[a]	10.5	10.3	11.9	12.6

Source: prepared by the authors, on the basis of official figures from the countries and S. Manuelito and L.F. Jiménez, "La inversión y el ahorro en América Latina: Nuevos rasgos estilizados, requerimientos para el crecimiento y elementos para una estrategia para fortalecer su financiamiento", *Macroeconomía del Desarrollo series*, No. 129 (LC/L.3603), Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC), 2013.

[a] Simple average for the countries included.

GDP: gross domestic product.

A number of reasons underlie the performance of public saving. As noted earlier, the countries have in common the rise in national saving resulting from steadily improving terms of trade in 2003-2010. During those years, many countries also adopted fiscal policies geared towards building public finance sustainability throughout the commodity price cycle, during what was a strong price upswing.[13] In the cases of Argentina and Ecuador, the rise in public saving also reflected the need to work around the consequences of restricted access to external financing.

Private saving also rose considerably as a percentage of GDP, especially in 2003-2010, the second subperiod in which the investment rate maintained an upward trend. This trend, which is evident in two thirds of the countries, reflected increased disposable gross national income (see tables 5 and 6). In some cases, the rise in private saving includes the savings of public enterprises that were not transferred to the central government. Although private saving rose in the great majority of the countries, it came down in El Salvador, Chile, the Dominican Republic and Paraguay (see table 6).

Trends in public and private savings help to explain the rise in national saving seen in 1990-1997 and, especially, in 2003-2008, when the investment rate rose steadily. In several countries, national saving also rose faster than investment, which led to a sharp fall in the share of investment financing accounted for by external saving in over half the countries examined (see table 7). In addition, in 8 of the 19 countries and in relation to GDP, public saving rose more than private saving in 2003-2008 compared to the preceding subperiod (1999-2002).[14] However, these larger rises in public saving were not reflected in similar rises in public investment.

From the foregoing it may be concluded that, as well as exogenous factors (higher prices for export commodities, swelling migrant remittances, lower interest rates on external debt) that helped increase disposable gross national income in 2003-2010, policies on public finance sustainability and management of international reserves also had a hand in lowering the use of external saving. As a counterpart to decreased use of external saving, external debt came down as a proportion of GDP, net international reserves swelled considerably, and public savings were built up in sovereign funds in several countries of the region.[15] From this perspective, the main contrast with the economic conditions prevailing in the subperiods 1990-1998 and 2003-2010 was the larger share of national saving in financing regional investment in the latter subperiod, representing a shift towards growth sustainability and reduced vulnerability to the vicissitudes of external financial markets. When the global financial crisis of 2008-2009 broke out, the more limited use of external saving thanks to national saving in prior years enabled several countries to adopt countercyclical policies, and the region in general was able to weather the episode on a better footing, so that growth took less of a hit than in previous episodes.

With international prices for manufactures varying little, the rise in national saving boosted the purchasing power of exports again (see figure 4). The South American economies felt this effect the most, owing to their greater specialization in production and export of raw materials.

In addition, in 2003-2010 local currencies began to appreciate again in five countries (Brazil, Chile, Colombia, Mexico and Peru) which, among other things, made it cheaper to import capital goods. However, the international prices of capital goods did not play such a strong role in these years as in 1990-1998. Although capital goods prices continued to trend downwards, the variations were smaller from 2002 on, at -6.4% between 2002 and 2011. Nevertheless, the fact remains that in 2005 capital goods prices stood at just 40% of the equivalent prices in 1980. So, amid improving terms of trade, falling prices for capital goods and exchange-rate appreciation, national saving increased in dollar terms. Together with robust economic growth in this period, this created the conditions for greater investment in machinery and equipment.

[13] See ECLAC (2011, box I.1), which describes the gradual adoption of fiscal rules in the region starting in 2000. Box III.1 also presents the main characteristics of funds aimed at easing the impacts of fluctuations in public revenues resulting from variations in primary goods prices.

[14] Where public and private saving fell, the decline in public saving was smaller than in private saving.

[15] It will also be recalled that during this period several countries (for example, Argentina and Brazil) made early payment of their liabilities to the International Monetary Fund (IMF). Chile, too, adopted a policy of prepayment of loans from multilateral institutions from 2004 to 2006 and, like other countries, repurchased some of its external bonds.

TABLE 7

Latin America: external saving as a percentage of GDP, 1980-2010
(Local currency at constant prices)

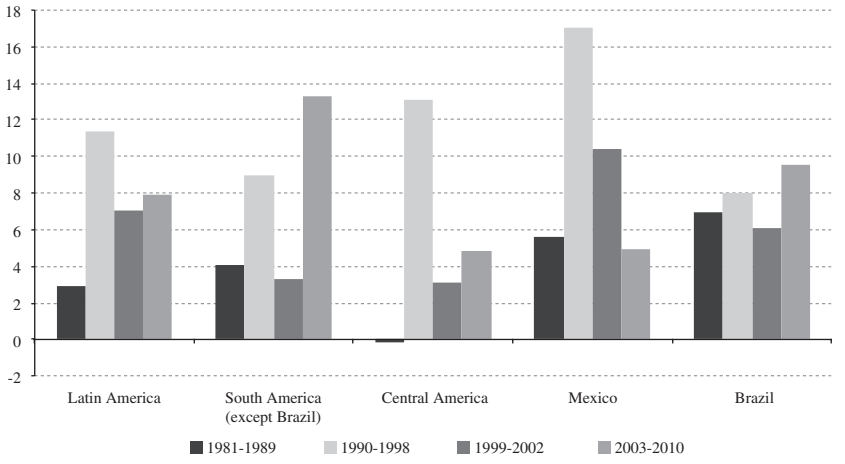
Country	1980-1989	1990-1998	1999-2002	2003-2010
Argentina	2.1	2.7	0.1	-2.7
Bolivia (Plurinational State of)	-1.6	6.9	4.7	-7.3
Brazil	2.1	1.8	3.6	0.3
Chile	7.1	3.2	0.9	-1.6
Colombia	1.3	1.1	0.0	1.9
Costa Rica	9.5	5.5	5.9	6.1
Cuba	...	...	...	1.0
Ecuador	...	4.4	-0.8	2.1
El Salvador	...	2.2	2.3	3.9
Guatemala	3.8	3.4	6.4	4.1
Honduras	6.8	5.6	5.7	6.7
Mexico	0.5	3.8	2.8	0.7
Nicaragua	17.0	23.2	20.6	16.0
Panama	-6.7	-0.1	2.5	1.2
Paraguay	-5.0	0.8	1.7	-2.5
Peru	3.6	5.9	2.3	0.1
Dominican Republic	5.6	1.8	3.1	3.0
Uruguay	2.1	1.3	1.7	2.5
Venezuela (Bolivarian Republic of)	-2.0	-3.3	-5.8	-9.9
Latin America[a]	2.9	3.9	3.2	1.3

Source: prepared by the authors, on the basis of official figures from the countries and S. Manuelito and L.F. Jiménez, "La inversión y el ahorro en América Latina: Nuevos rasgos estilizados, requerimientos para el crecimiento y elementos para una estrategia para fortalecer su financiamiento", *Macroeconomía del Desarrollo series*, No. 129 (LC/L.3603), Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC), 2013.

[a] Simple average for the countries included.
GDP: gross domestic product.

FIGURE 4

Latin America: annual average variation in purchasing power of goods exports, 1981-2010
(Percentages)



Source: prepared by the authors, on the basis of Economic Commission for Latin America and the Caribbean (ECLAC), CEPALSTAT data base.

Note: the average for Latin America is the regional weighted average. Each country is given a weighting equal to its share of regional exports. The average for each of the subregions is a simple average.

III

An empirical approach to the relation between growth and investment in Latin America

This section uses the data described and analysed above to perform an empirical examination of the relationship between growth and investment in the Latin American countries from 1980 to 2010.

From a long-term perspective, economic theory holds that achievement of a given level of economic activity depends basically on factor accumulation, technical progress and, in certain approaches, such as the one proposed by ECLAC, the characteristics of the production structure. Empirical studies show that capital accumulation is a necessary, but not a sufficient, condition for growth. This connection has been studied extensively; a good summary in this respect may be found in the work of Sala-i-Martin (1997), which uses robust estimation methods to identify at least 22 variables which are significantly correlated with economic growth. Among these, investment in machinery and equipment is prominent, contrasting with a low impact for other types of investment (for example, in construction). Real-exchange-rate distortions and the spread between the official and black market exchange rates also have a strong (negative) influence on growth (Sala-i-Martin, 1997).

Recent studies have addressed another two key aspects: the effect of public investment and FDI on economic growth. Both have been found to have a positive impact (Toulaboe, Terry and Johansen, 2009; Cullison, 1993; Bukhari, Ali and Saddaqat, 2007).

By contrast, from a short- and medium-term perspective, the level and momentum of economic activity are treated as the outcome of levels of aggregate demand, key relative prices and supply-side constraints.

This dichotomy between the timescales of theoretical analyses contrasts with the results of empirical economic growth analyses, the experience of the countries and economic policy practice, inasmuch as policies adopted for the short term weigh on long-term outcomes. The short- and medium-term emphasis on the importance of investment in fact has more to do with demand-side factors. Investment galvanizes aggregate demand (multiplier effect) and is key in determining the level of demand, especially demand with a high impact on employment. At the same time, present and future growth expectations increase the pace of investment (accelerator effect). The long-term nature of investment decisions means that growth and returns expectations are very significant factors. This is why a good present performance in a scenario of sustained growth (understood as economic performance free of heavy or persistent disequilibria) helps to generate positive expectations which favour present decisions on future investments, thereby raising the growth trajectory.

However, several empirical studies propose that short- and medium-term causality between GDP growth and the investment rate may be two-directional (Blomström, Lipsey and Zehjan, 1993; Peltonen, Sousa and Vansteenkiste, 2012; Cheung, Dooley and Sushko, 2012). Greater investment thus helps boost economic activity by impacting positively on demand, which in turn stimulates investment by reducing idle capacity and improving expectations of future returns.

In light of the points made in the preceding two paragraphs, the empirical review that follows of the investment-growth nexus is set within a short-term perspective and does not rule out mutual causality. For this reason, it uses a different methodology from empirical analyses of long-term growth.[16] Focusing the analysis on the short-term link between the investment rate and growth spotlights the importance of countercyclical policies and crisis prevention in sustaining or increasing the investment rate. This, in turn, links macroeconomic policy to long-term growth, whose importance is evident in both literature and practice.

In the empirical literature, causality between growth and investment is still a matter of debate. The results obtained are inconclusive and depend to a great extent on the economy and the timescale examined and considerations such as the number of lags in the estimations, or the estimation method itself. These exercises are also complicated by the fact that the link between the two variables is examined ex post in the identity relations of the national accounts, which generates

[16] The total effects of investment on growth could well take longer to materialize than the number of years analysed here. However, the quantification of those effects would require a different methodology from that employed here, as well as longer statistical series. For a recent analysis of long-term growth in Latin America and the Caribbean, see ECLAC (2014, cap. III).

problems of simultaneity and makes it more difficult to demonstrate causality in one direction or the other. Bearing these limitations in mind, the existence of (Granger) causality was explored between GDP variation and the investment rate. The results are presented below, with a single lag between the variables. Exercises were performed with a higher order of lags, but a lag order of 1 produced significant results for the largest number of countries.[17]

Two null hypotheses were tested:

(i) Null hypothesis (1): the investment rate does not Granger-cause the rate of GDP variation. Rejection of null hypothesis (1) is interpreted as meaning that changes in the investment rate precede changes in the GDP growth rate.

(ii) Null hypothesis (2): the rate of GDP variation does not Granger-cause the investment rate. Rejection of null hypothesis (2) is interpreted as meaning that changes in the GDP growth rate precede changes in the investment rate.

For simplicity's sake, null hypothesis (1) and null hypothesis (2) will be referred to as Hn(1) and Hn(2), respectively.

Table 8 shows the results obtained from testing Hn(1), which examines the existence of short-term causality of the GDP growth rate by the investment rate, the public investment rate, the private investment rate, the rate of investment in construction and the rate of investment in machinery and equipment.

The results obtained from the tests performed suggest that, in general, Hn(1) cannot be rejected, with certain exceptions. For the 18 countries studied, in 14 Hn(1) is not rejected at significance of at least 95%, which may be interpreted as the absence of evidence of short-term causality of GDP by the investment rate. Exceptions to this result are the cases of Argentina, Brazil, Costa Rica and Panama, for which the investment does appear to have Granger-caused GDP growth in the period under study. At 90% significance, the Bolivarian Republic of Venezuela may be added to this list.

The absence of a short-term effect on growth tends to hold in the examination of causality of GDP growth by public and private investment and by investment in machinery and equipment. By contrast, in the case of investment in construction, the number of countries for which Hn(1) is rejected rises to 8. Consequently, in these cases, investment in construction does appear to have Granger-caused GDP growth.

Table 9 shows the results of the Hn(2) test, which examines short-term causality by GDP of total investment, public and private investment and investment in construction and in machinery and equipment. As may be seen, the hypothesis of non-causality by GDP of total investment may be rejected for 9 of the 18 countries with at least 95% significance, and for 13 at 90% significance. This implies, with a high degree of probability, that for several countries in the region, changes in the GDP growth rate preceded and impacted positively on changes in the investment rate in the period under study. Brazil, Chile, Ecuador, Guatemala and Mexico are the exceptions to this result.

With regard to the effects of GDP growth on the components of investment, in just over half the cases, GDP growth appears to Granger-cause private investment, investment in machinery and equipment and, especially, investment in construction. By contrast, there is no evidence of GDP causality of public investment.

Comparison of the results presented in tables 8 and 9 shows that in several cases (Argentina, Costa Rica and Panama) both hypotheses are rejected, so that Granger causality between the two variables appears to be two-directional, which bears out to some extent the studies mentioned earlier. However, formal proof of this would require a different exercise to the one performed here.

The overall results suggest that in the period 1980-2010 increases in the investment rate were related to stimuli coming from aggregate demand (growth expectations or actual increase in demand). Trends in regional aggregate demand and in the factors driving it offer certain leads to explain this performance. As for external demand, the main increases have been in global demand for commodities and energy products, which triggered a rise in investment in these sectors.[18] In turn,

[17] Application of a higher lag order does not change the interpretation of the results obtained using order 1, although the significance is lower. The qualitative results are unchanged inasmuch as no sign reversals occur, so nothing additional is learned about the nexus between the two variables. In addition, although these disaggregated series are as long as possible, they have only 30 observations, so including a larger number of lags would mean sacrificing degrees of freedom for the econometric analysis. Consequently, it was considered preferable to report simpler exercises, which can be readily replicated and contrasted in other research once the database is made available.

[18] Although the great majority of the countries do not have statistics on gross fixed capital formation (GFCF) by destination sector of investment, partial information and data from other sources suggest that in raw material producers and exporters, most investment has gone to mining and energy. In the case of FDI, from 2007 to 2012 in South America (excluding Brazil), between 44% and 51% went to the natural resources sector and around 40% to services, including commerce and financial and infrastructure services. By contrast, in Mexico and Central America, between 35% and 48% went to manufacturing, and between 42% and 55% to services. In Brazil, between 38% and 43% went to manufacturing and between 34% and 48% to services (ECLAC, 2013b, figure I.11).

TABLE 8

Results of the test of null hypothesis 1 on Granger causality of GDP growth by the investment rate

	GFCF does not cause GDP		INVPUB does not cause GDP		INVPRIV does not cause GDP		CONST does not cause GDP		MACHEQ does not cause GDP	
	p value	significance	*p* value	significance	*p* value	significance	*p* value	significance	*p* value	significance
Argentina	0.025	**	0.741		0.013	**	0.024	**	0.062	*
Bolivia (Plurinational State of)	0.468		0.506		0.391		0.756		0.431	
Brazil	0.016	**	0.744		0.010	***	0.078	*	0.179	
Chile	0.979		0.522		0.980		0.583		0.635	
Colombia	0.346		0.898		0.503		0.880		0.037	**
Costa Rica	0.026	**	0.088	*	0.648		0.013	**	0.221	
Ecuador	0.391		0.905		0.407		0.119		0.959	
El Salvador	0.358		0.715		0.271		0.645		0.161	
Guatemala	0.704		0.000	***	0.704		0.912		0.141	
Honduras	0.595		0.330		0.964		0.232		0.981	
Mexico	0.140		0.191		0.716		0.251		0.325	
Nicaragua	0.791		0.033	**	0.176		0.087	*	0.239	
Panama	0.010	**	0.362		0.011	**	0.006	***	0.313	
Paraguay	0.795		0.602		0.618		0.481		0.664	
Peru	0.175		0.355		0.224		0.024	**	0.529	
Dominican Republic	0.156		0.012	**	0.911		0.108		0.689	
Uruguay	0.161		0.120		0.300		0.084	*	0.364	
Venezuela (Bolivarian Republic of)	0.059	*	0.152		0.126		0.002	***	0.176	

Source: prepared by the authors.

Note: GFCF: gross fixed capital formation; INVPUB: public investment; INPRIV: private investment; CONST: construction; MACHEQ: machinery and equipment.
Confidence levels for rejection of the null hypothesis: *** = 1%; ** = 5%; * = 10%.
GDP: gross domestic product.

TABLE 9

Results of the test of null hypothesis 2 on Granger causality of the investment rate by GDP growth

	GDP does not cause GFCF		GDP does not cause INVPUB		GDP does not cause INVPRIV		GDP does not cause CONST		GDP does not cause MACHEQ	
	p value	significance	*p* value	significance	*p* value	significance	*p* value	significance	*p* value	significance
Argentina	0.001	***	0.006	***	0.001	***	0.013	**	0.001	***
Bolivia (Plurinational State of)	0.060	*	0.581		0.210		0.164		0.043	**
Brazil	0.915		0.689		1.000		0.859		0.781	
Chile	0.125		0.357		0.098	*	0.003	***	0.470	
Colombia	0.021	**	0.467		0.088	*	0.299		0.007	***
Costa Rica	0.008	***	0.761		0.165		0.081	*	0.018	**
Ecuador	0.153		0.695		0.155		0.314		0.119	
El Salvador	0.008	***	0.100	*	0.017	**	0.088	*	0.038	**
Guatemala	0.109		0.047	**	0.533		0.004	***	0.880	
Honduras	0.058	*	0.481		0.022	**	0.575		0.109	
Mexico	0.393		0.427		0.999		0.925		0.183	
Nicaragua	0.024	**	0.736		0.130		0.809		0.037	**
Panama	0.000	***	0.012	**	0.000	***	0.000	***	0.022	**
Paraguay	0.070	*	0.952		0.084	*	0.051	*	0.563	
Peru	0.050	**	0.343		0.050	**	0.082	*	0.175	
Dominican Republic	0.078	*	0.252		0.330		0.044	**	0.347	
Uruguay	0.000	***	0.030	**	0.001	***	0.000	***	0.002	***
Venezuela (Bolivarian Republic of)	0.034	**	0.081	*	0.194		0.011	**	0.042	**

Source: prepared by the authors.

Note: GFCF: gross fixed capital formation; INVPUB: public investment; INPRIV: private investment; CONST: construction; MACHEQ: machinery and equipment.
Confidence levels for rejection of the null hypothesis: *** = 1%; ** = 5%; * = 10%.
GDP: gross domestic product.

rising domestic demand has been based largely on steadily expanding household demand, in response to improving labour market indicators (falling unemployment, rising employment and gains in real wages) and more ready bank lending to families. Another significant element underlying the increase in household consumption was poverty reduction. This is no small matter, since lower-income segments of the population who gain broader access to goods and services show a very high consumption propensity (generally equal or close to 1), so the gain in income in these families translates almost entirely into greater consumption.[19] An important factor in explaining consumption rises in the region is the fact that in 2002-2011 the poverty rate in Latin America fell from 43.9% to 29.4%. Although the poverty rate is still high and reducing it remains one of the region's major challenges, the change over these 10 years represents a very significant achievement (ECLAC, 2013c). The expansion of the consumption base caused by this set of factors has been key in sustaining the growth of investment in the commerce sector seen in several Latin American economies.

In a second group of countries, consisting of Argentina, the Bolivarian Republic of Venezuela, Brazil and Nicaragua, it appears more likely that changes in investment drive growth. This could be a sign that, at least in the period under study, growth constraints have tended to come less from insufficient aggregate demand than from limited growth in production capacity as a result of lengthy periods of slack investment in these countries.

Which of the two groups a country corresponds to is of key importance for designing macroeconomic policies for growth and stability. In countries where GDP growth is more likely to precede investment, more importance should be afforded to demand-side policies and countercyclical efforts to keep capacity use high, unless other growth constraints, such as availability of external financing, give rise to a different recommendation. Conversely, where the investment rate precedes changes in GDP growth, policies geared towards stimulating production capacity expansion are more important. In cases lying between the two extreme, the emphasis will vary depending on where the growth constraint lies at any given time, whether in the level of demand or in production capacity.

[19] Te link between rising consumption and the investment rate is reflected in a high correlation between the two variables. Jiménez and Manuelito (2013, annex 2) present the results obtained from estimating the correlation coefficients of the rate of variation in total consumption and total investment for the 19 countries included in this study.

IV

Summary and conclusions

On the basis of estimates not previously available on investment and its components in Latin America, this article reviews the main stylized facts in this connection for the period 1980-2010 and explores causal factors in the nexus between economic growth and gross fixed capital formation (GFCF).

The analysis of the data reveals the low level of investment in Latin America by comparison with other regions and, in particular, with countries that have narrowed the per capita GDP vis-à-vis the developed countries. Three stylized facts emerge in relation to investment in Latin America:

(i) The investment rate remained below 20% for lengthy periods in 8 of the 19 countries examined.

(ii) Compared with the 1980s, public investment fell as a percentage of GDP in 15 of the 19 countries in the period 1990-1998. Although it began to recover in some of them from 2003 onwards, in 12 of the 19 countries public investment has not regained its 1980s level.

(iii) In the 1990s, private investment was at its most dynamic for the entire 1980-2010 period and the investment rate rose in 14 of the 19 countries, but its performance was uneven from 2003 on. The private investment rate fell in the subperiod 2003-2010 in 8 countries compared with the figures for 1999-2002, but in 7 it reached its highest levels for the entire 1980-2010 period. This, combined with a slight upturn in public investment in 2003-2010, meant that total investment was at its highest levels in those years.

One of the main factors underlying the increase in investment rates in the subperiod 1990-1998 was the easing of the external constraint, thanks to increased availability

of foreign exchange owing to economic opening and the rising purchasing power of exports on the back of higher prices and plummeting international prices for capital goods. Nevertheless, national saving continued to be insufficient to cover investment, so external saving remained an important source of financing. However, in contrast to the 1980s, the components of external saving changed significantly from the 1990s onward, with FDI playing an increasingly important role.[20]

The investment rate rose again in the subperiod 2003-2010. Contributing to this, as in 1990-1998, was the diminishing influence of the external constraint a limitation on financing. Some countries in the region even experienced negative external saving for several years running, owing to the combined effect of rising disposable national income on the back of terms-of-trade gains and changes in the macroeconomic policy framework, which led to a hefty increase in national saving. The counterpart of this was a decline in external borrowing and build-up of international reserves and savings in sovereign funds. The patterns of national saving in the 2003-2010 represented the main difference with respect to the subperiod 1990-1998. The investment ratio rose in both subperiods, but higher national saving during the second, together with a persistently larger share of less volatile financial flows in external saving —which had begun in the 1980s— reduced external vulnerability and opened up space for countercyclical policy action when the recent global financial crisis hit.

With respect to the empirical analysis of the link between growth and investment, the results obtained show that, in general, changes in the rate of GDP variation precede changes in the investment rate. Similar results are obtained from analysis of the link between GDP growth rate and the rates of private investment and investment in machinery and equipment. In only a few cases —although important ones because of their relative size in the region— it was found that change in investment Granger-caused (1969) growth. These results are significant because they help to identify the factors acting as growth constraints in each case, and thus to design macroeconomic policy to stimulate growth accordingly.

[20] In this regard, see ECLAC (2013a, chapter I).

Bibliography

Blomström, Magnus, Robert Lipsey and Mario Zehjan (1993), "Is fixed investment the key to economic growth?", *NBER Working Paper*, No. 4436, Cambridge, Massachusetts, National Bureau of Economic Research (NBER).

Bukhari, Adnan, Liaqat Ali and Mahpara Saddaqat (2007), "Public investment and economic growth in the three little dragons", *International Journal of Business and Information*, vol. 2, No. 1.

Cheung, Yin-Wong, Michael Dooley and Vladyslav Sushko (2012), "Investment and growth in rich and poor countries", *NBER Working Paper*, No. 17788, Cambridge, Massachusetts, National Bureau of Economic Research (NBER).

Cullison, W.E. (1993), "Public investment and economic growth", *Federal Reserve Bank of Richmond Economic Quarterly*, vol. 79, No. 4, Richmond, Federal Reserve Bank of Richmond.

ECLAC (Economic Commission for Latin America and the Caribbean) (2014), *Economic Survey of Latin America and the Caribbean, 2014* (LC/G.2619-P), Santiago, Chile. United Nations publication, Sales No. E.14.II.G.3.

_____ (2013a), *Economic Survey of Latin America and the Caribbean, 2013* (LC/G.2574-P), Santiago, Chile. United Nations publication, Sales No. E.13.II.G.3.

_____ (2013b), *Foreign Direct Investment in Latin America and the Caribbean 2012* (LC/G.2571-P), Santiago, Chile. United Nations publication, Sales No. E.13.II.G.4.

_____ (2013c), *Social Panorama of Latin America, 2012* (LC/G.2557-P), Santiago, Chile. United Nations publication, Sales No. E.13.II.G.6.

_____ (2012), *Statistical Yearbook for Latin America and the Caribbean*, 2012 (LC/G.2554-P), Santiago, Chile. United Nations publication, Sales No. E/S.13.II.G.1.

_____ (2011), *Economic Survey of Latin America and the Caribbean 2010-2011* (LC/G.2506-P), Santiago, Chile. United Nations publication, Sales No. E.11.II.G.3.

_____ (2009), "América Latina y el Caribe: Series históricas de estadísticas económicas 1950-2008", *Cuadernos Estadísticos de la CEPAL*, No. 37 (LC/G.2415-P), Santiago, Chile. United Nations publication, Sales No. S.09.II.G.72.

Granger, C.W.J. (1969), "Investigating causal relations by econometric models and cross-spectral methods", *Econometrica*, vol. 37, No. 3, Econometric Society.

Jiménez, Luis Felipe and Sandra Manuelito (2013), "Rasgos estilizados de la relación entre inversión y crecimiento en América Latina y el Caribe: 1980-2012", *Macroeconomía del Desarrollo series*, No. 136 (LC/L.3704), Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC).

Manuelito, Sandra and Luis Felipe Jiménez (2013), "La inversión y el ahorro en América Latina: nuevos rasgos estilizados, requerimientos para el crecimiento y elementos para una estrategia para fortalecer su financiamiento", *Macroeconomía del Desarrollo series*, No. 129 (LC/L.3603), Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC).

Peltonen, Thomas, Ricardo Sousa and Isabel Vansteenkiste (2012), "Investment in emerging market economies", *Empirical Economics*, vol. 43, No. 1, Springer.

Sala-i-Martin, Xavier (1997), "I just ran two millions regressions", *American Economic Review*, vol. 87, No. 2, Nashville, Tennessee, American Economic Association.

Toulaboe, Dosse, Rory Terry and Thomas Johansen (2009), "Foreign direct investment and economic growth in developing countries", *Southwestern Economic Review*, vol. 36, No. 1, Southwestern Economic Society.

International technological dynamics in production sectors: An empirical analysis

Fernando Isabella Revetria

ABSTRACT

A new methodology is proposed for evaluating the economic development opportunities associated with the different industries making up a country's economic structure. To this end, neo-Schumpeterian concepts are used to reinterpret the tools afforded by the "product space" literature in an attempt to assess the technological pervasiveness and sophistication of different production sectors. The ultimate objective is to develop a description of today's techno-productive paradigm and the differential role that the various sectors play in it. An analysis of export data from 113 countries and territories for 2005-2009 indicates that the key sectors in the world economy are: industrial machinery, scientific and medical instruments, and pharmaceuticals. The strong performance of sectors based on mature technologies suggests that key sectors originating in different stages in history can survive and overlap one another, much like geological strata, owing to the persistence of older technological systems.

KEY WORDS

Economic development, industrial production, production diversification, product quality, technological innovations, exports, Latin America

JEL CLASSIFICATION

033, 049, 050

AUTHOR

Fernando Isabella Revetria is an assistant professor at the Institute of Economics of the School of Economics and Administration at the University of the Republic in Montevideo, Uruguay. fisabella@iecon.ccee.edu.uy

I
Introduction

In the past few years, certain changes in a number of South American economies, such as the boom in agricultural and mining sectors and the exponential growth of their exports, have rekindled an academic and political debate about the medium- and long-term prospects for economic growth. Specifically, the discussion has focused on whether the commodity-based sectors that are leading growth will put the economies on a sustainable growth path or whether the current boom will prove to be nothing more than a fleeting windfall.

Various schools of thought characterize the agricultural and mining sectors and their industrial chains as having a very limited potential for driving economic growth over the long term. These sectors are often contrasted with manufacturing sectors that are not so closely linked to commodity production and offer greater opportunities for the application of scientific knowledge. Adherents of this view therefore feel that sectoral trends in these South American countries are a cause for concern from a long-term perspective and that proactive policies are needed to deal with the situation and to fuel the development of new, more technology-intensive production sectors (Lall, 2000; Cimoli, 2005; ECLAC, 2007).

At the regional level, economists at the Economic Commission for Latin America and the Caribbean (ECLAC) have recently been making an effort to integrate the Commission's structuralist tradition with an evolutionary microeconomic approach in order to develop what has been called an "evolutionary structuralist synthesis". This approach articulates various lines of economic thought that share a number of basic concepts, such as the intrinsic differences between different production sectors' contributions to development, the importance of knowledge and technology specificities, the frequent absence of automatic adjustment processes, the influence that disequilibria have on the development process, and the role of institutions and State action in surmounting obstacles to structural change (Peres and Primi, 2009; ECLAC, 2012).

The evolutionary neo-Schumpeterian school of thought also espouses the view that the different types of productive specialization are not neutral in terms of their implications for development and stresses the different sectors' opportunities for learning and for the application of technical progress (Pavitt, 1984; Lall, 2000; Antonelli, 2007). Special emphasis is placed on the pervasiveness of certain new technologies (radical innovations), referring to the broad array of opportunities that exist for their application not only in the sector where they were developed, but throughout the economy.

These economic schools of thought are in agreement about the important role of sectoral specialization in enhancing an economy's development potential. However, an empirical analysis is needed in order to gather evidence for use in evaluating the different production sectors. Numerous studies have drawn upon pre-established industrial taxonomies, which derive from empirical studies on specific points in time and countries, and seek to evaluate different industries' capacity to absorb innovations and generate positive spillovers or externalities (see Pavitt (1984); Hatzichronoglu (1997); Lall (2000); Katz and Stumpo (2001). The usefulness of these taxonomies has been demonstrated, and these studies' findings have generally stood up when cross-checked against current data. Nonetheless, in a constantly changing world in which production processes are continually being reorganized and rearranged, the specific conditions under which certain products were produced at one point in time and location do not necessarily inform the potential for their production under a different set of circumstances.

Therefore, the question which this paper seeks to address is how to arrive at a dynamic evaluation of different production sectors' potential to steer an economy towards a sustainable growth path.

Starting from a reinterpretation of the tools developed in the literature on "product space" and drawing on neo-Schumpeterian and structuralist concepts, an empirical methodology is developed for using international trade data to assess two attributes of production sectors: technological sophistication and pervasiveness. The application of this methodology leads to the conclusion that the key sectors in the world economy are industrial machinery, scientific and medical instruments, and pharmaceuticals, while the more commodity-based production sectors are

☐ This article is an outgrowth of my Master's thesis. I would like to express my gratitude to my thesis advisers, Lucía Pittaluga and Juan José Goyeneche, to the panel of examiners (Henry Willebald, Gustavo Bittencourt and Gabriel Porcile) for their comments and to my colleagues, Carlos Bianchi and Carolina Román, for their unwavering support.

ranked the lowest. This corroborates the concerns about the areas of production specialization that have recently been observed in Latin America.

This study is divided into six sections. Section II introduces the conceptual framework on which the project is based. The methodology and proposed empirical strategy are discussed in section III. The fourth section reviews the data used in this analysis and the sectoral classification of the relevant products. Finally, the study's findings and conclusions are presented in section V and VI respectively.

II
Conceptual framework

1. The "product space"

In recent years, a group of Harvard researchers has developed a tool referred to as "product space", which is linked to the concept of the proximity between different goods. Product space is calculated as the conditional probability that a given country which exports product A is able to produce and export a given product B.

Hausmann and Klinger (2006a) posit that the proximity between goods *i* and *j* at a point in time *t* can be described as:

$$\phi_{i,j,t} = min\left\{P\left(x_{i,t} \mid x_{j,t}\right), P\left(x_{j,t} \mid x_{i,t}\right)\right\} \qquad (1)$$

where $P\left(x_{i,t} \mid x_{j,t}\right)$ is the conditional probability that if a country exports product *j* on the basis of a revealed comparative advantage[1] (RCA) greater than 1, it will also have an RCA for exports of product *i*.

Global trade data can be used to calculate the proximities between all the different pairs of goods, which reflect the conditions in the various countries. This is what these authors refer to as the "proximity matrix," which is basically a representation of the product space. They identify goods that are closely connected to many others because they show a high sum of proximities to the rest of the products (referred to as the "total proximity" to the product space), while other goods are more isolated. The first group can be found in the hard core of the product space, while the second group is located on the periphery of the graphic representation of the product space.

As can be seen, this is a completely empirical indicator that measures the links between goods in international markets and is independent of whatever theories may be used to interpret those links.

In terms of what determines the proximity between two products, the Harvard researchers contend that the capabilities required for the competitive production of particular goods is of central importance. The production of each product requires a specific set of skills which would be an imperfect substitute for the capabilities required for the production of any other good. If any two products tend to co-occur in countries' export baskets, this indicates that the set of capabilities required for each is a good substitute for the other. In other words, a country which develops the skills necessary for the production of one of these goods can easily develop the capability to produce the other. The concept of capabilities used by these authors is very broad and includes everything from infrastructure and institutions to physical assets and technological knowledge. However, the authors adopt an explicitly "agnostic" stance in the sense that they avoid taking a position on which of these factors may be the most important in determining a country's overall production capabilities (Hidalgo and others, 2007). This leaves ample room for a less "agnostic" interpretation which would provide a clearer theoretical basis and a more detailed interpretation of the results obtained through the use of these tools. This idea is explored further in the next section.

The foregoing considerations support the hypothesis that the probability that a country will incorporate a good that it does not yet produce into its production structure[2] will be determined by that item's proximity to the goods that already form part of that structure.

[1] Using the definition of revealed comparative advantages proposed by Balassa (1964).

[2] Given that this tool approaches the concept of production structure as based on a country's export basket and, in particular, only takes into consideration goods for which a country has an RCA>1, from this point on we will consider these concepts to be interchangeable and accept the inherent limitations.

The reason for this is that the capabilities that the economy has developed in order to produce its existing products will bear a greater or lesser similarity to the capabilities required to produce the new item. This is exactly what Hausmann and Klinger (2006a) demonstrate empirically.

Consequently, a country's existing production pattern can tell us a great deal about its possibilities for diversification.

Hausmann, Hwang and Rodrik (2005) find that some products are exported primarily by rich countries while others are exported mainly by poor countries and conclude that "you become what you export"; in other words, poor countries that specialize in products that are generally exported by rich countries gradually tend to move closer and closer to rich countries' income levels. One of the most interesting indicators that these authors have developed to measure these dimensions is the PRODY, which associates each product with the per capita incomes of the countries that specialize in exporting that good. Formally:

$$PRODY_i = \sum_c \frac{\left(x_{ci} / X_c\right)}{\sum_c \left(x_{ci} / X_c\right)} Y_c \qquad (2)$$

where x_{ci} represents the value of exports of product i by country c, X_c represents country c's total exports, and Y_c stands for country c's per capita GDP.

The PRODY is used as an indicator of a good's sophistication. It reflects the level of productivity that is associated with that good because it links the product to the per capita income of the countries that produce it. The authors statistically test the links between the level of income and the PRODY and, importantly, gauge the high level of statistical significance of the deviations between that relationship and future growth. In other words, countries that have a higher PRODY than would appear to correspond to their level of income at a given point in time tend to experience more rapid growth in subsequent periods, and they consequently move closer and closer to the corresponding income level. This is what gives rise to the idea that "you become what you export."

This approach opens up many empirical possibilities and paves the way for the development of analytical tools that do not rely on pre-established taxonomies for the classification of goods and the corresponding production sectors.

2. Interpretation

As discussed earlier, the authors adopt an "agnostic" position when it comes to the theoretical interpretation of this tool and to weighing in on the most influential factors that influence the proximity between goods and the relationship between those proximities and economic rents. This paper reinterprets these product-space tools as a basis for the development of new and effective analytical tools. This brings the concept of the technological capabilities necessary for the efficient production of a good back into the foreground. In line with the evolutionary view, technological capabilities are understood to be specific, cumulative and partially tacit. The first of these characteristics implies that a certain degree of effort is needed to adapt capabilities to meet a firm's specific requirements. These capabilities involve much more than straightforward scientific knowledge, and it is therefore not enough simply to have the appropriate manuals and handbooks. Furthermore, these skills entails sector-specific components, and technological developments designed to meet the needs of a given production sector will therefore not automatically be applicable in another. The second characteristic of technological capabilities —that they are cumulative— signals the importance of each firm's development path, which has marked implications in terms of the capabilities that the firm will acquire over time. The significance of these types of growth paths can also be a factor for wider economic systems, such as those of regions or countries. In other words, the cost (and chances of success) of adapting a technology to fit in with the specific needs of a given sector or country will depend on what types of capabilities it has built up over time. Finally, the tacit nature of technological capabilities is closely tied in with the other two attributes mentioned above. Unlike what is commonly understood as "information", a good part of applied production expertise is not codifiable; acquiring that kind of expertise is the result of practice and experience, rather than being a skill which can be learned from manuals or bought like some other asset on the markets.

This constitutes a departure from neoclassical models that depict technology as consisting of information as a free good that other firms can easily reproduce. The idea of the appropriability of innovations is also reinforced, since the benefits derived from innovation efforts can be reaped, for a time, only by the innovator because imitation is neither easy nor cost-free. Thus, the diffusion of new production technologies is not an automatic process; it requires time and learning and incurs costs. Finally, if

technological capabilities are specific, cumulative and partially tacit, then the generation and accumulation of capabilities is heavily path-dependent.

Production sectors that allow for (and require) the development of certain sophisticated technological capabilities that come into widespread use (that is, sophisticated and pervasive sectors) have spillovers on the rest of the economy by driving an increase in a society's technological capabilities. These skills then provide society with more effective tools that it can bring to bear in the development of new related industries (Nelson and Winter, 1982; Pavitt, 1984; Lall, 2000; Antonelli, 2007).

The historical context determines which sectors will become pervasive. The neo-Schumpeterian view maintains that, at given points in time, a series of radical innovations will tend to cluster and strongly influence economic characteristics and trends. New methods of production and new products will have an impact on the whole of the economy and society. These innovations are extremely profitable at the outset but, because of the complexity of the technological capabilities embedded in them, only a few firms can make use of them. Little by little, their profitability drives imitation, as well as the development of new (incremental) innovations which do not alter production trends but do perfect these innovations and build on the opportunities opened up by the pioneerinnovations. Related technologies then prove to be applicable in sectors far removed from those for which they were developed. As a result, they become increasingly widespread and, as they do so, begin to modify production, consumption, distribution and other patterns. This paves the way for considerable productivity gains in a wide variety of sectors and drives economic growth.

At the same time, however, other sectors (and other technologies) are relegated to a secondary position, and these periods are therefore associated with an intensive restructuring process. The new technologies and goods require new infrastructure, worker skills and management techniques. They also usher in new consumption patterns and regulatory schemes, and all of this feeds into the formation of a new techno-productive paradigm. This branch of neo-Schumpeterian thought holds that in recent decades we have been witnessing the creation of a new paradigm in which information and communication technologies (ICTs) play a central role (Freeman and Pérez, 1988; Freeman and Louça, 2001).

Pervasive sectors will therefore be linked with goods that have a high "total proximity" to the product space, which signals the ubiquity of the associated technologies. However, goods which require very specific production capabilities do not entail an intensive use of the technologies which are pervasive in the current paradigm. They therefore do not serve as a "testing ground" for the accrual of capabilities that can then be applied in the development of new sectors and products. As a result, their role in driving growth will be much less influential, and the economies of countries that specialize in these products will tend to be much less diversified.

Many of these goods are closely linked to the basic commodities produced by an economy (Hausmann and Klinger, 2006a), which generally involve the intensive use of natural resources. While there are opportunities for applying new technologies in these industries, the associated production capabilities are focused on making a more efficient use of those resources, and the transfer of these new technologies and capabilities to sectors where those specific resources does not play a key role is more difficult.

Therefore, the diversification of production —which entails the incorporation of a wider range of sectors into a country's or region's production structure— will be more straightforward or more likely when a country has a track record of producing goods linked to the pervasive sectors of today's paradigm that are in close proximity to the product-space core, since they will then be accruing "broad spectrum" capabilities.

This interpretation should not, however, overshadow the fact that there are factors other than technological capabilities, in the strict sense of the term, that may determine the proximity between goods and their relative position in the product space. Some of these factors may fall within a broader definition of technological capabilities (regulations, infrastructure), while others fall completely outside of any possible definition of that concept (for example, the availability of natural resources).

The other fundamental concept in this approach is the technological sophistication of different production sectors, which the PRODY can be used to measure, at least in approximate terms. From a theoretical standpoint, the capability to appropriate economic rents is a very important one because the radical innovations that define a production paradigm are characterized, initially, by the ability to capture windfall profits. This is directly related to a sector's technological sophistication and the fact that a recently developed product is hard to imitate, which gives the pioneering industry or firm monopolistic power for a time. As time passes, however, and the corresponding technologies mature, imitation and the development of new incremental innovations become more possible. These technologies then become

diffused and more pervasive, but lose their ability to enable a producer to capture windfall rents —in other words, they become less "sophisticated." In this paper, the PRODY (which refers to rents rather than directly to technologies) will therefore be used as a proxy for technological sophistication.

In this study, then, a high level of sophistication (high PRODY) will be interpreted as an indicator that there is a close link between the goods and the radical innovations that define the present production paradigm. These goods and the sectors that produce them are therefore also considered to hold out promising prospects for structural change.

The production sectors that exhibit the greatest combination of these characteristics will be referred to as "key sectors" because they display two fundamental aspects that are necessary for development: technological pervasiveness, which paves the way for diversification, and sophistication, which makes them profitable.

The link between sophistication and pervasiveness is not a given. At least at certain stages of innovation, a trade-off may exist between the two. This is because a high degree of pervasiveness is associated with a high degree of diffusion of the technologies in question. This would, in turn, mean that the innovators would have very little capacity to appropriate economic rents, since competition would drive down prices (towards the level of marginal costs). This subject will be explored further in a later section.

The way in which economies become specialized in key sectors involves an overarching restructuring process that lies at the centre of the concerns addressed by this study.

3. Pathways of structural transformation in the product space: a proposal

The structural transformation process is an ongoing one that should enable society to incorporate new capabilities at every step along the way that will lay the groundwork for further sophistication and diversification. A combination of these two facets is therefore of crucial importance in defining the profiles of key sectors. A good in a key sector not only needs to be sophisticated and to be in proximity to many other goods, but it also must be in close proximity to other sophisticated goods. This is of crucial importance for structural transformation processes in which the economy not only becomes more diversified as it incorporates new production sectors, but these new sectors also help drive it towards higher levels of income and growth.

Proximities therefore map out the road for structural change, while the degree of sophistication points out the way to go. The principal contribution that this study seeks to make is to provide a methodology for evaluating these two factors in conjunction with one another.

By the same token, the degree of pervasiveness of a given good will be determined by its proximity to many other products but, in particular, to other pervasive goods. Close proximity to any specific product is not as important in terms of structural change as close proximity to products that, in turn, are in close proximity to many others. Therefore, the central proposal being put forward in this study is that, in order to identify key sectors, all the different paths for structural change that are opened up by each product should be explored. This idea will be developed more fully in the following pages.

The product space can be defined on the basis of an inter-product proximity matrix that traces the proximity between the goods in each row and those in each column. This also provides a way of looking at the opposite dimension, i.e. the distance between different goods, which would be a measurement of their dissimilarity in terms of the skill set required to produce them on a competitive basis and, hence, the degree of difficulty involved in adapting the capabilities required to produce one of them in order to produce the other.

The next step is to define exactly what is meant by the "distance" that has to be covered in order to progress along a path of change while moving from one product to another and then another. Measuring the distance between product A and product B is fairly straightforward and can be accomplished simply by inverting the concept of proximity. But how can we measure the total distance to be covered if we start with product A, then incorporate product B and then go on to incorporate product C? This is an essential question to be answered if we are to explore the myriad paths of change that are opened up when a given good (product A) is introduced into a country's production structure. If we start from the point of product A, we can arrive at the production of good C by following any number of different paths. Some of those paths will lead us directly through good B, but others will lead us through any number of other goods.

Now, if proximity is to be defined in a probabilistic sense, then the concept of joint probability should be employed, as defined here:

$$\text{Given } \phi(A,B) \text{ and } \phi(B,C);\ \phi(A,C) \text{ via B is: } \phi(A,B) \cdot \phi(B,C)$$

This has to be interpreted within the theoretical framework developed here. If the proximity between A and B signals the degree of substitutability between the capabilities required to produce each of those goods on a competitive basis, then, when considering a path that involves three different goods, we need to think about how adaptable the capabilities associated with product A are in terms of fulfilling the technical and production requirements of the other two goods simultaneously. Thus, the fit between the capabilities associated with three different products will be lower than the fit when dealing with just two products, since the various specificities accumulate. As the concept of joint probability dictates, as we add more and more goods to the path (i.e. as we lengthen that path), the degree of proximity will diminish (because we are adding new multiplicands that are always less than 1), which is the same thing as saying that the distance increases.

One of the fundamental features of the product space when defined as we have done here is that it does not have some of the requisite features of a Euclidean space. In a Euclidean space, the shortest distance between any two points is a straight line. If we were to carry this over to the framework being discussed here, it would mean that in order to make the transition from one good to another good that is not yet being produced, the shortest distance between the two would equate with simply beginning to produce the second good using the capabilities that are already in place.

However, in the product space, it may be the case that the shortest distance between two goods entails passing through another one.[3] Hence, it is possible to find "shortcuts" along the path leading from a given production structure towards the incorporation of a series or group of goods that are seen as being desirable by virtue of their pervasiveness and sophistication. These "shortcuts" through other products reduce the total distance that has to be covered. Consequently, in order to evaluate products in terms of the opportunities for structural change that their presence in an economy creates, it becomes necessary to explore all the different possible paths that they open up —including the direct ones (proximity between the product being evaluated and each of the other products) and the indirect ones (paths that involve various other products).

The development of new capabilities takes time, since they are cumulative. The longer the path (i.e. the less total proximity there is between the starting and ending points), the longer it will take to develop the necessary capabilities out of the ones already existing in the production structure and the more it will cost to do so.

[3] This happens, for example, when working with the matrix of proximities available in www.chidalgo.com, where the indirect path between cereals (SITC 0412) and other organic chemicals (SITC 5162) that passes through fertilizers (SITC 5629) entails greater total proximity (a shorter distance) than the direct transition.

III
Methodology

1. Developing the methodology

The methodology to be used in evaluating the different production sectors has to be such as to provide a straightforward way of updating the framework for that evaluation. Equation (1) —in sample terms— is therefore applied to the trade statistics that will be detailed below, recalculating the product space with updated data. These data will be the basic inputs for our study of pervasiveness in current paradigm.

The sophistication of products, as well as their pervasiveness, has to be assessed, since the combination of these two dimensions is what determines what sectors are of key importance. As explained earlier, the PRODY will be used as an indicator of sophistication.

As discussed in the section on the theoretical framework, the combined presence of sophistication and pervasiveness is of greater interest than those two features in isolation. In other words, proximity per se is not as useful as proximity to sophisticated goods. It is therefore important for the empirical strategy to be used to provide a way of assessing the combination of these features.

Finally, we want to assess products' strategic position in terms of the combined presence of pervasiveness and sophistication, both when taking the "direct route"

and when taking "indirect routes". In other words, we want to explore all the possible pathways that have each products as their starting point. The following indicator, which can be thought of as a succession of steps (and will be referred to as "successive steps") is proposed here:

$$\frac{\sum_j \phi_{b,j,t} S_j}{n} + \frac{\sum_j \phi_{b,j,t} \sum_{r \neq b} \phi_{j,r,t} S_r}{n(n-1)} + \frac{\sum_j \phi_{b,j,t} \sum_{r \neq b} \phi_{j,r,t} \sum_{k \neq j; k \neq b} \phi_{r,k,t} S_k}{n(n-1)(n-2)} + \ldots \quad (3)$$

where S is the indicator used to measure product sophistication (the PRODY in this case). This indicator is applied to all goods ("b") in the product space and is used to assess a good's potential in terms of the features that we have defined as being desirable. This is done by looking at both its direct proximity to the other goods ("j") and its proximity when indirect paths are taken: its proximity to goods "r" via goods "j" (the second addend) or to goods "k" via a pathway that starts at goods "j" and from there goes on to goods "r" and then jumps to good "k" and so on. This indicator can thus be used to try to measure the values associated with the direct and indirect (via other products) paths that lead from each good to highly sophisticated goods.[4]

This indicator therefore can be used to gauge the value of each good "b" in terms of all the possible paths that can be followed from that good to other products and from those other products to yet others and so on until all the goods in question have been covered, without "turning back" (i.e. without considering products that have already been passed on the path that is being explored).

Each term (which represents "each step") is multiplied by the product of the proximities between the goods located at earlier stages along the pathway (i.e. parts of the path that have already been travelled). Each successive step that can be taken away from the product being evaluated influences the indicator less and less, which reflects the idea that longer paths entail more complex adaptations of existing capabilities and greater investments of time and money.

Consequently, the "b" goods that have the highest values on this indicator will be signalling the key sectors in the world economy of today.

At each one of these steps, the number of addends rises. If "n" represents the number of goods in the product space, then that is the number of addends in the first term of the equation. In the second term (second step), however, for each of the possible first steps ("n" terms), the indicator reflects all the possible second steps ("n-1" terms, since the original good "b" would be a backward step and is therefore explicitly excluded). Therefore, the number of addends in the second term equals n(n-1). Likewise, the third term is going to include n(n-1)(n-2) addends, and so on, with the last term including n steps. This is because, at each step, for every good that could possibly be reached by taking that step, all the possible next steps are considered. We have decided to divide each term by the number of addends that it includes in order to avoid artificially inflating the influence of each successive step.

In practice, given the difficulties involved in making these calculations and the exponentially downward trend in the value of each term,[5] only the first three steps have been computed for this indicator. However, in view of that trend, it can confidently be assumed that the amount of information lost by excluding the rest of the steps is trivial.

Finally, after having calculated the product space for the years covered by this study and have computed the indicator for all the goods concerned, all that remains to be done is to group them into sectors so that a clearer picture of the results can be obtained (this point will be discussed in more detail later on). The sectors in which the highest average values are found will be the key sectors in today's economy.

In order to arrive at a fuller interpretation of the results, they can be broken down into their component attributes (pervasiveness and sophistication).

2. Limitations

This methodology does suffer from certain limitations that should be taken into account when interpreting the results that it generates.

[4] The first term of the "successive steps" indicator is similar to the strategic value indicator of Hausmann and Klinger (2006b), except that the $\Sigma\phi_{ij}$ (sum of the proximities of all the goods in the product space to good "b") quotient has been removed, since this introduces an element of relativity to the value assigned to the product that is unsuitable for our purposes.

[5] Each term provides a result equivalent, on average, to 20% of the result provided by the preceding term. Thus, the result from the third step is equivalent to only 4% of the derived from the first; if a fourth step were to be computed, the resultt would be equivalent to no more than 0.8% of that of the first step.

First of all, although the methodology can theoretically be applied both to trade in goods and trade in services, given the high level of disaggregation required in order to apply it correctly, its application is actually restricted to trade in goods (this will be explained more fully in the next section). This is a highly significant constraint, since many of the sectors in today's production systems are service sectors. Examples cited by Freeman and Pérez (1988) include software, databanks and information services.

An additional consideration is that the observation of production sectors on the basis of international trade data alone fails to pick up a number of factors or processes. This is especially true of sectors whose output is used as inputs for other sectors in the same country, since their products will not be measured directly because they are not being traded internationally. Consequently, their contribution to an economy's total output is not going to be fully reflected in the figures.

The classifications of goods (and sectors) that are used also impose certain limitations. This is partly because any product classification introduces a degree of rigidity, since it will inevitably place different types of goods under the same code. In addition, in this study we are making use of an older classification (SITC Rev. 2), which cannot properly describe new products that are just being developed and which employs a substantial degree of aggregation.

This methodology may also suffer from some weaknesses in capturing the attributes being used to identify key sectors. The PRODY is an imperfect indicator of products' sophistication, since it actually measures profits, and high profits are not always associated with high levels of sophistication (owing to the influence of protectionist policies, for example). What is more, this indicator uses the income level of the country in which a given good is produced rather than the income level of the industry that produces it. At a time when offshoring is such a common practice, the PRODY may therefore not provide a good estimate of a product's sophistication. This may also be the case for the indicator of pervasiveness used in this study.

IV
Data and sectors

The Commodity Trade Statistics Database (COMTRADE) compiles international trade statistics from all reporting countries and is the main source of the data used in this study, which covers the period 2005-2009 for 182 countries and territories. A cut-off point of a population of no less than 3 million was set, however, in order to avoid distortions due to highly specialized economies or ones that have very little influence on the global economy, and this study therefore covers 113 countries and territories. Export statistics on 765 products are reported at the four-digit level of the Standard International Trade Classification (SITC Rev. 2). In order to assess areas of productive specialization while preventing atypical figures from distorting the computations, five-year averages were used.

Information on the gross domestic product (GDP) and per capita GDP and demographic data were drawn from Penn World Table 7.0. The per capita GDP data have been adjusted on the basis of purchasing power parities (PPP) using the Geary-Khamis method at current prices. Five-year averages have been used in this case as well.

The data have been grouped into sectors in order to make it easier to interpret the results intuitively, since a list of the results for these indicators for all 765 goods would be unmanageable. It is important to bear in mind, however, that this analysis has focused on individual products rather than sectors; the classification of products by sector has been done only for the purpose of presenting the results of that analysis. Accordingly, we will refer back to products when appropriate in order to interpret the results more accurately.

An attempt was therefore made to arrive at the most "aseptic" sector classification possible (i.e. one that would have the least possible impact on the final results). To achieve this, we tried to define sectors that conform to the sections and divisions used in the SITC classification. We departed from that approach only when a somewhat different category would make it easier to understand the results.

The result was the definition of the 12 sectors shown in table 1:

TABLE 1

Sectors

No.	Sector	SITC goods included
1	Food, beverages and tobacco	Up to and including Division 12
2	Unprocessed or semi-processed raw materials	Divisions 21-43
3	Basic chemicals	Divisions 51-53
4	Pharmaceuticals	Division 54
5	Other chemicals	Divisions 55-59
6	Basic manufactures	Divisions 61-59
7	Industrial machinery	Divisions 71-74 and, at the 3-digit level, 771, 772, 773
8	Transport equipment	Divisions 78 and 79
9	Electronics	Divisions 75-77, except the products included in sectors 7 and 10
10	Scientific and medical instruments	Division 87 and, at the 3-digit level, 774
11	Armaments	Division 95
12	Miscellaneous unsophisticated manufactures	Divisions 81-85, 88 and 89, and section 9 with the exception of Division 95

Source: prepared by the author.

V
Results

The results obtained for the "successive steps" indicator, with the different products being grouped into sectors, are shown in table 2. While this classification was developed on the basis of the average values of the indicator for the goods in each sector, that figure was nearly identical to the figure obtained by ranking the sectors by the average decile for the goods making up each sector, with the first decile corresponding to the 10% of the goods with the lowest value for the indicator and the tenth decile corresponding to the highest-ranking products. Only the latter are shown in the following table in order to simplify the interpretation of the results. The key sectors, then, are those that are ranked the highest in table 2:

TABLE 2

Classification of key sectors based on the "successive steps" indicator

Sector	Average decile
Industrial machinery	7.7
Scientific and medical instruments	7.0
Pharmaceuticals	6.4
Transport equipment	6.3
Other chemicals	6.4
Basic manufactures	6.3
Basic chemicals	5.7
Miscellaneous unsophisticated manufactures	5.5
Armaments	5.0
Food, beverages and tobacco	4.6
Electronics	4.2
Unprocessed or semi-processed raw materials	3.3

Source: prepared by the author on the basis of Commodity Trade Statistics Database (COMTRADE).

It is not surprising that industrial machinery, scientific and medical instruments, and pharmaceuticals are the sectors exhibiting the greatest combined presence of sophistication and pervasiveness. To continue on with the interpretation of the results, table 3 shows the different sectors' rankings in terms of the basic indicators used to gauge pervasiveness (total proximity to the product space) and sophistication (the PRODY).[6]

TABLE 3

Sophistication and pervasiveness (PRODY and total proximity to the product space)

(Averages, by sector)

Sector	Ranking by sophistication	Ranking by pervasiveness
Pharmaceuticals	1	7
Scientific and medical instruments	2	9
Industrial machinery	3	1
Basic chemicals	4	8
Electronics	5	11
Other chemicals	6	5
Armaments	7	10
Transport equipment	8	3
Basic manufactures	9	2
Miscellaneous unsophisticated manufactures	10	4
Food, beverages and tobacco	11	6
Unprocessed or semi-processed raw materials	12	12

Source: prepared by the author on the basis of the Commodity Trade Statistics Database (COMTRADE).

[6] Actually, looking at these attributes separately provides no more than an approximation of the breakdown for the results for the aggregate indicator since, as noted earlier, the "successive steps" indicator yields results for the combination of pervasiveness and sophistication. There may therefore be slight departures from what the aggregate indicator shows and what the individual observations of these attributes indicate.

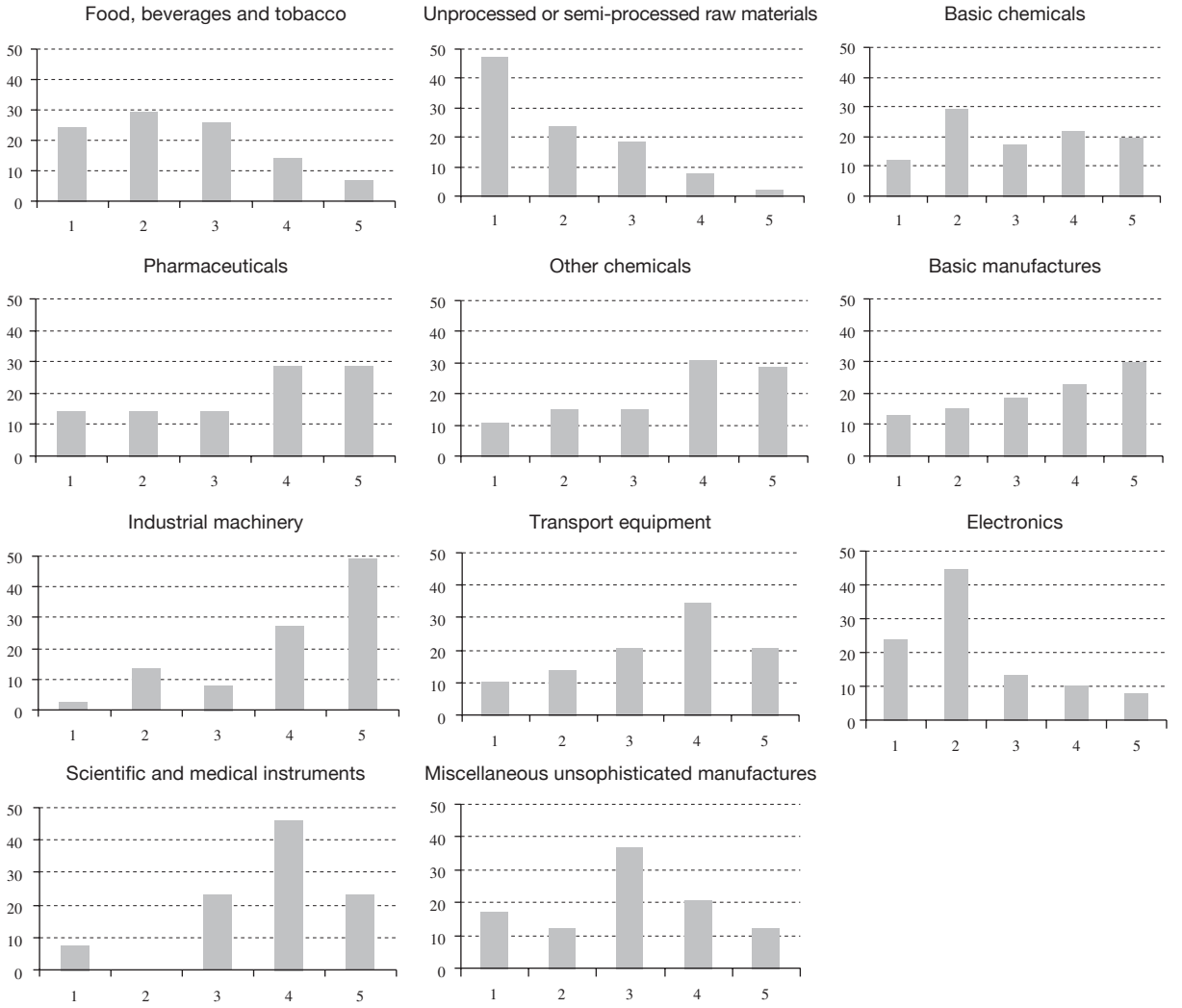
While the pharmaceuticals sector is the most sophisticated, its pervasiveness indicator is relatively low (i.e. it is profitable but requires technological capabilities that are not widespread). The situation is much the same for the sector of scientific and medical instruments. On the other hand, the industrial machinery sector is highly sophisticated (third-highest ranking) and is pervasive (top ranking). This sector therefore ranks the highest on the "successive steps" indicator and is thus clearly a key sector. Other sectors, such as basic manufactures and transport equipment, are pervasive but are fairly unsophisticated. These sectors therefore have mid-range rankings on the overall indicator.

Since these are averages for sectors that include a number of different products, the results of our computations do not provide a clear enough picture of the results for the goods making up each sector. Figure 1 plots out the distribution of the indicator for these products by quintile within each sector (except for the armaments sector, which represents a single product):

FIGURE 1

Distribution of goods within each sector, by quantile, based on the "successive steps" indicator

(Percentages)



Source: prepared by the author on the basis of Commodity Trade Statistics Database (COMTRADE).

The table shows that 50% of the goods in the industrial machinery sector are in the fifth quintile and almost no products are in the first. These results shape a very clear-cut trend towards a concentration of the component products in the higher quintiles. The situation in the sector of unprocessed or semi-processed raw materials is almost the opposite. The results for the scientific and medical instruments category are similar to those for the industrial machinery sector, but there is a greater concentration of products in the fourth quintile. A similar result, although the trend is less clear, is obtained for the transport equipment sector. Other sectors, however, such as those of basic chemicals, basic manufactures and miscellaneous unsophisticated manufactures, display a great deal of internal heterogeneity, with significant percentages of their component goods in all the quintiles. Accordingly, caution has to be used when interpreting these results. That being said, in the case of basic manufactures, a trend towards the higher quintiles is clearly discernible.

The results for the electronics sector are interesting. While this sector has an intermediate level of sophistication, its pervasiveness indicator is very low. This is a very large sector that has been heavily impacted by the trend towards a segmentation of production processes and greater use of offshoring in recent years. This trend, which has been widely commented upon in the literature (see, for example, Srholec, 2005; Lall, Weiss and Zhang, 2005), suggests (although further research would be needed) that it provides an opportunity for multinationals to set up assembly plants in countries where they have very few linkages with the surrounding economy. This kind of situation is associated with very few technological spillovers and less pervasiveness. In addition, cost-reduction strategies driven by the fierce competition that exists in this sector prompt producers to site certain links in the production chain in low-income countries, which tends to diminish the sophistication of products when measured by the PRODY.

It should be remembered that the goods in this sector are primarily final consumer products. The highly advanced electronic inputs in the industrial machinery and scientific and medical instruments categories, for example, are not included, as was discussed in the section on the shortcomings of the methodology being used for this study.

One noteworthy facet of the results is that the correlation between sophistication and pervasiveness, while positive, is quite weak. In fact, the correlation between the coefficients for the PRODY and the proximity to the product space is 0.11. This calls into question the hypothesis advanced in the product-space literature according to which there is a close relationship between the two attributes and appears to indicate that the most pervasive technologies are very mature ones.

As for the overarching interpretation of the results, at first glance it is not clear that they corroborate the presence of the ICT-based techno-productive paradigm that the neo-Schumpeterian school of thought describes as being characteristic of today's economy. An examination of the key sectors points up the fact that a number of them, such as industrial machinery (first place) or transport equipment (fourth place) and even basic manufactures (sixth place, when the results are averaged with those shown in table 2) appear to fit in with what the neo-Schumpeterians describe as the earlier techno-productive paradigm (which Freeman and Pérez (1988) call the "mass-production era"). If we narrow the focus to include only the attribute of pervasiveness, which is the main characteristic of a "key input", this is even more evident, as the classification is headed up by industrial machinery, followed by transport equipment and basic manufactures, many of which are produced by metallurgical and metal-working industries.

It should be borne in mind that the industrial machinery sector includes highly automated goods in which crucial electronic components, robotics, software and ICTs are embedded. Verspagen (2004) develops this argument and concludes that the new ICTs are more properly supplementary or complementary components rather than substitutes for their predecessors. The industrial machinery sector's position in the classification thus does not necessarily refute the hypothesis of an ICT-based paradigm; it may be a question of looking more closely at the technological applications of products rather than simply cataloguing final goods. This approach is outside the scope of the methodology being used here, however. The rankings of the scientific and medical instruments and the pharmaceutical sectors can be interpreted in the same way. This latter sector is closely linked to biotechnologies, which are commonly cited as being a fundamental component of today's production paradigm (Freeman and Pérez, 1988).

In order to take a more in-depth look at the results and gauge the degree to which they correspond to earlier theoretical constructs, an examination of the products in all the sectors that are in the tenth decile of the "successive steps" indicator is informative. The complete list is provided in annex 1, but in order to provide an idea of the situation without being overwhelmed by the sheer volume of data, table 4 list the divisions (at the two-digit level) or groups (at the three-digit level) that have at least three products in that decile.

TABLE 4

Product divisions and groups with at least three products in the tenth decile

Sector	Divisions or groups
Industrial machinery	Power-generating machinery and equipment; machinery specialized for particular industries; agricultural machinery, general industrial machinery and equipment, heating and cooling equipment and parts thereof, pumps and compressors, centrifuges
Scientific and medical instruments	None
Pharmaceuticals	None
Transport equipment	Road vehicles
Other chemicals	Polymers and copolymers
Basic manufactures	Rubber manufactures, non-metallic mineral manufactures, iron and steel, metal manufactures n.e.s.
Basic chemicals	Pigments, paints, varnishes and related products
Other unsophisticated manufactures	None
Armaments	None
Food, beverages and tobacco	None
Electronics	None
Unprocessed or semi-processed raw materials	None

Source: prepared by the author on the basis of Commodity Trade Statistics Database (COMTRADE).

n.e.s.: not elsewhere specified.

This review leads to the conclusion that, rather than witnessing a new ICT- and biotechnology-based production paradigm, what we are seeing is a mix of sectors originating in different stages of the technological revolution. There are signs of the new paradigm in the rankings of the pharmaceutical and the scientific and medical instruments sectors. A number of the products in the industrial machinery sector certainly represent examples of the electronics or robotics that make up part of the new paradigm as well. But others hark back to the previous paradigm (transport equipment, many types of industrial machinery, some chemicals), and there are also sectors that have their origins in still older paradigms (metallurgical products, for example).

This could provide some useful clues for the interpretation of the surprisingly low correlation between sophistication and pervasiveness. If the key sectors in previous paradigms continue to be centrally positioned, then they should presumably register a high degree of pervasiveness. In the case of mature technologies, however, the level of sophistication is not going to be very high. And this is precisely the situation with respect to sectors such as transport equipment, basic manufactures, and other chemicals, as shown in table 3.

As noted earlier, however, this study may also suffer from methodological constraints that prevent it from providing a clear picture of the sectoral patterns that are shaping the current paradigm. The most influential of these limitations is surely the fact that trade in services is not included in the calculations, since services are an increasingly important factor in international trade and in production.

VI
Conclusions

The results back up the concerns expressed about Latin America's recent export trends, since most of the key sectors that have been identified are far removed from commodity production sectors. Specifically, the main key sectors in the world economy are, in descending order, industrial machinery, scientific and medical instruments, and pharmaceuticals. The first of these sectors combines a high level of sophistication with a high level of pervasiveness and thus fully qualifies as what we have defined here as a key sector. The other two, however, exhibit a high degree of sophistication but no more than an intermediate degree of pervasiveness. In addition, the poor overall results for the electronics sector and the high degree of pervasiveness registered

for mature-technology categories such as the basic manufactures and transport equipment sectors indicate that what we are witnessing is not the consolidation of a new ICT-based paradigm but rather a mixture of overlapping key sectors originating in different stages of technological development that can be likened to a cross-cutting view of different geological strata. This does not necessarily mean that the posited paradigm does not exist; it may be simply that the methodology used in this study does not provide a full picture of the situation. It would appear to be the case that the level of sophistication of sectors that come to play a key role in a given technological paradigm tends to be eroded as opportunities for incremental innovations diminish and as new, radical innovations alter the trend and characteristics of economic growth. Nonetheless, these sectors remain pervasive for extended periods of time. In other words, they have lost the ability to generate windfall profits because of the effects of technological diffusion and greater competition, but they continue to play a key role in terms of the production system. These findings are in line with earlier studies (Freeman and Louça, 2001; Verspagen, 2004). This could also help to explain another striking result, which is that, while positive, the correlation between sophistication and pervasiveness is very low. While, a priori, a strong correlation was expected, this finding seems to be consistent with the other results. This suggests the possibility that a trade-off exists between sophistication and pervasiveness at certain stages in the innovation process. When radical, highly sophisticated innovations are first introduced, they are capable of generating huge profits, since they have not yet become diffused and they are therefore the domain of very few companies. There may then be a phase during which the technology become diffused but is still highly sophisticated because many incremental innovations follow in its wake. This makes it possible for firms that have mastered that technology to continue to reap large profits even while other companies, countries and production sectors are beginning to do so, which heightens the product's pervasiveness. Ultimately, as the technology becomes standardized and more diffused, and as the imitation of that technology increases, its profitability declines as does its sophistication while, at the same time, it is becoming more pervasive. It is only when new radical innovations completely overhaul existing production processes and products that older technologies will gradually become less pervasive as they are replaced by newer technologies throughout the economic system.

If production sectors that use mature technologies remain pervasive over an extended period of time, even if their degree of sophistication declines, they may offer a potential pathway for structural change in developing countries. The high degree of pervasiveness associated with these sectors may open up a pathway that leads to a gradual restructuring of these countries' production systems. This may open the way for a learning process that starts from simple, standardized technologies and progress to more and more sophisticated ones. This line of reasoning is backed up by the track record of technologically mature sectors (textiles, steel, motor vehicles) in countries that have been making major strides in their development in recent years.

These findings are a powerful argument for the development of new approaches capable of analysing the individual technologies that are embedded in different products, as distinct from studies such as this, which are based on classifications of final products. The approach used here assumes that all the products subsumed under a given SITC code are based on the same technologies, and it is therefore impossible to discern the influence that new technologies that are introduced into existing products exert on the production process or on the possibility of new and better applications or reformulations.

ANNEX

TABLE A.1

Products (SITC Rev. 2 at the 4-digit level) in the tenth decile of the successive steps indicator

Code	Description	Sector	Code	Description	Sector
8939	Miscellaneous articles of materials in Division 58	12	6997	Articles of iron or steel n.e.s.	6
8922	Newspaper, journals, periodicals, whether or not illustrated	12	6996	Misceallneous articles of base metal	6
8743	Instruments for measuring and checking flow, pressure andother variables for liquids and gases	10	6994	Springs and leaves for springs of iron, steel or copper	6
8219	Other furniture and parts, n.e.s.	12	6992	Chain and parts thereof, of iron or steel	6
8124	Lighting fixtures and fittings, lamps, lanterns and parts, n.e.s.	12	6975	Base metal indoors sanitary ware and parts thereof, n.e.s.	6
8121	Central heating equipment, not electrically heated, parts, n.e.s.	12	6954	Interchangeable tools for hand or machine tools	6
7919	Railway and tramway track fixtures and fittings and parts, signalling equipment	8	6953	Other hand tools	6
7868	Other vehicles, not mechanically propelled, parts	8	6940	Nails, screws, nuts, bolts, rivets, etc., of copper, iron or steel	6
7849	Other parts and accessories for vehicles under headings 772, 781, 782, 783	8	6924	Casks, drums, etc. of iron, steel, aluminium, for packing goods	6
7810	Passenger motor cars for transport of passengers and goods	8	6912	Structures and parts of aluminium; plates, rods and the like	6
7783	Electrical equipment for internal combustion engines and vehicles and their parts	9	6911	Structures and parts of iron and steel (hangars, bridges, buildings and their parts)	6
7493	Transmission shafts, cranks, bearing housings, etc.	7	6842	Aluminium and aluminium alloys, worked	6
7492	Taps, cocks, valves, etc. for pipes, tanks, vats, etc.	7	6794	Castings of iron or steel, in rough state	6
7449	Parts for machinery classified under section 7442	7	6785	Tube and pipe fittings, of iron and steel	6
7441	Work trucks of the type used in factories, dock areas, etc.	7	6782	Seamless tubes, pipes or iron or steel	6
7439	Parts of machinery classified under headings 7435 and 7436	7	6644	Glass, cast, rolled, etc.	6
7436	Filetering and purifying machinery, apparatus for liquids and gases	7	6635	Wool (expanding or insulating mineral materials, n.e.s.)	6
7432	Parts, n.e.s., of the pumps and compressors falling under section 7431	7	6633	Manufactures of mineral materials, n.e.s. (other than ceramic)	6
7431	Air pumps, vacuum pumps and air or gas compressors	7	6632	Abrasive powder or grain, natural or artificial	6
7429	Parts, n.e.s., of pumps and liquids elevators falling under section 742	7	6572	Bonded fibre fabrics	6
7416	Machinery, plant, laboratory equipment for heating and cooling, n.e.s.	7	6546	Fabrics of glass fibre	6
7414	Non-domestic refrigerators and refrigrerating equipment, n.e.s.	7	6424	Paper and paperboard, cut to size or shape, n.e.s.	6
7413	Industrial and laboratory furnaces and ovens, etc., parts, n.e.s.	7	6422	Correspondence stationary	6
7412	Furnace burners, mechanical stokers, etc. and parts thereof, n.e.s.	7	6289	Other articles of rubber, n.e.s.	6
7372	Rolling mills, rolls therefor and parts, n.e.s. of rolling mills	7	6282	Transmission, conveyor or elevator belts of vulcanized rubber	6
7369	Parts n.e.s. and accessories for machine-tools falling under heading 736	7	6210	Materials of rubber	6
7269	Parts n.e.s. of machines falling under headings 7263 and 7264	7	5836	Acrylic and metha-acrylic polymers; acrylo-methacrylic copolymers	5

Table A.1 (conclusion)

Code	Description	Sector	Code	Description	Sector
7247	Textile machinery n.e.s. for cleaning, cutting, etc. and parts n.e.s.	7	5834	Polyvinyl chloride	5
7224	Wheeled tractors	7	5831	Polyethylene	5
7219	Agricultural machinery and appliances, n.e.s. and parts thereof, n.e.s.	7	5824	Polyamides	5
7212	Harvesting and threshing machines	7	5542	Organic surface-active agents n.e.s.	5
7211	Agricultural and horticultural machinery for soil preparation, etc.	7	5335	Glazes, driers, putty, etc.	3
7188	Engines and motors n.e.s. (wind, hot-air engines, water wheels, etc.)	7	5334	Varnishes and lacquers; distempers, etc.	3
7169	Parts n.e.s. of roating electric plants	7	5332	Printing inks	3
7162	Electric motors, generators, generating sets	7	5162	Aldehyde, ketone and quinone-function compounds	3
7139	Piston engine parts, n.e.s., falling under the headings of 7132, 7133 and 7138	7	3345	Lubricating petroleum oils and preparations n.e.s.	2
7132	Motor vehicle piston engines under Division 78	7	913	Lard, pig and poultry fat, rendered or solvent-extracted	1
7129	Parts, n.e.s. of steam power units that come under heading 7126	7	142	Sausages and the like, of meat, meat offal or animal blood	1
6998	Articles of copper, nickel, aluminium, lead, zinc and tin n.e.s.	6			

Source: prepared by the author on the basis of Commodity Trade Statistics Database (COMTRADE).

SITC: Standard International Trade Classification.
n.e.s.: not elsewhere specified.

Bibliography

Antonelli, C. (2007), "The foundations of the economics of innovation", *Working Paper*, No. 02/007, Turin, University of Turin.

Balassa, B. (1964), "The purchasing-power parity doctrine-A reappraisal", *Journal of Political Economy*, vol. 72, No. 6, Chicago, University of Chicago Press.

Cimoli, M. (comp.) (2005), *Heterogeneidad estructural, asimetrías tecnológicas y crecimiento de América Latina* (LC/W.35), Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC)/Inter-American Development Bank (IDB).

Dalum, B., K. Laursen and B. Verspagen (1999), "Does specialization matter for growth?", *Industrial and Corporate Change*, vol. 8, No. 2, Oxford, Oxford University Press.

ECLAC (Economic Commission for Latin America and the Caribbean) (2012), *Structural Change for Equality: An Integrated Approach to Development* (LC/G.2524(SES.34/3)), Santiago, Chile.

_____ (2007), *Progreso técnico y cambio estructural en América Latina* (LC/W.136), Santiago, Chile.

Freeman, C. and F. Louça (2001), *As Time Goes By: From the Industrial Revolution to the Information Revolution*, New York, Oxford University Press.

Freeman, C. and C. Pérez (1988), "Structural crises of adjustment, business cycles and investment behavior", *Technical Change and Economic Theory*, G. Dosi and others (eds.), London, Pinter Publishers.

Hatzichronoglu, T. (1997), "Revision of the high technology sector and product classification", *OECD Science and Technology Working Papers*, No. 1997/02, Paris, OECD Publishing.

Hausmann, R. and B. Klinger (2007), "The structure of the product space and the evolution of comparative advantage", *CID Working Paper*, No. 146, Center for International Development, Harvard University.

_____ (2006a), "Structural transformation and patterns of comparative advantage in the product space", *CID Working Paper*, No. 128, Center for International Development, Harvard University.

_____ (2006b), "South Africa's export predicament", *CID Working Paper*, No. 129, Center for International Development, Harvard University.

Hausmann, R., J. Hwang and D. Rodrik (2005), "What you export matters", *CID Development Working Paper*, No. 123, Center for International Development, Harvard University.

Hidalgo, C. and others (2007), "The product space conditions the development of nations", *Science*, vol. 317, No. 5837, American Association for the Advancement of Science.

Katz, J. and G. Stumpo (2001), "Sectoral regimes, productivity and international competitiveness", *CEPAL Review*, No. 75 (LC/G.2150-P), Santiago, Chile.

Lall, S. (2000), "The technological structure and performance of developing country manufactured exports, 1985-1998", QEH *Working Papers*, No. 44, Oxford, University of Oxford.

Lall, S., J. Weiss and J. Zhang (2005), "The 'sophistication' of exports: a new measure of product characteristics", QEH *Working Papers*, No. 123, Oxford, University of Oxford.

Nelson, R. and S. Winter (1982), *An Evolutionary Theory of Economic Change*, London, The Belknap Press.

Pavitt, K. (1984), "Sectoral patterns of the technical change: towards a taxonomy and a theory", *Research Policy*, vol. 13, No. 6, Amsterdam, Elsevier.

Peres, W. and A. Primi (2009), "Theory and practice of industrial policy. Evidence from the Latin American experience", *Desarrollo Productivo series* (LC/L.3013-P), Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC). United Nations publication, Sales No. E.09.II.G.34.

Schumpeter, J. (1939), *Business Cycles: a Theoretical, Historical and Statistical Analysis of the Capitalist Process*, New York, McGraw-Hill Book Company.

Srholec, M. (2005), "High-tech export from developing countries: A symptom of technology spurts or statistical illusion?", *Working Papers on Innovation Studies*, No. 20051215, Oslo, University of Oslo.

Thirlwall, A.P. (1979), "The balance of payments constraint as an explanation of international growth rate differences", *BNL Quarterly Review*, vol. 32, No. 128, Rome, Banca Nazionale del Lavoro.

United Nations (1975), *Standard International Trade Classification (SITC) Revision 2*, Series M, No. 34/Rev. 2, New York. United Nations publication, Sales No. 75.XVII.6.

Verspagen, B. (2004), "Structural change and technology. A long view", *Revue économique*, vol. 55, No. 6, Presses de Science Po.

Does public financial support stimulate innovation and productivity? An impact evaluation

Diego Aboal and Paula Garda

ABSTRACT

This paper contributes to the empirical literature that evaluates the effects of public financial support to innovation on innovation expenditures, innovation itself and productivity in developing countries. Propensity score matching techniques and data from Innovation Surveys are used to analyse the impacts of public financial support to innovation on Uruguayan firms. The results indicate that there is no crowding-out effect of private innovation investment by public funds and that public financial support in Uruguay seems to increase private innovation expenditures. Financial support also appears to induce increased research and development expenditures and innovative sales, with these effects being greatest for service firms. Public funds do not, however, significantly stimulate private expenditures by firms that would have carried out innovation activities even in the absence of financial support.

KEYWORDS Innovations, financing, public sector, productivity, developing countries, evaluation, case studies, Uruguay

JEL CLASSIFICATION O31,O32, O38, C21

AUTHORS

Diego Aboal is the director of the Centre for Economic Research (CINVE), Montevideo, where he also conducts research, and a professor with ORT University and the Faculty of Economic Sciences and Administration of the University of the Republic, Montevideo, Uruguay. aboal@cinve.org.uy

Paula Garda is a researcher and economist at the Centre for Economic Research (CINVE), Montevideo, and at the Organization for Economic Cooperation and Development (OECD), Paris, France. pgarda@cinve.org.uy

I
Introduction

The idea that there is a need for public support to innovation, and public financial support in particular, rests on the assumption that innovation is a non-rival good (i.e. that it can be used by multiple firms) and cannot be fully protected because its output is basically knowledge (i.e. ways of producing new or improved goods or services), most of which is tacit (i.e. uncodified). Therefore, firms cannot fully internalize the return to their innovation investment. In other words, there is a problem of positive externalities for innovation. This creates a gap between the social and the private return on innovation, and consequently firms tend to underinvest relative to the social optimum.

As noted by Hall and Lerner (2010), there is evidence that imitations are not free, and in fact can cost between 50% and 75% of the original research and development (R&D) investment. This can mitigate the above-mentioned externality problem, but it persists because the returns are not fully internalized by the original investor. Moreover, this available evidence is for manufacturing. We believe the problem affects service innovations even more than those in manufacturing because service innovations rely less on codified knowledge (which can be more easily protected), and the costs of imitation are presumably lower for innovations of this type.

The argument for public financial support goes beyond the externality problem mentioned above. Even if this problem can be solved with intellectual property protection, there are other characteristics of innovation investment that justify public financial support. In particular, innovation investment is highly uncertain and the information asymmetry between the innovator and the investor could be greater than with other types of investment, leading to larger problems of moral hazard and adverse selection.[1] Therefore, credit constraints and high borrowing costs are likely to affect the level of innovation investment and consequently the amount of innovation. The intangible characteristics of services and the non-technological and relatively ad hoc characteristics of many innovations in the service sector make these problems even more challenging there than in manufacturing.

These theoretical considerations have stimulated public intervention in different countries with the objective of increasing innovation investment, innovation itself and productivity. But of course, there are a number of reasons why R&D and innovation policies more generally could fail to have positive or significant effects on productivity at the firm and aggregate level. Andrews and Criscuolo (2013) mention the following. First, R&D and innovation policies could lead to an increase in the cost of innovation (e.g. through increases in scientists' pay). Second, innovation incentives could lead to duplication or the relabelling of existing non-innovation activities as innovation activities. Third, innovation agencies may have a limited ability to direct funds to the projects with the highest impact on productivity. Finally, incentives are sometimes taken up by firms that are less likely to generate spillovers and aggregate productivity gains. The existence of these interventions and the uncertainty about their effects meant that there was a need to evaluate their impacts.

So far, most of the available empirical literature has focused on public financial support policies for R&D activities and their impact on R&D expenditures. As pointed out by Hall and Lerner (2010), the focus on R&D instead of the broader concept of innovation investment is largely due to considerations of measurement feasibility and data availability. In addition, most of the available evidence does not distinguish between manufacturing and services, and in fact most papers deal with the manufacturing sector only. The potential positive effects of public support could be even greater for services than for manufacturing, not only for the reasons given above, but also because the service sector represents more than 70% of gross domestic product (GDP) in advanced economies and more than 60% in less developed economies. Therefore, the service sector is crucial to countries' aggregate productivity and needs to be better understood. Finally, most of the studies available are for Organization for Economic Cooperation and Development (OECD) or European countries, and thus evidence is lacking for less developed economies.

☐ Financial support from the Inter-American Development Bank is gratefully acknowledged. We wish to thank Gustavo Crespi and Marcelo Perera for their comments and suggestions. Maren Vairo provided excellent research assistance. The views expressed in this paper are the author's and are not necessarily shared by OECD or its member countries.

[1] Given that the innovator has more information about the project than the investor, the innovator can use this advantage to increase his profit to the detriment of the investor.

This paper aims to help fill some of these gaps by evaluating the impact of public financial support on innovation in a developing country. Quasi-experimental methods and Innovation Survey data from Uruguay are used.

This paper contributes to the literature in three ways. First, it evaluates the effects of public financial support to innovation on innovation expenditures, innovation itself and productivity, thus extending research beyond the R&D context. Second, it analyses the possible heterogeneity of the effects on services and manufacturing. Finally, the evaluation is based on data from a developing Latin American country, where empirical evidence is scarce.

The findings showed no crowding-out effect, either full or partial, between public and private innovation expenditures. Moreover, there is evidence of a crowding-in effect and of positive effects on innovation (measured by the percentage of innovative sales). Firms that received financial support increased their ratio of R&D expenditures to total innovation expenditure relative to those that did not. There were no effects on productivity or patent applications, probably due to the short time frame in which the evaluation was conducted. We found similar, but not identical, effects when we analysed the service and manufacturing sectors separately. While there was no crowding-out effect in either sector, we found that public financial support stimulated private innovation expenditures only in manufacturing. Productivity increased in service firms. Public funds did not, however, significantly stimulate private expenditures by firms that would have carried out innovation activities even in the absence of financial support.

This paper is organized as follows. Section II discusses the available evidence on public financial support and innovation in developing countries. Section III describes the empirical strategy and data. Section IV presents the main results. Section V reports the conclusions.

II

Public financial support and innovation: the available evidence

Most of the available evidence is for developed countries and manufacturing firms, and uses R&D expenditures as the outcome variable. David, Hall and Toole (2000) extensively surveyed this literature, finding substitution effects between public and private R&D in one third of the studies analysed. More recent studies have focused mostly on matching methodologies to evaluate the crowding-out effect. With this approach, different studies have found that public financial support stimulates privately financed R&D, so the crowding-out hypothesis is rejected. Examples are Almus and Czarnitzki (2003), who use data from a survey of German manufacturing firms; Duguet (2004), who uses a pool of French R&D-performing firms; and González and Pazó (2008), who use a sample of Spanish firms to evaluate the effect of subsidies. As for the service sector, Czarnitzki and Fier (2002) found that financial support stimulated private expenditures on innovative activities by studying a panel of German service firms. However, there are no studies that we know of that allow for direct comparison of the impact that a certain policy has on the service and manufacturing sectors.

As for evidence regarding the impact of policy on innovation (rather than on R&D and innovation efforts which are inputs for innovation), Aerts and Czarnitzki (2004) found no significant effects of public support to innovation on patent applications from a survey of Flemish firms. Czarnitzki and Hussinger (2004) found that the impact on this variable was positive for a set of German manufacturing firms, and Czarnitzki, Hanel and Rosa (2011) found a positive impact on the number of new products introduced by Canadian manufacturing firms.

Evidence regarding the impact on firm performance, particularly productivity, is scarcer. Czarnitzki, Hanel and Rosa (2011) found that the impact on firms' profitability was not significant, while Wallsten (2000) found no significant impact on employment for small American high-technology firms. This may be because such policy effects often do not arise until several years after policy implementation, and thus the results may not have been observed over the short periods of analysis. On a different note, Lokshin and Mohnen (2013) found that fiscal incentives did have a positive impact on the wages of R&D workers at Dutch firms.

The evidence available for the effects of public financial support on innovation is scarce in emerging and developing countries. A few examples can be found in Crespi, Maffioli and Meléndez (2011), Hall and Maffioli (2008) and López-Acevedo and Tan (2010).

Crespi, Maffioli and Meléndez (2011) evaluated the effects of financial incentives for R&D (matching grants and contingent loans) provided by the Administrative Department of Science, Technology and Innovation (COLCIENCIAS) in Colombia on a beneficiary firm's economic performance. Using a dataset that allowed for analysis of long-term effects, the authors found that public funding from COLCIENCIAS had a significant impact on firm performance. More precisely, they found that new product introduction and labour productivity increased by about 12% and 15%, respectively, with these effects becoming more significant between three and five years after the firms began to receive the funding.

Hall and Maffioli (2008) synthesized the results of a number of evaluations of technology development funds (TDFs) in Argentina, Brazil, Chile and Panama. The authors evaluated TDF recipients using data from innovation and industrial surveys. They found that TDFs did not crowd out R&D funding from private sources and that they had a positive impact on the intensity of R&D. Also, although low-cost credit had a more positive effect than matching grants on R&D projects, suggesting that different types of financing affected firms differently, matching grants were more effective for new innovators. The authors also found that participating in a TDF resulted in a more proactive attitude towards innovation strategy. Although Argentina and Brazil were not included in this part of the study, when the authors took a firm's willingness to engage with external financing and knowledge sources as proxies for innovation strategy shifts, they found that TDFs had a positive effect on innovation. Conversely, participation in a TDF did not positively affect patent grants or new product sales, which were used as measures of innovative output, although the authors noted that the time frame may have been too short for the full effects of TDF participation in this regard to be observed. Evidence concerning the potential effects on firm performance was not uniform, with TDF participation being found to positively impact firm growth but not firm productivity. The authors argued that this could be due to the short time frame in which the evaluations were conducted, and that additional impact evaluations based on longer-term panel data were needed to shed some light on long-run effects.

López-Acevedo and Tan (2010) evaluated small and medium-sized enterprise (SME) credit programmes in Chile, Colombia, Mexico and Peru. The authors found positive gains in labour productivity, sales and employment in Chile and higher value added, sales, exports and employment in Mexico. In Colombia, the results suggested positive effects on exports, R&D investment and total factor productivity. Finally, in Peru the findings showed significant positive effects on sales and profits. Confirming the findings of Hall and Maffioli (2008), López-Acevedo and Tan (2010) noted that some of the estimated effects on firm performance did not materialize for several years.

Table A.1 in the annex summarizes the results of 26 impact evaluations.

III

The empirical strategy and data

1. The empirical strategy

The objective of this paper is to estimate the impact of public financial support on innovation expenditures, innovation itself and productivity. Since we cannot observe what would happen if the "treated" firms did not get such financial support (the counterfactual), a suitable proxy is required. Firms that did not get public financial support could be considered candidates for a comparison (or control) group; however, it is possible that these firms did not get support because of some characteristic that could also affect the outcome variables. For example, it could be more difficult for small firms to get public financial support, and we know that the size of firms affects innovation. Therefore, if the innovation performance of firms that got support is compared with that of firms that did not get support, firms that received financial support are likely to show more innovation, but this could simply be because they are bigger and not because of the public financial support.

Luckily, this problem can be circumvented by using certain assumptions. In this study, we used propensity

score matching methods.[2] The following briefly explains the rationale behind this strategy and makes some methodological decisions explicit.

One of the parameters of interest in this paper is:

$$\tau_{ATT} = E[Y(1)|D = 1] - E[Y(0)|D = 1]$$

where τ_{ATT} is the average treatment effect on the treated; $E[Y(1)|D = 1]$ is the mean value of the outcome variable $Y(1)$ (e.g. innovation investment), given that the firms received public financial support; and $E[Y(0)|D = 1]$ is the counterfactual (i.e. the expected value of outcome variable $Y(0)$) for the firms in the treatment group had they not received public financial support. D = 1 means that the firm belongs to the treatment group.

Unfortunately, we cannot observe the counterfactual. What we can observe is $E[Y(0)|D = 0]$, which in this case is mean innovation investment at firms not belonging to the treatment group (D = 0) and not receiving treatment. Of course, $E[Y(0)|D = 0]$ need not be equal to $E[Y(0)|D = 1]$, which means that a bias can be introduced into the estimation if it is used as a proxy for $E[Y(0)|D = 1]$. Note that

$$\tau_{ATT} = E[Y(1)|D = 1] - E[Y(0)|D = 1] - E[Y(0)|D = 0] + E[Y(0)|D = 0],$$

and therefore

$$E[Y(1)|D = 1] - E[Y(0)|D = 0] = \tau_{ATT} + bias,$$

where $bias \equiv E[Y(0)|D = 1] - E[Y(0)|D = 0]$. As previously noted, if firms with particular characteristics tend to be selected for the treatment group and these characteristics affect outcomes, then there will be bias. Conversely, if assignment to the two groups is completely random, such bias should not be a concern. Because this condition does not normally hold for Innovation Survey data, a further step was needed.

Assuming the differences between the treated and control groups lie in observable characteristics (e.g. firm size or capital and knowledge intensity) that are not affected by the treatment, we can proceed to find firms that are similar on these characteristics in the two groups and compare them. The identification assumption is that, given a set of observable covariates X that are not affected by treatment, potential outcomes are independent of treatment assignment, this being the unconfoundedness or conditional independence assumption. This implies that selection for the treatment group is only based on observable variables X, which can be controlled for.

Usually, X is of high dimension. Hence, to deal with this dimensionality problem, propensity scores can be balanced. We can use the Xs to estimate the probability of selection for treatment P(D = 1 | X) = P(X) —using a probit or logit model in the case of binary treatment— and use this probability to find similar firms in the two groups (treated and control).

The propensity score matching (PSM) estimator for the average treatment effect on the treated is

$$\tau_{ATT}^{PSM} = E[Y(1)|D = 1, P(X)] - E[Y(0)|D = 0, P(X)].$$

Assuming conditional (on the propensity score P(X)) independence of outcome variables with respect to treatment, this estimator is unbiased.

A further important condition for the use of PSM, besides the conditional independence assumption, is for there to be enough treated and control firms on the common support. More formally, we need $0 < P(D = 1|X) < 1$. This condition ensures that firms with the same values of X have a positive probability of being both participants and non-participants, and we avoid predicting perfectly whether a firm belongs to the control or the treatment group.

The matching algorithm used in this work is nearest neighbour matching with replacement, using a caliper of 20% of the standard deviation as suggested in the literature. We use oversampling, taking advantage of the large number of potential controls in our sample. In particular, for each treated firm, we found the five nearest neighbours (matching partners) and compared them with the treated firm.

We combined the propensity score matching with Mahalanobis metric matching over size and sectoral dummies. Hence, a treated firm is matched with the closest control firm of the same sector and similar size using the Mahalanobis distance, which is a way to determine similarity between two random multidimensional variables. It differs from the Euclidean distance, in which the correlation between random variables is taken into consideration.

2. Data

We applied the above methodology to evaluate the effects of financial support granted to Uruguayan service and manufacturing firms during the period from 2004 to 2009.

[2] See Caliendo and Kopeinig (2008) and Crespi and others (2011) for very intuitive presentations of these methods.

For this purpose, we used two rounds of the Innovation Survey: 2004-2006 and 2007-2009.

The Innovation Survey data were collected in parallel with those of the Economic Activity Survey, using the same sample and statistical framework. All firms with more than 49 workers were required to participate in these surveys. Firms with 20 to 49 employees and those with fewer than 19 were selected using simple random sampling within each economic sector at the International Standard Industrial Classification of All Economic Activities (ISIC) two-digit level up to 2005. From that point forward, random strata were defined for units with fewer than 50 workers within each economic sector at the ISIC four-digit level.

We matched the Innovation Surveys with the 2004 and 2007 Economic Activity Surveys because we needed information on firms' size at the beginning of the period, capital (fixed assets) and productivity. To avoid endogeneity problems associated with size, capital and productivity, we used these variables at the beginning of the period. All the other variables used in the empirical exercise came from the Innovation Survey. When matching was carried out with the Economic Activity Survey, some firms were lost because of sampling problems, so that the sample size was reduced when data collected from the Economic Activity Survey were used.

To reduce the loss of observations and recover the information for the missing variables at the beginning of the period in each survey, we used an imputation procedure based on a regression between log size (t - 1) and age and sectoral dummies. We used this regression to predict size at (t - 1) for the missing observations. The same was done for capital stock and productivity. Note that this technique uses the information available at the beginning of the survey period, not the end, to avoid interaction between causal effects. However, for the sake of robustness, we presented the results with the reduced sample (i.e. without the imputation procedure).

For the service sector, the final number of firms included in the Innovation Survey was 1,868, with 885 being from the first survey and 983 from the second. For the manufacturing sector, the final number of included firms was 1,727, with 816 from the 2004-2006 survey and 911 from the 2007-2009 survey.

The treatment variable was financial support. The treatment group comprised those firms that received financial support. We considered a firm to be financially supported if it received some financial support from the public sector in the period of reference. The survey includes information on financial support to innovation received from the public sector, excluding public firms from the definition of the public sector. The Innovation Survey asks firms what percentage of innovation expenditure came from public sources. Therefore we know not only whether the firm received public financial support, but the amount of this support. In Uruguay, financial support is given mostly in the form of subsidies (matching grants). R&D tax credits did not exist in the period considered in this research. Table A.2 in the annex shows the characteristics of some of the programmes supporting innovation in Uruguay.

In the first instance, we evaluated the effect of financial support on the innovation expenditure effort (expenditures on innovation over sales). Total innovation expenditures comprised investment in design, installation of machinery, industrial engineering, embodied and disembodied technology, marketing and training (we were able to distinguish between total and private innovation expenditures). Then, we analysed the effect of financial support on R&D expenditures (both internal and external) over innovation expenditure, the share of innovative sales, patent applications and productivity. Productivity was defined as the logarithm of sales over total employment.

Table 1 reports the number of firms in each sector, divided into knowledge-intensive business services and traditional services, or high-technology and low-technology manufacturing sectors. Manufacturing-sector firms tend to invest more in innovation activities than service firms. The high-technology sector innovates the most, followed by knowledge-intensive business service sectors. The third column of the table shows the manufacturing bias of innovation policies. While more than 4% of the manufacturing firms received public financial support during 2004-2009, only 2% of the service firms obtained financial support.

Table 2 reports the innovation effort (innovation expenditures divided by sales) of firms with and without financial support. On average, firms in the manufacturing sector invested more in innovation activities than firms in the service sector. One fact to highlight is that in the manufacturing sector the private effort made by firms with financial support (column 2) was considerably greater than the effort by firms with innovation activities but without financial support (column 4). The difference averaged 0.9 percentage points for manufacturing firms, with the gap being largest in the high-technology sector at 1.77 percentage points. In the service sector, conversely, the private effort was smaller among firms

receiving financial support than among those undertaking innovation activities without financial support, by an average of 0.7 percentage points. This difference was driven by traditional service firms. Knowledge-intensive business services with financial support made a larger private effort than those without it (a gap of 2.65 percentage points).

These raw data lead us to conclude that a crowding-out effect could exist in the service sector, but not in the manufacturing sector. Our empirical strategy seeks to disentangle whether this effect arises because public financial support tends to be directed to firms in the manufacturing sector that invest more rather than to firms in the service sector with poor innovation performance. This will be done by comparing firms with a similar likelihood of obtaining financial support.

Finally, table 3 presents the means of the selected matching variables for the control and treatment groups by sector. Firms in the treatment group tend to be larger than those in the control group. Also, firms in the treatment group tend to have obtained more patents than those in the control group. Firms in the treatment group tend to be located in Montevideo (the capital of the country), belong to networks, and have more outlets. With respect to age and ownership status, there are no clear differences.

TABLE 1

Firms with innovation activities and financial support, 2004-2009
(Number of observations and percentages)

	Observations	Proportion with innovation activities	Proportion with financial support
Services	1 868	38.5	2.1
Knowledge-intensive business services	628	42.0	1.9
Traditional services	1 240	36.7	2.3
Manufacturing	1 727	42.3	4.2
High-technology	399	52.4	5.8
Low-technology	1 328	39.3	3.7

Source: prepared by the authors on the basis of the 2004-2006 and 2007-2009 Innovation Surveys conducted in Uruguay.

TABLE 2

Average innovation effort at firms with and without financial support, 2004-2009
(Percentages)

	With support		Without support	
	Total	Private	All	IE > 0
Services	6.37	3.62	1.61	4.33
Knowledge-intensive business services	9.77	6.93	1.75	4.28
Traditional services	4.91	2.21	1.54	4.35
Manufacturing	7.50	5.05	1.66	4.16
High-technology	6.27	5.07	1.64	3.30
Low-technology	8.08	5.04	1.67	4.50

Source: prepared by the authors on the basis of the 2004-2006 and 2007-2009 Innovation Surveys conducted in Uruguay.
IE = innovation expenditure.

TABLE 3

Mean comparison of firms with and without financial support on selected controls
(Numbers and percentages)

	Services		Knowledge-intensive business services		Traditional services	
	With	Without	With	Without	With	Without
Size (log employees)(t - 1)	4.48	3.85	4.11	3.87	4.64	3.84
Foreign-owned[a]	7.5	10.4	16.7	13.8	3.6	8.7
Age (years)	23.9	18.3	11.6	13.7	29.4	20.7
Patents obtained[a]	5.0	1.2	8.3	1.3	3.6	1.2
Network[a]	30.0	19.9	50.0	18.3	21.4	20.6
Group[a]	15.0	15.6	16.7	16.2	14.3	15.3
Outlets	4.7	3.9	1.6	1.4	6.0	5.1
In Montevideo[a]	85.0	74.3	100.0	87.2	78.6	67.8
	Manufacturing		High-technology		Low-technology	
	With	Without	With	Without	With	Without
Size (log employees)(t - 1)	4.24	3.80	4.09	3.56	4.30	3.87
Foreign-owned[a]	9.7	11.5	8.7	17.3	10.2	9.9
Age (years)	32.29	25.56	35.96	28.01	30.57	24.84
Patents obtained[a]	2.8	2.7	0.0	3.2	4.1	2.5
Network[a]	16.7	7.9	17.4	10.1	16.3	7.2
Group[a]	18.1	13.2	8.7	16.0	22.4	12.4
Outlets	1.85	1.74	1.57	1.60	1.98	1.79
In Montevideo[a]	83.3	78.0	91.3	87.0	79.6	75.4

Source: prepared by the authors on the basis of Innovation Surveys (2004-2006 and 2007-2009) conducted in Uruguay.
[a] Percentages.

IV
Results

Initially, the results for the complete sample of firms, including both manufacturing and service-sector firms, are presented together. To reduce endogeneity issues, the strategy is to match observations according to their pre-treatment behaviour. With this objective, the variables worked with are size, capital per worker and productivity at t - 1.

We also present results dividing the sample into manufacturing and service sector firms. We used two different groups of observations to select the controls for the average treatment effects on the treated estimator. First, we used the full sample, including observations for firms both with and without innovation expenditures. Second, we restricted the sample to observations with innovation activities. In the first case, we took into account the potential effect of financial support on the inducements to undertake innovation activities. In the second, we evaluated the stimulus of financial support for the effort, considering that all supported firms would have performed innovation activities in the absence of support.

1. Complete sample results

In the first stage, we investigated factors that influence the probability of receiving public financial support. The dependent variable took the value 1 if the firm received public funding and 0 if it did not. Table 4 displays marginal effects after probit estimation. The first column takes all firms as the possible control group, while the second column is restricted to firms that reported positive innovation expenditures.

The vector of explanatory variables includes firm characteristics that may influence the probability of getting public funds. We included firm size in a quadratic form, measured as the logarithm of the number of employees at

TABLE 4

Estimation of propensity scores

	(1) All firms	(2) Innovative firms only
Size(t - 1)	0.0408***	0.0663*
	(0.0147)	(0.0374)
Size(t - 1) squared	-0.00292*	-0.00499
	(0.00160)	(0.00396)
Foreign-owned	-0.0163***	-0.0405***
	(0.00588)	(0.0156)
Age	-0.000182	-0.000475
	(0.000287)	(0.000693)
Age squared	2.54e-06	6.49e-06
	(2.66e-06)	(6.22e-06)
Patents obtained	0.0129	-0.00653
	(0.0222)	(0.0327)
K/L(t - 1)	-0.000361	-6.85e-05
	(0.00252)	(0.00532)
Productivity(t - 1)	0.00315	-0.00434
	(0.00362)	(0.00898)
Network	0.0123	0.00562
	(0.00891)	(0.0173)
Group	0.000225	-0.00245
	(0.00818)	(0.0193)
Outlets	-6.75e-05	-0.000243
	(0.000152)	(0.000452)
Montevideo	0.00814	0.0181
	(0.00638)	(0.0163)
Industry dummies	Yes	Yes
Observations	2 914	1 382
Log likelihood	-423.1	-356.4

Source: prepared by the authors on the basis of Innovation Surveys (2004-2006 and 2007-2009) and Economic Activity Surveys conducted in Uruguay.

Note: standard errors in parentheses. *** $p < 0.01$; * $p < 0.1$.

t - 1, age (as a proxy for experience), a dummy variable for foreign ownership (when firms were more than 10% foreign-owned), capital intensity (measured as fixed assets per worker) and productivity at t - 1. We also included dummies indicating whether the firm had obtained patents in the period of reference (as a proxy for past innovation effort), whether it belonged to a network or to a group of firms, whether it was located in Montevideo, how many outlets it had and how old it was, plus the quadratic form. The dummy for patents obtained is meant to control for persistence in innovation, since obtaining a patent is a long process and when a patent is obtained it is probably a consequence of past innovations. Finally, we included 33 sectoral dummies (at the two-digit level).

The results show that the most important determinant of the probability of receiving public funds is size: the larger the firm, the higher its probability of receiving public funds. Conversely, being foreign-owned decreases the probability of receiving public funds for innovation. These were the only two significant variables (with the exception of some sectoral dummies).

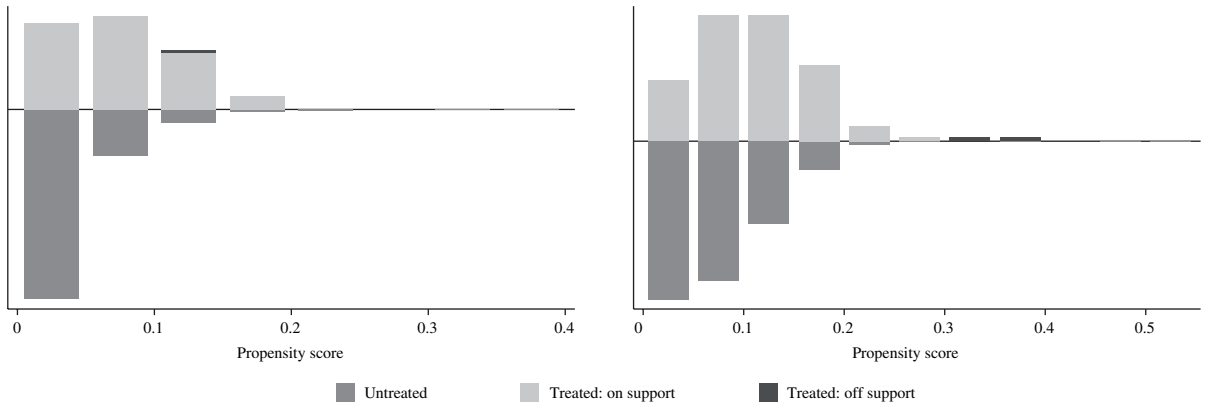
In accordance with our empirical strategy, the matching was done using the propensity score calculated. Hence, some important assumptions needed to be validated. The first requirement was to check the common support or overlap condition. For this purpose, we performed a visual analysis of the density distribution of the propensity scores in the two groups.

Figure 1 shows the propensity scores calculated for the treated and control groups. Observations are more left-skewed in the control group than in the treatment group, but a comparison of the minimum and maximum propensity scores leads to the conclusion that there is significant overlap. When firms with positive innovation expenditures are considered, some firms are found to be off common support. We restricted the estimation to the propensity score region of common support.

Finally, since we did not condition on all covariates but on the propensity score, it was necessary to check whether the matching procedure was balancing the distribution of the relevant variables in both the control and the treatment groups.

FIGURE 1

Propensity scores of treated firms and potential controls for all firms (left panel) and firms with positive innovation expenditures only (right panel)



Source: prepared by the authors on the basis of Innovation Surveys (2004-2006 and 2007-2009) and Economic Activity Surveys conducted in Uruguay.

In table 5, the treated group appears to be different from the potential control groups on some relevant variables before the matching, but similarity between the treated and control groups is achieved after the matching. Table 5 also shows that the differences were significantly reduced and were not statistically significant.

Table 6 reports the results for the average treatment effect, considering the following performance variables: investment expenditures, private innovation effort, the share of R&D in innovation expenditures, the share of innovative sales, patent applications and (log) productivity.

TABLE 5

Mean comparison of financially supported and non-supported firms on selected variables, before and after matching

Variable		All firms in the potential control group						Potential control group with positive innovation expenditure					
		Mean				t-test		Mean				t-test	
		Treated	Control	% bias	% reduct bias	t	p > t	Treated	Control	% bias	% reduct bias	t	p > t
Size	Unmatched	4.34	3.84	46.2		4.69	0.00	4.34	4.08	23.4		2.27	0.02
	Matched	4.35	4.28	6.5	85.9	0.52	0.61	4.37	4.28	7.7	66.8	0.61	0.54
Foreign-owned	Unmatched	0.090	0.107	-5.8		-0.58	0.56	0.09	0.16	-20.7		-1.90	0.06
	Matched	0.091	0.146	-18.6	-221	-1.26	0.21	0.09	0.18	-25.3	-22	-1.77	0.08
Age	Unmatched	29.342	21.816	33.7		3.90	0.00	29.15	24.80	18.6		1.98	0.05
	Matched	29.491	27.513	8.8	73.7	0.64	0.52	29.51	28.05	6.3	66.4	0.45	0.65
Patents obtained	Unmatched	0.04	0.02	11.5		1.43	0.15	0.04	0.04	0.3		0.03	0.98
	Matched	0.04	0.03	6	47.5	0.41	0.69	0.04	0.04	-0.5	-50.5	-0.03	0.98
K/L	Unmatched	0.634	0.620	1		0.08	0.94	0.64	0.73	-5.1		-0.40	0.69
	Matched	0.639	0.686	-3.3	-236.6	-0.34	0.73	0.65	0.80	-8.3	-62.7	-0.93	0.35
Productivity t - 1	Unmatched	13.738	13.361	36.1		3.59	0.00	13.74	13.67	6.5		0.63	0.53
	Matched	13.746	13.739	0.7	98	0.05	0.96	13.75	13.91	-15.5	-138	-1.18	0.24
Network	Unmatched	0.21	0.16	12		1.31	0.19	0.20	0.22	-5.6		-0.55	0.58
	Matched	0.209	0.141	17.6	-46.6	1.32	0.19	0.206	0.195	2.5	54.3	0.19	0.85
Group	Unmatched	0.171	0.147	6.6		0.70	0.48	0.165	0.200	-8.9		-0.87	0.39
	Matched	0.173	0.169	1	85.4	0.07	0.95	0.168	0.221	-13.7	-54.4	-0.96	0.34
Outlets	Unmatched	2.883	2.781	0.5		0.04	0.97	2.917	3.982	-3.9		-0.29	0.77
	Matched	2.90	2.27	3.3	-518.4	0.80	0.42	2.94	2.24	2.6	34.2	0.89	0.38
In Montevideo	Unmatched	0.847	0.757	22.6		2.18	0.03	0.853	0.796	15.1		1.44	0.15
	Matched	0.845	0.783	15.7	30.8	1.17	0.24	0.850	0.783	17.8	-18	1.26	0.21

Source: prepared by the authors on the basis of Innovation Surveys (2004-2006 and 2007-2009) and Economic Activity Surveys conducted in Uruguay.

The results show that financial support had a stimulating effect on both private and total innovation expenditures. Financially supported firms invested 4.5% more of their sales in innovation than non-supported firms. This result indicates that not only is there no crowding-out effect, but that firms invested more from their own budgets.

Financially supported firms spent 8% more of their innovation expenditures on R&D than control firms. This result was expected since financial support is usually directed to R&D. It should be recalled that this sample includes all potential firms in the control group (i.e. it includes firms that may have zero innovation expenditures). Hence, this result can be interpreted as public financial support having inducement effects on innovation activities.

Receiving financial support significantly increased the share of innovative sales relative to firms in the control group.

Finally, receiving financial support had no statistically significant effect on productivity. This result is not surprising since we were looking at a very short time horizon, and effects on productivity can become apparent only much later. Probably for the same reason, the results show that there was no statistical effect on patent applications in the current period.

Table 7 presents the results for firms with positive investment only. They show that financial support had no stimulating effect on private investment, indicating that there was no crowding-in effect. Firms added the amount of subsidies to their private investment, not replacing private investment with public funds, but also not increasing their private innovation investment. The results show that financially supported firms made larger R&D investments. On the other hand, there were no significant effects on the share of innovative sales, patent applications or productivity.

TABLE 6

Financial support effects

Dependent variable	(1) Innovation expenditure effort	(2) Private effort	(3) R&D[a]	(4) Innovative sales[b]	(5) Patent applications	(6) Productivity
ATT	4.492***	1.922**	8.242***	14.63***	0.0268	0.123
	(1.230)	(0.850)	(2.643)	(4.306)	(0.0263)	(0.0990)
Treated group	110	110	110	110	110	110
Off support	1	1	1	1	1	1
Potential control group	2 803	2 803	2 803	2 803	2 803	2 803

Source: prepared by the authors on the basis of Innovation Surveys (2004-2006 and 2007-2009) and Economic Activity Surveys conducted in Uruguay.

[a] Share of innovation expenditures that is R&D.
[b] Share of sales due to innovation.
Note: bootstrapped standard errors in parentheses. 100 replications *** $p < 0.01$; ** $p < 0.05$.

TABLE 7

The effects of financial support on firms with positive innovation expenditure

	(1) Innovation expenditure effort	(2) Private effort	(3) R&D[a]	(4) Innovative sales[b]	(5) Patent applications	(6) Productivity
ATT	2.531**	-0.107	5.427*	6.436	0.00561	-0.0151
	(1.055)	(0.937)	(3.005)	(3.928)	(0.0250)	(0.100)
Treated group	107	107	107	107	107	107
Off support	2	2	2	2	2	2
Potential control group	1 273	1 273	1 273	1 273	1 273	1 273

Source: prepared by the authors on the basis of Innovation Surveys (2004-2006 and 2007-2009) and Economic Activity Surveys conducted in Uruguay.

[a] Share of innovation expenditure that is R&D.
[b] Share of sales due to innovation.
Note: bootstrapped standard errors in parentheses. 100 replications ** $p < 0.05$; * $p < 0.1$.

To check the robustness of our results, we used the same methodology but without applying the imputation procedure. In this case, the treatment group comprised 80 firms, compared with 109 firms when the imputation procedure was used. The results shown in tables A.3 and A.4 of the annex indicate that the findings were robust to the imputation procedure. Quantitative results were very similar, with the exception of the results for R&D, where the impact was smaller when the imputation procedure was not followed.

To summarize, the conclusion from the results is that private funds were not crowded out by public funds. Also, public financing in Uruguay seems to induce some increase in private innovation effort, R&D and innovation expenditures, and has positive effects on sales derived from innovation. However, public funds do not seem to significantly stimulate private expenditures by firms that would have carried out innovation activities in the absence of subsidies. Finally, there were no effects on patent applications and productivity, probably because of the short time period in which the evaluation was conducted. In what follows, we distinguish between the service and manufacturing sectors.

2. Results for the service and manufacturing sectors

Because of the heterogeneities between service and manufacturing firms, and thence the different impact that financial support could have on each sector, this section presents results for the manufacturing and service sectors separately.

Table 8 reports the marginal effects of the probability of receiving public financial support. Size is still a very important determinant in the service sector, more than in the manufacturing sector. When the sample is restricted to firms that show positive innovation expenditures, size becomes statistically insignificant. In the manufacturing sector, being foreign-owned negatively affects the probability of being financially supported, while no other variable seems to have statistically significant effects on probability, except some of the sectoral dummies.

TABLE 8

Propensity score estimates

Control group	Services		Manufacturing	
	(1)	(2)	(3)	(4)
	All	IE > 0	All	IE > 0
Size(t - 1)	0.00801***	0.0175***	0.0194***	0.0116
	(0.00212)	(0.00629)	(0.00682)	(0.0124)
Foreign-owned	-0.00714	-0.0249	-0.0357**	-0.0545**
	(0.00674)	(0.0190)	(0.0144)	(0.0270)
Age	-0.000133	-0.000621	-4.91e-05	0.000109
	(0.000282)	(0.000816)	(0.000701)	(0.00119)
Age squared	9.31e-07	4.29e-06	4.08e-06	5.32e-06
	(2.37e-06)	(6.38e-06)	(7.02e-06)	(1.16e-05)
Patents obtained	0.0243	0.0204	-0.00501	-0.0408
	(0.0338)	(0.0515)	(0.0365)	(0.0408)
K/L(t - 1)	3.34e-05	2.85e-05	-0.00756	-0.00822
	(0.000974)	(0.00262)	(0.00873)	(0.0138)
Productivity(t - 1)	0.00326	0.00427	0.00385	-0.0158
	(0.00313)	(0.00862)	(0.00897)	(0.0172)
Network	0.00576	-0.00558	0.0298	0.0209
	(0.00732)	(0.0168)	(0.0253)	(0.0335)
Group	-0.00492	-0.0150	0.0110	0.0209
	(0.00631)	(0.0185)	(0.0222)	(0.0372)
Outlets	-7.17e-05	-0.000261	-0.00238	-0.00335
	(0.000121)	(0.000425)	(0.00339)	(0.00563)
Montevideo	0.00954*	0.0267	0.00308	0.00826
	(0.00557)	(0.0167)	(0.0176)	(0.0291)
Industry dummies	Yes	Yes	Yes	Yes
Observations	1 758	684	1 156	698
Log likelihood	-167.1	-135.1	-255.6	-218.9

Source: prepared by the authors on the basis of Innovation Surveys (2004-2006 and 2007-2009) and Economic Activity Surveys conducted in Uruguay.

Note: IE = innovation expenditure. Standard errors in parentheses. *** p < 0.01; ** p < 0.05; * p < 0.1.

Tables A.5 and A.6 and figures A.1 and A.2 in the annex report the balance test results for the covariates in the treatment and control groups and the estimated propensity score (to check for common support). The results are satisfactory, showing that, after matching, the hypothesis that the mean of the covariates in the control and treatment groups is equal in the sample cannot be rejected. Also, the conclusion from analysis of the estimated propensity scores is that there is significant overlap.

Table 9 shows the effects of financial support on the financially supported firms in the service and manufacturing sectors. The results show that financial support stimulated both private and total investment in the manufacturing sector. Financially supported firms invested 2% more of their sales in innovation than non-supported firms. This result indicates that not only does no crowding-out effect exist, but that financial support increases private innovation investment. In the service sector, conversely, the mean of private innovation effort is positive but not significantly different from zero, while total investment is higher for treated firms. This also signals that there is no crowding-out effect and that instead firms add the amount of the support to their private investment. This led us to conclude that there was no crowding-out effect in either sector and that for the manufacturing sector there was evidence of a positive effect on private investment.

R&D investment as a proportion of innovation expenditures was higher at treated firms, in both the service and manufacturing sectors. Innovative sales were higher at financially supported firms than at control firms in both sectors. Innovative sales were 20% higher than for control firms in the service sector, compared with 9% in the manufacturing sector. Productivity was higher at financially supported firms in the service sector, while in the manufacturing sector this effect was negative, though not statistically significant. The first result was unexpected given the short time frame of the evaluation.[3] Finally, there were no significant effects on patent applications.

When the sample is restricted to firms with positive innovation expenditures (table 10), the mean difference in private effort between the treated and control groups was not statistically significant in either sector. This means that public financial support had no crowding-out effect. Also, there was no stimulating effect on total innovation expenditures, R&D expenditures as a proportion of innovation expenditures, patent applications or private effort. Further, the effects on innovative sales and productivity were not significant.

To summarize, when the differential impact of financial support in the service and manufacturing sectors was analysed, the results led us to conclude that public funds did not crowd out private funds in either sector, but that there were no effects on firms that would have carried out innovation activities in any case.

[3] The recent literature has suggested alternative hypotheses for the failure of innovation policy to affect productivity. See the introduction for some of these. We are grateful to an anonymous referee for pointing this out.

TABLE 9

The effects of financial support on supported firms

Dependent variable	(1) Innovation expenditure effort	(2) Private effort	(3) R&D[a]	(4) Innovative sales[b]	(5) Patent applications	(6) Productivity
Service sector	4.370**	1.490	8.753*	20.73***	0.0632	0.366**
	(1.815)	(1.223)	(4.969)	(7.287)	(0.0487)	(0.178)
Treated group	38	38	38	38	38	38
Off support	1	1	1	1	1	1
Potential control group	1 758	1 758	1 776	1 775	1 777	1 778
Manufacturing sector	4.402**	1.951*	6.704**	9.924*	-0.0139	-0.0102
	(1.999)	(1.159)	(3.303)	(5.240)	(0.0224)	(0.110)
Treated group	72	72	72	72	72	72
Off support	0	0	0	0	0	0
Potential control group	1 156	1 156	1 157	1 156	1 158	1 159

Source: prepared by the authors on the basis of Innovation Surveys (2004-2006 and 2007-2009) and Economic Activity Surveys conducted in Uruguay.

[a] Share of innovation expenditure that is R&D.

[b] Share of sales due to innovation.

Note: bootstrapped standard errors in parentheses. 100 replications. *** p < 0.01; ** p < 0.05; * p < 0.1.

TABLE 10

The effects of financial support on supported firms with positive innovation expenditures

	(1)	(2)	(3)	(4)	(5)	(6)
	Innovation expenditure effort	Private effort	R&D[a]	Innovative sales[b]	Patent applications	Productivity
Service sector	2.866	-0.0910	4.364	6.341	0.0288	0.230
	(1.908)	(1.227)	(5.793)	(8.986)	(0.0615)	(0.174)
Treated group	38	38	38	38	38	38
Off support	0	0	0	0	0	0
Potential control group	684	684	684	684	684	684
Manufacturing sector	3.005	0.501	3.912	4.585	-0.0435	0.00676
	(1.899)	(1.287)	(3.662)	(4.955)	(0.0333)	(0.125)
Treated group	69	69	69	69	69	69
Off support	2	2	2	2	2	2
Potential control group	698	698	698	698	698	698

Source: prepared by the authors on the basis of Innovation Surveys (2004-2006 and 2007-2009) and Economic Activity Surveys conducted in Uruguay.

[a] Share of innovation expenditure that is R&D.
[b] Share of sales due to innovation.

V
Conclusion

This paper evaluates the impact of public financial support to innovation using quasi-experimental methods and Innovation Survey data from Uruguay for the manufacturing and service sectors. It contributes to the literature in three ways. First, it presents an evaluation of the impact of public financial support to innovation on innovation expenditures. The analysis is therefore extended beyond the R&D context. Second, it analyses the possible heterogeneity of effects on services and manufacturing. Finally, the evaluation is for a developing Latin American country where the empirical evidence is scarce.

On the basis of the results, we conclude that public funds do not crowd out private funds and that public financing in Uruguay seems to induce some increase in private innovation effort. Moreover, financial support induces some increase in R&D expenditures as a proportion of innovation expenditures and in innovative sales. However, public funds do not significantly stimulate private expenditures by firms that would have carried out innovation activities in the absence of financial support.

From analysing the differential impact of financial support in the service and manufacturing sectors, we conclude that public funds are not crowding out private funds in either sector, but that there is a crowding-in effect at manufacturing firms. The positive impact of public funding on R&D and innovative sales is larger in the service sector than in manufacturing. An unexpected (given the short time frame of the evaluation) positive effect of public funding on productivity was found for service firms.

When the control group was restricted to firms that innovated, the above-mentioned positive effects vanished. This implies that the positive impact is probably an inducement effect (i.e. firms are induced to innovate thanks to the public funding).

These results call for a rethink of public innovation policy. There is evidence that public financial support is biased towards manufacturing firms, but the results show that the positive effects could be even bigger for service firms. This finding raises the question of how public funds are and should be targeted on the service sector.

Finally, more research is needed on the relative effectiveness of different innovation support instruments. Such research could help with the effort to target instruments wherever they would have the biggest impact.

ANNEX

TABLE A.1

Summary of available evidence

Author(s)	Country	Policy measure	Outcome variable(s) and impact	Data source	Method
Aerts and Czarnitzki (2004)	Belgium (Flanders)	Financial support	R&D expenditure (net of subsidy): + Patent applications: n.s.	Community Innovation Survey 3 (1998-2000) linked to other data resources for patents and financial statements *Unit of analysis*: manufacturing, computer services, R&D services and business-related services firms	Non-parametric matching
Almus and Czarnitzki (2003)	Germany (eastern)	All public R&D schemes	R&D expenditure (net of subsidy): +	Innovation panel (1995, 1997, 1999) *Unit of analysis*: manufacturing firms	Non-parametric matching
Avellar (2011)	Brazil	Fiscal incentives	R&D expenditure (net of subsidy): + Expenditure on innovative activities (net of subsidy): +	Innovation Survey (2006-2008) *Unit of analysis*: all firms	Non-parametric matching
		Financial support	R&D expenditure (net of subsidy): + Expenditure on innovative activities (net of subsidy): +		
Bloom, Griffith and Van Reenen (2002)	Australia, Canada, France, Germany, Italy, Spain, United Kingdom and United States	Fiscal incentives	R&D expenditure: +	Panel with tax information from national sources and R&D expenditure at the country level from OECD database (1979-1997) *Unit of analysis*: national manufacturing sectors	Instrumental variables with fixed effects
Busom (2000)	Spain	Financial support	R&D expenditure (net of subsidy): + R&D personnel: +	Innovation Survey (1988) *Unit of analysis*: all firms	Heckman's selection model (1979)
Crespi, Maffioli and Meléndez (2011)	Colombia	Financial support and promotion of research alliances	Product innovation: + Labour productivity: +	Industrial, innovation and administrative panel (1995-2007) *Unit of analysis*: manufacturing firms	Fixed effects
Czarnitzki (2002)	Germany	Financial support	R&D expenditure: +	Innovation panel (1994, 1996, 1998), database with credit information from a credit rating agency and patenting activity from the national patent office *Unit of analysis*: manufacturing SMEs	Tobit model
Czarnitzki and Fier (2002)	Germany	Financial support	Expenditure on innovative activities (net of subsidy): +	Innovation panel (1997, 1999) *Unit of analysis*: service firms	Non-parametric matching
Czarnitzki, Hanel and Rosa (2011)	Canada	Fiscal incentives	Number of new products: + Sales of new products: + Profitability: n.s. Domestic market share: n.s. International market share: n.s. Enabled to keep up with competitors: n.s.	Innovation Survey (1999) *Unit of analysis*: manufacturing firms	Non-parametric matching
Czarnitzki and Hussinger (2004)	Germany	Financial support	R&D expenditure (net of subsidy): + Patent applications: +	Innovation panel, public information on R&D funding, database with credit information from a credit rating agency and patenting activity from the national patent office *Unit of analysis*: manufacturing firms	Non-parametric matching to estimate the policy effect on R&D expenditure and probit model to estimate the effect of R&D on patent applications
Duguet (2004)	France	Financial support	R&D expenditure (net of subsidy): +	R&D surveys and fiscal information on firms (1985-1997) *Unit of analysis*: all firms	Non-parametric matching
González, Jaumandreu and Pazó (2005)	Spain	Financial support	Decision to invest in R&D: + R&D expenditure (net of subsidy): +	Entrepreneurial panel (1990-1999) *Unit of analysis*: manufacturing firms	Tobit model

Table A.1 (continued)

Author(s)	Country	Policy measure	Outcome variable(s) and impact	Data source	Method
González and Pazó (2008)	Spain	Financial support	R&D expenditure (net of subsidy): +	Entrepreneurial panel (1990-1999) *Unit of analysis*: manufacturing firms	Non-parametric matching
Görg and Strobl (2007)	Ireland	Financial support	R&D expenditure (net of subsidy): n.s.	Entrepreneurial panel and public database on R&D grants (1999-2002) *Unit of analysis*: manufacturing firms	Difference in differences with non-parametric matching
Hall (1993)	United States	Fiscal incentives	R&D expenditure (net of subsidy): +	Entrepreneurial panel (1980-1991) *Unit of analysis*: manufacturing firms	Instrumental variables
Hall and Maffioli (2008)	Argentina (1994-2001)	Financial support	R&D expenditure (net of subsidy): +	Innovation panel (1995-2001) *Unit of analysis*: all firms	Instrumental variables with fixed effects
	Argentina (2001-2004)		R&D expenditure: + Sales of new products: n.s. Sales growth: n.s. Employment growth: n.s. Export growth: n.s. Productivity growth: n.s.	Innovation panel (2002-2004) *Unit of analysis*: all firms	Difference in differences with non-parametric matching
	Brazil (1996-2003)		R&D expenditure (net of subsidy): +	Innovation panel (1997-2003) *Unit of analysis*: all firms	Differences with non-parametric matching
			Patents: n.s. Employment growth: + Sales growth: + Productivity growth: n.s.		Difference in differences with non-parametric matching
	Brazil (1999-2003)		R&D expenditure (net of subsidy): +	Innovation panel (1999-2003) *Unit of analysis*: all firms	Differences with non-parametric matching
			Patents: + Employment growth: n.s. Sales growth: n.s. Productivity growth: n.s.		Difference in differences with non-parametric matching
	Chile (1998-2002)		R&D expenditure: n.s. Patents: n.s. New products: n.s. Sales growth: n.s. Employment growth: n.s. Export growth: n.s. Productivity growth: n.s.	Innovation panel (1999-2001) *Unit of analysis*: all firms	Difference in differences with non-parametric matching
			Product innovation: n.s. Process innovation: n.s. Financial access: n.s. Training and organization activities: n.s. Use of external knowledge: +		Differences with non-parametric matching
	Panama (2000-2003)		R&D expenditure: + Sales growth: n.s. Productivity growth: + Export growth: n.s. Sales of new products: +	Innovation panel (2001-2003) *Unit of analysis*: all firms	Fixed effects with non-parametric matching
			Product innovation: + Process innovation: + Financial access: + Training and organization activities: n.s. Use of external knowledge: +		Differences with non-parametric matching

Table A.1 (conclusion)

Author(s)	Country	Policy measure	Outcome variable(s) and impact	Data source	Method
Hujer and Radić (2005)	Germany	All public R&D schemes	New products: + New or improved products: n.s.	Entrepreneurial panel (1999-2000) *Unit of analysis*: all firms	Probit model
			New products: + New or improved products: +		Non-parametric matching
			New products: n.s. New or improved products: -		Simultaneous two-equation probit model
			New products: n.s. New or improved products: n.s.		Difference in differences
Hussinger (2003)	Germany	Financial support	R&D expenditure (net of subsidy): +	Innovation panel, public information on R&D funding and patent applications and database with credit information from a credit rating agency *Unit of analysis*: manufacturing firms	Heckman's selection model and semi-parametric two-step selection models
Klette and Moen (2012)	Norway	Financial support	R&D expenditure: +	Innovation panel (1982-1995) *Unit of analysis*: high-technology firms	Fixed effects regression
Lach (2002)	Israel	Financial support	R&D expenditure (net of subsidy): n.s.	Innovation panel (1990-1995) *Unit of analysis*: manufacturing firms	Difference in differences
Lokshin and Mohnen (2013)	Netherlands	Fiscal incentives	Wages of R&D workers: +	Innovation panel and census data on production (1997-2004) *Unit of analysis*: all firms	Instrumental variables
Lööf and Heshmati (2005)	Sweden	Financial support	R&D expenditure (net of subsidy): +	Community Innovation Survey 3 (1998-2000) *Unit of analysis*: all firms	Non-parametric matching
López-Acevedo and Tan (2010)	Mexico	Different programmes supporting innovation at SMEs	Sales: + Employment: + Wages: n.s.	Industrial panel and programme participation information (1994-2005) *Unit of analysis*: SMEs	Fixed effects with non-parametric matching
	Chile		Product or process innovation: + Probability of investing in R&D: + Implementation of quality control systems: + Provision of training for employees: + Sales: - Labour: + Productivity: -	Innovation and entrepreneurial panel (1992-2006) *Unit of analysis*: SMEs	Difference in differences with non-parametric matching
	Colombia		Sales: + Employment: + Wages: + Exports: n.s.	Innovation and entrepreneurial panel and administrative tax information (1992-2006) *Unit of analysis*: SMEs	Fixed effects with non-parametric matching
	Peru		Profits: + Sales: +	Industrial panel and programme participation information (1994-2005) *Unit of analysis*: SMEs	Fixed effects with non-parametric matching
Özçelik and Taymaz (2008)	Turkey	Financial support	R&D expenditure (net of subsidy): +	Innovation panel, entrepreneurial panel and database with information on R&D support (1993-2001) *Unit of analysis*: all firms	Random effects Tobit, fixed effects regression and dynamic models
Suetens (2002)	Belgium (Flanders)	Financial support	R&D personnel: n.s.	Innovation panel and annual national accounts database (1992-1999) *Unit of analysis*: all firms	Instrumental variables with fixed effects
Wallsten (2000)	United States	Financial support	R&D expenditure (net of subsidy): n.s. Employment: n.s.	Financial reports (1990-1992) *Unit of analysis*: small high-technology firms	Instrumental variables

Source: prepared by the authors.

Note: n.s. = no significant effect at the 5% level; +(-) = positive (negative) effect found.
R&D = research and development.

TABLE A.2

Some innovation support programmes in use in Uruguay as of end-2011

	Wide-coverage innovation projects		High-impact innovation projects	Prototypes with innovative potential	Certification and new markets for exports	Improved management and certification
	Small (SMEs)	Large				
Objective	Promote business innovation to improve the competitiveness, productivity and profitability of enterprises.		Promote high-impact innovations.	Promote business innovation in order to improve competitiveness, productivity and profitability.		
Type	Subsidy to innovation projects.		Subsidy to projects with high economic, environmental and social impact.	Subsidy and support to companies in the process of converting new ideas into prototypes or creating spin-offs.	Subsidy to certification projects that show direct impact on the opening of new export markets or the maintenance of markets that are important to the company.	Subsidy for improving or implementing quality certifiable management systems to international standards, technical standards or process and product certification.
Rate of subsidy	60%		70%			
Rate of extra subsidy	5% if the project is presented with an R&D institution in a relevant association					
Maximum (*dollars*)	24 000	250 000	400 000	70 000	50 000	12 000
Duration (*months*)	24	36	36	24	24	12

Source: National Research and Innovation Agency (ANII), "Resultados de instrumentos de apoyo a la innovación empresarial", *Documento de Trabajo*, No. 5, Montevideo, 2012.

TABLE A.3

The effects of financial support in a sample without imputed observations

Dependent variable	(1) Innovation expenditure effort	(2) Private effort	(3) Innovative sales[a]	(4) R&D[b]	(5) Patent applications	(6) Productivity
ATT	4.534***	2.134**	15.23***	5.032*	0.0154	-0.0263
	(1.489)	(1.027)	(4.672)	(3.015)	(0.0312)	(0.130)
Treated group	78	78	78	78	78	78
Off support	2	2	2	2	2	2
Potential control group	1 861	1 861	1 861	1 861	1 861	1 861

Source: prepared by the authors on the basis of Innovation Surveys (2004-2006 and 2007-2009) and Economic Activity Surveys conducted in Uruguay.

[a] Share of sales due to innovation.
[b] Share of innovation expenditure that is R&D.
Note: bootstrapped standard errors in parentheses. 100 replications *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
R&D = research and development.

TABLE A.4

The effects of financial support in a sample without imputed observations and with positive innovation expenditure

	(1) Innovation expenditure effort	(2) Private effort	(3) Innovative sales[a]	(4) R&D[b]	(5) Patent applications	(6) Productivity
ATT	3.335**	0.903	6.690	2.511	0.00281	-0.0981
	(1.508)	(1.111)	(5.721)	(3.516)	(0.0357)	(0.119)
Treated group	77	77	77	77	77	77
Off support	2	2	2	2	2	2
Potential control group	918	918	918	918	918	918

Source: prepared by the authors on the basis of Innovation Surveys (2004-2006 and 2007-2009) and Economic Activity Surveys conducted in Uruguay.

[a] Share of sales due to innovation.
[b] Share of innovation expenditure that is R&D.
Note: bootstrapped standard errors in parentheses. 100 replications ** $p < 0.05$.
R&D = research and development.

TABLE A.5

Service sector: mean comparison of supported firms and non-supported firms on selected controls

Variable	Matching	Mean				t-test		Mean				t-test	
		Treated	Control	% bias	% reduct bias	t	p > t	Treated	Control	% bias	% reduct bias	t	p > t
Size	Unmatched	4.69	3.70	63.7		4.4	0	4.74	4.18	35.3		2.30	0.02
	Matched	4.57	4.44	8.5	86.6	0.38	0.704	4.62	4.48	8.7	75.2	0.39	0.70
Foreign-owned	Unmatched	0.08	0.09	-6.2		-0.37	0.714	0.08	0.15	-21.1		-1.14	0.33
	Matched	0.08	0.10	-9	-46.9	-0.38	0.708	0.08	0.16	-23.8	-12.7	-0.98	0.35
Age	Unmatched	23.90	18.25	24.9		1.89	0.058	23.95	20.64	13.8		0.94	0.51
	Matched	24.34	18.75	24.7	1.1	1.02	0.31	24.41	20.64	15.7	-13.7	0.66	0.38
Patents obtained	Unmatched	0.05	0.01	22.6		2.2	0.028	0.05	0.03	12.5		0.88	0.97
	Matched	0.05	0.03	11.2	50.4	0.41	0.681	0.05	0.05	1	91.8	0.04	0.97
K/L	Unmatched	0.84	0.65	11.7		0.58	0.565	0.86	0.74	5.2		0.24	0.81
	Matched	0.86	0.79	4.1	64.5	0.18	0.861	0.88	0.63	10.9	-110.7	0.98	0.33
Productivity (t - 1)	Unmatched	13.39	13.10	25.5		1.73	0.084	13.40	13.31	8.2		0.53	0.60
	Matched	13.41	13.29	10.4	59.3	0.44	0.665	13.42	13.42	-0.4	94.7	-0.02	0.99
Network	Unmatched	0.28	0.20	19.4		1.28	0.2	0.26	0.30	-8.9		-0.52	0.60
	Matched	0.29	0.21	18.8	2.9	0.8	0.429	0.27	0.25	4.8	46	0.21	0.84
Group	Unmatched	0.15	0.14	3.3		0.21	0.833	0.16	0.20	-12		-0.69	0.49
	Matched	0.16	0.13	8.8	-164.8	0.38	0.702	0.16	0.20	-8.9	26	-0.37	0.70
Outlets	Unmatched	4.79	3.39	5.7		0.27	0.791	4.89	6.07	-3		-0.14	0.89
	Matched	4.89	2.95	7.9	-39.2	0.95	0.344	5.00	3.22	4.6	-51.1	0.83	0.41
In Montevideo	Unmatched	0.8718	0.7353	34.7		1.92	0.055	0.8947	0.7988	26.7		1.45	0.15
	Matched	0.8684	0.8022	16.8	51.5	0.76	0.447	0.8919	0.8382	15	44	0.66	0.51

Source: prepared by the authors on the basis of Innovation Surveys (2004-2006 and 2007-2009) and Economic Activity Surveys conducted in Uruguay.

TABLE A.6

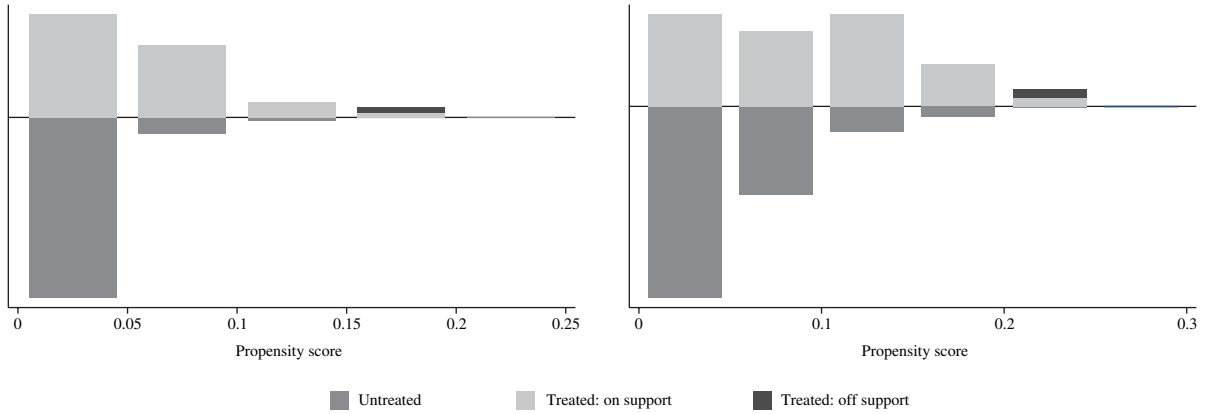
Manufacturing sector: mean comparison of supported firms and non-supported firms on selected controls

Variable	Matching	Mean				t-test		Mean				t-test
		Treated	Control	% bias	% reduct bias	t	p > t	Treated	Control	% bias	% reduct bias	p > t
Size	Unmatched	4.22	3.81	36.6		2.83	0.006	4.22	4.12	8.9		0.69
	Matched	4.22	4.21	1.3	96.5	0.08	0.773	4.26	4.29	-2.9	67.6	-0.18
Foreign-owned	Unmatched	0.10	0.13	-9.8		-0.77	0.651	0.10	0.18	-22.4		-1.64
	Matched	0.10	0.17	-21.5	-119.3	-1.2	0.841	0.10	0.19	-25.9	-15.6	-1.45
Age	Unmatched	32.29	27.48	21.8		1.9	0.973	31.93	29.09	12.5		1.03
	Matched	32.29	28.01	19.4	11.1	1.19	0.635	32.57	28.84	16.4	-31.2	0.97
Patents obtained	Unmatched	0.03	0.03	0.6		0.05	0.008	0.03	0.04	-8.8		-0.65
	Matched	0.03	0.04	-7.8	-1 149	-0.42	0.721	0.03	0.05	-12.1	-37.2	-0.66
K/L	Unmatched	0.52	0.59	-6.7		-0.43	0.401	0.53	0.72	-17.7		-1.13
	Matched	0.52	0.66	-12.9	-94.3	-0.81	0.422	0.54	0.73	-17.6	0.5	-0.95
Productivity (t - 1)	Unmatched	13.93	13.78	16.2		1.2	0.444	13.92	14.05	-15.3		-1.15
	Matched	13.93	13.90	2.5	84.6	0.15	0.787	13.94	14.05	-12.4	19.1	-0.70
Network	Unmatched	0.17	0.10	19.7		1.81	0.001	0.17	0.14	7		0.58
	Matched	0.17	0.12	14.1	28.7	0.81	0.964	0.17	0.16	4.3	37.8	0.24
Group	Unmatched	0.18	0.15	6.8		0.58	0.058	0.17	0.19	-6.6		-0.52
	Matched	0.18	0.17	1.8	74	0.1	0.684	0.17	0.20	-5.9	10.6	-0.33
Outlets	Unmatched	1.85	1.81	1.9		0.12	0.958	1.86	1.83	1.7		0.11
	Matched	1.85	1.76	4.3	-130	0.25	0.654	1.87	1.61	13.7	-717.3	1.14
In Montevideo		0.8333	0.7915	10.7		0.85		0.831	0.7927	9.8		0.76
		0.8333	0.7913	10.7	-0.5	0.64		0.8261	0.8	6.7	31.9	0.38

Source: prepared by the authors on the basis of Innovation Surveys (2004-2006 and 2007-2009) and Economic Activity Surveys conducted in Uruguay.

FIGURE A.1

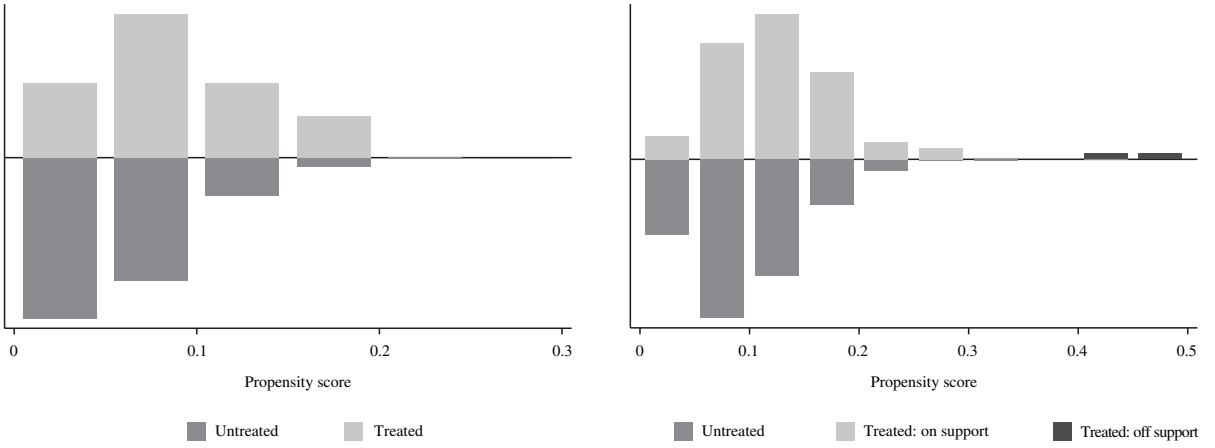
Service sector: propensity scores of treated and potential controls for all firms (left panel) and observations with positive innovation expenditure only (right panel)



Source: prepared by the authors on the basis of Innovation Surveys (2004-2006 and 2007-2009) and Economic Activity Surveys conducted in Uruguay.

FIGURE A.2

Manufacturing sector: propensity scores of treated and potential controls for all firms (left panel) and observations with positive innovation expenditure only (right panel)



Source: prepared by the authors on the basis of Innovation Surveys (2004-2006 and 2007-2009) and Economic Activity Surveys conducted in Uruguay.

Bibliography

Aerts, K. and D. Czarnitzki (2004), "Using innovation survey data to evaluate R&D policy: the case of Belgium", *Discussion Paper*, No. 04-055, Mannheim, Centre for Economic European Research (ZEW).

Almus, M. and D. Czarnitzki (2003), "The effects of public R&D subsidies on firms' innovation activities: the case of Eastern Germany", *Journal of Business and Economic Statistics*, vol. 21, No. 2, American Statistical Association.

Andrews, D. and C. Criscuolo (2013), "Knowledge based capital, innovation and resource allocation", *OECD Economics Department Working Papers*, No. 1046, Paris, OECD Publishing.

ANII (Innovation and Research National Agency) (2012), "Resultados de instrumentos de apoyo a la innovación empresarial", *Documento de Trabajo*, No. 5, Montevideo.

Avellar, A.P. (2011), "Evaluating the Impacts of Innovation Policy: Evidences from Brazil", unpublished.

Avellar, A.P. and P.F. Alves (2008), "Avaliação de impacto de programas de incentivos fiscais a inovação: um estudo sobre os efeitos do PDTI no Brasil", *Economia*, vol. 9, No. 1, National Association of Centers for Post-graduation in Economics.

Bloom, N., R. Griffith and J. Van Reenen (2002), "Do R&D tax credits work? Evidence from a panel of countries 1979-1997", *Journal of Public Economics*, vol. 85, No. 1, Amsterdam, Elsevier.

Busom, I. (2000), "An empirical evaluation of the effects of R&D subsidies", *Economics of Innovation and New Technology*, vol. 9, No. 2, Taylor & Francis.

Caliendo, M. and S. Kopeinig (2008), "Some practical guidance for the implementation of propensity score matching", *Journal of Economic Surveys*, vol. 22, No. 1, Wiley.

CIS (Community Innovation Survey) [online] http://ec.europa.eu/eurostat/web/microdata/community_innovation_survey.

Crespi, G., A. Maffioli and M. Meléndez (2011), "Public support to innovation: the Colombian COLCIENCIAS' experience", *Technical Notes*, No. IDB-TN-264, Washington, D.C., Inter-American Development Bank.

Crespi, G. and others (2011), "Evaluating the impact of science, technology and innovation programs: a methodological toolkit", *Technical Notes*, No. IDB-TN-333, Washington, D.C., Inter-American Development Bank.

Czarnitzki, D. (2002), "Research and development: financial constraints and the role of public funding for small and medium-sized enterprises", *ZEW Discussion Paper*, No. 02-74, Mannheim, Centre for Economic European Research (ZEW).

Czarnitzki, D. and A. Fier (2002), "Do innovation subsidies crowd out private investment? Evidence from the German service sector", *ZEW Discussion Paper*, No. 02-04, Mannheim, Centre for Economic European Research (ZEW).

Czarnitzki, D., P. Hanel and J.M. Rosa (2011), "Evaluating the impact of R&D tax credits on innovation: a microeconometric study on Canadian firms", *Research Policy*, vol. 40, No. 2, Amsterdam, Elsevier.

Czarnitzki, D. and K. Hussinger (2004), "The link between R&D subsidies, R&D spending and technological performance", *ZEW Discussion Paper*, No. 04-056, Mannheim, Centre for Economic European Research (ZEW).

David, P., B.H. Hall and A.A. Toole (2000), "Is public R&D a complement or substitute for private R&D? A review of the econometric evidence", *Research Policy*, vol. 29, No. 4-5, Amsterdam, Elsevier.

Duguet, E. (2004), "Are R&D subsidies a substitute or a complement to privately funded R&D? Evidence from France using propensity score methods for non-experimental data", *Revue d'Économie Politique*, vol. 114, No. 2, Dalloz.

González, X., J. Jaumandreu and C. Pazó (2005), "Barriers to innovation and subsidy effectiveness", *RAND Journal of Economics*, vol. 36, No. 4, The RAND Corporation.

González, X. and C. Pazó (2008), "Do public subsidies stimulate private R&D spending?", *Research Policy*, vol. 37, No. 3, Amsterdam, Elsevier.

Görg, H. and E. Strobl (2007), "The effect of R&D subsidies on private R&D", *Economica*, vol. 74, No. 294, Wiley.

Hall, B.H. (1993), "R&D tax policy during the 1980s: success or failure?", *Tax Policy and the Economy*, vol. 7, Cambridge, Massachusetts, National Bureau of Economic Research.

Hall, B.H. and J. Lerner (2010), "The financing of R&D and innovation", *Handbook of the Economics of Innovation*, B.H. Hall and N. Rosenberg (eds.), Amsterdam, Elsevier.

Hall, B.H. and A. Maffioli (2008), "Evaluating the impact of technology development funds in emerging economies: evidence from Latin America", *OVE Working Papers*, No. 0108, Washington, D.C., Inter-American Development Bank.

Heckman, J.J. (1979), "Sample selection bias as a specification error", *Econometrica*, vol. 47, No. 1.

Hujer, R. and D. Radić (2005), "Evaluating the impacts of subsidies on innovation activities in Germany", *Scottish Journal of Political Economy*, vol. 52, No. 4, Scottish Economic Society.

Hussinger, K. (2003), "R&D and subsidies at the firm level: an application of parametric and semi-parametric two-step selection models", *ZEW Discussion Papers*, No. 03-63, Mannheim, Centre for Economic European Research (ZEW).

Klette, T.J. and J. Moen (2012), "R&D investment responses to R&D subsidies: a theoretical analysis and a microeconometric study", *World Review of Science, Technology and Sustainable Development*, vol. 9, No. 2, Inderscience.

Lach, S. (2002), "Do R&D subsidies stimulate or displace private R&D? Evidence from Israel", *Journal of Industrial Economics*, vol. 50, No. 4, Wiley.

Lokshin, B. and P. Mohnen (2013), "Do R&D tax incentives lead to higher wages for R&D workers? Evidence from the Netherlands", *Research Policy*, vol. 42, No. 3, Amsterdam, Elsevier.

Lööf, H. and A. Heshmati (2005), "The impact of public funds on private R&D investment: new evidence from a firm level innovation study", *Discussion Papers*, No. 3, Helsinki, MTT Agrifood Research Finland.

López-Acevedo, G. and H. Tan (2010), "Impact evaluation of SME programs in Latin America and the Caribbean", Washington, D.C., World Bank.

Özçelik, E. and E. Taymaz (2008), "R&D support programs in developing countries: the Turkish experience", *Research Policy*, vol. 37, No. 2, Amsterdam, Elsevier.

Suetens, S. (2002), "R&D subsidies and production effects of R&D personnel: evidence from the Flemish region", Antwerp, University of Antwerp, unpublished.

Wallsten, S.J. (2000), "The effects of government-industry R&D programs on private R&D: the case of the small business innovation research program", *RAND Journal of Economics*, vol. 31, No. 1, The RAND Corporation.

Digital inclusion in education in Tarija, Plurinational State of Bolivia

Sulma Farfán Sossa, Antonio Medina Rivilla and María Luz Cacheiro González

ABSTRACT

This study analyses digital inclusion in secondary education in the Tarija School District in the Plurinational State of Bolivia for the 2012-2013 school year, using the indicators in the Plan of Action for the Information Society in Latin America and the Caribbean (Plan of Action eLAC). This is an exploratory and descriptive analysis based on a sample of 311 students, 108 teachers and 15 school principals. According to the findings, teenagers use the Internet to look for information and entertainment; the expansion of mobile technology among them offers numerous educational opportunities; and insufficient training for teachers on how to integrate information and communications technologies (ICTs) into the learning process is a top challenge. The existence of ICTs in schools has been confirmed, but not their use. Local and national efforts are helping to reduce the digital divide and promote equality of opportunity for young people.

KEYWORDS

Education, secondary education, public schools, digital divide, educational innovations, Internet, information technology, communication technology, programmes of action, equal opportunity, ICT indicators, Bolivia (Plurinational State of)

JEL CLASSIFICATION

I24, I25, I28

AUTHORS

Sulma Farfán Sossa is an educational technology advisor at Saint Louis University-Madrid, Spain. sfarfan@slu.edu

Antonio Medina Rivilla is a professor at the National Distance Education University (UNED), Spain. amedina@edu.uned.es

María Luz Cacheiro González is a professor at the National Distance Education University (UNED), Spain. mlcacheiro@edu.uned.es

I
Introduction

Information and communications technologies (ICTs) are a necessary tool of daily life. Their advantages make them strategic resources for the development of new knowledgebased economies.

Since the World Summit on the Information Society (WSIS, 2003), ICT access, availability and use have become key issues in the social and economic development of societies. This new reality has required governments to implement policies and programmes that guarantee the integration of ICTs into the information and knowledge society. One of the basic ways of achieving this integration is through the education system, which is responsible for training new generations in the skills that are indispensable for the information society.

Although ICTs are increasingly available, there are significant disparities between developed and developing countries, giving rise to a major gap in access known as the "digital divide".

To overcome ICT-based inequalities, digital inclusion plans that go beyond simple technological equipment are being implemented in various countries (UNESCO, 2013a; Eurydice, 2011). In the case of the Plurinational State of Bolivia, some initial steps to develop ICT policies were taken in 2002 but it was only in 2005 that these policies were deployed in the educational system, paving the way for various initiatives to reduce the digital divide.

This study draws on a number of proposed indicators of ICT in education to help determine the state of digital inclusion, and the indicators proposed in the Plan of Action for the Information Society in Latin America and the Caribbean (Plan of Action eLAC) (ECLAC, 2012a) are used to analyse data collected on the Tarija School District. In addition, studies conducted in other departments in the Plurinational State of Bolivia and neighboring countries have been considered.

The article is structured as follows. Section II addresses the challenges raised by the socalled information society. Section III discusses the digital divide and inclusion, as well as the major inequalities in access to ICTs. Section IV points up the need to use indicators of the levels of digital inclusion in education. Section V covers the implementation of ICTs in education, and section VI examines digital inclusion in the Plurinational State of Bolivia. Sections VII and VIII provide context and present the methodology used to conduct the research, and section IX discusses characteristics of the sample. Section X and XI analyse the findings based on the indicators, as well as other studies. Lastly, section XII offers the study conclusions.

II
Challenges of the information society

The World Summits on the Information Society at Geneva (WSIS, 2003) and at Tunis (WSIS, 2005) produced an explicit declaration of the political will of the participating countries "to build an inclusive Information Society; to put the potential of knowledge and ICTs at the service of development; to promote the use of information and knowledge for the achievement of internationally agreed development goals, including those contained in the Millennium Declaration […]" (WSIS, 2003, p. 2). The declaration emphasized the need to incorporate ICTs in education as a strategic element for a digitally inclusive society. A first step in this task is to eradicate basic illiteracy and "develop domestic policies to ensure that ICTs are fully integrated in education and training at all levels, including in curriculum development, teacher training, institutional administration and management, and in support of the concept of lifelong learning" (WSIS, 2003, p. 6), as well as "ensure that young people are equipped with knowledge and skills to use ICTs, including the capacity to analyse and treat information in creative and innovative ways, share their expertise and participate fully in the Information Society" (WSIS, 2003, p. 6).

The World Summit on the Information Society and the Millennium Development Goals (MDGs) are the basis for the Plan of Action eLAC being promoted by the Economic Commission for Latin America and the Caribbean

(ECLAC). The plan is a political agenda agreed upon by the countries in the region that views ICTs as instruments for economic development and social inclusion.

Under the 2007 and 2010 Plans of Action eLAC, the first steps were taken to lay the technological groundwork in the education sector (eLAC2007 (2005) and eLAC2010 (2008)) but it was the 2015 Plan of Action eLAC that asserted that "the policy for maximizing use of digital technologies in the context of education must be viewed as a policy of State. This policy must include advanced training for teachers in technological, cognitive and pedagogical areas, the production of digital contents and interactive applications, innovative teaching and learning methodologies and the use of cutting-edge technological resources, including the provision of broadband and other systems with the potential to transform teaching" (eLAC2015, 2010, p. 13). In response, 31 of the 38 Latin American and Caribbean countries analysed in the UNESCO study (2013a) reported having adopted a formal definition (national policy, national plan, regulatory institution and others) tied to initiatives for using ICTs in education.

The eLAC2015 Plan of Action (2010) proposes four goals related to education, aimed at promoting broadband connectivity and increasing computer density in schools, implementing policies to promote research and education networks, offering more training for teachers and management teams, fostering the development of interactive multimedia applications for and by students and teachers, and lastly, obtaining the support of the Latin American Network of Educational Portals (RELPE). The progress made towards these goals in Latin America and the Caribbean varies considerably, owing primarily to lack of continuity of projects, consensuses, political support, policies and resources and other factors (Rovira and Stumpo, 2013).

III

The digital divide and digital inclusion

Although the eLAC plans have brought about real progress in terms of integrating ICTs into the member countries, there are still major inequalities in ICT access, known as the "digital divide".

The concept of the digital divide first emerged in 1999 in a report by the Department of Commerce of the United States titled "Falling through the Net: Defining the Digital Divide" (NTIA, 1999). The report defined the digital divide as the gap between two groups: those who have access to a computer, the Internet, telephone service and the contents thereof and those who do not. It also discussed the effects of technologies on people's lives.

The Organization for Economic Cooperation and Development (OECD, 2001, p. 5) defines the digital divide as "the gap between individuals, households, businesses and geographic areas at different socio-economic levels with regard both to their opportunities to access information and communication technologies (ICTs) and to their use of the Internet for a wide variety of activities."

The United Nations (2001) indicates that the existence of the digital divide can be attributed to the income gap seen in countries around the world, the reduction of which is a global objective. It also indicates that ICTs are a factor of human development and that all countries should have national policies in place to ensure that they are widely disseminated and used to optimal advantage in different areas and among various groups.

Ballestero (2002) identifies four elements related to the digital divide:

- Availability of hardware to connect to the Internet
- Possibility of access to the Internet
- Knowledge to access and navigate the Internet
- Ability to transform online information into knowledge benefiting the user

Several studies (Ballestero, 2002; Agustín and Clavero, 2010; Rovira and Stumpo, 2013) document the significant benefits that these technologies provide to those who have and know how to use them, benefits to which those who do not have or know how to use them are excluded. To address this situation, a concept has been proposed that is about more than equipment. It is called digital inclusion and it refers to a form of societal integration necessary for community growth that goes far beyond the purely quantitative and technological aspects of the concept of the digital divide (Agustín and Clavero, 2010, p. 149).

Digital inclusion has been defined as the set of public policies related to the installation, administration, expansion, creation and development of content on wired and wireless public digital networks in individual countries, regions and communities. It includes privacy

and security guarantees exercised fairly for all and encompasses training and incentives to develop new tools (Robinson, 2005, p. 127).

In addition, a report titled "Informe sobre la implantación y el uso de las TIC en los centros docentes de educación primaria y secundaria" [Report on ICT implementation and use in primary and secondary schools] emphasizes the central role that ICTs play in the development of the economy and society. It suggests that any community that fails to work towards digital inclusion will be left out of global development (Instituto de Evaluación y Asesoramiento Educativo/Neturity/ Fundación Germán Sánchez Ruipérez, 2007).

Since the WSIS, a number of indicators have been developed to gauge the degree of digital inclusion in society, compare the different efforts made in the countries and establish actions to take in the future for better results.

IV

Indicators of digital inclusion in education

The United Nations has suggested a rethinking of education systems, considering the advantages of ICTs and their repercussions on human development (United Nations, 2001). As a first step in this task, the levels of digital inclusion in education must be determined, using indicators developed for that purpose at the global or regional level.

On the occasion of the WSIS, a set of ICT indicators were published in 2005 that were developed by members of the Partnership on Measuring ICT for Development (2010), who have reviewed and expanded the indicators in all areas. The indicators related to education are as follows:

1. Proportion of schools with a radio used for educational purposes.
2. Proportion of schools with a television used for educational purposes.
3. Proportion of schools with telephone communication facility.
4. Learners-to-computer ratio.
5. Proportion of schools with Internet access, by type of access.
6. Proportion of learners who have access to the Internet at school.
7. Proportion of learners enrolled at the post-secondary level in ICT-related fields.
8. Proportion of ICT-qualified teachers in primary and secondary schools.
9. Proportion of schools with electricity.

According to a study by the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2013a), the WSIS targets directly related to education are targets 2 and 7 and their indicators:

Target 2. Connect all secondary schools and primary schools with ICTs.

1. Proportion of schools with a radio used for educational purposes.
2. Proportion of schools with a television used for educational purposes.
3. Learners-to-computer ratio.
4. Proportion of schools with Internet access, by type of access.

Target 7. Adapt all primary and secondary school curricula to meet the challenges of the information society, taking into account national circumstances.

1. Proportion of ICT-qualified teachers in schools.
2. Proportion of teachers trained to teach subjects using ICT.
3. Proportion of schools with computer-assisted instruction.
4. Proportion of schools with Internet-assisted instruction.

The eLAC2015 Plan sets out six indicators related to education (ECLAC, 2012a):

1. Students-to-computer ratio by educational level.
2. Proportion of school-going children and youth who have used the Internet at an educational institution.
3. Proportion of school-going children and youth who have used the Internet in educational or learning activities, by educational level.
4. Percentage of primary and secondary schoolteachers trained to teach one or several subjects using ICT resources, by educational level.
5. Percentage of grades using ICT-assisted learning (levels 1-3), by subject: mathematics, sciences, basic computer skills (computer science), languages, art.
6. Proportion of public educational content that is digitalized.

For its part, the Inter-American Development Bank (IDB) published a set of indicators for a project on ICTs

in education (Severin, 2010). The proposal establishes two types of indicators: input and output indicators, which include measurable aspects such as infrastructure, contents, administration, policies and others.

The Organization of Ibero-American States for Education, Science and Culture (OEI) proposed four indicators to assess the degree of digital inclusion in education: availability of ICTs, organization of schools for use of ICTs, ICT training for teachers, and the presence of ICTs in teaching practices (OEI, 2011).

Although there is some overlap between the proposed indicators described in this section, given the context of this study, only the indicators for the eLAC Plan of Action are analysed.

V

Implementation of ICTs in education

The developed countries have led the way in implementing ICTs in education. In the case of the European Union, important advances and achievements have been made, and the most outstanding aspects are as follows (Eurydice, 2011):

- All the countries have national ICT policies that address the entire learning process.
- The average number of students per computer ranges from two to four.
- Public assistance is available to procure ICTs for educational purposes.
- All the countries evaluate their national ICT and education strategies.
- The majority of the European countries use ICTs in all areas of the curriculum.
- Broadband access to the Internet is nearly universal in the European Union countries.
- Schools have websites, academic monitoring systems and other tools.

The report by Eurydice (2011) identifies the following challenges:

- ICT training is an area of weakness that must be specifically addressed to achieve digital inclusion for teachers.
- The Internet is used more for recreation than education.

The report confirms that students access the Internet at home more than at school, which may primarily have to do with the low-cost, high-speed service offered in the European Union (ECLAC, 2012b).

It should be noted that the percentages of each one of the indicated aspects vary by individual member country of the European Union.

In the case of Latin America and the Caribbean, there has been significant progress in terms of integrating ICTs into primary and secondary education, thanks to the adoption of national policies and programmes. A study conducted by the UNESCO Institute of Statistics in the countries of Latin America and the Caribbean (UNESCO, 2013a) documented the following results:

(a) *Proportion of schools with a radio used for educational purposes*

Fourteen countries in the Caribbean radio use for educational purposes, though at varying rates (e.g. 100% in primary and secondary schools in the Bahamas, but 38% in primary schools and 80% in secondary schools in Dominica).

(b) *Proportion of schools with a television used for educational purposes*

Twenty-two countries report television-assisted learning, with the Caribbean countries reporting the highest rate of use of this technology. Of the Latin American countries, Brazil and Mexico report the greatest use.

The countries indicated in the report have invested heavily to establish radio and/or television stations for educational purposes.

(c) *Learners-to-computer ratio*

There are major differences between the Latin American countries and the Caribbean countries. For example, there is one computer per student in Uruguay, in contrast with other countries, such as the Dominican Republic, where there is one computer for every 122 students. Excluding extreme cases, the learner-to-computer ratio is 27 at the primary level and 17 at the secondary level.

Of the 28 countries covered by the study, all have computer labs at both the primary and secondary levels. The study indicates that computer labs help reduce the gap in access to ICTs.

(d) *Proportion of schools with Internet access, by type of access*

In 15 Caribbean countries, all secondary schools have Internet access. However, rates of access by broadband connection vary.

The Latin American countries reports high rates of Internet access, though not all have universal access. The gap in access is greater when considering schools with broadband Internet access.

In the case of Uruguay, 95% of primary schools and 100% of secondary schools have broadband access.

The data show that secondary schools tend to have greater Internet access, including broadband access, than primary schools.

(e) *Proportion of ict-qualified teachers in primary and secondary schools*

According to the report, only 14 countries report data on teacher training. Fewer than 10% of primary and secondary schoolteachers are qualified to use ICTs in education. There are major discrepancies between countries, with Argentina, for example, reporting 3% of teachers as ICT-qualified, and Aruba reporting 100%.

(f) *Proportion of schools with electricity*

According to the study, all primary and secondary schools in the Caribbean countries, with the exception of the Dominican Republic, have electricity.

In Uruguay, 96% of primary schools and 100% of secondary schools have electricity.

There are significant differences between the South American countries and the Central American countries. Less than 80% of primary schools in the Bolivarian Republic of Venezuela, Ecuador, Guyana and Panama have electricity.

The study points out that secondary schools are more likely to have electricity.

The indicators presented, for European and Latin American countries alike, reveal significant differences in ICT access and equipment in education, but both studies agree on the need to train teachers on the didactic use of technologies in order to successfully incorporate these into the learning and teaching process.

VI

Digital inclusion in the Plurinational State of Bolivia

Like all member countries of ECLAC, the Plurinational State of Bolivia has been taking important steps to achieve digital inclusion and promote the information society. A clear example of this was the creation in 2002 of the Agency for the Development of the Information Society in Bolivia (ADSIB), which is tasked with reducing the digital divide.

In early 2004, the Bolivian Strategy of Information and Communications Technologies for Development (ETIC) was created. In 2007, the National Digital Inclusion Plan was established to develop the knowledge society in the Plurinational State of Bolivia. Then, in the period 2012-2014, the Bolivian Digital Agenda was established for the implementation of an ICT development strategy (Rovira and Stumpo, 2013).

Major strides were made in the area of education in 2005 with the introduction of the National Policy on New Information and Communications Technologies for Education. One year later, the National ICT Programme was established, with the objective of providing adequate ICT access and use for the entire national education system and the public in general through the installation of Community Education Telecentres and the dissemination of the Educational Portal, with suitable content tailored to the national context, thus promoting broad citizen participation (Ministry of Education, 2006).

Alongside the establishment of ICT policies, efforts have been made to democratize access to electricity, a crucial indicator for digital inclusion and the development of the information society. According to the Ministry of Hydrocarbons and Energy (2010), access to electricity stands at 90.4% in cities and 50.8% in the countryside, with universal access projected for cities by 2015 and for the countryside by 2025. The expansion in electricity coverage, along with mobile technologies, is giving more and more Bolivians access to ICTs and related services (see table 1).

TABLE 1

ICT indicators in the Plurinational State of Bolivia, 2012-2013

Service	Units
Internet connections	2 000 000
Facebook users	2 002 000
Mobile telephones	9 306 800
Smartphones	527 185
Households with fixed or wireless telephones	2 013 623
Households with radios	2 101 942
Households with televisions	1 891 270
Computers in households	657 050

Source: prepared by the authors, on the basis of data from National Statistics Institute, *Bolivia. Características de la población y vivienda. Censo Nacional de Población y Vivienda 2012*, 2012 [online] http://www.ine.gob.bo:8081/censo2012/PDF/resultadosCPV2012.pdf; and M. Campos, "Santa Cruz, líder en usuarios de internet y redes sociales", *El Día*, 2013 [online] http://eldia.com.bo/index.php?cat=357&pla=3&id_articulo=120867.

Note: population in the Plurinational State of Bolivia: 10,027,254. Number of households: 2,812,715.

According to data presented by the Regional Broadband Observatory at the Economic Commission for Latin America and the Caribbean, the rate of Internet penetration in the Plurinational State of Bolivia is 30% of the population. The cost of a fixed broadband connection is equivalent to 31.42% of per capita income and the cost of mobile broadband is 11.28%. According to the same report, Internet upload and download speeds are the lowest in South America (ECLAC, 2012b). In response to this situation, the Bolivian government has launched the Túpac Katari satellite to improve access to and reduce the costs associated with Internet, telephone and television service (ABI, 2013).

The 2010 Avelino Siñani-Elizario Pérez Education Law establishes as its objectives to develop scientific, technical, technological and productive training in line with advances in universal technology and science throughout the Education System, as well as to promote scientific, technical, technological and pedagogical research throughout the Plurinational Education System (Ministry of Education, 2010, pp. 9 and 12). In this framework, several projects and programmes are being pursued, including "One Computer per Teacher", "Community Education Telecentres", the "National Educational Portal", "One Computer per Student", as well as educational material for radio and television and other initiatives (see table 2), designed to integrate ICTs at all levels of education (Crespo and Medinaceli, 2013).

TABLE 2

Digital inclusion in Bolivian education, 2011-2013

Indicator	Units
Laptop computers distributed to teachers	132 693
Community education telecentres installed	340
Computers in educational facilities	10 000
Teachers trained by state programmes	15 000
Student-to-computer ratio	55[a]

Source: prepared by the authors, on the basis of Ministry of Education, "Una computadora por docente", 2011 [online] http://computadora.educabolivia.bo/; and United Nations Educational, Scientific and Cultural Organization (UNESCO), "Uso de las TIC en la Educacion en América Latina y el Caribe. Análisis regional de la integración de las TIC en la educación y de la aptitud digital (e-readiness)", Quebec, 2013 [online] http://www.uis.unesco.org/Communication/Documents/ict-regional-survey-lac-2012-sp.pdf.

[a] United Nations Educational, Scientific and Cultural Organization (UNESCO, 2013a).

The project "One Computer per Teacher" is one of the most important actions for the digital inclusion of Bolivian teachers. Its objective is to give teachers access to ICTs so they can develop educational plans using these tools and the content installed on computers (Ministry of Education, 2011). This project includes technical training in the use of equipment and pedagogical training for work in the classroom.

In addition to government initiatives, actions for digital inclusion in education are being pursued by international cooperation agencies and local and foreign nongovernmental organizations (Red TICBolivia, Ayni Bolivia, Educatic and others) to offer ICT training, content development, dissemination of information and equipment and other opportunities.

ICTs are becoming more integrated into Bolivian education with every passing day, which makes it vitally important to have publications or reports on results to help quantify progress and evaluate digital inclusion in education.

In the case of the department of Tarija, no prior studies have been conducted on this topic, although investments in ICTs have been made on an ongoing basis by both the national and regional governments.

VII
Research context

The department of Tarija, located in the southern part of the Plurinational State of Bolivia, has six provinces (Cercado, Aniceto Arce, Burdet O'Connor, Gran Chaco, Eustaquio Méndez and José María Avilés). It is home to 482,196 people, of whom approximately 40% live in the province of Cercado, where Tarija is the capital city (INE, 2012). The entire province constitutes the Tarija School District, which is where this study has been conducted.

In 2013, 42% of the department's student population between the ages of 5 and 19 (53,829 students) were enrolled in the Tarija School District, according to data provided by the Department of Education for the Department of Tarija, which is the public institution responsible for education in the department.

According to the District Department of Education, which is the public institution responsible for education in the District of Tarija, there were 2,700 teachers employed and 20,043 students enrolled at the secondary level in the public school system in 2013. Of the 197 schools, 64 offered public secondary education and were located in urban and rural areas of the province of Cercado. Of the district's student population, 40% were enrolled in secondary school and were soon to become members of the region's labour force, which is why the study's analytical focus is on this level of education.

VIII
Research methodology

The objective of this study is to analyse digital inclusion in Bolivian public secondary education in the Tarija School District, using the ICT indicators established in the eLAC Plan of Action. The study incorporates three additional indicators related to the basic conditions of electricity, radio and television as educational resources.

This is an exploratory and descriptive study based on closed surveys administered to schoolteachers, students and principals.

The surveys were based on others that were prepared in the fields of education and ICTs, such as: Profesión y Docencia (Profession and Teaching) (Gallego, 2009); Informe de las Tecnologías de la Información y de la Comunicación en la Educación (Report on Information and Communications Technologies in Education) (Instituto de Evaluación y Asesoramiento Educativo/ Neturity/ Fundación Germán Sánchez Ruipérez, 2007); and Proyecto Universidad y Sociedad del Conocimiento: ¿Es el e-learning la única respuesta? (Knowledge Society and University Project: Is e-learning the only way?) (Gewerc, 2007), which was administered at two Bolivian universities. The surveys have been validated by professionals working in the fields of ICTs and education in the Plurinational State of Bolivia and Spain.

The data were collected in the 2012 and 2013 academic years by administering surveys in paper form, due to connectivity limitations. The data collection process was supported by the education departments in Tarija district, the department and the municipal autonomous government.

The selected educational institutions were all secondary schools. Each received a number and was randomly selected. Random sampling was also used to administer the surveys in each school.

IX

Sample characteristics

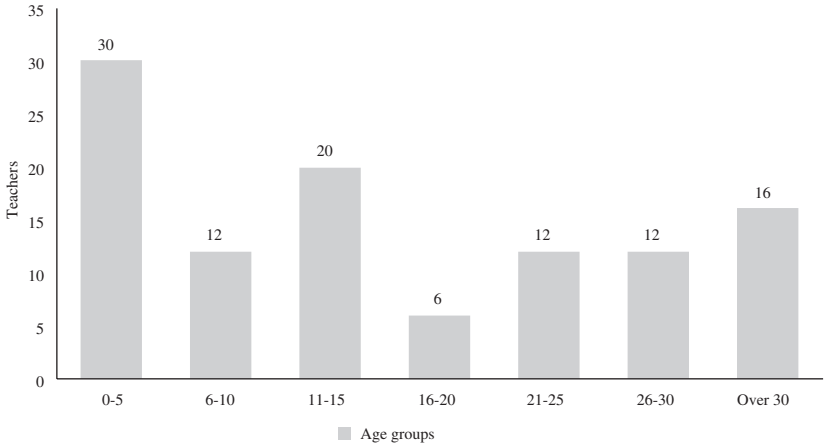
The sample consists of 311 students between the ages of 13 and 18, of whom 52% are female and 48% are male. Of these students, 67% live in urban areas and 33% live in rural areas.

Of the 108 teachers, 51% are men and 49% are women, with the largest concentrations of female teachers in two age groups: 25 to 30 years (21%) and 51 to 55 years (19%), whereas the largest concentration of male teachers is in the age group from 31 to 35 years (24%). The survey gathered data from a wide range of teachers, from those just getting started in their careers to those with many years of experience (see figure 1).

The information provided by the 15 school principals responding to the survey revealed that 60% of the participating schools offer early childhood, primary and secondary education, while 40% provide secondary education only. According to the data, 10 schools are located in city centres and outlying areas, and 5 are located in rural areas of the Tarija School District.

FIGURE 1

Years of experience among teachers surveyed



Source: prepared by the authors, on the basis of data from the survey administered to teachers as part of this study.

X

Analysis of results based on the indicators

The analysis begins with three indicators of ICT conditions in schools (Partnership on Measuring ICT for Development, 2010). Beginning with the fourth (student/computer ratio by educational level), the indicators are those specified in the eLAC Action Plan.

1. A basic indicator: access to electricity

According to a report by the Ministry of Hydrocarbons and Energy (2010), electricity coverage in Cercado province in the department of Tarija exceeds 80%. According to data provided by the Education Department of the Municipal Autonomous Government of Tarija, 194 (98%) schools have electricity, including 100% of secondary schools. This is consistent with the UNESCO study (2013a), which points out that secondary schools are more likely than primary schools to have electricity.

2. Proportion of schools with a radio used for educational purposes

Based on information provided by the Tarija District Department of Education, 100% of educational institutions have at least one radio for educational purposes, and 20%

of the schools surveyed have a radio in the classrooms for educational purposes.

Secondary schools have radios, but the study found that in the Plurinational State of Bolivia, educational radio stations focus exclusively on adult education (IRFA, ACLO, FIDES and others).

3. Proportion of schools with a television used for educational purposes

According to the Tarija District Department of Education, 52% of schools have a television used for educational purposes. Survey data reveal that 40% of schools have televisions in classrooms.

In this regard, the Bolivian government has established a strategy to develop radio and television content (Crespo and Medinaceli, 2013) and is promoting a digital television project with educational and cultural programming (*El Deber*, 2012). This new environment is paving the way for new opportunities to use television in the teaching and learning process in the Plurinational State of Bolivia.

4. Students-to-computer ratio by educational level

To offer equality of opportunity in access to computers, the Bolivian government has set itself the goal of one computer for every student, an initiative that was launched in the Tarija School District in September 2014 at the secondary level (Ministry of Education, 2014). This project will help reduce the ratio of 18 students per computer found in this study.

Of the schools surveyed, 93% have at least one computer lab containing 17 computers, on average. However, with computer lab personnel cuts, the installed infrastructure is underused, as the study found when surveying education authorities.

A comparison of these findings with the data collected in the Plurinational State of Bolivia in 2009, when there were 55 students per computer (UNESCO, 2013a), reveals significant progress towards digital inclusion.

5. Proportion of school-going children and youth who have used the Internet at an educational institution

According to the survey, 28% of students access the Internet at school. The study found that Internet-cafés are the space most used by students to access the Internet (46%), as shown in figure 2.

The study findings also show that of the 74 students with a computer and Internet access at home, 28% use Internet-cafés.

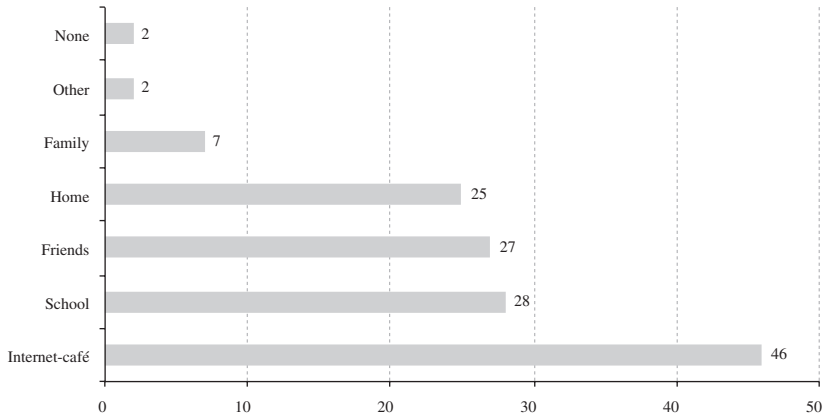
In addition, the study found that 53% of school computer labs have 100% of their hardware connected to the Internet, 27% have some machines connected and the remaining 20% have no Internet connection.

In the 15 schools surveyed, ICTs are present in classrooms to varying degrees. For example, 47% have computers in the classroom, 27% have Internet connections, 20% have multimedia projectors and 13% have loudspeakers.

A full 47% of schools do not have technological equipment in the classroom. This is one of the reasons

FIGURE 2

Spaces used by students to access the Internet
(Percentages)



Source: prepared by the authors, on the basis of data from the survey administered to students as part of this study.

why ICTs are not used in the teaching and learning process, as explained by the principal of the Aniceto Arce School, Sonia Lema Ruiz, to the newspaper El Nacional (Velásquez, 2013).

School limitations do not prevent students from accessing the Internet, since 93% of survey respondents report having a cellular phone, and 46% of them have connected to the Internet using the device. This information coincides with a report by the Telecommunications and Transport Oversight and Regulatory Authority (ATT) of the Plurinational State of Bolivia, which notes that everyday more Bolivians are connecting to the Internet using wireless devices (ATT, 2012). This is very relevant in the context of education, given that the spread of mobile technologies and their ease of use offer numerous possibilities for work in the classroom (UNESCO, 2013b).

According to the survey results, 44% of the students access the Internet at least twice per week and remain connected for an hour on average.

The hardware already in place in schools is a positive aspect, although there are significant challenges yet to tackle, such as the number of computers available for students, Internet access on all machines and use of ICTs in the classroom as a resource for the teaching and learning process.

6. Proportion of school-going children and youth who have used the Internet in educational or learning activities, by educational level

In all, 80% of the students report having at least one class per week that uses ICTs, and 43% of them attend rural schools, which suggests that teachers are interested in introducing ICTs in education.

Of the students surveyed, 87% report using the Internet for educational purposes, especially to find information. This percentage indicates the importance of the Internet as an information source for adolescents (see figure 3).

The findings suggest that recreational activities in cyberspace are of great importance in the lives of teenagers.

The study also shows that students have become skilled at using ICTs, especially when it comes to automated office software programmes (PowerPoint, Word and others) and Internet browsers (see figure 4).

In this new context, the challenge for teachers is to help their students cultivate these skills, both for the acquisition of specific knowledge and for lifelong learning.

By cross-referencing data, the study finds that 50% of the students who know how to use PowerPoint and Word and 47% of those who use Internet Explorer and Google Chrome do not have a computer at home.

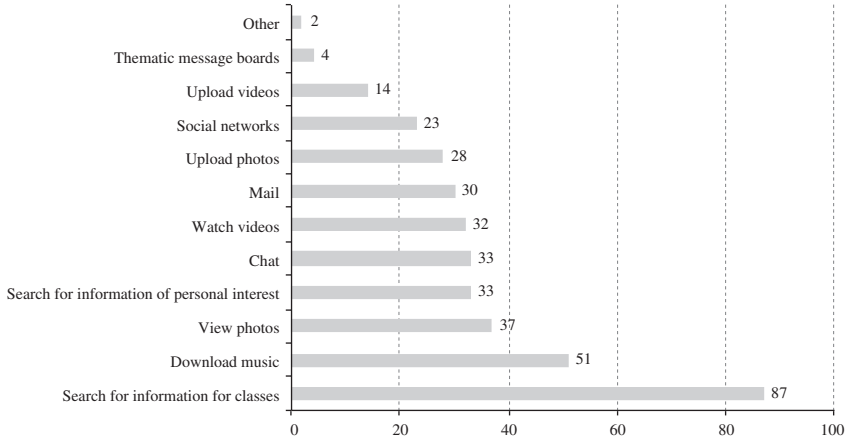
Of the students surveyed, 65% indicate that they have a profile on Facebook, 15% on Google Plus and 14% on Twitter. And 23% of adolescents report using more than one social network. This is a new space that teachers that could use to promote learning through collaborative group work.

The percentage of students who access Internet services is high, yet 37% of young women and 23% of young men do not have an email account. Meanwhile, 41% of female students and 45% of male students check email two or more times per week. This information

FIGURE 3

Students and Internet uses

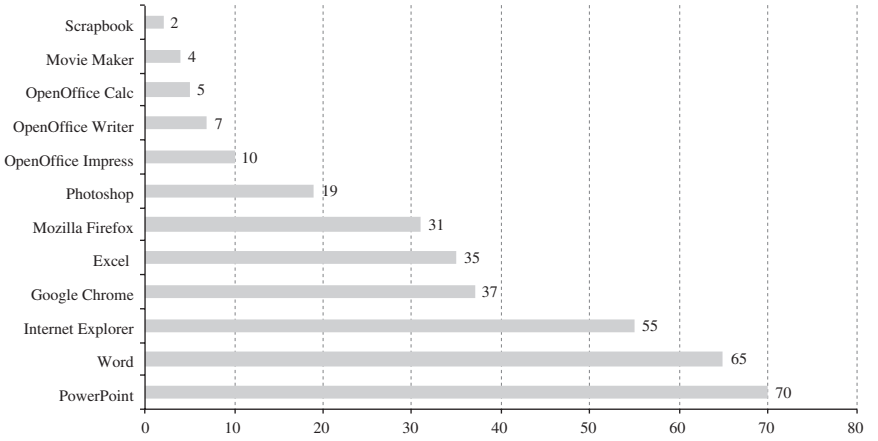
(Percentages)



Source: prepared by the authors, on the basis of data from the survey administered to students as part of this study.

FIGURE 4

Computer programmes used by students
(Percentages)



Source: prepared by the authors, on the basis of data from the survey administered to students as part of this study.

indicates that adolescents access the Internet frequently, so the task for teachers is to steer their ICT use towards educational purposes.

Of the students surveyed, 53% report having published content on the Internet. Within that group, 23% have uploaded a video to YouTube, 17% have created an animated slideshow online, 11% have created a webpage and 9% have uploaded photos to Flickr. This findings show that young people are becoming not just consumers but creators of online content, thus the importance of programmes to prevent and control risks to youth online.

Students are looking for different ways to access technologies, especially the Internet, as a means of expression and construction of identity (Morduchowicz, 2012, p. 68). In addition, "in the world of the teenager, not being able to understand maths is OK; not being able to use a computer or not having a mobile phone is not 'cool'" (TACCLE, 2009, p. 55). In this new reality, the teacher's guidance role is crucial for channeling teenagers' enthusiasm for ICTs towards learning.

7. Percentage of primary and secondary schoolteachers trained to teach one or several subjects using ICT resources, by educational level

The participating teachers, male and female alike, report having acquired ICT skills through individual tutoring or paid classes and by teaching themselves (self-study). The percentage of male teachers trained in ICTs is greater than the percentage of female teachers (see figure 5).

The findings point up the need to continue working on training programmes, in order to reduce gender gaps and ensure digital inclusion for the entire teaching corps.

The surveyed teachers prefer classroom training (44%) and mixed training (classroom and virtual, 43%) to completely virtual training (12%).

One of the reasons why virtual education is not an option for teachers is limited Internet access. According to the survey, 53% of female teachers and 56% of male teachers do not have Internet access at home.

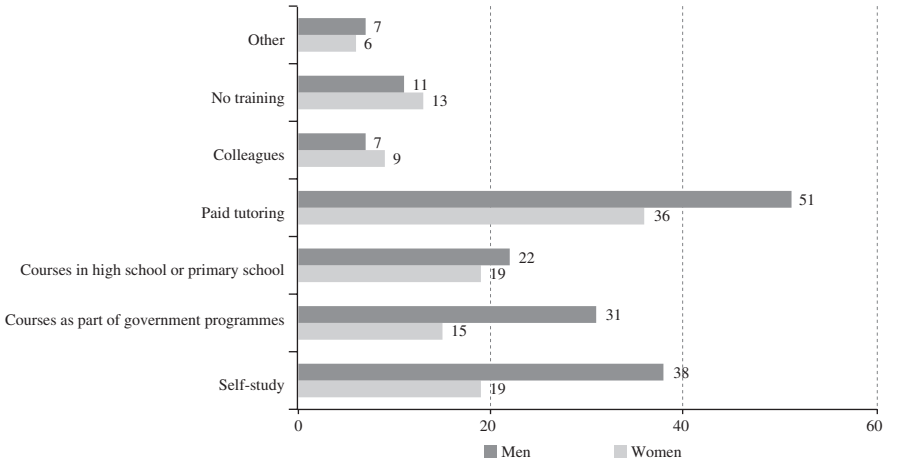
In all, 58% of the teachers say they need to receive training on integrating ICTs into the curriculum and their teaching practices, as well as technical training on using computers and software programmes (see figure 6).

The results suggest the need for a comprehensive pedagogical and technological training plan to help teachers develop creativity and acquire skills in the area of ICTs.

The surveyed teachers report having skills with office automation software (44% with spreadsheets, 53% with word processing and 28% with multimedia presentations), use of hardware (51%) and basic operating system functions (69%). However, they are less familiar with software for editing audio (67%), images (61%) and video (68%). This is an obstacle to building interactive and contextualized content that addresses new educational needs. In response, the Ministry of Education, as part of its "One Computer per Teacher" project, will provide instruction in the development of educational resources as a component of its training plan (Ministry of Education, 2011).

FIGURE 5

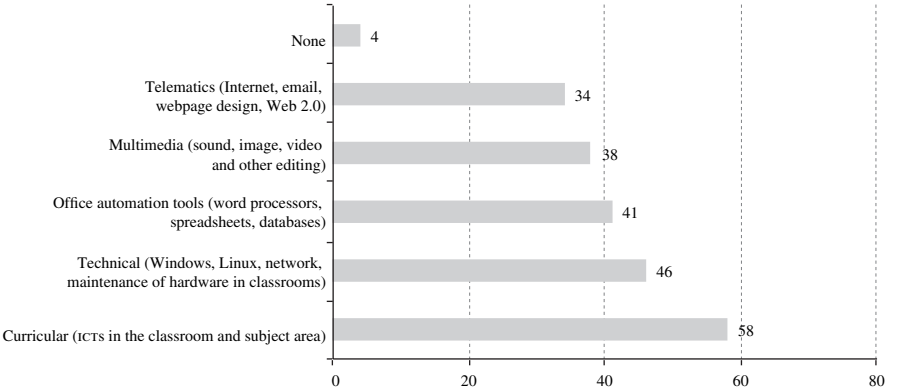
ICT training for teachers
(Percentages)



Source: prepared by the authors, on the basis of data from the survey administered to teachers as part of this study.
ICT: information and communications technologies.

FIGURE 6

ICT-training needs for teachers
(Percentages)



Source: prepared by the authors, on the basis of data from the survey administered to teachers as part of this study.
ICT: information and communications technologies.
Office automation tools: set of software programmes to facilitate office work.

With respect to Internet resources, a high percentage of teachers report using email (80%), chat services (63%), Internet browsers (60%) and search engines (74%). However, they are unfamiliar with but would like to learn how to use blogs (87%), wikis (92%), message boards (79%), online videos (72%), educational platforms (85%), social networks (68%), videoconferencing (85%) and other online resources. These results reveal that teachers are unfamiliar with the diverse educational possibilities offered by cyberspace.

A full 63% of the teachers report using the Internet to prepare their lessons, which demonstrates the importance of online content as an information source for teachers.

The findings show that teachers prepare diverse resources for their classes, based especially on office automation software, yet 22% of them say they do not prepare any resources using computer-based tools (see figure 7).

According to data obtained from the Tarija District Department of Education, the training currently provided

to teachers is focused on how to use a computer, but the challenge is to provide training in ICT use to improve the teaching and learning process, which includes the creation of digital resources.

8. Proportion of public educational content that is digitalized

According to information provided by the Department of Education of the Municipal Autonomous Government of Tarija, the Tarija School District does not have a portal of regional resources, though there is a project underway to develop one.

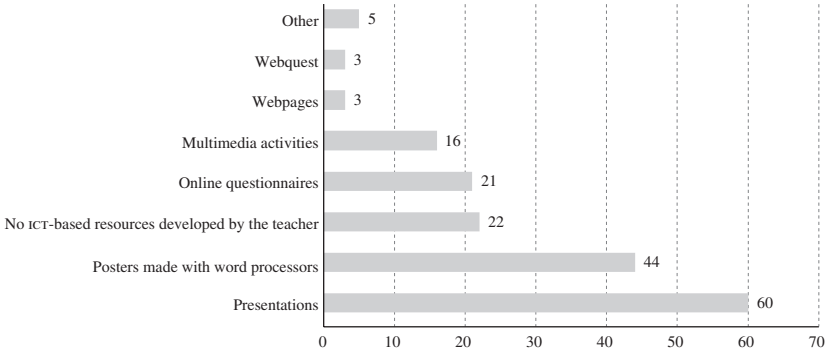
At the national level, the Ministry of Education has created the Educabolivia portal as a project within the National Programme for New Information and Communications Technologies for Education, for stakeholders in the educational process: parents, teachers and students. The portal provides elements to complement education and community development by offering quality educational experiences, services, resources and information that meet the needs and interests of the educational community (Educabolivia, 2013).

The portal has four sections: Teachers, Community, Students and Resources. The first three sections provide access to current information for the respective target group. The last section is intended to provide access to educational resources (see table 3).

The Educabolivia portal, created in 2007, represents a major step forward, especially in terms of introducing resources that are in line with the education law and the local context.

FIGURE 7

Resources developed by teachers
(Percentages)



Source: prepared by the authors, on the basis of data from the survey administered to teachers as part of this study.

TABLE 3

Resources on the Educabolivia portal

Section of the portal	Content	Number and type of resources
Educational websites	Link from the portal to external education-related websites.	1 061 links to websites
Plans	Gives teachers guidelines for planning lessons with educational content.	329 lesson plans
Texts	Provides access to abstracts on the listed titles and enables downloads.	347 titles
Games	There is a series of educational games created by nongovernmental organizations with offices in the Plurinational State of Bolivia. The games are classified by subject area.	15 educational games for the preschool level, 32 for the primary level and 23 for secondary level
Libraries	List of virtual libraries that can accessed free of charge.	11 links
Audio	Space to facilitate access to audio books that can be downloaded from the portal.	11 audio books
Presentations	Space that contains PowerPoint presentations on different subjects, by educational level.	15 presentations
Software	Enables downloads of different educational software programmes, which are accompanied by a short description and an indication of the suggested level.	
Images	A bank of images accompanied by short descriptions.	495 images
Videos	Provides educational videos/cartoons.	24 videos/cartoons

Source: prepared by the authors, on the basis of information from Educabolivia, 2013 [online] http://www.educabolivia.bo/.

XI

Analysis of results vis-à-vis other studies

As this study was being conducted, Terrazas and Ibarra (2013) conducted their own on ICTs and education in the department of La Paz in the Plurinational State of Bolivia with a sample of 100 secondary school students. This study has made it possible to analyse aspects in common (see table 4).

According to the study by Terrazas and Ibarra (2013), the students in La Paz use ICTs to build social relationships but use them very infrequently to search for information on the Internet.

As for the teachers, the researchers indicate that the computers donated under the project "One Computer per Teacher" are being underused due to the generational digital divide between students and teachers, lack of training in their use and teachers' reticence to use new technologies, which is consistent with the findings of this study.

The trend of the results of the work by Terrazas and Ibarra (2013) generally coincides with a number of aspects in this study.

A study conducted by the Centre for Studies into Economic and Social Reality (CERES), the organization Ciudadanía and the newspaper *Los Tiempos* in the department of Cochabamba (CERES/Ciudadanía/*Los Tiempos*, 2013) found that the population, in general, uses the Internet to: study or learn (38%), work (36%), participate in social networks (23%) and communicate with family and friends (21%).

The cited study shows that young people between the ages of 18 and 25 use the Internet to study and learn. This data point reveals a trend in Internet use that is consistent with the finding by the present study that teenagers use the Internet to search for information for their classes.

Similar studies have been carried out throughout Latin America, such as the one conducted in Peru by Balarin (2013), which indicates that the country's schools have low rates of Internet access (17.4% in primary schools and 36.7% in secondary schools). The student-to-computer ratio is 5 at the primary level and 9 at the secondary level, due primarily to the One Laptop Per Child (OLPC) programme under the model "one child, one computer", as well as the installation of technology resource centres in schools. In addition to the delivery of computers, 12,860 televisions and 80,000 robotics kits have been distributed to primary and secondary schools. Since 2008, Peruvian schools have a television channel and an educational portal with a variety of digital resources. Moreover, 67.9% of primary schoolteachers and 70.7% of secondary schoolteachers have received training in using a computer.

According to the cited study, Peruvian teenagers have developed ICT-related skills (office automation software, search engines and computers), which will help ensure their digital inclusion. However, Internet access at school and training for teachers on how to use ICTs in the classroom continue to be major challenges (Balarin, 2013).

Another study, conducted in Buenos Aires (Lago, 2012), highlights the important progress that has been made in digital inclusion in education, mainly due to local and national projects, such as the Conectar Igualdad [Connect Equality] project launched in 2010, which distributed one computer to every student and every teacher in the public school system. This initiative has been accompanied by a large investment in the installation of the technologies needed for schools to connect to the Internet.

The Lago study (2012) has identified teacher training, Internet connection, broadband and technical difficulties as some of the challenges involved in bringing ICTs to the classroom. It also discovered that students tend to use computers for entertainment purposes (games, videos, music and other forms of entertainment). According to the study, computers are having a very strong impact on households, inasmuch as they are drawing the students' families closer to the digital world, a major step forward for the Information Society.

The cited international studies coincide with this study in their identification of teacher training, hardware and broadband connectivity as some of the priorities for digital inclusion in education.

TABLE 4

Comparison of studies conducted in La Paz and Tarija, 2012-2013

Students in La Paz	Students in Tarija
For the most part, the students access the Internet at Internet-cafés.	46% of the students access the Internet at Internet-cafés.
Students report accessing the Internet from their cell phones.	46% of the students surveyed in Tarija report having accessed the Internet using their telephone.
The percentage of students who access the Internet at home is 1%.	25% of the students indicate that they access the Internet at home.
The majority do not have a computer or Internet at home.	51% of the students do not have a computer at home.
The teenagers do not have access to a telecentre or to computer labs at school because infrastructure is inadequate.	28% of the students use computer labs at school to access a computer and the Internet.
The students report having practiced with office automation software.	The students use various office automation software programmes: PowerPoint (70%), Word (65%), Excel (35%).
They use social networks like Facebook.	43% of the student surveyed have a profile on Facebook. In addition, they have accounts on more than one social network.
54% of survey respondents state that the focus of their Internet use is on improving searches for information and research.	87% of the students report using the Internet to search for information for their classes.
16% do not identify the specific use of ICTs in their educational activities.	30% of the students report having at least one class per week with ICTs.

Source: prepared by the authors, on the basis of L. Terrazas and J. Ibarra, *Estrategia de integración de las TIC en el sistema de educación en los municipios de La Paz y El Alto*, 2013 [online] http://www.pieb.com.bo/sipieb_notas.php?idn=8169.

XII

Conclusions

The study produced the following conclusions:

- The indicators used, as well as the local and international studies analysed, clearly demonstrate the education system in the Plurinational State of Bolivia, and especially in Tarija, is advancing towards digital inclusion.
- The study has verified the existence, but not the use, of ICTs in the teaching and learning process at the secondary level.
- All secondary schools have access to electricity, a key condition of digital inclusion.
- The existence of televisions in schools is positive, though it does not guarantee connectivity to the digital television station that carries the educational channel.
- In the case of radio, educational programming for adults has been offered; however, there are no specific projects at the secondary level, although a high percentage of schools have a radio.
- The One Computer Per Student project is having a direct effect on the student-to-computer ratio and reducing the digital divide at the secondary level in the Tarija School District.
- In response to the country's low rate of broadband Internet connectivity (ECLAC, 2012b) and the still-high student-to-computer ratio, students look for alternate ways of getting online, such as at Internet-cafés.
- With the rapid expansion of mobile technologies in the Plurinational State of Bolivia, large numbers of students are now able to access these technologies, creating a new space with numerous possibilities for education (UNESCO, 2013b).
- The students have acquired skills in using a computer and various software programmes, a finding corroborated by the research cited in the study.
- Students tend to use the Internet for information searches and entertainment.
- Students connect to the Internet at least two times per week.
- Training for teachers is largely a product of their own enthusiasm and personal effort, but gender gaps have been identified in terms of the type of training received.
- The integration of ICTs into educational curricula is one of the top priorities identified by teachers, a

reminder that the challenge of incorporating ICTs in education is not necessarily related to hardware, but rather to training for teachers on the didactic, pedagogical and creative use of ICTs in order to improve the teaching and learning process (Crespo and Medinaceli, 2013).

- Schools are contributing to digital inclusion, and to the extent that they extend their hours and improve technological and connectivity conditions, they will contribute to equality of opportunities for youth in the Information and Knowledge Society.
- Existing technological conditions and government projects are fostering digital inclusion in the Tarija School District, but this is a process that requires heavy investment over time to maintain, upgrade and expand the technological infrastructure, as well as ongoing training for stakeholders in the educational process.
- This study constitutes an important quantitative and descriptive input that could be complemented by open-ended questions to survey the participants on their perceptions, which would lay the groundwork for a broader quantitative-qualitative analysis of ICTs in education.

Bibliography

ABI (Agencia Boliviana de Información) (2013) [online] http://www3.abi.bo/#.

ACLO (n/d) [online] http://aclo.org.bo/bolivia/.

Agustín, M.C. and M. Clavero (2010), "Indicadores sociales de inclusión digital: Brecha y participación ciudadana", *Derecho, gobernanza y tecnologías de la información en la sociedad del conocimiento*, F. Galindo-Ayuda and A. Rover (eds.), Zaragoza, Prensas Universitarias de Zaragoza [online] http://eprints. rclis.org/14264/.

ATT (2012) [online] http://att.gob.bo/index.php/component/content/category/124-sisatt.

Ayni Bolivia [online] http://www.redayni.org/.

Balarin, M. (2013), "Programa TIC y educación básica. Las políticas TIC en los sistemas educativos de América Latina. Caso Perú" [online] http://www.unicef.org/argentina/spanish/Peru_ok.pdf.

Ballestero, F. (2002), *La brecha digital. El riesgo de la exclusión en la sociedad de la información*, Madrid, Fundación Retevisión.

Campos, M. (2013), "Santa Cruz, líder en usuarios de internet y redes sociales", *El Día* [online] http://eldia.com.bo/index.php?cat=357&pla=3&id_articulo=120867.

CERES (Centre for Studies into Economic and Social Reality)/Ciudadanía/*Los Tiempos* (2013), "Cochabambinos usan Internet principalmente para estudiar o aprender y luego para trabajar" [online] http://www.ceresbolivia.org/ archivos/745.

Crespo, A. and K.I. Medinaceli (2013), "Políticas en tecnologías de la información y comunicación en el nuevo contexto social y educativo en Bolivia", *Revista OIDLES*, vol. 7, No. 14 [online] http://www.eumed.net/rev/oidles/14/educacion-bolivia.html.

ECLAC (Economic Commission for Latin America and the Caribbean) (2012a), "Lista de indicadores para el eLAC2015", *Project Document*, Santiago, Chile [online] http://www.iadb.org/ intal/intalcdi/PE/2012/10486.pdf.

_____ (2012b), *Estado de la banda ancha en América Latina y el Caribe, 2012. Informe del Observatorio Regional de Banda Ancha* (ORBA), Santiago, Chile [online] http://www. eclac.org/publicaciones/xml/9/48449/EstadobandaAnchaenAMLC.pdf.

Educabolivia (2013) [online] http://www.educabolivia.bo/.

Educatic (n/f) [online] http://www.educatic.org.bo/.

eLAC (2010), *Plan of Action for the Information and Knowledge Society in Latin America and the Caribbean (eLAC 2015)*, Lima [online] http://www.cepal.org/cgi-bin/getProd.asp?xml=/socinfo/noticias/documentosdetrabajo/5/41775/P41775.xml&xsl=/socinfo/tpl-i/p38f.xsl&base=/elac2015/tpl-i/top-bottom.xsl.

eLAC2010 (2008), *Plan de Acción Regional sobre la Sociedad de la Información en América Latina y el Caribe (eLAC2010)*, El Salvador [online] http://www.eclac.org/cgi-bin/getprod.asp?xml=/elac2015/noticias/paginas/9/44099/P44099.xml&xsl=/elac2015/tpl/p18f.xsl&base=/elac2015/tpl/top-bottom.xsl.

eLAC2007 (2005), *Plan of Action for the Information Society in Latin America and the Caribbean eLAC 2007*, Rio de Janeiro [online] http://www.cepal.org/socinfo/noticias/documentosdetrabajo/5/21685/eLAC%202007%20English.pdf.

El Deber (2012), "Presidente lanza el canal estatal", 10 May [online] http://www.eldeber.com.bo/nota.php?id=120510222153.

Eurydice (2011), *Key Data on Learning and Innovation through ICT at School in Europe 2011* [online] http://eacea.ec.europa.eu/education/eurydice/documents/key_data_series/129EN.pdf.

Gallego, D. (2009), "Profesión y docencia: El nuevo perfil de la profesión docente. Informe 2007", IV Congreso Internacional de Educared "Educar en comunidad", Madrid, Fundación Telefónica.

Gewerc, A. (coord.) (2007), "Universidad y sociedad del conocimiento: ¿Es el e-learning la única respuesta?" [online] http://unisic.usc.es/informes/Informe_final_proyectoA-Definitivo.pdf.

INE (National Institute of Statistics) (2012), *Bolivia. Características de la población y vivienda. Censo Nacional de Población y Vivienda 2012* [online] http://www.ine.gob.bo:8081/censo2012/PDF/resultadosCPV2012.pdf.

Instituto de Evaluación y Asesoramiento Educativo/Neturity/Fundación Germán Sánchez Ruipérez (2007), *Las tecnologías de la información y de la comunicación en la educación. Informe sobre la implantación y el uso de las TIC en los centros docentes de educación primaria y secundaria (curso 2005- 2006)*, Madrid [online] http://www.oei.es/tic/TICCD.pdf.

IRFA (Instituto Radiofónico Fe y Alegría) [online] http://www.irfabolivia.org/.

Lago, S. (2012), "Inclusión digital en la educación pública argentina. El programa Conectar Igualdad", *Revista Educación y Pedagogía*, vol. 24, No. 64 [online] http://aprendeenlinea.udea.edu.co/revistas/index.php/revistaeyp/article/viewFile/14204/12547.

Ministry of Education (2014), "Gobierno inició la entrega de computadoras quipus a estudiantes de primero a sexto secundaria de Tarija" [online] http://www.minedu.gob.bo/index.php/component/k2/3-noticias-recientes/3056-gobierno-inicio-la-entrega-de-computadoras-quipus-a-estudiantes-de-secundaria-en-tarija.

_____ (2011), "Una computadora por docente" [online] http://computadora.educabolivia.bo/.

_____ (2010), "Ley de la Educación 'Avelino Siñani-Elizario Pérez'" [online] http://www.oei.es/quipu/bolivia/Leydla%20.pdf.

_____ (2006), "Programa Nacional TICS. Tecnologías de información y comunicación para el fortalecimiento del sistema

educativo y el desarrollo comunitario" [online] http://www. gesci.org/old/files/docman/About_Programa_Nacional_de_TICS.pdf.

Ministry of Hydrocarbons and Energy (2010), "Plan de Universalización Bolivia con Energía 2010-2015" [online] http://www2.hidrocarburos.gob.bo/phocadownload/PLAN%20DE%20UNIVERSALIZACI%C3%93N%20BOLIVIA%20CON%20ENERG%C3%8DA.pdf.

Morduchowicz, R. (2012), *Los adolescentes y las redes sociales*, Madrid, Fondo de Cultura Económica.

NTIA (National Telecommunications and Information Administration) (1999), "Falling Through the Net: Defining the Digital Divide" [online] http://www.ntia.doc.gov/legacy/ntiahome/fttn99/contents.html.

OECD (Organization for Economic Cooperation and Development) (2001), *Understanding the Digital Divide*, Paris [online] http://www.oecd.org/sti/ieconomy/1888451.pdf.

OEI (Organization of Ibero-American States for Education, Science and Culture) (2011), *La integración de las TIC en la escuela. Indicadores cuantitativos y metodología de la investigación* [online] http://www.oei.es/idie/IntegracionTIC.pdf.

Partnership on Measuring ICT for Development (2010), "Indicadores clave sobre tic" [online] http://www.itu.int/ dms_pub/itu-d/opb/ind/D-IND-ICT_CORE-2010-PDF-S.pdf.

Red TICBolivia [online] http://www.ticbolivia.net/.

Robinson, S.S. (2005), "Reflexiones sobre la inclusión digital", *Nueva Sociedad*, No. 195 [online] http://www.nuso.org/upload/articulos/3244_1.pdf.

Rovira, S. and G. Stumpo (comp.) (2013), *Entre mitos y realidades. TIC, políticas públicas y desarrollo productivo en América Latina* (LC/L.3600), Santiago, Chile, Economic Commission for Latin America and the Caribbean [online] http://www.iadb.org/intal/intalcdi/PE/2013/10767.pdf.

Severin, E. (2010), "Tecnologías de la información y la comunicación (TICS) en educación. Marco conceptual de indicadores", *Technical Notes*, No. 6 [online] http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=35128349.

TACCLE (Teachers' Aids on Creating Content for Learning Environments) (2009) [online] http://www. taccle.eu/index2.php?option=com_docman&task=doc_view&gid=16&Itemid=46.

Terrazas, L. and J. Ibarra (2013), *Estrategia de integración de las TIC en el sistema de educación en los municipios de La Paz y El Alto* [online] http://www.pieb.com.bo/sipieb_notas. php?idn=8169.

UNESCO (United Nations Educational, Scientific and Cultural Organization) (2013a), "Uso de las TIC en la educación en América Latina y el Caribe. Análisis regional de la integración de las tic en la educación y de la aptitud digital (e-readiness)", Quebec [online] http://www.uis. unesco.org/Communication/Documents/ict-regional-survey-lac-2012-sp.pdf.

_____ (2013b), UNESCO *Policy Guidelines for Mobile Learning*, Paris [online] http://unesdoc.unesco.org/images/0021/002196/219641E.pdf.

United Nations (2001), *Informe sobre desarrollo humano 2011. Poner el adelanto tecnológico al servicio del desarrollo humano*, Madrid, Mundi-Prensa Libros S.A. [online] http:// hdr.undp.org/sites/default/files/hdr_2001_es.pdf.

Velásquez, V. (2013), "Las computadoras donadas a los maestros no son empleadas en el aula", *El Nacional*, 2 July [online] http://www.elnacionaltarija.com/?p=33769.

WSIS (World Summit on the Information Society) (2005), "Tunis Commitment" [online] http://www.itu.int/wsis/docs2/tunis/off/7.html.

_____ (2003), "Declaration of Principles" [online] http://www.itu.int/wsis/docs/geneva/official/dop.html.

Macroeconomic trade-offs and external vulnerabilities of human development in Nicaragua

Marco V. Sánchez Cantillo

ABSTRACT

Nicaragua is making progress towards the Millennium Development Goals, but is set to miss a number of targets in 2015. This paper's general equilibrium analysis shows that it is unfeasible for the government to step up spending in order to meet these targets by the 2015 deadline. Any boost to public spending and financing would have to be front-loaded, which would entail pernicious macroeconomic trade-offs. A more realistic scenario would be to postpone meeting the goals until 2020. In that case, the allocation of public spending would spur economic growth without causing macroeconomic hardships, although the country would nevertheless remain highly vulnerable to external shocks.

KEYWORDS Economic conditions, macroeconomics, human development, economic development, millennium development goals, development indicators, Nicaragua

JEL CLASSIFICATION C68, O2, O11, O54

AUTHOR Marco V. Sánchez Castillo is a Senior Economic Affairs Officer, Development Policy and Analysis Division, Department of Economic and Social Affairs, United Nations. sanchez-cantillo@un.org

I
Introduction

Despite the structural changes that its economy has undergone in the past two decades, Nicaragua lags behind most Latin American and Caribbean countries in terms of economic and human development. This is largely attributable to the long-lasting effects of armed conflict in the 1980s and the resulting decision of the United States and international financial institutions to break off economic and financial relations with the country (Sánchez and Vos, 2006). The country's foreign debt position was unsustainable in the late 1980s, with this debt representing 940% of gross domestic product (GDP) in 1989. Both the peace process and the resumption of economic and financial relations with the United States and international financial institutions allowed Nicaragua to shift course in the early 1990s.

Massive inflows of foreign grant aid paved the way for the government to implement an economic stabilization programme involving restrictive monetary policies and rigorous fiscal discipline. The first signs of economic stability were followed by fiscal and State reforms; the gradual liberalization of trade, foreign-exchange and financial regimes; and the phasing-out of controls on foreign direct investment (FDI). During the 1990s, the public finances were healthier and better controlled, inflation was curbed and international trade picked up speed. Although it was still very high, foreign debt had shrunk to 175% of GDP by 1999.

In the late 1990s and early 2000s, the Government of Nicaragua, with assistance from international financial institutions, introduced a number of programmes and strategies to reduce the country's stubbornly high levels of poverty. In 2000, the country endorsed the United Nations Millennium Declaration and pledged to pursue the Millennium Development Goals. The Government adopted a number of targets associated with human development indicators and extreme poverty reduction to be met by 2015, and incorporated those targets into the country's poverty reduction strategies —including the Heavily Indebted Poor Countries (HIPC) Initiative— and development plans. Some headway has been made on social indicators and poverty reduction, but significant gaps remain, thus derailing the country's progress towards a number of the Millennium Development Goals. Some targets, such as the national target on extreme poverty reduction, have already been met, but others remain pending. For example, a large number of boys and girls still do not complete primary school, coverage of basic sanitation services is worryingly low and maternal mortality remains a challenge. Policymakers will have to step up their efforts to achieve the Millennium Development Goals and put the country on a solid footing towards furthering human development. The level and effectiveness of public spending and financing will need to be raised, but in practice achieving this will also depend on the speed and sustainability of economic growth.

Structural changes in the 1990s did not translate into a fast and sustained economic recovery. Economic growth slowed in the second half of the 2000s owing to internal and external factors. Remittances from abroad —a fundamental source of income for a large portion of the poor population— and FDI flows showed unexpected downturns, and the terms of trade deteriorated as a result of oil and food price hikes and reductions in the world prices of key export commodities (Gámez and others, 2011; Sánchez, 2011). Slow economic growth and external vulnerabilities were exacerbated by the global financial crisis in 2008-2009 when international trade, FDI and remittances once again contracted, thus exerting pressure on the balance of payments and pushing per capita GDP growth down to -2.5% in 2009. This crisis also manifested itself through setbacks in a number of human development indicators, making the achievement of the Millennium Development Goals more challenging and costly for Nicaragua (Sánchez and Vos, 2009).

☐ This paper is one of the outputs of the project "Strengthening Macroeconomic and Social Policy Coherence through Integrated Macro-Micro Modelling", which was implemented by the United Nations Department of Economic and Social Affairs, in collaboration with the country office of the United Nations Development Programme (UNDP) in Nicaragua and the Ministry of Finance and Public Credit of Nicaragua. The author is grateful to all those who participated in the project and the institutions with which they are affiliated, especially to Manuel A. Deshon for his inputs into the initial drafts and Janet Ramírez and Martín Cicowiez for their prominent role in compiling and using datasets to assist in the calibration of the modelling tools used. The author also thanks all those who provided comments on a previous version of the paper presented at the Annual Conference of the Human Development and Capability Association (HDCA) held in Managua on 9-13 September 2013. Martín Cicowiez and Marcelo Lafleur also provided valuable comments to improve the paper. The views expressed are those of the author and do not necessarily reflect those of the United Nations or the implementing partners of the Department of Economic and Social Affairs capacity development project.

The economy recovered from the global financial crisis to grow by about 5.0% on average in 2011-2012. While foreign debt has been decreasing steadily, it is also true that social programmes continue to rely on foreign resources for their funding. In view of international donors' diminishing allocation of aid to developing countries, human development aspirations in Nicaragua will depend on access to foreign credit under favourable terms. Against this backdrop, this paper addresses three questions.

- Can the government step up public spending in order to achieve the Millennium Development Goals by 2015 without causing macroeconomic hardships?
- Can the government rely on higher and more sustained economic growth to mobilize resources for financing public spending requirements?
- If not, what would be a more realistic scenario for securing that financing and what external vulnerabilities could prevent the country from achieving the Goals?

This paper updates the estimates published by Sánchez and Vos (2009 and 2010) on the additional public spending that would be required to meet the Millennium Development Goals by 2015 in Nicaragua. The period of analysis is extended beyond 2015 in order to assess feasible scenarios for furthering human development (within the Millennium Development Goal framework) without causing marcroeconomic hardships. In addition, the vulnerability of these feasible scenarios to external shocks, given the small size and open nature of Nicaragua's economy, is also evaluated. In this regard, the paper draws conclusions that could inform the setting of the post-2015 sustainable development agenda. That process, led by the United Nations, to help define the future global development framework will seek to address the gaps associated with the Millennium Development Goals and complement the development agenda with new sustainability goals. The analysis involves the application of a computable general equilibrium (CGE) model calibrated with Nicaraguan data to generate a series of scenarios that can be evaluated. The results from the CGE model are in turn used to apply a microsimulation model that allows income poverty and inequality indicators to be estimated for these scenarios. Rather than focusing on describing these models in detail, the emphasis of the paper is on interpreting the results of the scenarios in order to draw conclusions that can be used to make policy recommendations.

Following this introduction, section II highlights salient aspects of past progress made towards a number of the Millennium Development Goals and the outlook for the future, outlines the main challenges confronted by Nicaragua with respect to meeting these development goals, and underscores the need for sustained economic growth in the face of external shocks. The modelling framework is described in section III. The data sources used for the economy-wide and microsimulation models and for the baseline scenario are described in section IV, followed in section V by the analysis of the findings from the baseline scenario and several alternative scenarios. Key conclusions and policy recommendations are summarized in section VI.

II

Millennium Development Goal achievements and pending tasks

1. Progress, gaps and challenges

Nicaragua's poverty reduction strategy emphasizes the attainment of the Millennium Development Goals. Since the mid-2000s, resources freed up by debt relief and additional donor contributions granted through the HIPC Initiative have been allocated to the poverty reduction strategy. Under the strategy, the government has stepped up social spending, although not to the extent required to put the country fully on-track towards meeting the Goals, as will be shown below. Public social spending rose slightly from 9.1% of GDP to 9.6% of GDP between 2002 and 2012 (see table 1), but it remains well below the regional weighted average of 18.6% of GDP estimated by the Economic Commission for Latin America and the Caribbean (ECLAC, 2013).[1] The sectoral allocation of this spending as a percentage of GDP is also fairly stable.

[1] Public social spending in Nicaragua would have represented just over 12% of GDP had it not been for a change in the base year for calculating GDP, which corrected a 30% underestimation in the level of output.

Measured in per capita terms, rather than as a share of GDP, public social spending grew from US$ 69.5 in 2002 to US$ 166.6 in 2012; yet it remains low by regional standards. Efforts to step up public social spending have not been bold enough in Nicaragua: the country still faces profound human development deficits despite having absorbed considerable sums of foreign grand aid. Part of the problem is that only a fraction of the debt relief is earmarked for poverty reduction programmes. In 2005, for example, only 53% of those funds were earmarked for poverty reduction and the remaining 47% were allocated to the repayment of domestic central government debt (Guimarães and Avendaño, 2011). The government has stepped up efforts to finance public social spending and has even used fiscal revenues to safeguard such spending at times of crisis. Nonetheless, these efforts are not reflected in higher public social spending as a proportion of GDP because foreign financing of this spending has been declining (see table 1).

The programmes and strategies targeting poverty reduction and human development goals have enabled progress towards the Millennium Development Goals, but has not brought all of them within reach by 2015 (see table 2). Poverty at the national level has decreased for several reasons, in particular, improved living conditions in rural areas. That improvement is attributable in part to the effectiveness of programmes promoting the production of food staples, lower consumer prices for these products and, in more general terms, inflows of remittances. The national extreme poverty target (16.3%) has already been met; however, the international target (9.7%) of halving the level of extreme poverty relative to its 1993 level remains a daunting aspiration. The volatility of economic growth has impeded further reductions in extreme poverty. Measured as the percentage of the population living on less than US$ 1 a day, extreme poverty rose somewhat between 1998 and 2001 as the economy slowed. During these years, a fraction of public social spending was reallocated to natural disaster recovery measures. The population living in moderate and extreme poverty expanded again in 2005 during another economic downturn. Poverty reduction programmes helped to revert this situation: moderate and extreme poverty had fallen by 2009, however, the most recent survey data available during the drafting of this paper do not reflect the full impact of the global financial crisis on poverty.

Outcomes in primary education have by and large been satisfactory. Net enrolment has increased, but must rise by a further 11 percentage points in order for the country to meet one of the key targets of Goal 2. Nonetheless, the major challenge in education is not net enrolment, but the fact that less than 50% of the students who enrol in primary school succeed in completing the cycle. Through public spending on education, infrastructure in the sector has been improved and assistance has been provided to poor students through school lunch programmes and conditional cash transfers. Teaching quality has also been addressed by modernizing the education sector. In spite of these efforts, spending to date has been either insufficient or ineffective, or both, because repetition and dropout rates remain high. The public sector faces enormous limitations on infrastructure capacity in terms of schools and teaching materials.

TABLE 1

Nicaragua: public spending earmarked for the poverty reduction strategy, 2002-2012

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Public social spending (*percentages of GDP*)	9.1	11.1	12.0	13.1	9.6	10.2	10.3	9.9	9.9	9.6	9.6
Education	2.6	2.9	2.8	3.1	2.4	2.6	2.8	2.9	2.7	2.5	2.4
Health	2.9	3.2	2.9	3.2	2.5	2.8	2.7	2.7	2.8	2.6	2.7
Water and sanitation	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1
Other	3.5	4.9	6.2	6.7	4.6	4.8	4.7	4.1	4.4	4.3	4.4
Per capita public social spending (*dollars*)	69.5	85.4	99.2	116.9	117.9	135.7	150.0	140.7	145.8	156.6	166.6
Financing of public spending (*percentages*)											
Fiscal resources	54.8	33.2	28.3	38.7	52.0	51.7	49.6	55.2	57.3	61.9	65.6
External development cooperation	36.5	45.5	48.4	42.3	33.3	32.3	33.5	28.3	27.3	22.6	21.2
External debt relief	8.7	21.3	23.3	19.0	14.6	15.9	16.9	16.5	15.5	15.5	13.3

Source: budget reports from the Ministry of Finance and Public Credit.

Note: some figures from the budget reports were converted into local currency using the average exchange rate of the Central Bank of Nicaragua. The reduction in public social spending as a percentage of GDP from 2005 to 2006 is explained by a change in the base year for calculating GDP from 1994 to 2006, which corrected a 30% underestimation in the level of GDP. Fiscal resources include tax revenues and earmarked revenues. External development cooperation includes grants and loans. External debt relief includes debt relief under the Heavily Indebted Poor Countries Initiative and cancellation of Paris Club debt.
GDP: gross domestic product.

TABLE 2

Nicaragua: Millennium Development Goal and poverty indicators, 1990-2011 and target for 2015

Indicator	1990	2000	2005	2011	Target for 2015
National moderate poverty (*percentages*)	50.3 (1991)	45.8 (2001)	48.3	42.5 (2009)	
Goal 1: national extreme poverty (*percentages*)	19.4 (1991)	15.1 (2001)	17.2	14.6 (2009)	9.7
Goal 2: net enrolment rate in primary education (*percentages*)	72.6 (1991)	80.5	87.1	88.9	100.0
Goal 2: students who begin and complete primary education (*percentages*)	...	35.4	43.0 (2006)	41.5 (2010)	
Goal 4: under-five child mortality (deaths per 1 000 live births)	72.0	37.0 (2001)	35.0 (2006)	25.0	17.0
Goal 5: maternal mortality (deaths per 100 000 live births)	160.0	87.0	86.5	62.0	40.0
Goal 7: population with access to an improved water supply (*percentages*)	57.7	78.6 (2002)	90.5	...	85.0
Goal 7: population with access to improved sanitation (*percentages*)	...	27.9 (2002)	37.2	39.8 (2008)	72.5

Source: National Institute of Information for Development (INIDE) for poverty data; Ministry of Education (MINED) for education data; Ministry of Health (MINSA) and Pan American Health Organization (PAHO) for mortality data except for 2011; National Human Development Plan 2012-2016 for mortality data for 2011; and Nicaraguan Water and Sewerage Enterprise (ENACAL) for data on water and sanitation.

Note: poverty rates represent the percentage of the population whose per capita consumption falls below the respective official poverty lines.

There are not enough qualified teachers and their pay is low. Only recently were all primary schools in rural areas instructed to deliver education for all grades of the cycle. Poor well-being conditions, migration and the cost of education critically limit the demand for education such that a large number of boys and girls drop out of school or never enrol, especially in the rural areas where poverty is higher and child labour remains a worrisome reality.

Under-five mortality has decreased systematically as social policy has promoted better and more comprehensive care provision in order to reduce children's nutritional and educational vulnerability. This trend has been strengthened by the extension of vaccination and breastfeeding campaigns to larger swathes of the population, the wider use of oral rehydration and infection control therapies, new public investment in basic services in rural areas, and integrated social protection systems targeting extremely poor children under the age of 6 years. Yet meeting the target of 17 deaths per 1,000 live births remains a challenge and will require a larger share of public spending on health being earmarked to further reduce the prevalence of diarrhoeal diseases, acute respiratory infections, premature births and the problems associated with low birth weight, asphyxia and sepsis.

The outlook is less encouraging for maternal mortality, even though the number of deaths per 100,000 live births fell from 160 in 1990 to 62 in 2011.[2] Complications during childbirth continue to be one of the main causes of death for women of reproductive age. Achieving the target of reducing maternal mortality to 40 deaths per 100,000 live births by 2015 will require higher and more sustained growth in public health spending. The priority areas are to improve the quality and coverage of prenatal and postnatal care, assistance during childbirth and the prevention of complications in pregnancy. Improvements must be made in terms of health service efficiency, increasing the coverage and capacity of health infrastructure, especially at the primary and secondary levels of care, and expanding preventive care and health promotion for households and communities, especially in rural areas.

Last, but not least, Nicaragua also committed to halving the proportion of the population without access to drinking water and improved sanitation services between 1990 and 2015. The target for drinking water has already been met, owing mostly to investment programmes by the Nicaraguan Water and Sewerage Enterprise (ENACAL), which have expanded the coverage of drinking water supplies in rural areas and in neighbourhoods in Managua.

[2] Maternal mortality figures for Nicaragua vary significantly depending on the source.

The sewerage programmes of ENACAL and the rural latrine projects of the Emergency Social Investment Fund have benefited thousands of households in recent years. Nonetheless, only 40% of the population had access to improved sanitation services in 2011. The country will struggle to meet its target of increasing coverage to 72.5% of the population by 2015, unless there is a more sustained increase in public spending to expand and improve the sewerage and rural latrines infrastructure.

Only by stepping up public social spending to implement cost-effective policies will the gaps in primary education, maternal mortality and basic sanitation be eliminated. Sánchez and Vos (2009 and 2010) found that continued economic growth and the implementation of the public spending policies in place before the global financial crisis would contribute to notable progress on a number of indicators, but not enough to meet all targets by 2015. These authors estimate that, before the global financial crisis, the additional public social spending required to meet these targets in Nicaragua ranged from 3.6% of GDP to 4.7% of GDP per year for the period 2000-2015, depending on the source of financing. These estimates were revised upward by 1.7 percentage points of GDP after taking into consideration the effects of the global financial crisis on private social spending and the Millennium Development Goals.[3]

2. Economic growth and external vulnerability

Sustained economic growth is badly needed in Nicaragua to close the development gaps described above. An emphasis should be placed on increasing incomes and boosting private demand for social services, which would enable the government to raise tax revenues and thus increase public social spending and investments in infrastructure. As indicated above, the Government of Nicaragua has stepped up efforts to finance public social spending and has even used fiscal revenues to safeguard that spending during crisis periods. This is particularly important at a time when access to concessional loans and grant aid has been declining; in fact, grant aid represented a mere 2.6% of GDP per year in the period 2010-2012 (see table 3).

Tax revenues have risen steadily on the back of a number of tax reforms since the mid-1990s: they represented 20.8% of GDP per year in the period 2010-2012, 8 percentage points higher than in the second half of the 1990s (see table 3). The most recent tax reform was the Tax Coordination Act (Act No. 822), passed in 2012. However, new reforms to expand the tax base and boost revenues are not expected to raise revenues substantially. It is precisely the success of past fiscal reforms that has narrowed the scope for generating even higher tax revenues in a relatively short period of time. Public spending policies will continue to rely heavily on foreign resources, although there is also a remote possibility that shallow domestic financial markets will be able to mobilize some domestic resources.

Fragile access to concessional loans and aid, debt sustainability concerns and a lack of scope for further raising tax revenues in the short term undermine the country's ability to mobilize resources in support of human development goals. Sustained economic growth is thus critical to creating more space for domestic resource mobilization in support of human development. Alas, the economic achievements resulting from stabilization efforts and economic reforms, as well as some episodes of favourable external conditions, have not translated into the fast and sustained economic recovery that Nicaragua needs in the long run (see figure 1). Per capita GDP growth was unstable in the 1990s, when it averaged 2.7% per year, and it subsequently declined to 2.2% per year in 2000-2004 (see table 3). The prospects subsequently improved, though, as per capita GDP grew by 5.8% in 2005-2009 and by 6.8% in 2010-2012.

Various studies show that the stability of economic growth in Nicaragua has been adversely affected by unfavourable external conditions (see, for instance, Gámez and others, 2011; Sánchez, 2011; Sánchez and Vos, 2006). External vulnerabilities are rooted in a number of factors. For example, export promotion policies and mini-devaluations of the exchange rate have enhanced export competitiveness, but a lack of export diversification remains a major concern, especially because exports are among the main drivers of economic growth in Nicaragua. Textiles (including leather products), meat and coffee represented, respectively, 16%, 17% and 9% of total exports in 2011. Together, these three product groups accounted for nearly half of total exports. Fortunately for Nicaragua, the value of its key exports has not been undermined seriously by world prices, which on the whole remained favourable between 1994 and 2011. Yearly export prices show only one fall in textile prices (8% in 2009) and four reductions in coffee prices (each by about 20% in 1996, 1999, 2000 and 2001) (see figure 2). Coffee prices fell by 23% in 2013 (data not

[3] An update of these estimates is presented below, but the scenario analysis is refined in two respects. First, in view of the short time span to 2015, the simulation period was extended to assess feasible financing strategies for the spending required to achieve the Millennium Development Goals. Second, the analysis sheds light on the vulnerability to external shocks of a feasible scenario of MDG achievement.

TABLE 3

Nicaragua: macroeconomic indicators, 1990-2012
(Annual averages)

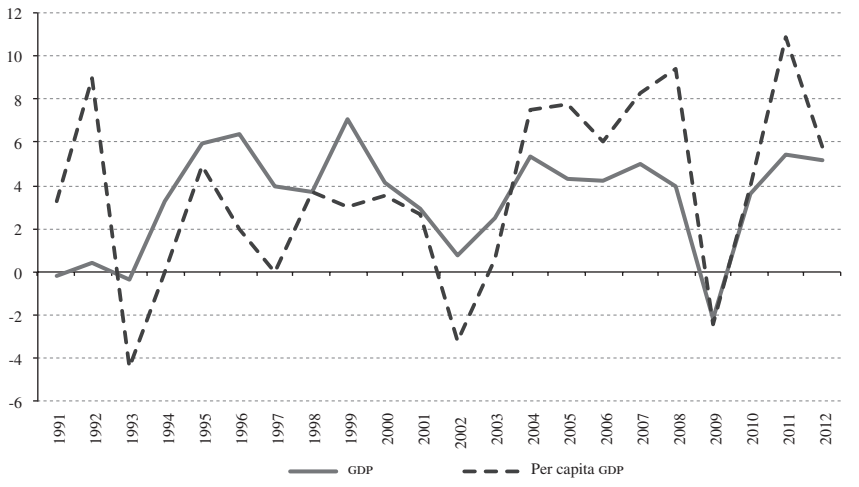
Indicator	1990-1994	1995-1999	2000-2004	2005-2009	2010-2012
Public finances, official development assistance and foreign public debt (*percentages of GDP*)					
Tax revenue	20.5	12.9	15.3	18.7	20.8
Fiscal balance, before grants	-10.2	-5.7	-6.9	-3.3	-1.8
Fiscal balance, after grants	-3.7	-1.4	-3.3	-0.3	-0.2
Foreign borrowing	7.6	3.9	4.3	2.8	2.1
Domestic borrowing	-4.0	-2.5	-2.2	-2.6	-1.9
Official development assistance	41.4	17.1	13.7	9.0	5.4
Concessional loans	18.9	8.9	6.5	4.0	2.8
Grants	22.6	8.2	7.2	5.0	2.6
Foreign public debt	593.9	206.6	152.8	61.9	42.7
External sector (*percentages of GDP*)					
Current account balance	-46.2	-23.4	-18.7	-14.5	-12.0
Foreign direct investment	1.7	4.8	5.2	5.4	7.9
Remittances	1.1	4.7	9.6	10.4	9.6
Production (growth rate)					
Real GDP	0.6	5.4	3.1	3.1	4.8
Real GDP per capita	13.3	2.7	2.2	5.8	6.8

Source: Central Bank of Nicaragua.

Note: the fiscal balance and its financing refers to the non-financial public sector. The net concession of loans was considered part of the fiscal balance until 2000, after which it became part of domestic borrowing. Grants include some liquid foreign grants linked to projects and interim debt relief from the Heavily Indebted Poor Countries Initiative.
GDP: gross domestic product.

FIGURE 1

Nicaragua: GDP and per capita GDP growth in real terms, 1991-2012
(Percentages)



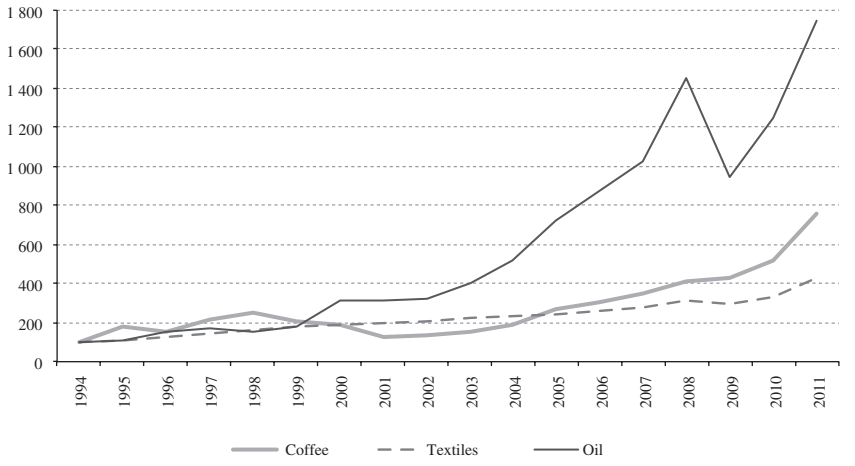
Source: Central Bank of Nicaragua.
GDP: gross domestic product.

shown in the figure). World prices remain a potential source of external vulnerability in view of the lack of export diversification.

The value of total imports has grown faster than the value of total exports, largely because of the rising refined oil import bill. Refined oil represented 11% of total imports in 2011 and its price has risen by 21% per year since 1994 (see figure 2). The resulting trade deficit has been offset by remittances from abroad and FDI, which have contributed to the narrowing balance-

FIGURE 2

Nicaragua: implicit price index for key export and import commodities, 1994-2011
(1994=100)

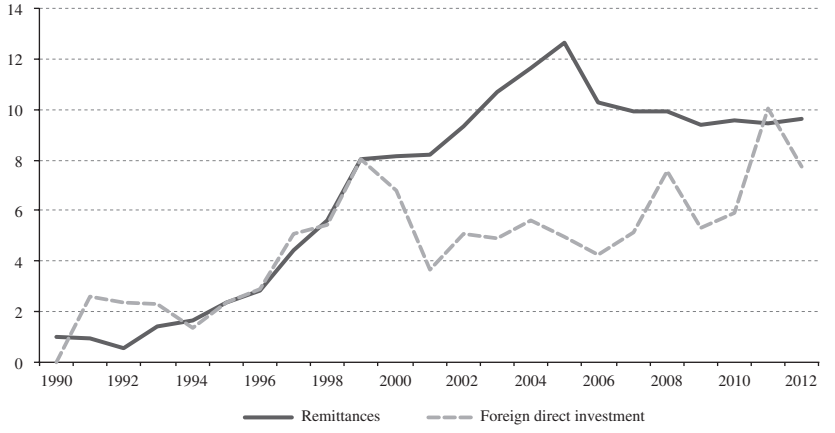


Source: Central Bank of Nicaragua.

of-payments current account deficit (see table 3). FDI has risen sharply since the second half of the 1990s, levelling off at around 5% of GDP per year in the 2000s and subsequently climbing to almost 8% of GDP in 2010-2012 (see table 3). In the period 1990-2012, FDI inflows to Nicaragua fell 10 times, and by a substantial drop of over 1 percentage point of GDP on five of those occasions (see figure 3). Remittances inflows have been relatively steadier than FDI, although they also fell seven times between 1990 and 2012, most notably by 1.4 percentage points of GDP in 2006 and by 0.5 percentage points of GDP in 2009. The balance of payments, which is critical to achieving sustained economic growth, is highly vulnerable to weaker inflows of remittances and FDI. Those external vulnerabilities could jeopardize the country's efforts to pursue human development goals.

FIGURE 3

Nicaragua: net foreign direct investment and remittances inflows, 1990-2012
(Percentages of GDP)



Source: Central Bank of Nicaragua.
GDP: gross domestic product.

III
Modelling framework

An economy-wide modelling framework is needed for the scenario analysis conducted to quantify the additional public social spending and financing required to meet the Millennium Development Goal targets. The Maquette for MDG Simulations (MAMS) is used in this paper. This dynamic-recursive CGE model is a system of simultaneous, non-linear equations whereby an equilibrium is achieved using equations that define behaviour (for consumers, producers, and so on), macroeconomic balance (fiscal accounts, balance of payments, savings-investment balances, and so on) and market equilibrium (for goods and services, factors, and so on), among other elements. MAMS is described in detail in Lofgren and Díaz-Bonilla (2010) and Lofgren, Cicowiez and Díaz-Bonilla (2013). As these documents explain, the model is innovative in its inclusion of a set of basic human development objectives in its module on the Millennium Development Goals and education, on which more detail is provided below. This paper goes further by applying MAMS to address the external vulnerabilities of Millennium Development Goal achievement in Nicaragua.

The use of a dynamic-recursive CGE model such as MAMS is justified because the strategies implemented in pursuit of development goals are likely to have a major impact throughout the economy. Such strategies can affect demand and supply in the different markets (goods and services, factors and foreign exchange), and the related adjustments may call for significant trade-offs throughout the period for achieving the development goals and beyond. MAMS specifically takes into consideration the possible synergies between the different Goals in its module on the Millennium Development Goals and education. Such synergies may influence the required expansion of services (for example, greater safe water supply coverage may reduce the need for health service expansion) or the speed at which the various Goals are achieved.

The strategy adopted to finance the public spending required to achieve these development goals also affects the outcomes. For example, foreign financing could have an impact on the real exchange rate, while financing through domestic tax revenues could reduce private consumption demand and domestic borrowing could crowd out credit resources for private investment. Without doubt, increased public spending is essential for meeting human development goals, but adjustments in the real exchange rate, real wages and other relative prices could raise the unit costs for meeting these goals —along with the costs for other sectors— or discourage exports, thereby widening the external deficit that needs to be financed, among other consequences. Productivity gains accruing exclusively from reaching higher human development standards will take some time to materialize and are thus unlikely to trigger an immediate impact on economic growth. MAMS is a useful tool for assessing the macroeconomic trade-offs of financing development through public spending in order to establish whether the potential economic and social gains to be reaped in the long run would offset these trade-offs.

The module on the Millennium Development Goals and education specifies the main determinants of achieving the Goals that are not directly associated with income poverty (that is, the non-poverty Goals) and the direct impact of enhanced public spending on infrastructure and services related to the Millennium Development Goals (see table 4). It considers specific targets for achieving the non-poverty Goals of universal primary education (Goal 2), reducing under-five and maternal mortality (Goals 4 and 5) and increasing access to safe water and basic sanitation (Goal 7). The indicator used for Goal 2 is not enrolment but the net on-time primary completion rate, which is a function of student behaviour (enrolment, promotion, graduation), since most developing countries have already achieved acceptable levels of enrolment in primary education. A target is set for the timely completion, without repetition and for the relevant age cohort, of primary school. Student behaviour, in turn, depends on the quality of education (service delivery per student), household consumption per capita (as an indicator of living standards), income incentives (the expected wage premium from education), child mortality (a proxy for the health status of the student population) and public infrastructure (such as roads, bridges, electricity networks, and so on, which facilitate access to and the functioning of education centres). As the completion rate in all education cycles rises, the skill composition of the labour force shifts towards a larger share of skilled workers, leading to a direct association between the functioning of the education system and the labour market. Under-five and maternal mortality

rates, on the other hand, are determined by the per capita availability of public and private health services, household consumption per capita, the level of public infrastructure (such as roads, bridges, electricity networks, and so on, which facilitate access to and the functioning of health centres and hospitals), and the coverage of water and sanitation services. The determinants of access to water and sanitation are household consumption per capita, the provision of water and sanitation services by public or private providers and public infrastructure.

The effectiveness of the determinants of the non-poverty Goals follows a non-linear pattern. Logistic functions for the "production" of the different Millennium Development Goal indicators and student behaviours are generated in such a way that each determinant becomes relatively less effective as progress is made towards the target. This non-linearity feature makes MAMS a more appropriate tool to establish whether a country is on-track towards its development goals than other models that have tried to establish this by projecting past trends forward in a linear fashion. Although social services can be provided publicly or privately, only new government investment and current spending will lead to the kind of policy-driven increase in the supply of social services and public infrastructure that can secure the attainment of one or more development targets. Scenarios are simulated in which the government mobilizes sufficient domestic or foreign resources to finance the new spending required to meet the targets. The mathematical statement of the model that captures these transmission mechanisms is explained in detail in Lofgren and Díaz-Bonilla (2010) and Lofgren, Cicowiez and Díaz-Bonilla (2013).

The goal of reducing extreme poverty (Millennium Development Goal 1) is not targeted in the same way as the non-poverty Goals because of the absence of tools that policymakers could realistically use to achieve specific poverty outcomes in most real-world, developing-country contexts. Owing to the use of representative households, CGE models such as MAMS typically fail to give the level of income distribution detail that is required to properly estimate poverty at the household level. This shortcoming is overcome by using the non-parametric microsimulation model described and applied in Vos and Sánchez (2010).

Thus, income distribution as recorded in household surveys is taken into account, without making assumptions about the income distribution within the CGE model representative household. For a number of labour market variables taken from the CGE model scenarios (unemployment by occupation type, employment and wages by sector, overall average remuneration level and skill composition of the employed population), changes for each year of the scenarios are calculated relative to a base year for the microsimulations. These changes are approximated in the microsimulations using a random selection procedure within labour market segments narrowly defined according to occupational categories by educational level and sectors of employment. A random selection process is applied to determine, for each year, which working-age persons change their labour force status (employment versus unemployment); which change their sector of employment; which employed persons upgrade their level of education; and how new labour incomes are assigned to individuals in the sample. The

TABLE 4

Determinants of the non-poverty Millennium Development Goals

Millennium Development Goal	Service delivery	Household consumption per capita	Wage incentives	Public infrastructure	Other Millennium Development Goals
2: Primary education					
(i) Enrolment	1.0000	0.3063	1.3650	0.3815	-0.6300 (MDG 4)
(ii) Promotion	1.0000	0.1187	1.5167	0.1715	-0.0035 (MDG 4)
4: Under-five mortality	-0.8550	-0.6133		-0.2000	-0.3268 (MDG 7w)
					-0.3268 (MDG 7s)
5: Maternal mortality	-0.9500	-0.6133		-0.2000	-0.1315 (MDG 7w)
					-0.1315 (MDG 7s)
7: Access to safe water	0.3600	0.1120		0.0020	
7: Access to basic sanitation	0.8000	0.6625		0.5880	

Source: H. Lofgren, M. Cicowiez and C. Díaz-Bonilla, "MAMS–A computable general equilibrium model for developing country strategy analysis", *Handbook of Computable General Equilibrium Modelling*, P.B. Dixon and D.W. Jorgenson (eds.), vol. 1A, Amsterdam, North-Holland, 2013, p. 223; and estimates of underlying elasticities for Nicaragua (presented in brackets) based on the analysis documented in J. Pacheco, "Determinantes socioeconómicos de la educación, la mortalidad y el acceso al agua potable y el saneamiento en Nicaragua: Un análisis econométrico", 2013 [online] http://www.un.org/en/development/desa/policy/capacity/country_documents/nicaragua_determinantes.pdf.

Note: MDG 7w refers to the Millennium Development Goal target on access to drinking water and MDG 7s refers to the target on sanitation.

key assumption is that, on average, these occupational shifts caused by the random changes correctly reflect the impact of actual changes on the labour market. Because of the introduction of a process of random assignation, the microsimulations are repeated many times for each year of the simulation period, in Monte Carlo fashion. Each time, the changes in the labour market are imposed on a given distribution derived from a recent household survey in order to generate a new labour income distribution. In order to run the microsimulations, the household survey year and the year with respect to which all occupational shifts taken from the CGE model are expressed are consistent. Changes in non-labour incomes, such as government transfers and remittances from abroad, are also computed for each year of the scenarios relative to the base year for the microsimulations, using values taken from the CGE model. These changes are proportionally scaled up or down to re-estimate the new household income distribution. That figure and the marginal propensity to consume by product are in turn used to generate a new consumption distribution. On the basis of this process, 95% confidence intervals are constructed for the poverty and inequality indices estimated using the newly generated income and consumption distributions.

IV

Data, calibration and baseline scenario

The basic accounting structure of MAMS is derived from a Social Accounting Matrix (SAM) for 2006. It integrates data from official national accounts (supply and use tables, institutions' accounts and key macroeconomic aggregates), fiscal accounts, balance-of-payments information and a recent household survey into a consistent accounting framework. This matrix possesses the following key characteristics: (i) a fairly detailed treatment of public investment and its financing; (ii) the inclusion of seven areas of government service provision in primary education, secondary education, tertiary education, health, water and sanitation, public infrastructure and other government services; (iii) coverage of private-sector services, including primary education, secondary education, tertiary education, health and other private services; (iv) the disaggregation of other economic activities into various sectors, with separate accounting for those sectors most typically affected by external shocks (such as coffee, textiles and oil); (v) the division of labour as a factor of production into three categories that are each linked directly to an educational cycle, namely, workers who have not completed secondary education (unskilled), workers who have completed secondary but not tertiary education (skilled) and workers who have completed tertiary education (highly skilled),[4] and (vi) the inclusion of the government, a representative household (the domestic non-government sector) and the rest of the world as institutional agents.

In addition to the SAM, the MAMS dataset also includes data relating to the Millennium Development Goals (as recorded in table 1 for the non-poverty indicators), the labour market and a set of elasticities. Other key pieces of information used to calibrate the model are: (i) a possible scenario where the targets would be met on the basis of the past evolution of the determinants listed in table 4; (ii) the number of students at the different stages of the educational cycle; (iii) student behaviour patterns in terms of promotion rates and other indicators, and (iv) the number of workers and initial unemployment rates for the three categories of workers. All of these data are from official sources: the Central Bank of Nicaragua, the Ministry of Finance and Public Credit, the Ministry of Education and the National Institute of Information for Development. The elasticities define behaviour in production, trade, consumption and Millennium Development Goal functions (see table 4). Logistic models have been estimated econometrically to identify the influence of both supply and demand factors on outcomes in education, health, and access to safe water and sanitation. The findings of these empirical analyses are presented in Pacheco (2013) and have been used to define a set of elasticity values to calibrate the Millennium Development Goal functions. According to these values, the wage incentive appears to be the main

[4] Other factors of production include public capital stocks by government activity, private capital stock, and natural resources used in mining and agriculture.

determinant of enrolment and promotion in Nicaragua's primary education system, whereas per capita service delivery in health, water and sanitation —for which per capita public spending is the policy variable in MAMS— determines most changes in mortality rates and access to safe water and basic sanitation. All other elasticities have been defined on the basis of estimates carried out to calibrate similar CGE models for Nicaragua used and documented in Sánchez and Vos (2006 and 2010) and Gámez and others (2011).[5]

A baseline scenario was generated after completing the model calibration process, constituting a benchmark against which the different alternative scenarios could be compared. Starting from a base year (2006), the baseline scenario replicates actual economic performance under policies implemented in recent years (until around 2012) and projects these figures up to 2020. Economic growth assumptions include the deceleration in GDP growth caused by the global financial crisis of 2008-2009. GDP grew at an annual rate of 3.1% during the period 2007-2012 and is projected to continue growing by about 4.5% per year from 2013 to 2020, according to the Central Bank of Nicaragua. In order to mimic public expenditure policies of the recent past, government consumption and other components of recurrent spending follow a closure rule: that is to say, they represent a pre-defined share of GDP (3.3% for education, 2.3% for health and 0.5% for water and sanitation). Government investment spending depends on the demand for capital in the public services sector and that demand, in turn, varies as the government consumes to deliver services. According to another closure rule, any emerging fiscal deficit (or surplus) is assumed to be financed (adjusted) by (modest) transfers from the rest of the world, which consist essentially in grant aid. Official projections of foreign and domestic debt stocks are used, including programmed debt repayments and relief, and tax revenues are expected to continue growing slowly until they reach 18.5% of GDP in 2020. Private investment is assumed to remain fixed as a share of GDP, while savings rates of private agents adjust endogenously to ensure that the consistency requirement of the model is met and that total savings equal total investment. Observed progress towards the Goals until around 2011 is also reproduced through the calibration, using the elasticity values presented in table 4, and is further projected into the future under the aforementioned continuation of economic trends and public spending and revenue policies.[6]

The microsimulation model was applied using data from the Living Standards Measurement Study (LSMS) survey conducted by the National Institute of Information for Development in 2009. Thus, occupational shifts and changes in transfers with respect to 2009 were estimated for every year of the period 2010-2020, using the LSMS 2009 data to run the microsimulations for the baseline scenario and for all the other hypothetical alternative scenarios. Transfers include transfers to households associated with education, food stamps, grants from institutions and donations by friends or relatives (a proxy of remittances given that most of these donated funds come from abroad and remittances are not specifically identified as a variable in the survey).

The baseline scenario depicts the evolution of the Millennium Development Goal indicators under the continuation of economic conditions and public spending and revenue policies, taking into consideration the complementarities or synergies between the various Goals. As described above, MAMS takes into account the extent to which improved health helps to accelerate progress towards the education goal and to which increased access to safe water and basic sanitation contributes to reducing mortality rates. Continued public spending on services related to the Goals (primary education, health care and water and sanitation) is one of the key drivers of outcomes under the baseline scenario. As a result, primarily, of this driver, and also of all the other determinants listed in table 4 (including per capita consumption, which is propelled by steady economic growth), progress is made towards the Millennium Development Goals under the baseline scenario, but not all of them are met by 2015 (see figure 4). Under the baseline scenario, the target 87% completion rate at the expected age for boys and girls enrolled in primary school is not achieved even by 2020. The basic sanitation target is met in 2019. The outlook is more encouraging for the maternal mortality goal which is within reach by 2016, on the back of steady growth in public and private spending, as well as improved coverage of drinking water and sanitation services. As will be shown below, poverty decreases under the baseline scenario, but not enough to meet the international target for extreme poverty.

[5] The database of the model is not annexed to this paper because of its size; however, it is available upon request from the author.

[6] With regard to the rules used to clear factor markets, rents adjust to clear the market of the capital factor. Land and natural resources grow at an exogenous rate and are activity-specific. The labour market clears through unemployment; provided that the unemployment rate does not decline to a minimum or natural unemployment rate, at which point the labour market clears through wages.

FIGURE 4

Nicaragua: progress towards the Millennium Development Goals under the baseline scenario, 2006-2020

(Percentages)

Source: prepared by the author on the basis of the Maquette for MDG Simulations (MAMS) for Nicaragua.

Note: indicators and targets are consistent with those presented in table 2, except for those for Goal 2, which here refers to the net on-time primary completion rate. The 87% target for the Goal 2 indicator is derived from the 98% target for entry and promotion rates in primary education. Goal 7s refers to the Millennium Development Goal target on access to improved sanitation.

V

Analysis of hypothetical scenarios

Two sets of hypothetical scenarios are analysed by comparing their results against the baseline scenario. The first set comprises four financing scenarios that trace a path towards fully meeting the three non-poverty targets that are not met by 2015 under the baseline scenario, as shown in figure 4. The variable that is adjusted in these scenarios is public spending, which includes all investment and current spending needed to deliver public primary education and, to a lesser extent, sanitation services. This Goal-related public spending is scaled up starting in 2014 until all non-poverty targets under consideration are met by either 2015 or 2020, using either foreign resources or direct tax revenues as alternative sources of financing. Health spending does not increase because, by meeting the sanitation target and continuing to expand the coverage of the drinking water supply in these scenarios, mortality rates fall to the extent needed to meet the respective targets. As indicated above, the distance between mortality rates in 2015 and the targets is small under the baseline scenario (see figure 4). In the second set of hypothetical scenarios, the financing scenario —under which the non-poverty targets are met by 2020 using foreign resources to finance public social spending— is combined with one of the following five external shocks:[7]

— pcoffdec: 20% drop in the world price of coffee.
— ptextdec: 20% drop in the world price of textiles.
— poilinc: 20% increase in the world price of refined oil.
— fdidec: reduction of 2 percentage points of GDP in FDI inflows.
— remdec: reduction of 2 percentage points of GDP in remittances inflows.

All five external shocks are imposed for the 2014-2020 period, relative to the baseline scenario.[8] A deliberate decision was taken to simulate relatively

[7] The findings regarding the effects of external shocks on human development are almost the same under an alternative scenario where tax revenue is the source of financing for public spending. The results for the tax financing scenario in combination with external shocks are therefore not presented, although they are available upon request.

[8] Note that all the alternative scenarios start from 2006, but diverge from the baseline only from 2014.

modest external shocks in order to better understand the high degree of external vulnerability of Nicaragua's economic and human development. As will be shown below, the targets would not be met as fast or at all, in some instances, under the scenarios with external shocks.

1. Financing human development and macroeconomic trade-offs

The evidence under the baseline scenario shows that the time span to 2015 is too short for Nicaragua to achieve the Millennium Development Goals, most notably the target relating to primary school completion, but also the targets on increased access to basic sanitation services and reduced maternal mortality (see figure 4). The findings for the first set of alternative scenarios further suggests that these goals are not within reach by 2015 because considerable amounts of additional public spending would have to be front-loaded and then maintained beyond 2015 to avoid setbacks in human development.[9] Public spending on primary education would have to rise by approximately 6 percentage points of GDP —nearly 67% would be allocated to government consumption— in order for the primary completion rate to be on track by 2015 (see table 5). An additional percentage point of GDP or slightly more is required to enhance basic sanitation services, especially through investment in sanitation infrastructure, in order to meet the relevant target and, in turn, clear the way for the achievement of the maternal mortality goal by 2015. The additional public spending required to meet all the non-poverty targets together represents just over 7% of GDP, which is well above the Goal-related spending of 4.8% of GDP recorded in the baseline.[10]

Financing such large amounts of public spending would be unrealistic in the remaining time span to the end of 2015. Foreign public debt would rise by 23 percentage points of GDP in 2015 and by 44 percentage points of GDP in 2020, respectively, relative to the baseline, under a scenario in which additional Goal-related public spending was fully financed using foreign borrowing rather than aid (see figure 5.A).[11] The alternative analysed here is to finance the additional public spending required to achieve

[9] In fact, in the scenario in which the non-poverty targets are met by 2015, the share of Goal-related public spending as a percentage of GDP in 2015 is maintained constant in 2016-2020, such that Millennium Development Goal indicators continue to improve as a result of steady GDP growth.

[10] Sánchez and Vos (2009 and 2010) estimated that the additional public spending required to meet the Millennium Development Goal targets in Nicaragua by 2015 was equivalent to 6.4% of GDP. The figure in this paper is somewhat higher because the simulation period to 2015 is shorter —in other words, the base year is more recent— and the baseline scenario takes more accurate account of the adverse effects of the global financial crisis on the Millennium Development Goals because it uses more recent data.

[11] Foreign financing is needed beyond 2015 in order to ensure that the share of Goal-related public spending as a percentage of GDP in 2015 remains constant in 2016-2020. Under the baseline scenario, foreign public debt drops sharply, in line with the trend observed in past years and with official projections of foreign debt stocks that take into account programmed debt repayments and relief.

TABLE 5

Nicaragua: public spending required to meet the targets under the hypothetical Millennium Development Goal financing scenarios, 2006-2020

(Percentages of GDP)

	Spending under the baseline scenario		Additional spending required per year in 2014-2020 under the financing scenarios that seek to meet the targets by:			
	2006-2013	2014-2020	2015, with foreign borrowing	2015, with direct taxation	2020, with foreign borrowing	2020, with direct taxation
Education	1.63	1.67	6.04	6.10	3.71	4.29
Consumption	1.49	1.47	4.05	4.05	2.56	2.92
Investment	0.14	0.20	1.99	2.05	1.14	1.36
Health	2.33	2.50	0.00	0.00	0.00	0.00
Consumption	2.08	2.17	0.00	0.00	0.00	0.00
Investment	0.25	0.33	0.00	0.00	0.00	0.00
Water and sanitation	0.51	0.66	1.22	1.14	0.00	0.00
Consumption	0.01	0.01	0.34	0.34	0.00	0.00
Investment	0.51	0.65	0.88	0.80	0.00	0.00
Total	4.48	4.83	7.26	7.24	3.71	4.29

Source: prepared by the author on the basis of the Maquette for MDG Simulations (MAMS) for Nicaragua.

GDP: gross domestic product.

the non-poverty goals by raising additional direct tax revenues by 12 percentage points of GDP in 2015 and by 5 percentage points of GDP in 2020, respectively, with respect to the baseline (see figure 5.B). This financing strategy would also be unfeasible considering that the government has already made concerted efforts to raise taxes.

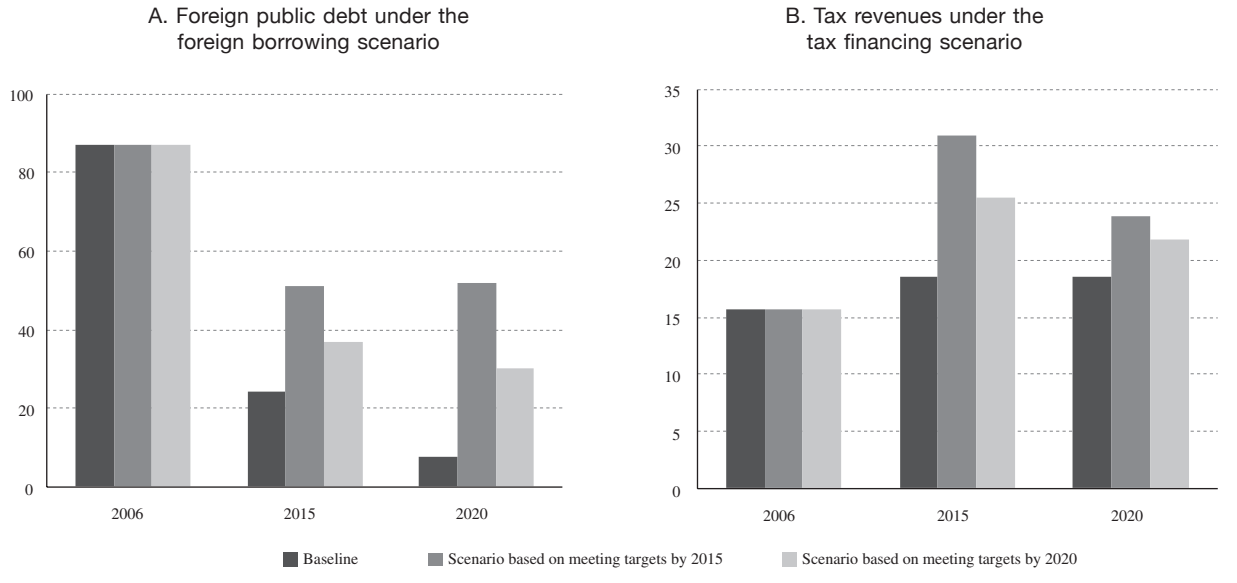
Nicaraguan policymakers would find it more realistic to pursue a Millennium Development Goal strategy with a relatively longer time frame whereby the front-loading of public spending and financing would be less demanding and would not jeopardize the fiscal stance. The alternative scenarios show that the government would save 3 percentage points of GDP or more in public spending by aiming to achieve the non-poverty Millennium Development Goals by 2020 instead of by 2015 (see table 5). The additional public spending required to ensure that the goal on primary completion is within reach by 2020 would subsequently spur economic growth under a less binding fiscal constraint, which would in turn stimulate employment and help reduce the incidence of poverty. The resulting increase in income per capita would boost private demand for education, health care, water and sanitation and thus have a positive impact on progress towards the Millennium Development Goals. Under the foreign borrowing scenario, access to basic sanitation would be on course for 2020, whereas the targets for under-five mortality and maternal mortality would be met in 2015 and 2016, respectively.

The additional public spending required to meet all the non-poverty targets by 2020 is 0.6 percentage points of GDP lower if foreign borrowing is the source of the financing rather than taxation (see table 5). Direct taxation reduces private disposable income and thus depresses private demand for social services, such as education, and constrains the private savings available for investment (see table 6). Under the direct taxation scenario, the government would be required to step up spending to a greater extent —than under the foreign financing scenario— in order to offset the reduction in private spending and meet the targets. New public spending injected into non-tradable sectors of the economy would exert pressure on the real exchange rate, leading to a degree of appreciation that would drag down export growth and push up import growth compared with the baseline scenario. The effect of the real exchange rate appreciation would be exacerbated if inflows of foreign resources were mobilized to finance additional public spending needs. Moreover, under a foreign borrowing scenario, relatively less financing would be needed to

FIGURE 5

Nicaragua: foreign public debt and tax revenues under the baseline and Millennium Development Goal financing scenarios, 2006, 2015 and 2020

(Percentages of GDP)



Source: prepared by the author on the basis of the Maquette for MDG Simulations (MAMS) for Nicaragua.

GDP: gross domestic product.

cover the additional public spending if the targets were met by 2020: foreign public debt would represent 30% of GDP in 2020 if the targets were met by that year, 20 percentage points less than under the corresponding scenario in which targets are met by 2015 (see figure 5).

The financing strategy chosen matters for GDP growth. In the foreign financing scenarios GDP growth was slightly higher than in the baseline scenario, whereas the use of direct taxation in the alternative financing scenarios would hurt economic growth by crowding out private spending compared with all the other scenarios (see table 6).[12] For the short to medium run, Nicaragua can continue to rely on foreign sources to complement domestic resources for financing spending towards the achievement of human development goals. However, reducing the dependence on aid and concessional loans will call for more fiscal reforms to gradually replace foreign financing with tax revenues. Furthermore, using foreign resources to finance development for a long period of time could undermine export competitiveness through the appreciation of the real exchange rate. This could, in turn, discourage exports, thereby widening the external deficit and leading to an undesirable structural change away from the most dynamic industries, thus hurting economic growth.

These simulated Millennium Development Goal financing strategies would also bear consequences for poverty and inequality. The incidence of poverty and extreme poverty at the national level fall dramatically under the baseline scenario by 8.7 percentage points and 4.2 percentage points, respectively, between 2009 and 2020 (see table 7). Of these reductions, 7.3 percentage points and 4 percentage points, respectively, are attributable to an overall increase in the population's well-being thanks to higher labour incomes, and the rest of the change is driven by transfers from the government and the rest of the world.

When additional public spending is stepped up and financed through resources from abroad to meet the non-poverty Millennium Development Goal targets by 2020, the demand push has a multiplier effect throughout the economy resulting in higher average wages and lower unemployment. These labour market effects produce net income gains that lead to further reductions in moderate and extreme poverty rates, thus achieving the international goal of reducing extreme poverty to 9.7% (see table 7). This outcome is not replicated under the tax financing scenario, however, where poverty rates are actually higher than under the baseline scenario as a result of the crowding-out effect on private spending, which offsets the demand push from public spending. Poverty rates do not decline to a greater extent in the financing scenarios because, in addition to the aforementioned adverse macroeconomic effects of financing public spending (crowding-out of private spending and reduced export competitiveness), wages are less equally distributed as public-sector demand for doctors, teachers and other highly qualified workers, who are in limited supply in Nicaragua, rises. The Gini coefficient of consumption per capita is larger in all of the Millennium Development Goal financing scenarios than in the baseline scenario.

[12] Growth in GDP, and its spending components, is expected to be slightly higher when financing is mobilized to achieve the Millennium Development Goals by 2015 because the stimulus from front-loading Goal-related public spending is much larger. This is not true under the tax financing scenario because of the crowding-out effect on private spending.

TABLE 6

Nicaragua: growth of real GDP and its spending components under the baseline and Millennium Development Goal financing scenarios, 2007-2020
(Percentages)

	2007-2013 under all scenarios	2014-2020 under the baseline scenario	2014-2020 under the financing scenarios that seek to meet the targets by:			
			2015, with foreign borrowing	2015, with direct taxation	2020, with foreign borrowing	2020, with direct taxation
Private consumption	2.13	3.58	4.15	3.21	3.89	3.22
Government consumption	0.89	4.48	8.71	8.78	6.97	7.34
Private investment	6.17	3.88	3.99	3.49	3.93	3.59
Government investment	4.37	7.77	57.50	48.97	22.18	22.92
Exports	6.36	5.46	5.15	4.74	4.68	4.95
Imports	2.73	4.06	4.64	3.62	4.26	3.75
GDP	3.24	4.42	4.59	4.34	4.51	4.37

Source: prepared by the author on the basis of the Maquette for MDG Simulations (MAMS) for Nicaragua.

TABLE 7

Nicaragua: poverty indicators and Gini coefficient under the baseline and Millennium Development Goal financing scenarios using a 2020 deadline for the targets, 2009, 2015 and 2020

	2009	Baseline		Foreign financing		Direct tax revenues	
		2015	2020	2015	2020	2015	2020
National moderate poverty (*percentages*)	42.5	39.5	33.8	33.4	27.6	39.8	34.1
National extreme poverty (*percentages*)	14.6	12.9	10.4	12.0	9.5	13.5	10.7
Gini coefficient of consumption per capita	0.4828	0.4798	0.4832	0.4876	0.4924	0.4802	0.4836

Source: prepared by the author on the basis of the Maquette for MDG Simulations (MAMS) for Nicaragua.

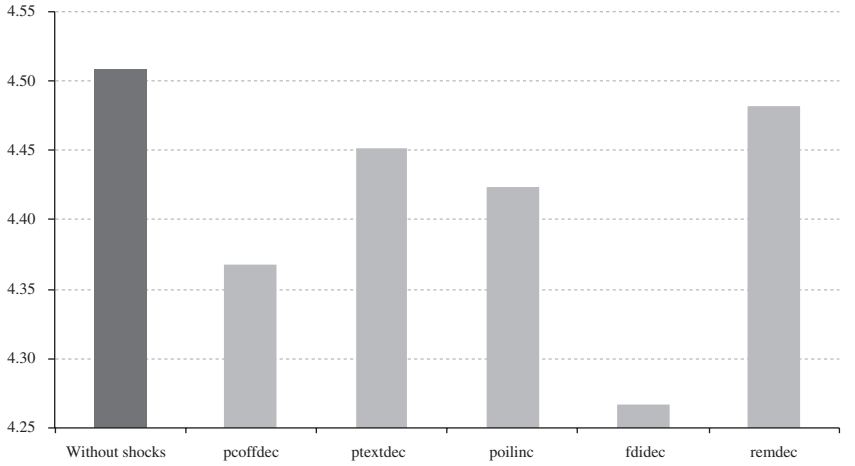
2. External vulnerability of human development

The economic outlook of Nicaragua is poised to improve if new stimulus from public spending on pursuing the development goals is not offset by the macroeconomic trade-offs of financing development. Nevertheless, external vulnerabilities must also be considered. Nicaragua has witnessed reductions in key export prices, oil price hikes resulting in swelling oil import bills, and unfavourable downturns in inflows of FDI and remittances. These external shocks jeopardize balance-of-payments stability and undermine economic growth, which can cause setbacks in human development. The external shocks simulated as part of the foreign financing scenario —using a 2020 deadline for the targets— were relatively modest in magnitude, yet they had the potential to weaken GDP growth (see figure 6). For example, a reduction of 2 percentage points of GDP in FDI inflows saps private investment and exports to a point where GDP growth falls by almost a quarter of a percentage point. Dips in world prices of key export commodities, such as coffee, have also taken a toll on economic growth.

Irrespective of the different transmission mechanisms through which they damage the economy, the simulated external shocks, though modest in magnitude, could limit economic growth in Nicaragua. These shocks

FIGURE 6

Nicaragua: real GDP growth under the foreign financing scenario using a 2020 deadline for meeting the targets, with and without external shocks, 2014-2020[a]
(Percentages)



Source: prepared by the author on the basis of the Maquette for MDG Simulations (MAMS) for Nicaragua.

[a] pcoffdec: 20% drop in the world price of coffee; ptextdec: 20% drop in the world price of textiles; poilinc: 20% increase in the world price of refined oil; fdidec: reduction of 2 percentage points of GDP in foreign direct investment inflows; remdec: reduction of 2 percentage points of GDP in remittances inflows.

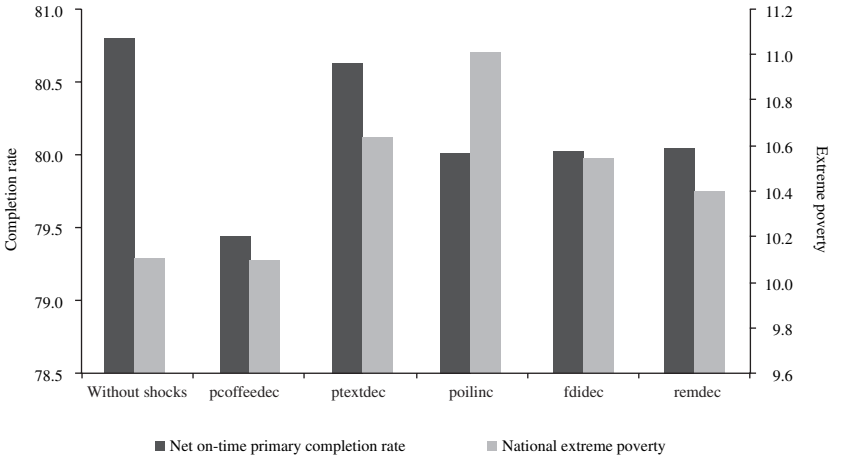
GDP: gross domestic product.

would have an impact on the key determinants of Millennium Development Goal achievement, such as service delivery (using public and private spending in social sectors as a proxy) and per capita household consumption. In proportional terms, public social spending as a percentage of GDP is the same in the financing scenarios with and without external shocks. However, the slowdown in GDP growth resulting from the simulated external shocks implies lower public social spending in absolute terms than in the scenario without external shocks. External shocks also have an impact on the Millennium Development Goal indicators through a fall in private spending on social services and per capita consumption. As a consequence, progress towards the Millennium Development Goals is less encouraging by any measure. In the financing scenario with any of the external shocks, the target on net on-time primary completion rate would not be met (see figure 7). Furthermore, the reduction in per capita consumption mirrors the fall in household labour incomes owing to the economic growth slowdown triggered by the external shocks. Hence, extreme poverty would also rise, especially when the financing scenario is combined with the oil price shock. Though not shown in figure 7 for the sake of simplicity, the international target for extreme poverty is no longer met with any of the shocks and the attainment of the maternal mortality and sanitation targets is delayed when oil price and remittances shocks are simulated as part of the financing scenario. Relatively modest external shocks, therefore, have the potential to increase the public spending required to meet the Millennium Development Goals, hence making human development a more challenging aspiration for Nicaragua.

FIGURE 7

Nicaragua: net on-time primary completion rate and incidence of national extreme poverty under the foreign financing scenario using a 2020 deadline for meeting the targets, with and without external shocks, 2020[a]

(Percentages)



Source: prepared by the author on the basis of the Maquette for MDG Simulations (MAMS) and the microsimulation model for Nicaragua.

[a] pcoffdec: 20% drop in the world price of coffee; ptextdec: 20% drop in the world price of textiles; poilinc: 20% increase in the world price of refined oil; fdidec: reduction of 2 percentage points of GDP in foreign direct investment inflows; remdec: reduction of 2 percentage points of GDP in remittances inflows.

GDP: gross domestic product.

VI
Conclusions and policy implications

Nicaragua is a small, open developing economy that has made notable economic and social progress in the past two decades, but still has high rates of extreme poverty and income inequality. Its economic growth typically fluctuates in response to external factors. The economy faces stubbornly pressing constraints with respect to generating resources domestically and by trading with the rest of the world, and relies heavily on foreign financing, including loans, grant aid and debt relief. In view of these resource mobilization constraints, Nicaragua faces challenges in its pursuit of development goals.

Progress towards the Millennium Development Goals has, by and large, been satisfactory. Extreme poverty and child and maternal mortality rates have fallen, and an ever larger share of the population has access to drinking water. But progress has been less encouraging with respect to achieving higher primary completion rates and coverage of basic sanitation services. This paper's scenario analysis corroborates the conclusions presented in Sánchez and Vos (2009 and 2010). That is to say, a continuation of existing economic trends and public spending and revenue policies is expected to translate into progress towards the Millennium Development Goals, including a marked trend towards poverty reduction, but not to the extent needed in order for Nicaragua to meet all the targets by 2015. This paper extends the simulation period to 2020 in order to assess more realistic scenarios.

Nicaragua would need additional public social spending of about 7% of GDP per year to close the Millennium Development Goal gaps by 2015 and maintain all indicators on track thereafter, relative to the baseline scenario of continued GDP growth and no change in public spending policies. Approximately 87% of this new spending would have to be allocated to primary education. The macroeconomic repercussions of financing such large amounts of additional spending are sizeable. Economic growth would be undermined should the government opt to use high levels of additional direct tax revenues, since this would curtail private spending and demand for private social services. Alternatively, inflows of foreign resources would not crowd out private spending but, in the form of borrowing, would halt the decline in foreign debt and erode export competitiveness through real exchange rate appreciation. The same trade-off would be seen if those foreign resources came in the form of grant aid —although without debt accumulation. In view of these findings, achieving the Millennium Development Goals by 2015 is unfeasible for Nicaragua.

The time span to 2015 is simply too short for the government to take policy measures with a view to achieving all the Millennium Development Goals by the deadline. It would be more feasible if the country were to postpone the achievement of the most challenging goals. Not only would that make securing the required financing more achievable, but it would also multiply the effects of increased public spending more broadly throughout the economy, accelerating economic growth and helping buy time for the government to reduce reliance on foreign resources and reap the benefits of recent fiscal reforms. The alternative scenarios show that postponing the achievement of the Millennium Development Goals until 2020 would bring the additional public social spending required down to 3.7% or 4.3% of GDP, depending, respectively, on whether the source of the financing was from abroad or direct taxation. These scenarios offer a much more realistic public financing situation: for example, using foreign borrowing, the foreign debt stock would rise by 20 percentage points of GDP less to achieve the Goals by 2020 rather than by 2015. In this case, the foreign debt trajectory would remain sustainable and closer to the relatively low, declining stock of the baseline scenario. The multiplier effect triggered by the government spending more gradually in social sectors over a longer period of time would contribute 1.3 percentage points of additional annual GDP growth relative to the baseline. These gains do not reflect the very long-term economic growth pay-offs that could be expected from investing in achieving the Millennium Development Goals. These pay-offs would be the result of factor accumulation and productivity growth from employing larger numbers of better educated and healthier workers over the years, as Sánchez and Cicowiez (2014) recently showed to be the case for four developing countries. Therefore, Nicaragua could realistically expect economic pay-offs from its past human development investments beyond 2020.

Nicaragua's policymakers will be unable to avoid relying on foreign borrowing to finance the investments needed to achieve the Millennium Development Goals.

Foreign grant aid is no longer a viable option (unless its decline is systematically reverted by donors) and the country needs time to reap the benefits of recent fiscal reforms. Nonetheless, foreign sources of financing will have to be substituted gradually by new tax revenues if the government is to meet its commitment to lowering foreign debt levels.

All interventions aimed at enhancing resource mobilization will have to consider public spending requirements, not only to meet human development goals, but also to keep the country on track in the face of turbulent economic episodes caused by external shocks. This paper's scenario analysis shows that human development in Nicaragua is highly vulnerable to modest external shocks, whether these are caused by unfavourable world prices or reduced inflows of FDI or remittances. As shown in the scenario analysis, these shocks have the potential to halt the economic stimulus from public spending and drag down per capita income, leading to a number of human development and poverty setbacks, to the extent that many of the targets would no longer be attainable even by 2020.

Reducing poverty and exposure to external vulnerabilities will require active policies that spur sustained economic and employment growth through the diversification of production and exports. Furthermore, economic growth should be made more inclusive by ensuring that productive transformation includes the integration of new technologies and activities that call for skilled labour and that teaching content is improved and the skills built by the education system are in high demand by the production sector. These changes could be triggered by the country's existing national development plans that are aimed at attracting FDI and implementing massive public infrastructure investment projects. In a broader sense, these conclusions and policy lessons apply to most small, open developing economies that are pursuing human development goals and could be a useful input for the United Nations post-2015 sustainable development agenda.

Bibliography

ECLAC (Economic Commission for Latin America and the Caribbean) (2013), *Social Panorama of Latin America 2012* (LC/G.2557-P), Santiago, Chile. United Nations publication, Sales No. E.13.II.G.6.

Gámez, O. and others (2011), "Nicaragua", *Vulnerabilidad económica externa, protección social y pobreza en América Latina*, M.V. Sánchez and P. Sauma (eds.), Quito, Latin American Faculty of Social Sciences (FLACSO)/Economic Commission for Latin America and the Caribbean (ECLAC)/United Nations Department of Economic and Social Affairs.

Guimarães, J. and N. Avendaño (2011), "The great experiment: testing the PRSP approach in Nicaragua, 2000-2007", *European Journal of Development Research*, vol. 23, No. 2, Palgrave Macmillan.

Lofgren, H. and C. Díaz-Bonilla (2010), "MAMS: an economy-wide model for analysis of MDG country strategies – an application to Latin America and the Caribbean", *Public Policies for Human Development. Feasible Financing Strategies for Achieving MDGs in Latin America and the Caribbean*, M.V. Sánchez and others (eds.), London, Palgrave Macmillan.

Lofgren, H., M. Cicowiez and C. Díaz-Bonilla (2013), "MAMS–A computable general equilibrium model for developing country strategy analysis", *Handbook of Computable General Equilibrium Modelling*, P.B. Dixon and D.W. Jorgenson (eds.), vol. 1A, Amsterdam, North-Holland.

Pacheco, J. (2013), "Determinantes socioeconómicos de la educación, la mortalidad y el acceso al agua potable y el saneamiento en Nicaragua: Un análisis econométrico" [online] http://www.un.org/en/development/desa/policy/capacity/country_documents/nicaragua_determinantes.pdf.

Sánchez, M.V. (2011), "Welfare effects of rising oil prices in oil-importing developing countries", *The Developing Economies*, vol. 49, No. 3, Institute of Developing Economies.

Sánchez, M.V. and M. Cicowiez (2014), "Trade-offs and payoffs of investing in human development", *World Development*, vol. 62, Amsterdam, Elsevier.

Sánchez, M.V. and R. Vos (2010), "Nicaragua", *Public Policies for Human Development. Feasible Financing Strategies for Achieving MDGs in Latin America and the Caribbean*, M.V. Sánchez and others (eds.), London, Palgrave Macmillan.

_____ (2009), "Impact of the global crisis on the achievement of the MDGs in Latin America", *DESA Working Paper*, No. 74, New York, United Nations Department of Economic and Social Affairs [online] http://www.un.org/esa/desa/papers/2009/wp74_2009.pdf.

_____ (2006), "DR-CAFTA: ¿Panacea o fatalidad para el desarrollo económico y social en Nicaragua?", *Estudios y Perspectivas series*, No. 57 (LC/MEX/L.752), Mexico City, ECLAC subregional headquarters in Mexico [online] http://www.eclac.cl/publicaciones/xml/0/27210/L752.pdf.

Vos, R. and M.V. Sánchez (2010), "A non-parametric microsimulation approach to assess changes in inequality and poverty", *International Journal of Microsimulation*, vol. 3, No. 1 [online] http://microsimulation.org/IJM/V3_1/IJM_25.pdf.

Classroom discipline, classroom environment and student performance in Chile

Carolina Gazmuri, Jorge Manzi and Ricardo D. Paredes

ABSTRACT

This paper assesses the extent to which teachers' actions in the classroom influence the school environment. The assessment is based on a statistical analysis of videotaped classroom observations of 51,329 teachers. The classroom environment was found to have a significant influence on students' performance. More specifically, the teacher's ability to handle the class as a group is consistently more significant than other measures of class environment. It was also founds that the overall school environment is a better predictor of students' test results than the environment in the classrooms of the students whose test results are being reported. This suggests that the most effective course of action would be to improve the overall school environment, although individual teachers have less control over this factor.

KEYWORDS Education, teaching personnel, academic achievement, evaluation, Chile

JEL CLASSIFICATION A20, I21

AUTHORS

Carolina Gazmuri has a Master of Arts degree in Education at Teachers College, University of Columbia. cgazmurib@gmail.com

Jorge Manzi is a full professor in the School of Psychology of the Pontificia Universidad Católica de Chile. jmanzi@uc.cl

Ricardo D. Paredes is a professor in the School of Engineering of the Pontificia Universidad Católica de Chile. rparedes@ing.puc.cl

I
Introduction

Most of the existing studies on scholastic performance focus on schools' sociodemographic variables but devote little attention to teacher performance. In part, this is because teacher evaluations are few and far between and are indirect measurements. In addition, the number of in-class observations that are carried out is quite limited. Furthermore, to the best of the authors' knowledge, no statistical analyses have been made of the effect exerted by the classroom environment. This is attributable to the cost involved in conducting that kind of study, to the resistance of teachers' unions to such a venture and to the fact that the coding of different forms of conduct is such a new area of research that it has not yet reached the stage where it could provide a basis for accurate metrics in this respect. Be this as it may, parents and educators cite the main school-related problems in Chile as being "students' lack of interest" and "a lack of discipline", while survey results indicate that discipline is one of the key considerations for parents when deciding what school to send their children to (Arancibia, 1994).

This study identifies and quantifies classroom-environment variables that influence academic performance. A distinction is drawn between factors that are basically teacher-determined and those that are more closely associated with the school as a whole. The data for this analysis are drawn from evaluations of over 50,000 public-school teachers in Chile based on video observations of one class per teacher that have been assessed and coded by educational psychologists and other education professionals.

☐ The authors are grateful for the comments provided by an anonymous referee and for the funding provided by the CIE-01 Project of the National Commission for Scientific and Technological Research (CONICYT) and Project 1140980 of the National Fund for Scientific and Technological Development (FONDECYT).

While a number of studies have been done in which an attempt is made to detect factors related to the classroom environment that can influence the learning process, most have taken a more psychological approach and have been based on one-off observations of small groups of students. This study's contribution to the literature is based on the measurement and quantification of the influence exerted by a number of classroom-related factors using a much larger sample (51,329 observations) than those used in any previous study. This method complements the more traditional approach to this subject and makes it possible to differentiate the impacts of various classroom-related factors that are difficult to distinguish from one another on the basis of direct observation and case studies.

The study deals with only one specific aspect of the school environment that can, at least in theory, be manipulated by the teacher in the classroom and can be analysed on the basis of observations of a course module. In addition, the focus is restricted to the relationship between this aspect of the school environment and academic performance, which is evaluated on the basis of standardized test results. It is understood, of course, that the school environment influences other aspects of students' and teachers' experiences within the school setting and is, in turn, influenced by the interaction of other, non-observable factors that affect the observations of that environment used in this study.

The rest of this study is divided into three sections. Section II describes the educational situation in Chile and provides other background information about the factors that led up to the development of a teacher evaluation system. It also reviews the existing literature. Section III deals with the model used to arrive at the estimates presented here, while section IV presents a number of conclusions.

II
Background

1. The education system in Chile

Education has been one of the most important issues for the Chilean government and, while there has been a policy of ongoing reform for quite some time, in the early 1980s major changes were introduced that have strongly influenced subsequent developments and have had a strong bearing on the situation that unfolded during the first decade of this century.

The reforms of the early 1980s decentralized the education system by handing over the administration of the country's public schools to its municipalities. In addition, the historical-cost funding system was replaced with per-student subsidies so that pupils could choose which school to attend. These changes did expand school coverage, but they failed to improve the quality of education, which had been one of the goals of the reform.

This decentralization process has a number of critics (Muñoz and Raczynski, 2007), while Beyer (2009) argues that it has been only partial, since, although it is true that the schools are no longer administered by the central government, the municipalities have not been endowed with the necessary capacity to manage them properly. The associated debate concerning the quality of the education provided by municipal schools has been heated, and there is an ample body of literature on the subject (see Drago and Paredes, 2011).

The economic crisis that broke out in 1981 triggered a steep reduction in funding for public schools. Between 1982 and 1990, government spending on education was cut by 29%. Moreover, Chile had no system in place for assessing the quality of education until 1988, when the Education Quality Measurement System (SIMCE) was introduced. The SIMCE tests are still in use today. At first, these test results were not made public, but they have been in the public domain since 1995.

In 1990, with the promulgation of the Teachers Statute, a wage floor was set for teachers and their rights as members of the teaching profession were codified. This law generated a series of rigidities associated with limitations on teacher mobility and on teacher dismissals. In 1991, schools began to be allowed to supplement government funding with school fees. As of 2008, 49% of the country's 11,905 schools were run by the municipalities, 44% were government-subsidized private schools and 6% were private educational institutions (Ministry of Education, 2008a).

The main tool used to measure the quality of education in Chile is the SIMCE test, which has yielded comparable results only since 1997. From that year on, test results were stable until 2010, when some improvement began to be seen. The figures attest to sharp inequalities in the quality of education. After 4, 8 or 10 years of schooling, a sizeable portion of the student body does not have the basic skills or knowledge expected of students in the corresponding grade (Muñoz and Weinstein, 2009). As of 2008, 35% of all fourth-grade students were rated as having an initial level of proficiency in reading and 41% scored at that level in mathematics (figures taken from reports on national test results: www.simce.cl).

Based on the test results for fourth-graders (9-year-olds, on average) and eighth-graders (13-year-olds, on average) in 1999 and 2000, Eyzaguirre and Le Foulon (2001) conclude that nearly 40% of all elementary school students cannot understand what they read; for students in the second year of secondary school, i.e. tenth grade (15-year-olds, on average), they put the figure at 33%. The 1999 SIMCE test scores indicate that 32% of the students in fourth grade had not mastered the skills and knowledge that a second-grade student should possess; 25% were at the third-grade level; another 25% had an initial level of proficiency for fourth grade; and only 11% had a satisfactory level of proficiency.

Other standardized tests, such the Trends in International Mathematics and Science Study (TIMSS), yield similar results. One out of every two eighth-grade students is at least four years behind in mathematics. What is more, the average score on this test for Chilean students from households having high levels of educational attainment, who perform better than other students in the country, is below the overall international average and is on a par with the average score of students from households having a low level of educational attainment in the Republic of Korea, Slovenia, the Russian Federation, Belgium and others. In addition to the fact that, on average, the quality of education is low, there is also a marked degree of inequality. Of the students who attend private schools, 1 out of 2 score over 300 points on the SIMCE mathematics tests, whereas only 1 out of 5 students in government-subsidized private schools and only 1 out

of 10 students in municipal schools score at least 300 (Fontaine, 2002; Brunner and Cox, 1995; García and Paredes, 2010).

2. The teachers

The assertion made by Barber and Mourshed (2008) that "the quality of an education system cannot exceed the quality of its teachers" (p. 15) has prompted many governments to focus on their faculty and on making a teaching career more attractive. In Chile, the situation is clear. Most of the country's teachers were not near the top of their class when they were in school, and only 1 out of every 24 of the younger teachers who studied education in universities belonging to the Chilean University Council of Rectors were in the top 10% of their graduating class (Claro, 2009). This is corroborated by Cabezas and others (2013), who draw attention to the need to upgrade teacher qualifications, especially in schools with the most vulnerable students.

In 2008, Chile had 176,472 practising teachers, of whom 46% were working at municipal schools, 43% in government-subsidized private schools and just 11% in private schools. A majority of teachers are women (71%). Teachers' salaries rose by around 200% between 1990 and 2008, but that increase has not been pegged to individual performance (Ministry of Education, 2008a).

The idea that the quality of instruction is the touchstone of learning was what underlay the decision in 2003, in the wake of protracted negotiations with the Teachers' Association, to begin evaluating teachers in municipal schools on an individual basis. The design of the teacher evaluation system was highly politicized and extensively negotiated, which might lead one to suspect that it would not provide an accurate evaluation of teacher performance. Contrary to expectations, however, León, Manzi and Paredes (2008) found that the results of teacher evaluations correlate relatively well with the learning outcomes of their students, which would appear to indicate that the evaluation system has been well-designed.

3. School environment and discipline

The surrounding environment, the way that teachers manage their classrooms and school discipline are generally regarded as crucial factors in students' learning experiences (see, for example, Ritter and Hancock, 2007; Nie and Lau, 2009, and references). While these concepts have been defined in various ways in the literature, generally speaking, all of these definitions encompass the steps taken by teachers to keep order in their classrooms, engage their students and elicit their cooperation (Emmer and Stough, 2001).

Kennedy (2005) suggests that the need to manage students in the classroom often interferes with teachers' efforts to convey ideas to them. She contends that, out of fear of losing their students' interest, teachers sacrifice intellectual content in order to keep the situation under control because, if they present material that is too intellectually challenging, some students will back off or become distracted and disruptive because they find that following the class requires too much intellectual exertion.

The classroom environment and discipline have also been identified as a critical factor in teachers' work satisfaction. Time and again, teachers mention school discipline as one of the greatest challenges that they face (Ritter and Hancock, 2007). Discipline problems are also frequently cited as one of the main reasons why some teachers decide to leave the profession (Morris-Rothschild and Brassard, 2006).

Given how strongly the classroom environment influences students' academic performance and teachers' work satisfaction, a number of studies have been conducted in an attempt to identify different discipline management styles and their effectiveness. Three main styles are identified in the literature (Lewis and others, 2008). The first is associated with the idea that teachers should closely control their classrooms and their students' behaviour and with the "assertive discipline" or "take-control" approach first developed by Lee and Marlene Canter in 1970 (Malmgren, Trezek and Paul, 2005). This approach calls for teachers to set out ground rules at the start of the school year in order to make the students aware of what kind of behaviour is expected of them and what types of consequences they can expect if they fail to comply. During class, teachers are encouraged to reward and recognize good behaviour and punish misbehaviour.

Along these same lines, the "interventionist style" is based on the idea that students learn to behave appropriately in the classroom when good conduct is rewarded and bad conduct is punished and that teachers should therefore maintain strict control over the students' activities in the classroom (Ritter and Hancock, 2007).

A second approach places greater emphasis on students' self-control and less on teachers' authority. This discipline management style is associated with the "teacher effectiveness training" model developed by Thomas Gordon, also in the 1970s. This style is based on the idea that students' self-control is key to their good

behaviour in class and that it should be achieved through negotiation and conversations with them (Malmgren, Trezek and Paul, 2005). In this non-interventionist style, students are expected to play an influential role in the classroom. Teachers are not supposed to worry about bringing students' behaviour into line with what they consider suitable because students will tend to behave more appropriately on their own (Ritter and Hancock, 2007).

The third style places emphasis on participation and group decision-making. In this approach, which is based on the "control theory" model developed by William Glasser, students should take responsibility for the behaviour of their classmates and make sure that they conduct themselves properly. This style of discipline calls for frequent course meetings to discuss various behavioural issues and to build consensus around them (Edwards and Mullis, 2003).

In developing countries and in Chile, in particular, few systematic studies have been conducted, although Eyzaguirre and Fontaine suggest that teachers in high-performing schools devote more classroom time to instruction by planning out classroom activities more thoroughly and by managing disciplinary issues and remediation policies more effectively (Eyzaguirre and Fontaine, 2008).

4. Teacher evaluations in Chile

Teacher evaluation procedures for municipal schools in Chile are set out in the 1991 Teachers Statute. The Teachers Association opposed the evaluation so fervently that it was not actually implemented until 12 years later, when the government and the Teachers Association reached an agreement. The agreement provides for the application of the National Teacher Evaluation System in the country's municipal schools. This system relies on four tools, which are weighted as follows: (i) a self-evaluation (10%); (ii) an interview by a peer evaluator (20%); (iii) a review conducted by the director of the corresponding technical pedagogical unit (10%), and (iv) a portfolio (60%).

The portfolio provides evidence about teachers' instructional practices and is composed of two different modules. The first consists of a description of a pedagogical unit, an evaluation of that unit and an analysis. The second contains a 40-minute video of a teacher in action in the classroom.

Teachers can receive the following performance ratings: (i) Outstanding (a score of between 3.1 and 4), which denotes a professional performance that consistently exceeds the level of expectation for the indicator in question; (ii) Competent (a score of between 2.51 and 3), which corresponds to a satisfactory level of performance as a teaching professional that meets at least the minimum established requirements; (iii) Basic (a score of between 2 and 2.4), which denotes a level of professional performance that sometimes meets the expectations for the indicator in question and sometimes does not, and (iv) Unsatisfactory (a score of between 1 and 1.99), which equates to a clearly weak performance on the part of the teacher concerned.

Teachers who receive ratings of "outstanding" or "competent" can apply for the Variable Individual Performance Allowance (AVDI). To obtain this allowance, they have to pass a disciplinary and pedagogical knowledge test. Those who obtain a rating of "outstanding", "competent" or "sufficient" on the test receive pay raises of between 25% and 5% above the national minimum basic wage (RBMN), which is about US$ 213 per month (figure based on the RBMN for 2010 and the average exchange rate for the dollar for that same year). As of 2010, somewhat fewer than 8,000 teachers in Chile were receiving this allowance.

Teachers who receive a "basic" rating in the teacher evaluation have to take part in a professional improvement programme that includes tutorials, courses, workshops, recommended lectures and class observations conducted by qualified teachers. Teachers who receive a rating of "unsatisfactory" have to participate in the improvement programme and be re-evaluated the following year. If a teacher receives an unsatisfactory rating in the second evaluation, he or she must stop teaching for a year, participate in the professional improvement programme and submit to a third evaluation. If the teacher receives another unsatisfactory rating in the third evaluation, he or she is required to leave the teaching profession.

As of 2009, more than 50,000 municipal-school teachers (67% of the total) had been evaluated. Out of that number, as of 2007, 1,050 teachers had received an unsatisfactory rating at some point; 95 of these teachers received an unsatisfactory rating a second time, and 8 were rated as unsatisfactory three times in a row (Araya and others, 2010).

The evaluation focuses on teachers' performance in the classroom, which is monitored by video recordings that are then analysed by a group of educators who evaluate specified items as measured against established standards. Clearly, the videotaping of teachers' performance in the classroom is open to criticism, since it may provide an inaccurate picture of what usually goes on there. Teachers may be nervous and may make

special preparations for the class that is to be filmed, and students may also act differently. In fact, 20% of the teachers who were evaluated in 2005 and 2006 said that it was a very difficult experience. However, nearly 80% said that students behaved, by and large, as they usually did, and less than 10% said that they behaved worse than usual. On another front, Lock and Strong (2010) suggest that in-class evaluations may overlook important psychological aspects of what goes on in the classroom.

This paper posits that videotaping provides a good metric of teachers' classroom performance insofar as any errors that they commit are not related with other characteristics of the educators, their students or the environment that also influence their performance. In other words, if the departures from usual modes of behaviour are random, then the accuracy of the associated estimates will decline, but the estimates will still not be skewed. This situation should be reflected in the data and in the estimates themselves.

III
Data and results

1. The data

The database includes fourth grade and tenth grade students' scores on the various SIMCE tests in 2008 and the test scores of eighth-graders in 2007 in the country's municipal schools. The information covers various characteristics of each student, including the student's gender, the educational level of the parents and household income, as well as features of the school that he or she attends, such as the teacher evaluation scores for 2005, 2006, 2007 and 2008. The individual scores for teachers' videotaped classroom performances are also available.

There are nine indicators for teachers' classroom performance and in-class interactions: (i) students' focus on proposed activities (INDF1); (ii) teachers' skill in handling the class as a group (INDF2); (iii) teachers' promotion of participation by all the students (INDF3); (iv) the quality of class structure (INDG1); (v) the use of time available for instruction (INDG2); (vi) the activities' contribution to the achievement of learning objectives (INDG3); (vii) the quality of teacher explanations (INDH1); (viii) the quality of teacher-fostered interactions (INDH2), and (ix) the learning-process coaching (INDH3).

Figure 1 depicts the distribution of teachers' scores (from 0 to 4) on these indicators. The areas enclosed in the boxes represent the second and third quartiles for this sample; as may be seen, there is little variance in the results, which could theoretically make it difficult to detect the impact of the different scores.

2. Estimation model

To estimate the influence of the classroom environment on student performance, we follow the traditional empirical literature, which considers that a student's academic achievement depends on several factors associated with family situation, the school setting (including teacher-related factors) and environmental factors. Specifically, the model used considers the student academic performance as the dependent variable, measured by the SIMCE test, and as explanatory variables, the student gender, the student socioeconomic situation, a measure of the peer effect, the rural or non-rural status of the school, teacher quality (measured as the overall teacher evaluation, usually a variety of instruments) and, lastly, the classroom climate, the component on which this research focuses. The model is shown in (1).

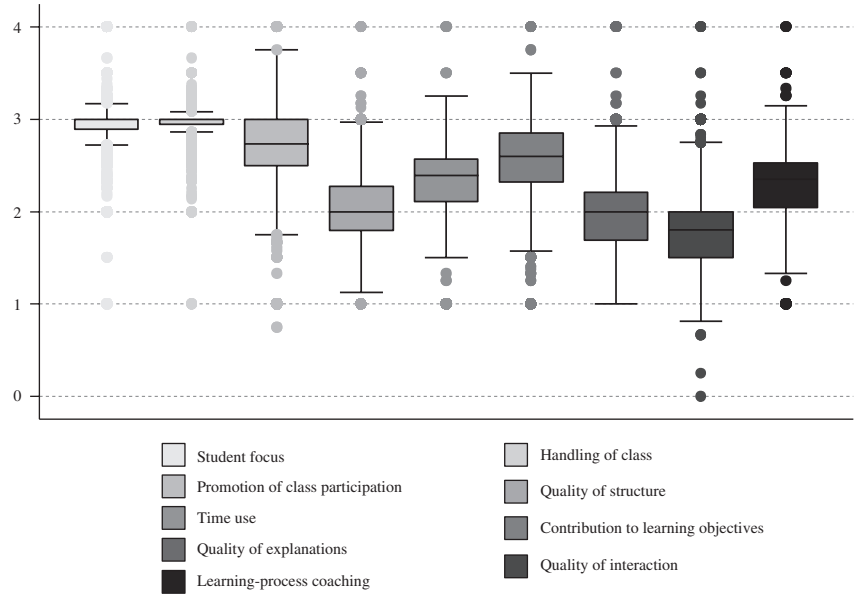
$$R_{ij} = f\left(A_{ij}, F_{ij}, P_{ij}, E_j, C_j\right) + \varepsilon_{ij} \qquad (1)$$

where R_{ij} is the level of scholastic achievement of student i in school j; A_{ij} denotes student characteristics; F_{ij} stands for the socioeconomic characteristics of the student's family; P_{ij} denotes the characteristics of the student's peers; E_j stands for the characteristics of school j; C_j reflects the environment in school j; and ε_{ij} is the random error.

Since there is no consensus among theorists as to the most appropriate functional form to specify these relationships and since the specification of an unsuitable functional form could generate biased or inconsistent estimates, a range of specifications were tested and then compared using the Bayesian information criterion (BIC). In particular, the criterion developed by Gideon E. Schwarz (1978) was employed to identify the functional form with the lowest BIC; this criterion is closely related to the maximization of the model's likelihood function.

FIGURE 1

Distribution of scores on classroom-environment indicators used in teacher evaluations



Source: prepared by the authors on the basis of the teacher evaluation database of the Ministry of Education.

The results suggest that the various models display a high degree of consistency and robustness. However, based on the BIC, the model employed here includes the following regressors: (i) gender; (ii) father's level of education; (iii) household income (linear and quadratic); (iv) mother's level of education (average); (v) average household income; (vi) rural place of residence; (vii) average score of the school's faculty on the teacher evaluations, and (viii) the average of nine different scores on classroom-environment indicators.

A number of different issues have to be dealt with. First, observations are not independent of one another, since the students are grouped into schools. Therefore, we have two different levels —student and school— and the error term ε_{ij} includes an error at the individual student level, ω_{ij} and an error for the educational institution as a whole, μ_j, which is shared by all the students in that school:

$$\varepsilon_{ij} = \omega_{ij} + \mu_j \qquad (2)$$

Although the aggregations do not yield substantially differing results, ignoring this data structure could lead to biased estimates. If the error term at the school level, μ_j, is correlated with the regressors, then the ordinary least squares (OLS) estimators will be biased, while if μ_j is independent of the regressors, then the OLS estimators will not be biased, but they will be inefficient.

One possible solution for this problem is to use fixed-effect estimation. The downside of this method when used for our purpose is that the fixed effect is linearly dependent on the variable of interest to us here, school climate, which would make it impossible to identify the effect.

The alternative to using fixed-effect estimators is to use random-effect estimation techniques. However, this method requires the assumption of independence between and the regressors; otherwise, we would obtain biased estimators. If this condition is fulfilled, then the effect estimator yields more efficient estimators (Baum, 2006).

To test the independence of μ_j and the regressors, we used the Hausman test. If μ_j and the regressors are correlated, the fixed-effect estimators will be consistent, but the random-effect estimators will be inconsistent. On the other hand, if μ_j and the regressors are independent, then the fixed-effect estimators will still be consistent (although not efficient) but the random-effect estimators will be both consistent and efficient. Thus, by using the Hausman test to compare fixed-effect and random-effect estimators, we can see whether or not they differ

significantly. If they do, then we can conclude that the assumption of independence is valid (Baum, 2006). The results of the Hausman test indicate that the hypothesis that μ_j and the regressors are independent should be rejected; therefore, the random-effect estimators and the OLS estimators are biased.

To surmount this problem, we follow Mundlak (1978) and use the mean square error estimator (MSEE). The first step in applying this method is to estimate the product solely on the basis of the in-school variables that may change, as in equation (3).

$$R_{ij} = f\left(A_{ij}, F_{ij}, P_{ij}\right) + \varphi_{ij} \tag{3}$$

The estimated error in equation (3) includes the error associated with a fixed-effect estimate plus the fixed variables effect. The second step is to estimate a regression between the estimated error of (3) ($\widehat{\varphi_{ij}}$) and in-school variables that are not subject to change using a random-effect model, as in (4).

$$\widehat{\varphi_{ij}} = f\left(E_j, C_j\right) + \pi_{ij} \tag{4}$$

This method yields unbiased estimators for the classroom-environment indicators, provided that there is no endogeneity.

The possible endogeneity of teacher quality, in particular, poses a potential problem. If teachers who have greater classroom skills could choose where they will work, they might prefer the schools that are attended by the best students. In this case, the direction of causality is opposite to the one that we are trying to measure, and our lack of suitable instruments will translate into biased estimators.

The problem of endogeneity is one of the most difficult ones to resolve because, strictly speaking, the only solution is to apply controlled experiments or pseudo-experiments. It can be argued that, because of the complexity of the interacting factors, it is impossible to be sure that no type of endogeneity is present. A weak endogeneity test was used in an attempt to detect any possible endogeneity in the model (Schaffer and Stillman, 2006). This test involves estimating a variable that reflects the effects of factors or characteristics that influence the performance of a school's teachers and have not been included in the model (this is obtained as a residual of the regression of teacher-related factors as a function of other variables that have been incorporated into the model). The next step is to assess the significance of this estimated variable (factor or characteristics that influence teacher performance that have not been included in the model) in accounting for the error in the original model at the school level. If this variable is significant, then weak endogeneity is found to be present. For our model, the variable is not significant with a *p*-value close to 1, which suggests that, given the above caveat, there is insufficient evidence to support the endogeneity hypothesis.

Estimates were calculated for the language and mathematics tests for 2007 and 2008 and for fourth and eighth grades. Tables 1 and 2 show the results generated by HLM for mathematics in the fourth and eighth grades.

The results of the Fisher test for all the variables for the school setting indicate that they are part of the model and have a significant effect. They also suggest that the model's predictive power is substantially greater for the higher grades, as the estimates for fourth grade have an R^2 of 7.8%, whereas the estimates for tenth grade have an R^2 of 28%. This differential is primarily due to inter-school differences in R^2: 10% for fourth grade and 49% for tenth grade.

The regressors have the sign and significance typically found in the literature (García and Paredes, 2010) and therefore seem to be satisfactory controls. The teacher-performance and classroom-environment variables are interesting: while the overall teacher evaluation is highly relevant, the only indicator for classroom environment that is consistently significant in the regressions for the different tests and courses is "handling of the class as a group."

This item is closely related to the teacher's objectives in terms of the direction in which he or she is trying to steer the class's learning experience, and although it does not incorporate the amount of time devoted to administrative tasks or to maintaining control (which is depicted in the literature as running counter to the achievement of educational objectives), it seems highly likely that the energy devoted to handling the class and the energy devoted to these other tasks do, in fact, represent trade-offs. The "handling of the class as a group" variable is consistently positive and significant in the different models. This appears to reflect a teacher's skill in handling the class and eliciting objectively desired forms of observable behaviour that will be conducive to learning (Kennedy, 2005).

More specifically, the significance and relevance of the estimated effect of "handling of the class as a group" in the fourth-grade SIMCE mathematics test scores

TABLE 1

Results for the fourth-grade SIMCE mathematics test

	Coefficient (standard error)	Coefficient (standardized)
First model		
Woman	-4.037*** (0.303)	-0.039
Father's education	0.450*** (0.042)	0.039
Mother's education	1.434*** (0.052)	0.103
Income (measured in $10 000 increments)	0.232*** (0.015)	0.128
Income (quadratic)	-.001*** (0.000)	-0.099
Peer effect – mother's education	5.886*** (0.334)	0.186
Peer effect – income	0.757 (0.715)	0.012
Model 1 constant	136.488*** (10.268)	
Second model		
Urban	-12.762*** (0.899)	-0.098
Teacher evaluation score	12.754*** (1.285)	0.072
Student focus on activities	0.725 (2.916)	0.002
Handling of the class as a group	12.191*** (3.674)	0.027
Encouraging all students to participate	3.437** (1.552)	0.015
Quality of class structure	-1.678 (1.266)	-0.009
Use of time available for instruction	1.566 (1.691)	0.006
Activities' contribution to objectives	1.358 (1.234)	0.006
Quality of explanations	0.976 (1.721)	0.005
Quality of teacher-fostered interactions	-3.187* (1.638)	-0.018
Learning-process coaching	0.246 (1.950)	0.001
Model 2 constant	-71.811*** (10.268)	
Number of observations	104 656	
Number of groups	4 281	
In-school R^2	0.036	
Inter-school R^2	0.104	
R^2	0.0787	

Source: prepared by the authors on the basis of Ministry of Education teacher evaluation data.

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

TABLE 2

Results for the tenth-grade SIMCE mathematics test

	Coefficient (standard error)	Coefficient (standardized)
First model		
Woman	-9.321*** (0.373)	-0.08
Father's education	0.075* (0.042)	0.007
Mother's education	0.729*** (0.059)	0.047
Income (measured in $10 000 increments)	0.138*** (0.017)	0.069
Income (quadratic)	-0.0004*** (0.0001)	-0.038
Peer effect – mother's education	9.419*** (0.26)	0.287
Peer effect – income	4.925*** (0.581)	0.079
Model 1 constant	102.367*** (2.66)	
Second model		
Urban	-5.316* (3.14)	-0.017
Teacher evaluation score	17.101*** (3.736)	0.124
Student focus on activities	39.699*** (11.98)	0.155
Handling of the class as a group	25.453** (10.79)	0.089
Encouraging all students to participate	3.599 (4.294)	0.019
Quality of class structure	0.065 (3.645)	0.001
Use of time available for instruction	11.485** (5.05)	0.08
Activities' contribution to objectives	-10.019** (4.378)	-0.083
Quality of explanations	3.79 (4.398)	0.031
Quality of teacher-fostered interactions	-2.752 (4.182)	-0.024
Learning-process coaching	-0.034 (6.247)	-0.0002
Model 2 constant	-256.283*** (27.046)	
Number of observations	74 912	
Number of groups	681	
In-school R^2	0.0509	
Inter-school R^2	0.4905	
R^2	0.2834	

Source: prepared by the authors on the basis of Ministry of Education teacher evaluation data.

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

is high. The standardized coefficient for this variable —0.27— means that, if teachers' scores on handling the class rise by one standard deviation (0.35 points out of a total of 4), then the SIMCE scores of their students would increase by 0.27 of a standard deviation (about 15 points).

The standardized effect of skill in handling the class on mathematics test scores tends to be three times as great at grade 10 relative to grades 4 and 8, although, because there is so little variance in the responses, we cannot be sure that this difference is statistically significant. While, for some years, the results for variables such as "students' focus on proposed activities," "quality of class structure," "activities' contribution to goal achievement" and "use of time available for instruction" yield the expected signs and significance levels, they do not do so consistently across different tests, courses and years. Finally, the variables "promotion of participation by all the students," "quality of teacher explanations," "quality of teacher-fostered interactions" and "learning-process coaching" are consistently not significant as explanatory variables for student performance.

There are two possible reasons why the variables other than "handling the class as a group" do not appear to be influential or are influential only for some tests. One is that the characteristics represented by these variables actually do not have a significant impact on students' academic performance. The other is that the instrument being used to measure them is not capturing the relevant characteristics, either because of imperfect observations or because teachers are able to modify these aspects for the classroom session that they know is going to be observed.

In order to delve more deeply into the significance of the school environment, one of the questions that needs to be answered is whether the aspects that are key to learning are ones that can be manipulated by the teacher or teachers, or whether they correspond more closely to the overall school environment. In other words, are there schools in which the overall environment is more welcoming and conducive to student commitment, and the actions of the teachers that take place within that framework exert less influence than the environment itself?

In order to test this hypothesis, we replace the variable constructed from the average for all the teachers in a school with a variable constructed only from the observations of the teachers in the relevant cycle and course subject area. Thus, for example, the regressors for the SIMCE mathematics test for fourth grade would now be the average scores obtained by instructors who teach mathematics in the first (elementary) cycle. Clearly, this is a more direct test of the effect of discipline in the classroom in which the relevant subject is taught, since, in addition to focusing on the teachers who are directly involved in the corresponding subject matter, it is also focusing on the relevant cycle. In this case, it is to be expected that the significance of the coefficients in question will be substantially greater.

The results are surprising. In general, the estimated effect of the "handling the class as a group" variable remains significant for nearly all the tests, but the specific estimate is almost halved, even though the estimator is not statistically smaller (the confidence intervals at a 95% significance level overlap).

As in the preceding case, the estimates were calculated for the 2007 and 2008 language and mathematics tests for fourth grade, eighth grade and the second year of secondary school (tenth grade). Table 3 shows the results for the tenth-grade mathematics tests. The estimates for the other grade levels and other tests reflect the same trends.

Finally, table 4 gives the values of this standardized coefficient for the various tests and the two specifications, i.e. using the average for all teachers and using the average for the teachers of the relevant subject in each cycle.

TABLE 3

Results for the tenth-grade SIMCE mathematics test based on secondary-school mathematics teachers

	Coefficient (standard error)	Coefficient (standardized)
First model		
Woman	-9.321*** (0.389)	-0.08
Father's education	0.079 * (0.044)	0.007
Mother's education	0.734*** (0.061)	0.047
Income (measures in $10 000 increments)	0.132*** (0.017)	0.066
Income (quadratic)	-0.0004 *** (0.0001)	-0.037
Peer effect – mother's education	9.692*** (0.269)	0.295
Peer effect – father's education	4.692*** (0.599)	0.075
Model 1 constant	99.816*** (2.772)	
Second model		
Urban	-5.562 (3.709)	-0.017
Teacher evaluation score	13.634*** (2.291)	0.099
Student focus on activities	-2.64 (4.987)	-0.01
Handling of the class as a group	12.523** (5.39)	0.044
Encouraging all students to participate	0.861 (2.862)	0.004
Quality of class structure	2.121 (1.763)	0.021
Use of time available for instruction	0.758 (2.521)	0.005
Activities' contribution to objectives	-4.506** (1.966)	-0.037
Quality of explanations	0.688 (2.031)	0.006
Quality of teacher-fostered interactions	-2.079 (1.938)	-0.018
Learning-process coaching	2.52 (2.819)	0.016
Model 2 constant	-67.412*** (15.159)	
Number of observations	69 265	
Number of groups	602	
In-school R2	0.052	
Inter-school R2	0.4459	
R^2	0.26892	

Source: prepared by the authors on the basis of Ministry of Education teacher evaluation data.

* p < 0.1; ** p < 0,05; *** p < 0,01.

TABLE 4

Comparison of the "handling the class as a group" indicator coefficients for schoolwide averages versus cycle-specific averages

Standardized coefficients for "handling the class as a group"			
		School	Cycle
4th	Mathematics	0.027	0.023
	Language	0.034	0.026
8th	Mathematics	0.021	0.024
	Language	0.032	0.022
10th	Mathematics	0.089	0.044
	Language	0.038	0.025

Source: prepared by the authors on the basis of Ministry of Education teacher evaluation data.

IV
Conclusions

In this study we measured and quantified the influence that the school and classroom environment has on academic performance. The fact that the way in which the class is handled proves to be statistically significant and educationally relevant suggests that guiding collective student behaviour in the classroom is key in successful learning. It can also be inferred from the results that the method used to measure the characteristics of interest (videotaping a class as a teacher evaluation tool) makes it possible to distinguish between teachers who are able to handle their class and those who are not. Consequently, evaluators can use this tool to evaluate teachers on their skill in handling their students' group behaviour.

The only facets of the school environment that have been considered, however, are those that can be modified by a teacher inside the classroom and can be perceived by a classroom observer. The atmosphere in the classroom is, of course, influenced by many other factors that do not show up on a video and that could skew the estimates if they correlate with variables used in the model. There is no actual indication of such a correlation, however, and the interpretation arrived at, albeit with some caution, is that the classroom atmosphere and, hence, a teacher's skill in exerting a positive influence on it, are important factors.

The public policy implications of these findings clearly point in the direction of the training provided to teachers-to-be at university, since this is where they develop leadership skills and their personal approach and acquire knowledge about student psychology and classroom management. A corollary may be that reducing class size would help teachers to manage their classes more successfully (Angrist and Lavy, 1999).

Finally, at the level of school policy, it seems clear that the overall school environment, above and beyond what goes on in the classroom, is a factor that has a significant influence on learning outcomes.

Bibliography

Angrist, J. and V. Lavy (1999), "Using Maimonides' rule to estimate the effect of class size on scholastic achievement", *The Quarterly Journal of Economics*, vol. 114, No. 2, Oxford University Press.

Arancibia, V. (1994), "La educación en Chile: Percepciones de la opinión pública y de expertos", *Estudios Públicos*, 54, Santiago, Chile, Centro de Estudios Públicos.

Araya, C. and others (2010), "Theory underlying a national teacher evaluation program", *Evaluation and Program Planning*, vol. 33, No. 4, Amsterdam, Elsevier.

Barber, M. and M. Mourshed (2008), *How the World's Best-performing School Systems Come out on Top*, London, McKinsey and Company.

Baum, C. (2006), *An Introduction to Modern Econometrics Using Stata*, Stata Press.

Beyer, H. (2009), "¿Qué hacer con la educación pública?", *Estudios Públicos*, No. 114, Santiago, Chile, Centro de Estudios Públicos.

Brunner, J.J. and C. Cox (1995), "Dinámicas de transformación en el sistema educacional de Chile", *Education, Equity and Economic Competitiveness in the Americas*, J.M. Puryear and J.J. Brunner (eds.), Washington, D.C., Organization of American States.

Cabezas, V. and others (2013), "Los determinantes del primer trabajo para profesores de Educación Básica de la Región Metropolitana", *Evidencias para políticas públicas en educación*, Sixth cycle of the Research and Development in Education Fund (FONIDE) competitive grant award process, Santiago, Chile.

Claro, F. (2009), "Comentarios a la presentación de Inger Enkvist en el CEP", *Inger Enkvist y la educación actual, Estudios Públicos*, No. 115, Santiago, Chile, Centro de Estudios Públicos.

Drago, J.L. and R. Paredes (2011), "The quality gap in Chile's education system", *CEPAL Review*, No. 104 (LC/G.2498-P), Santiago, Chile, August.

Edwards, D. and F. Mullis (2003), "Classroom meetings: encouraging a climate of cooperation", *Professional School Counseling*, vol. 7, No. 1.

Emmer, E. and L. Stough (2001), "Classroom management: a critical part of educational psychology, with implications for teacher education", *Educational Psychologist*, vol. 36, No. 2, Taylor & Francis.

Eyzaguirre, B. and L. Fontaine (2008), "Las escuelas que tenemos", *Estudios Públicos*, No. 111, Santiago, Chile, Centro de Estudios Públicos.

Eyzaguirre, B. and C. Le Foulon (2001), "La calidad de la educación chilena en cifras", *Estudios Públicos*, No. 84, Santiago, Chile, Centro de Estudios Públicos.

Fontaine, A. (2002), "Equidad y calidad de la educación: Cinco proposiciones interrelacionadas", *Estudios Públicos*, No. 87, Santiago, Chile, Centro de Estudios Públicos.

García, C. and R. Paredes (2010), "Reducing the educational gap: good results in vulnerable groups", *Journal of Development Studies*, vol. 46, No. 3, Taylor & Francis.

Hausman, J. and W. Taylor (1981), "Panel data and unobservable individual effects", *Econometrica*, vol. 49, No. 6, The Econometric Society.

Kennedy, M. (2005), *Inside Teaching, How Classroom Life Undermines Reform*, Harvard University Press.

León, G., J. Manzi and R. Paredes (2008), "Calidad docente y rendimiento escolar en Chile: Evaluando la evaluación", thesis, Santiago, Chile, Pontificia Universidad Católica de Chile.

Lewis, R. and others (2008), "Students' reaction to classroom discipline in Australia, Israel, and China", *Teaching and Teacher Education*, vol. 24, No. 3, Amsterdam, Elsevier.

Lock, A. and T. Strong (2010), *Social Constructionism*, Cambridge, Cambridge University Press.

Malmgren, K., B. Trezek and P. Paul (2005), "Models of classroom management as applied to the secondary classroom", *The Clearing House*, vol. 79, No. 1, Taylor & Francis.

Ministry of Education (2008a), *Estadísticas de la educación 2008* [online] www.mineduc.cl.

_____ (2008b), "Resultados nacionales 2008" [online] www.simce.cl.

Morris-Rothschild, B. and M. Brassard (2006), "Teachers' conflict management styles: the role of attachment styles and classroom management efficacy", *Journal of School Psychology*, vol. 44, No. 2, Amsterdam, Elsevier.

Mundlak, Y. (1978), "On the pooling of time series and cross section data", *Econometrica*, vol. 46, No. 1, The Econometric Society.

Muñoz, G. and D. Raczynski (2007), "Reforma educacional chilena: El difícil equilibrio entre la macro y la micro política", *Serie Estudios Socio/Económicos*, No. 31, Santiago, Chile.

Muñoz, G. and J. Weinstein (2009), "Calidad para todos: La reforma educacional en el punto de quiebre" [online] http://www.ceppe.cl/articulos-liderazgo-y-escuelas-efectivas/174-calidad-para-todos-la-reforma-educacional-en-el-punto-de-quiebre-weinstein-munoz.

Nie, F. and S. Lau (2009), "Complementary roles of care and behavioral control in classroom management: the self-determination theory perspective", *Contemporary Educational Psychology*, vol. 34, No. 3, Amsterdam, Elsevier.

OECD (Organisation for Economic Co-operation and Development)/ World Bank (2009), *Revisión de políticas nacionales de educación*, Paris.

Opdenakker, M.C. and J.V. Damme (2006), "Teacher characteristics and teaching styles as effectiveness enhancing factors of classroom practice", *Teaching and Teacher Education*, vol. 22, No. 1, Amsterdam, Elsevier.

Paredes, R. and J. Pinto (2009), "¿El fin de la educación pública en Chile?", *Estudios de Economía*, vol. 36, No. 1, Santiago, Chile, Universidad de Chile.

Ritter, J. and D. Hancock (2007), "Exploring the relationship between certification sources, experience levels and classroom management orientations of classroom teachers", *Teaching and Teacher Education*, vol. 23, No. 7, Amsterdam, Elsevier.

Schaffer, M. and S. Stillman (2006), "XTOVERID: Stata module to calculate tests of overidentifying restrictions after xtreg, xtivreg, xtivreg2, xthtaylor", *Statistical Software Components*, Boston College.

Schwarz, G. (1978), "Estimating the dimension of a model", *The Annals of Statistics*, vol. 6, No. 2, Institute of Mathematical Statistics.

Pricing and spread components at the Lima Stock Exchange

Luis Chávez-Bedoya, Carlos Loaiza Álamo and Giannio Téllez De Vettori

ABSTRACT

This paper analyses three aspects of the share market operated by the Lima Stock Exchange: (i) the short-term relationship between the pricing, direction and volume of order flows; (ii) the components of the spread and the equilibrium point of the limit order book per share, and (iii) the pricing, order direction and trading volume dynamic resulting from shocks in the same variables when lagged. The econometric results for intraday data from 2012 show that the short-run dynamic of the most and least liquid shares in the General Index of the Lima Stock Exchange is explained by the direction of order flow, whose price impact is temporary in both cases.

KEYWORDS Stock markets, stocks, prices, econometric models, Peru

JEL CLASSIFICATION G11, G12, G15

AUTHORS

Luis Chávez-Bedoya teaches finance at the ESAN Graduate School of Business, Lima, Peru. lchavezbedoya@esan.edu.pe

Carlos Loaiza Álamo teaches at the Faculty of Administration and Finance of the Peruvian University of Applied Sciences (UPC), Lima, Peru. cloaizaa@pucp.pe

Giannio Téllez De Vettori is a teaching assistant at the Department of Economics of the Catholic University of Peru and a researcher affiliated with the ESAN Graduate School of Business, Lima, Peru. giannio.tellez@pucp.pe

I
Introduction

The Peruvian stock market has struggled to develop sustainably as an investment alternative, yet little basic or applied research has been done on it. There is no significant body of research dealing theoretically, empirically, or both, with the workings of this market, and specifically the share market. This lack of research was the spur for the present paper, which aims to contribute to an understanding of the pricing dynamic and the composition of order execution costs in the trading mechanism operated by the Lima Stock Exchange.

The main asset pricing models, namely Markowitz's (1952) portfolio selection model and Sharpe's (1964) capital asset pricing model, present risk and expected yield as price determinants. Trading costs are zero in both models, an assumption that is relaxed in financial market microstructure theory. This theory is the study of the process and outcomes of exchanging financial instruments under explicit trading rules (O'Hara, 1995).

There are two major obstacles to studying the empirical evidence for the microstructure theory: (i) obtaining share trading microdata, and (ii) coping with bulky information in empirical testing. It was possible to obtain this information for the present study, however, with a view to obtaining a better understanding of the behaviour of the Lima Stock Exchange share market. In these favourable circumstances, the effects of the dynamic of pricing and the components of the bid-ask spread in the Lima Stock Exchange share market have been investigated along the lines of analyses carried out for the world's most developed stock markets. As far as we know, this is the first study to empirically test microstructure theory for the Peruvian equity market.[1]

This document is organized as follows. Section II describes the trading mechanism at the Lima Stock Exchange. Section III lays out the theoretical framework representing the current state of knowledge. Section IV describes the data and the treatment applied to them, and gives the results of the econometric estimations. Lastly, section IV presents the conclusions.

[1] See Loaiza (2013) for the first theoretical presentation on microstructure for the Lima Stock Exchange.

II
The share trading mechanism at the Lima Stock Exchange

The study of microstructure requires an understanding of a stock market's trading mechanism, so these characteristics will now be described for the Peruvian stock market.

The Lima Stock Exchange has an electronic trading mechanism[2] which aggregates buy and sell orders in the limit order book (LOB). There are no market-makers,[3] so liquidity is provided by the LOB alone. There is a price discrimination rule, which operates at every stage of a trade and means that an order may be executed piecemeal at different prices. Here, priority (the order of execution) and allocation (the matching of supply and demand) are as follows: first, the order that "betters the price"[4] in the LOB; second, the order with the "greatest exposure time in the market".[5]

[2] The trading mechanism is ELEX, a software system that aggregates buy and sell orders in the limit order book (LOB). These are automatically matched following best price and time rules in a continuous auction. Orders can also be executed at different prices.

[3] Although there are regulations for agents carrying out market-making functions, in practice there are no market-makers. See Loaiza (2013).

[4] What it means to better the price in the LOB depends on whether a buy or sell order is involved. Since the goal is to reduce spreads, a buy order betters the price if it is higher than the highest bid in the LOB. Conversely, a sell order betters the price if it is lower than the lowest offer in the LOB.

[5] The provision relating to exposure time in the market means that priority is given to whoever first initiates an order.

Initial price formation occurs in a first phase known as the pre-open session, when the auction system takes non-cancellable orders. At this stage, all market expectations are stored but not matched. The system then uses this information to allot a price in a "variable time period"[6] so that the orders can be executed.

The next phase is continuous trading, when traders enter orders in the expectation that they will be matched automatically. These are limit orders allowing securities to be bought or sold by specifying the order quantity, price and exposure period. With a limit order, it is not permitted to enter prices that fall below the minimum movement limit (tick) of 0.01 or that exceed a maximum variation of 15% for local securities and 30% for foreign securities relative to the last price cleared the day before.[7] The trading mechanism of the Lima Stock Exchange does not permit market orders (those not executed at a limit price). Traders can view a market by price in the book, on both the bid and ask sides. A best price is determined from the limit orders received and can be viewed in the aggregate (not individually) by traders participating in the LOB. The difference between the best bid and ask prices is the spread.

The final phase is the close, which works much like the pre-open session, with a closing price being set for shares within an arbitrary time range.[8] Once this price has been set, any buy or sell order entered is traded at that value. Thus, each share is priced on the basis of the net aggregate demand for it (purchases minus sales) at each point in time during continuous trading. This price dynamic may be affected by problems of information asymmetry between investors and the immediacy with which their trades are executed; these problems give rise to costs that are known as "frictions" in the microstructure literature, as they affect price formation.

[6] This means that the first trade of the day takes place in an interval of +/- 2 minutes from the start of the following stage, that of continuous trading.

[7] For all phases of trading.

[8] This means that the last trade in the trading phase takes place within an interval of +/- 2 minutes from the start of the following (closing) stage.

III
Microstructural models

This section reviews theoretical and empirical models based on microstructural stock market theory, which can be used to determine the best approach to explaining share trading on the Lima Stock Exchange.

1. Some models based on the stock market microstructure approach

With regard to the current state of knowledge, the work of Demsetz (1968) marks the beginning of research in the field of microstructure, analysing price-setting in share markets. This author incorporates the problem of trading immediacy owing to the existence of impatient traders requiring liquidity and patient traders without liquidity needs who come into the market at different points in the trade.

Garman (1976) was the first to model a trading process characterized by the presence of an agent managing an inventory of shares and cash. His model is characterized by temporary imbalances in flows of buy and sell orders (Demsetz, 1968), which produce uncertainty about when an order may be expected to come in. These imbalances justify the presence of a market-maker who can resolve the problem of uncertainty regarding the time it will take for an order to come in. The market-maker solves the problem by offering shares when the counterparty is buying, and cash when the counterparty is selling.

Stoll's (1978) model also sets out from the immediacy problem and defines a market-maker as a provider of liquidity or trading services. This agent will seek to compensate for the costs of offering immediacy via the spread, paying a lower price to those wishing to sell assets and selling at a higher price to those wishing to purchase assets. In this model, Stoll breaks costs down into: (i) maintenance costs; (ii) processing costs,[9] and (iii) information costs. However, the author focuses on the maintenance cost, assuming that the market is competitive and the other costs are zero.

[9] Stoll (1978 and 2000) calls processing costs those related to the routing or electronic transmission of orders, execution and settlement.

Glosten and Milgrom (1985) model the problem of information asymmetry creating adverse selection costs in share trading. The model assumes the sequential arrival of traders with private information (insider traders) and those requiring liquidity (liquidity traders) in a market with perfect competition. Market-makers revise their prices against the information they extract from the order flow, using a Bayesian learning process. In this model, information is extracted from order direction rather than size. A second important study modelling the problem of information asymmetry is that of Kyle (1985), which assumes a rational expectations equilibrium, single auctions (there is no spread) and a market with imperfect competition. Thus, the informed trader acts strategically by anticipating the reactions of other agents. The outcome is that the transaction costs of the uninformed agents are equivalent to the profits of the informed agents.

Stoll (2000) divides operating costs into two classes: "real frictions" and "informational frictions." Both classes affect price formation. In the first case, the market-maker sets out to compensate for order processing and inventory costs and to obtain rents from his market power, while in the second he is an intermediary who redistributes wealth between informed and uninformed traders, incurring adverse selection costs only. Then, Stoll (2000) attributes temporary price changes to real friction problems and permanent price changes to informational friction problems.

Hitherto, microstructure theory has centred on mechanisms where there is a market-maker. However, share trading is not always expedited by such an agent, as there is also the possibility of the LOB being the liquidity provider. The problem with LOB models is that they have only been developed theoretically (Rosu, 2009; Foucault, Kadan and Kandel, 2001); nonetheless, Glosten (1994) developed a theoretical LOB model with information asymmetry problems, where investor behaviour is modelled from a price revision equation, which can be empirically calculable and will determine the input of limit orders.

Jong, Nijman and Röell (1996) use the Glosten (1994) model to analyse the effect on intraday prices of the bid-ask spread components on the Paris Bourse. The empirical test consists of an econometric model where the spread is decomposed into two factors, one caused by order processing costs and the other by information asymmetry.

Jong, Nijman and Röell (1996) develop two estimates: in the first they use ordinary least squares (OLS) to analyse the immediate effect on prices, and in the second they use a vector autoregression (VAR) model to analyse whether the effect on prices is permanent, applying the methodology proposed by Hasbrouck (1991a). They conclude that processing costs are higher and adverse selection costs lower in smaller operations. They also find that the effect of order direction (buying or selling) on prices in later periods is permanent.

It can be concluded from this review of the literature that the share trading mechanism may be subject to operating costs comprising processing costs and adverse selection costs. Given the trading characteristics described for the Lima Stock Exchange, the model considered to be the best fit is the one based on the LOB. One theoretical approach that has been contrasted for models of this type is that of Glosten (1994). This empirical contrast is carried out by Jong, Nijman and Röell (1996) following the econometric methodology proposed by Hasbrouck (1991a). The present study will contrast this model. Glosten's (1994) model and its extension by Jong, Nijman and Röell (1996) will now be presented.

2. Glosten's (1994) model and its extension by Jong, Nijman and Röell (1996)

Glosten (1994) develops a theoretical model which assumes an LOB, discriminatory pricing and no market-maker, all three of which are characteristics of the trading model at the Lima Stock Exchange. As described in section III.1, this paper models investor behaviour and equilibrium characteristics in an LOB when a great many limit orders come in. The investor decides to enter a buy order if the marginal valuation is at least as great as the asset price, and the LOB equilibrium is characterized by an expected return of zero where, in a context of strong adverse selection, the losses of some traders are the profits of informed traders. Then, Jong, Nijman and Röell (1996) extend the model by developing a calculable equation for Glosten's (1994) theoretical model, incorporating processing costs. The derivation of the equation for the share pricing dynamic and the components of the price spread will now be presented.

In Glosten's (1994) original model, there are no order processing costs and buyer-initiated transactions are assumed. Let $R(q)$ be the "price revision" equation, denoted by the price a buyer executes on an order of size q over and above the initially expected value of the order. In Glosten's (1994) model, q represents the minimum level for price clearing,[10] with the marginal

[10] A trade must be worth at least one tax unit (UIT) to make a price at the Lima Stock Exchange; otherwise, the trade will not change the price even if executed.

value of a transaction of size q being determined by the following rule:

$$R'(q) = E_z\left(g(Z)\,\middle|\, Z \geq q\right) \quad (1)$$

where $g(Z)$ is the revision to the best public estimate of the value of the share when it is known that the buyer will execute an order of size Z in the market. E_z denotes the expectation that arises about the distribution of the size of transaction Z. This distribution is assumed to be exponential, so that:

$$F_z(z) = 1 - e^{\frac{-z}{\alpha}} \quad (2)$$

Price revision is described as the change in expectations about the true value of the share, owing to an operation of size Z. To simplify, this relationship is assumed to be linear:

$$g(Z) = g_0 + g_1 Z \quad (3)$$

On these assumptions, the marginal price ratio is:

$$R'(q) = g_0 + g_1 E_z(Z \mid Z \geq q) = g_0 + g_1(q + \alpha) \quad (4)$$

where the last equality derives from the properties of the exponential distribution, α being the average transaction size. Then, Jong, Nijman and Röell (1996) propose an extension to Glosten's (1994) model, introducing an order processing cost into the marginal pricing scheme. Let the function of the order processing cost, denoted by $C(q)$, be:

$$R'(q) = C'(q) + g_0 + g_1(q + \alpha) \quad (5)$$

Integrating (5) and dividing by q gives the average price:

$$\int R'(q)dq = \int C'(q)dq + \int (g_0 + g_1\alpha)dq + \int g_1 q dq \quad (6)$$

$$R(q) = C(q) + (g_0 + g_1\alpha)q + g_1\frac{q^2}{2} \quad (7)$$

$$\frac{R(q)}{q} = \frac{C(q)}{q} + (g_0 + g_1\alpha) + \frac{1}{2}g_1 q \quad (8)$$

To simplify, the average order processing cost is assumed to be a quadratic function of q,[11] i.e., $C(q) = c_0 q + c_1 q^2$. Thus,

$$\frac{R(q)}{q} = \frac{\left(c_0 q + c_1 q^2\right)}{q} + \left(g_0 + g_1\alpha\right) + \frac{1}{2}g_1 q \quad (9)$$

so that

$$\frac{R(q)}{q} = c_0 + c_1 q + \left(g_0 + g_1\alpha\right) + \frac{1}{2}g_1 q = R_0 + R_1 q \quad (10)$$

where $R_0 = c_0 + g_0 + g_1\alpha$ and $R_1 = c_1$ (½)g_1. R_0 captures the determinants of the average price that are unrelated to the quantity traded, whereas R_1 captures determinants that are directly related to the transaction amount. Lastly, the following breakdown of the bid-ask spread can be derived from Glosten's (1994) model:

$$ASC = \left(g_0 + g_1\alpha\right) + \frac{1}{2}g_1 q \quad (11)$$

$$OPC = c_0 + c_1 q \quad (12)$$

where ASC is the adverse selection cost and OPC is the order processing cost. To apply this model empirically, the following notation from Jong, Nijman and Röell (1996) is introduced:

p_t = logarithm of the purchase price (average price paid per share).
q_t = quantity (number of shares traded).
Q_t = direction of trade.[12]
y_t = expected value of the share before the trade.
$\in_t$ = change in share value.

It is established in the empirical model that the transaction price is equal to the expected value of the

[11] It should be noted that this implies a quadratic cost function with an intercept of zero.

[12] It is important to analyse the direction of the order, since this provides information about whether the intention is to acquire or dispose of shares, affecting LOB demand (buy) or supply (sell). If the operation is initiated by a buy order, the direction of trade will have a positive sign, taking a value of +1. If the operation is initiated by a sell order, the direction of trade will have a negative sign, taking a value of -1. The direction of a buy order is assumed to be positive because greater demand will drive up the price. Conversely, the direction of a sell order is assumed to be negative because greater supply will drive down the price.

share prior to the operation plus the average price premium, $R(q)/q$, given by equation (10). As in Madhavan, Richardson and Roomans (1994), a random price error, u_t, is added to capture other influences on the transaction price, such as pricing discretion.

The term u_t is not considered to be correlated with other variables in the price equation. Additionally, pricing is assumed to be determined by order direction and flow, which are made known at a time prior to execution $(t-1)$, revealing information to the market. The pricing equation thus becomes:

$$p_t = y_t + \left(R_0 + R_1 q_{t-1}\right)Q_{t-1} + u_t \tag{13}$$

The price revision can be modelled by the change in the expected value y_t, as well as future trades and order direction and flow, given pricing as follows:

$$y_{t+1} = y_t + \left(g_0 + g_1 q_{t+1}\right)Q_{t+1} + \in_{t+1} \tag{14}$$

Equation (14) derives from equation (3), where $\in_t$ is public information that is encountered between transactions t and $t+1$ but is not related to the current transaction. When equation (14) is used, we get:

$$y_{t+1} - y_t = \left(g_0 + g_1 q_{t+1}\right)Q_{t+1} + \in_{t+1} \tag{15}$$

$$\Delta y_{t+1} = \left(g_0 + g_1 q_{t+1}\right)Q_{t+1} + \in_{t+1} \tag{16}$$

And iterating one period back gives:

$$\Delta y_t = \left(g_0 + g_1 q_t\right)Q_t + \in_t \tag{17}$$

Now, if equation (13) is presented in terms of variations:

$$\Delta p_t = \Delta y_t + \left(R_0 + R_1 \Delta q_{t-1}\right)\Delta Q_{t-1} + \Delta u_t \tag{18}$$

Equation (17) is substituted into (18):

$$\Delta p_t = \left(g_0 + g_1 q_t\right)Q_t + \in_t + \left(R_0 + R_1 \Delta q_{t-1}\right)\Delta Q_{t-1} + \Delta u_t \tag{19}$$

$$\Delta p_t = \left(R_0 + R_1 \Delta q_{t-1}\right)\Delta Q_{t-1} + \left(g_0 + g_1 q_t\right)Q_t + e_t \tag{20}$$

where $e_t = \in_t + \Delta u_t$. Equation (20) is interpreted as follows: the coefficients of the difference variables are the intercept and the slope of the average price, while the coefficients of the levels are estimated from the intercept and the slope of the price revision function. In other words, the variations effect is the trading effect, and the levels effect is the clearing (liquidity) effect.

The equation to be estimated is obtained by reordering (20):

$$\begin{aligned}\Delta p_t = {} & c + R_0 \Delta Q_{t-1} + R_1 \Delta\left(q_{t-1} Q_{t-1}\right) \\ & + g_0 Q_t + g_1 q_t Q_t + e_t\end{aligned} \tag{21}$$

$$c_0 = R_0 - g_0 - g_1 \alpha \tag{22}$$

$$c_1 = R_1 - \left(1/2\right)g_1 \tag{23}$$

Equation (21) is the equation for the pricing dynamic; the constant c is included in this equation to capture average returns across transactions (i.e., a non-zero average of e_t). Equations (22)[13] and (23) are the determinants of order processing costs.

[13] α is the average transaction size divided by 2.

IV
Empirical testing

1. The data

Model estimation will be carried out using Lima Stock Exchange intraday (operation by operation) electronic trading data for 2012. The assets chosen for analysis are the five most liquid shares[14] and the five least liquid shares[15] in the General Index of the Lima Stock Exchange (IGBVL).[16]

The variables worked with are:

(i) Price variation (Δp_t): this is the differential of the logarithm of the purchase price relative to the previous price.

(ii) Direction of trade (Q_t): the operation will have a positive sign (+1) if initiated via a buy order and a negative sign (-1) if initiated via a sell order.

(iii) Pricing index (q_t_index): the index created is

$$q_t\_index = Ln\left(\frac{transaction\ amount_t}{1\,UIT}\right)$$

where the transaction amount is the order clearing price multiplied by the quantity traded:

$$Transaction\ amount_t = P_t{*}number\ of\ shares\ traded$$

Transaction size is normalized, since actual transaction amounts are too volatile and estimates are affected by information disclosure issues. This is why it is necessary to ascertain whether the actual transaction amount is enough to make a price or not,[17] this being the benchmark for positions and strategies in trading operations.

2. Econometric treatment

The econometric treatment applied in this study encompasses two methodologies, a Newey and West (1987) OLS model and a VAR model. With regard to the first methodology, Harris (1986) and Hasbrouck (1991a) argue that observed covariance patterns in transaction returns are more consistent with transaction time than with "calendar" time; it is therefore inferred that the relevant "clock" is transaction time. Since variations can depend on the time of day, trade size and other factors, errors are likely to be heteroskedastic. Again, if equation (21) is inaccurate, the regression error will have a series MA(1) correlation pattern.[18] With this error structure, the OLS model provides consistent point estimates; however, the usual standard error formula is incorrect. For this reason, the Newey and West (1987) methodology is used so that estimation of the parameters is consistent and the variance is properly estimated.

The model presented could have two disadvantages, however. First, the estimates assume a correct model specification. For example, it is assumed that all asymmetrical information is revealed immediately after the transaction, so that there is only an immediate effect on trading prices and there are no delayed effects. Secondly, the trading pattern is assumed to be exogenous.[19] If this pattern were not exogenous, the regression coefficients could be skewed because some relevant lagged variables could be omitted.

In the light of these considerations, we estimate a VAR model introduced into the market microstructure literature by Hasbrouck (1991a and 1993), which takes account of the problems mentioned in the previous paragraph. In the VAR, the clearing price and the trading dynamic are modelled using the following system of equations:

$$\begin{pmatrix} 1 & -b_0 \\ 0 & I \end{pmatrix}\begin{pmatrix} \Delta p_t \\ x_t \end{pmatrix} = \begin{pmatrix} a(L) & b(L) \\ c(L) & d(L) \end{pmatrix}\begin{pmatrix} \Delta p_{t-i} \\ x_{t-i} \end{pmatrix} + \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix}, \quad V\begin{pmatrix} e_{1t} \\ e_{2t} \end{pmatrix} = \begin{pmatrix} \sigma^2 & 0 \\ 0 & \Omega \end{pmatrix} \tag{24}$$

[14] Volcan "B" (VOLCABC1), Rio Alto Mining (RIO), Ferreycorp (FERREYC1), Cerro Verde (CVERDEC1) and ADR Buenaventura (BVN).

[15] Austral Group (AUSTRAC1), El Brocal (BROCALC1), Empresa Agroindustrial Pomalca (POMALCC1), Edelnor (EDELNOC1) and Scotiabank (SCOTIAC1).

[16] The IGBVL comprises shares representing 80% of total liquidity in the Peruvian stock market. The reference portfolio was established in the second half of 2012.

[17] For a stock price to be made in the Peruvian share market, the amount of an individual trade must be at least one tax unit (UIT), equivalent in 2012 to 3,650 nuevos soles. If this sum is not reached, the price will not change and the previous market price will continue to apply.

[18] See Jong, Nijman and Röell (1996).

[19] In other words, the explanatory variables do not depend on other variables (other than themselves) or on lags.

where Δp_t is the price variation and x_t is the vector of explanatory variables, with $a(L)$, $b(L)$, $c(L)$ and $d(L)$ being polynomials in the lag operator. In the present analysis, the vector of explanatory variables is the order direction (Q_t) and the size of the order flow for clearing ($Z_t = Q_t q_t$), assuming that the error terms are not correlated. This model can thus be used to analyse a dependency in the price variation, order direction and order flow size relative to past operations, without assuming that the order clearing pattern is exogenous.[20]

To analyse the shocks of the errors (e_1, e_2) on future returns (p) and on the exogenous variables $x_t = (Q_t, Z_t)$, we need to gauge the expected value of the price τ periods after the shock, given that the system has converged on a stationary state.[21]

$$pe_1(\tau) = E\left(p_{t+\tau} - y_t \,|\, e_{1t} = 1, e_{2t} = 0, \Delta p_{t-1} = 0, ..., x_{t-1} = 0, ...\right) \quad (25)$$

$$pe_2(\tau) = E\left(p_{t+\tau} - y_t \,|\, e_{1t} = 0, e_{2t} = 0, \Delta p_{t-1} = 0, ..., x_{t-1} = 0, ...\right) \quad (26)$$

Sims (1980) popularized the idea of calculating these price effects using the impulse-response functions of a VAR model, which can be calculated by inverting the VAR to the following vector moving average (VMA):

$$\begin{pmatrix} \Delta p_t \\ x_t \end{pmatrix} = \begin{pmatrix} \alpha(L) & \beta(L) \\ \gamma(L) & \delta(L) \end{pmatrix} \begin{pmatrix} e_{1t} \\ e_{2t} \end{pmatrix} \quad (27)$$

where $\alpha(L)$, $\beta(L)$, $\gamma(L)$ and $\delta(L)$ are the moving averages of the variables mentioned earlier. Lastly, specifying the VAR model using the microstructural approach yields the following system of equations:

$$\Delta p_t = \sum_{k=0}^{\infty} \alpha_k e_{1,t-k} + \sum_{k=0}^{\infty} \beta_k e_{2,t-k} \quad (28)$$

$$\Delta x_t = \sum_{k=0}^{\infty} \gamma_k e_{1,t-k} + \sum_{k=0}^{\infty} \delta_k e_{2,t-k} \quad (29)$$

It can be noted, for example, that the price differences in (28) are infinite sums of shocks in future returns and in exogenous variables. In that equation, too, the effect of the price and innovations in the trading variables (Q_t and Z_t) on the price is measured by the impulse responses α_k and β_k, respectively. Consequently, the effects of a shock on the price level (τ periods ahead) are measured by the partial sums of the impulse responses:

$$pe_1(\tau) = \sum_{k=0}^{\tau} \alpha_k \quad \text{y} \quad pe_2(\tau) = \sum_{k=0}^{\tau} \beta_k \quad (30)$$

The long-run effects of shocks would be the limits of the partial sums of $\tau \to \infty$:

$$pe_1(\infty) = \sum_{k=0}^{\infty} \alpha_k = \alpha(1) \quad \text{and} \quad pe_2(\infty) = \sum_{k=0}^{\infty} \beta_k = \beta(1) \quad (31)$$

Given this, if the impulse responses given by the shocks dissipate over time, it can be inferred that illiquidity shocks are merely temporary. Conversely, if they do not dissipate, the conclusion is that they are permanent and have an effect in the long run. Cochrane (1988) notes that this definition of the long-run effects of innovations is unique and independent of any particular decomposition of the price process into permanent and transitory parts.

Lastly, using sign for order direction in a simultaneous dynamic model creates some problems for the estimation and computation of dynamic effects. Because Q_t is a limited dependent variable that can only take the values -1 and +1, the first VAR equation cannot be a conditional expectation of Q_t for all values of $\Delta p_{t\text{-i}} \in$ IR unless the coefficients of $\Delta p_{t\text{-i}}$ are zero. For moderate values of $\Delta p_{t\text{-i}}$, however, the linear equation may be a good approximation to the true conditional expectation.[22] Consequently, the use of Q_t as an explanatory variable in the equation Δp_t does not cause problems, since the errors of the returns equation and the other equations of the VAR are not correlated.[23] It is proposed that five

[20] This assumption was made in Glosten and Harris (1988); Harris (1986); Hasbrouck (1988), and Stoll (1989).

[21] This equation is for the case where x_t and e_{2t} are scalar. In the case of a multidimensional trading vector, the impulse responses must be calculated from a VAR model with orthogonal innovations. In this study, that is obtained by adding the variable Q_t as an explanatory variable in the size equation Z_t to obtain the orthogonal errors.

[22] See Jong, Nijman and Röell (1996).

[23] See Heckman (1978).

lags[24] in the VAR are enough, given the general lack of residual serial correlation in the equations estimated and the fact that the standard errors are consistent estimates of heteroskedasticity.

3. Estimation results

The first equation estimated is (21), which represents the price dynamic and is presented again in this section to facilitate reading of the results.

$$\Delta p_t = c + R_0 \Delta Q_{t-1} + R_1 \Delta\left(q_{t-1} Q_{t-1}\right) + g_0 Q_t + g_1 q_t Q_t e_t \quad (32)$$

The hypothesis contrasted is that the price variation depends on order direction (Q_t) and volume traded (q_t). The results are presented in two tables: table 1 shows the results for the five most liquid shares in the IGBVL, table 2 for the five least liquid. Table 1 shows that the order direction coefficients R_0 and g_0 have positive and negative signs, respectively, for the five most liquid shares. However, R_1 and g_1 (due to RIO and CVERDEC1) do not meet the condition of always having a negative and positive sign, respectively. The regression for the Cerro Verde stock differs only in the sign of the R_1 parameter and that for the Rio Alto stock in the sign of the g_1 parameter. The five regressions in table 2 present coefficients with the same signs as are expressed in the table 1 results, with no exceptions.

Table 1 shows the coefficients estimated for the Jong, Nijman and Röell (1996) model via equation (21), the price variations being expressed in hundredths of a percentage point, and the quantities denominated in the pricing index (q_t_*index*). The securities chosen are the five most liquid shares in the IGBVL in 2012. Likewise, α is estimated from the median of the q_t_*index* distribution, divided by 2, and p is the first-order error autocorrelation coefficient. The p-values, corrected by the Newey-West methodology, are shown in square brackets.

Table 2 shows the coefficients estimated for the Jong, Nijman and Röell (1996) model via equation (21), measuring price variations in hundredths of a percentage point, and using the pricing index (q_t_*index*) as a proxy for the number of shares traded. The securities chosen are the five least liquid shares in the IGBVL in 2012, with α being estimated as the median of the q_t_*index* distribution divided by 2, and p being the first-order error autocorrelation coefficient. The p-values, corrected by the Newey-West methodology, are shown in square brackets.

The positive sign of R_0 means that the market enters consecutive orders of the same direction and this determines whether the variation is positive or negative; if the operation is initiated as a buy order, it will tend to "better" the price[25] (since there will begin to be more buy orders in the LOB and demand will increase); conversely, if it is initiated as a sell order, it will tend to reduce it (since there will begin to be more sell orders in the LOB and supply will increase). The negative sign of R_1 is interpreted as the counterparty position that closes the operation. Here, it should be recalled that the model is

[24] See Hasbrouck (1991b).

[25] What it means for a price to be "bettered" depends on who initiates the trade. If it is a buyer, the price is bettered if the variation is positive. If it is a seller, the price is bettered if the variation is negative. In both cases, the price is bettered because offer limits are forced up or down (depending on whether the trade is initiated as a buy or sell operation), narrowing the spread.

TABLE 1

Estimated price coefficients for the five most liquid shares in the IGBVL, 2012

Security	Stock symbol	R_0	R_1	g_0	g_1	α	ρ	C_0	C_1
Volcan "B"	VOLCABC1	2.074 [0.000]	-0.281 [0.000]	-5.434 [0.000]	0.666 [0.000]	0.732	-0.046	7.020	-0.614
Rio Alto Mining	RIO	1.597 [0.000]	-0.044 [0.757]	-7.400 [0.000]	-0.372 [0.019]	0.686	-0.172	9.252	0.142
Ferreycorp	FERREYC1	1.749 [0.000]	-0.108 [0.426]	-6.901 [0.000]	0.558 [0.001]	0.716	-0.051	8.250	-0.387
Cerro Verde	CVERDEC1	0.809 [0.113]	0.025 [0.928]	-5.792 [0.000]	0.524 [0.013]	0.973	-0.072	6.091	-0.238
ADR Buenaventura	BVN	1.246 [0.354]	-0.765 [0.096]	-15.832 [0.000]	3.408 [0.000]	0.868	-0.234	14.119	-2.469

Source: prepared by the authors.

TABLE 2

Estimated price coefficients for the five least liquid shares in the IGBVL, 2012

Security	Stock symbol	R_0	R_1	g_0	g_1	α	ρ	C_0	C_1
Austral Group	AUSTRAC1	27.760 [0.000]	-4.687 [0.000]	-48.051 [0.000]	8.887 [0.000]	0.474	-0.180	71.602	-9.131
El Brocal	BROCALC1	2.789 [0.017]	-0.357 [0.524]	-10.243 [0.000]	0.109 [0.900]	0.492	-0.060	12.978	-0.411
Empresa Agroindustrial Pomalca	POMALCC1	13.416 [0.000]	-0.930 [0.666]	-42.864 [0.000]	4.989 [0.054]	0.075	-0.235	55.905	-3.425
EDELNOR	EDELNOC1	1.257 [0.359]	-0.521 [0.490]	-7.083 [0.000]	0.960 [0.200]	0.810	-0.225	7.562	-1.001
Scotiabank	SCOTIAC1	6.836 [0.025]	-2.750 [0.010]	-16.164 [0.000]	4.613 [0.002]	0.546	-0.372	20.482	-5.056

Source: prepared by the authors.

formulated from the buyer's side; this being so, an order can only be executed if there is a counterparty operation, so that if an investor issues a buy order (positive sign), this must be set against a sell order (negative sign). The g_0 and g_1 coefficients are interpreted with the same logic as the "variations" coefficients, with the sole difference that the former capture the dynamic of past trades, while the levels coefficients reflect the cost of the current trade.

As regards the size of the coefficients estimated, it can be seen in both tables that the order direction coefficients (R_0 and g_0) are greater than the share volume coefficients (R_1 and g_1). However, it can also be seen that the most liquid shares (table 1), on average, have order direction and share volume coefficients that are larger in absolute terms than the coefficients for the least liquid shares (table 2). The natural interpretation of this difference is that variations in the prices of the least liquid shares are more sensitive to order direction and share volume.

Tables 3 and 4 give the composition of the cost to investors of executing an order, according to Glosten's (1994) model as extended by Jong, Nijman and Röell (1996). This cost comprises the adverse selection cost, calculated from equation (11), and processing costs, calculated from equation (12), with quantities being denominated relative to the pricing index (q_t_*index*). For example, in the case of the most liquid share in the IGBVL, VOLCABC1, the minimum share purchase required to generate positive returns would be 6,224 shares, and the operation would generate a total cost of 18,671 nuevos soles, this being the transaction amount, i.e., the share price multiplied by the number of shares traded. Of this cost, 57.76% would be the order processing cost (10,784 nuevos soles) and 42.24% the adverse selection cost (7,887 nuevos soles). When it comes to the least liquid share in the IGBVL, SCOTIAC1, the minimum purchase of shares in the firm required to generate positive returns would be 595. This purchase would generate a total cost of 22,905 nuevos soles, with 54.40% of this being the order processing cost (12,460 nuevos soles) and 45.60% the adverse selection cost (10,445 nuevos soles).

Both these costs are greater in absolute terms for the least liquid shares than for the most liquid ones, so that the optimum share trading volume required to obtain returns of zero is greater for the least liquid shares. As regards the proportion of each cost to the total cost, the processing cost portion is greater than the adverse selection cost portion for both the most liquid and the least liquid shares.

Table 3 shows the point at which returns become positive (zero and above) in market trading in 2012, depending on share type. The securities chosen are the five most liquid shares in the IGBVL in 2012. The median of the natural price logarithm is the reference value used to work out the number of shares traded from the transaction amount.

Table 4 shows the point at which returns become positive (zero and above) in market trading in 2012, depending on share type, with quantities being denominated relative to the pricing index (q_t_*index*). The securities chosen are the five least liquid shares in the IGBVL in 2012. The median of the natural price logarithm is the reference price used to work out the number of shares traded from the transaction amount.

Processing and adverse selection costs change depending on whether the share trading volume index value rises or falls. This exercise has been repeated for the other eight shares and can be found in annex A. The case of two shares, VOLCABC1 (figure 1) and POMALCC1 (figure 2), will now be shown, illustrating the differences in behaviour between a share from the most liquid group and one from the least liquid group. It

TABLE 3

Cost composition of order fulfilment for the five most liquid shares in the IGBVL, 2012

	VOLCABC1	RIO	FERREYC1	CVERDEC1	BVN
$\hat{q}_t$_index	1.6186	1.5290	1.5783	0.8290	0.7059
Transaction amount (nuevos soles)	18 671	17 070	17 933	8 476	7 495
Number of shares traded	6 224	3 924	7 599	215	192
Processing cost (normalized)	6.02	9.47	7.64	5.89	12.38
(in terms of q_t_index, and absolutely)	57.76%	54.39%	55.76%	53.78%	51.47%
Adverse selection cost	4.41	7.94	6.06	5.06	11.67
(in terms of q_t_index, and absolutely)	42.24%	45.61%	44.24%	46.22%	48.53%

Source: prepared by the authors.

TABLE 4

Cost composition of order fulfilment for the five least liquid shares in the IGBVL, 2012

	AUSTRAC1	BROCALC1	POMALCC1	EDELNOC1	SCOTIAC1
$\hat{q}_t$_index	4.8810	2.0560	6.9510	0.8266	1.8230
Transaction amount (nuevos soles)	487 539	28 916	3 863 510	8 457	2 905
Number of shares traded	1 875 151	629	7 289 639	2 135	595
Processing cost (normalized)	27.03	12.13	32.10	6.73	11.26
(in terms of q_t_index, and absolutely)	54.96%	54.63%	56.07%	53.27%	54.40%
Adverse selection cost	22.15	10.08	25.15	5.91	9.44
(in terms of q_t_index, and absolutely)	45.04%	45.37%	43.93%	46.73%	45.60%

Source: prepared by the authors.

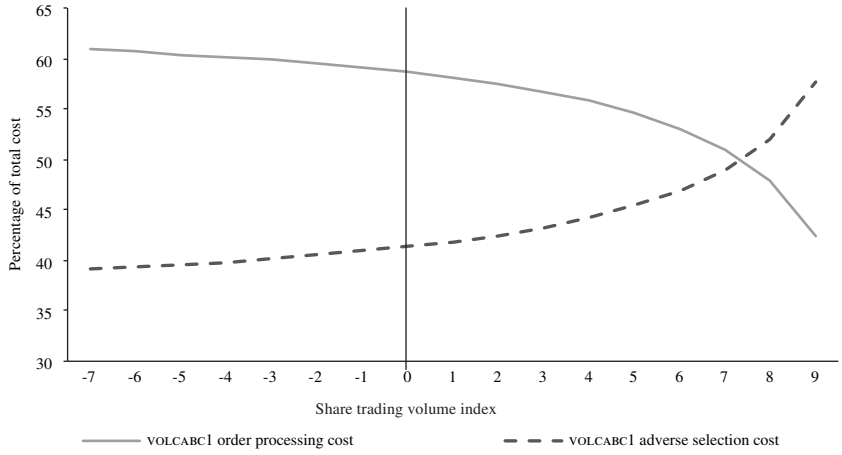
may be noted that in the case of VOLCABC1, processing costs fall in relative terms and adverse selection costs rise, a very different outcome from that seen with POMALCC1, where the proportion of each cost remains practically unchanged.

Figure 1 shows the behaviour of the cost components for VOLCABC1, which belongs to the group of the most liquid shares in the IGBVL. It can be seen that as the share trading volume index value rises, the processing cost falls and the adverse selection cost consequently increases.

Figure 2 shows the behaviour of the cost components for POMALCC1, which belongs to the group of the least liquid shares in the IGBVL. It can be seen that as the share trading volume index value rises, the processing cost falls very slightly, so that the adverse selection cost increases slowly.

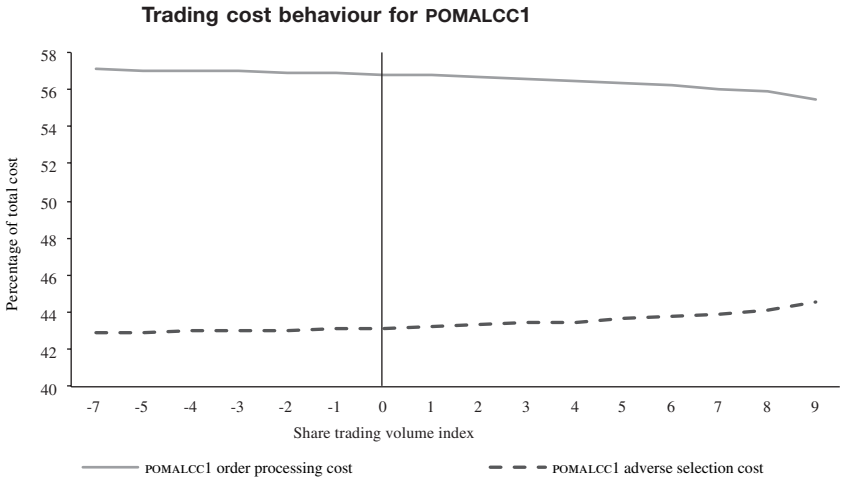
FIGURE 1

Trading cost behaviour for VOLCABC1



Source: prepared by the authors.

FIGURE 2



Source: prepared by the authors.

With regard to the spread components, the theoretical model predicts that when transaction amounts rise, the order processing cost will fall and the adverse selection cost increase. This behaviour is expected because when transactions involve sums which are too small to make a price and which in terms of the q_t_*index* are]–∞,0[, they do not affect the market or future positions in market expectations, so that the most substantial cost is the intrinsic cost of trading (the processing cost). When larger sums are transacted, conversely, the information becomes relevant and transaction amounts are indicators that provide information about positions in the asset. In this situation, investors will wish to take a position or set a price, since significant positions within a portfolio create a high level of portfolio exposure to changes in the prices concerned.

The effect of order direction and volume on price variation can be assessed in the periods following the effect at time *t*, with a view to analysing its continuing influence on trades thereafter. The results show that the residual price effect is less for the most liquid shares group than for the least liquid shares group. This analysis can be found in annex B. Figure 3 below presents the analysis for VOLCABC1 and figure 4 that for POMALCC1, illustrating the finding set out above.

Figures 3 and 4 shows the results of the VAR model in respect of the price dynamic ($\Delta p_t = D_{PTSHARE}$, where SHARE takes the name of the share concerned), order direction (Q_t = SIGN) and the size of the order flow for clearing (q_t Q_t = SIGN_QT_INDEX). It will be seen that shocks in the variables are corrected for all the shares analysed. Although the shares all evince different impulse magnitudes, it will be seen that the more liquid a share is, the faster the market correction.

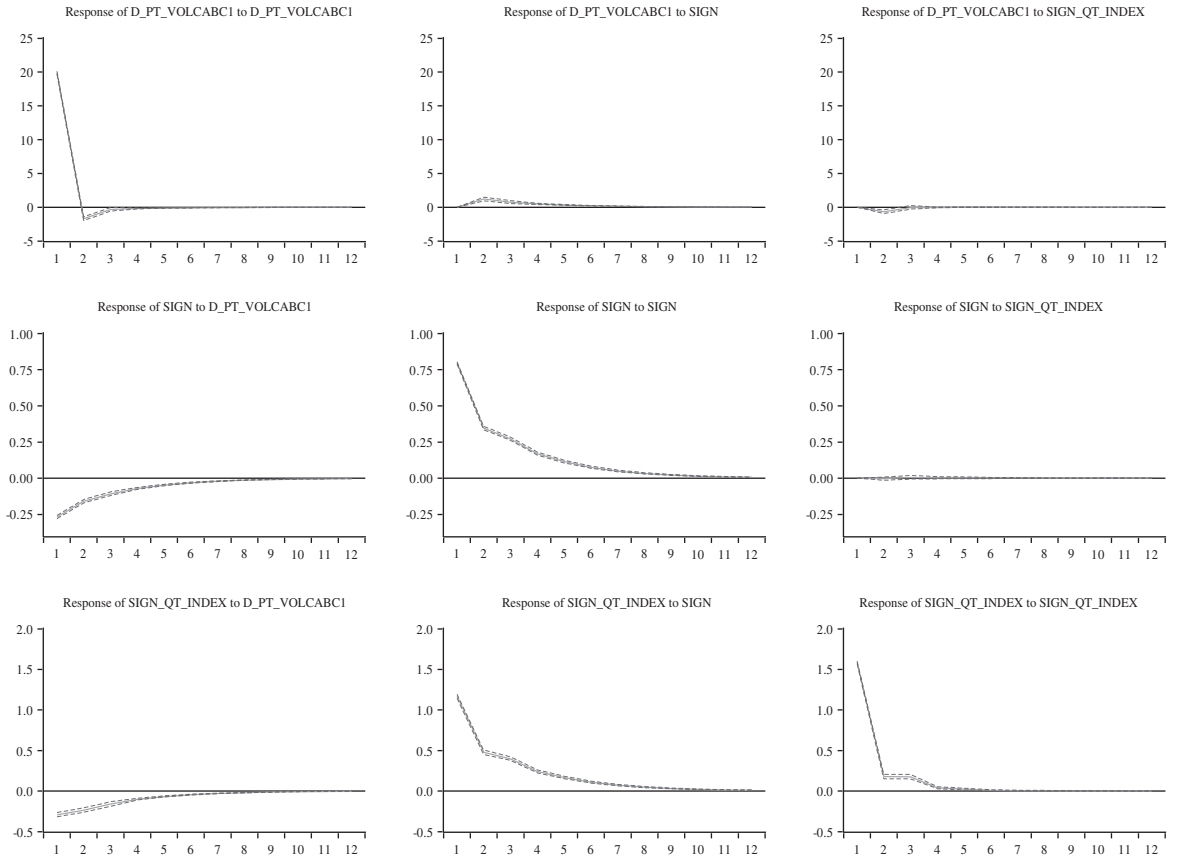
Regarding the analysis of the dynamic of order direction and transaction amount before a shock, on average the market enters orders with the same direction and then corrects. Where the variation is positive (negative), impatient agents enter buy (sell) orders in the expectation that the security will carry on rising (falling). The market will settle, i.e., the shock will be diluted, when sellers (buyers) take advantage of this rush (drop) to run down (build up) their positions, probably in order to take profits on day-trading operations.[26] This is why, depending on the state of liquidity of an asset, an indicator of whether the market is drying up[27] or not, the counterparty will "close" or trade on the best bid or ask, the level of the spread and the depth of the LOB being critical here.

[26] Day-trading means buying cheaply at the start of trading and selling the same shares at a higher price at the close for a profit.

[27] For the market to "dry up" means that the demand for or supply of an asset begins to decline, so that traders are unable to find matching orders on which to complete the operation.

FIGURE 3

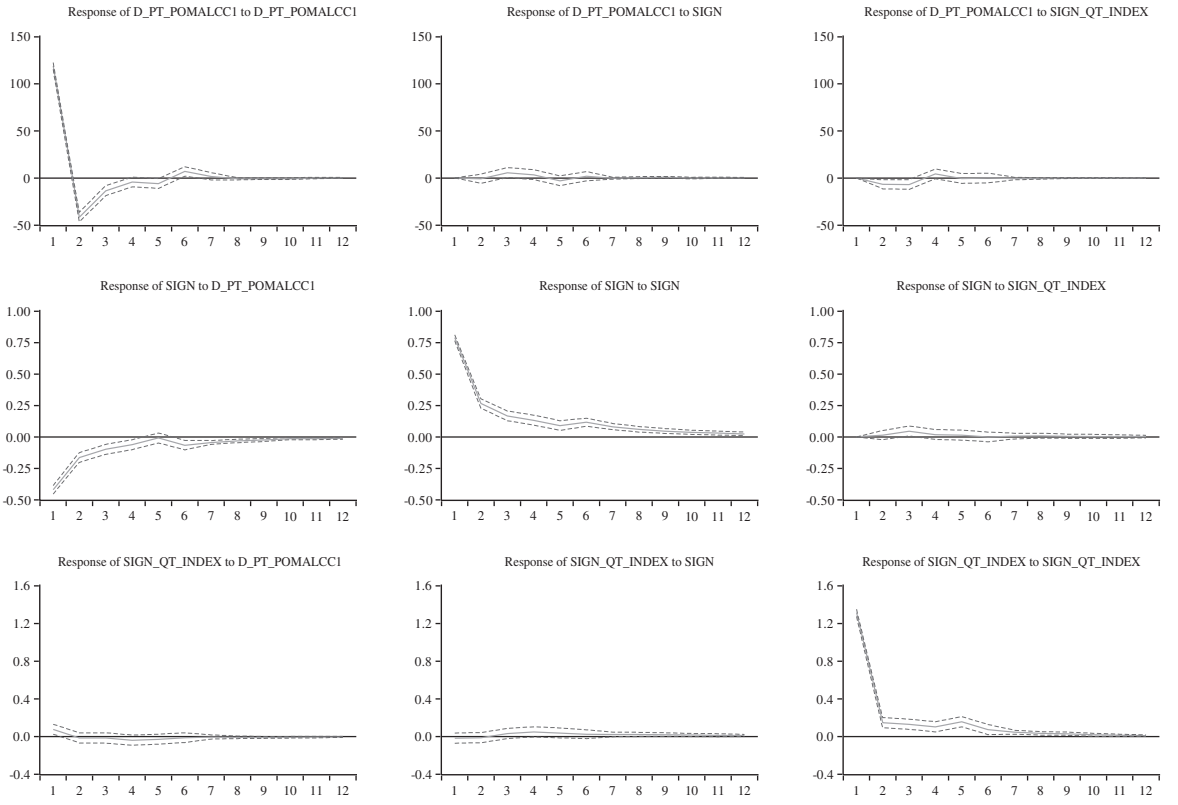
Impulse-response functions of the VAR econometric model for VOLCABC1



Source: prepared by the authors.

FIGURE 4

Impulse-response functions of the VAR conometric model for POMALCC1



Source: prepared by the authors.

V
Conclusions

The empirical results obtained by applying the Newey and West (1987) methodology show that pricing on the Lima Stock Exchange depends on the direction and number or volume of shares traded. The most important effect on the price is order direction. The group of least liquid shares presents greater sensitivity to these exogenous variables than the most liquid group. Then, the results obtained with the VAR methodology in the analysis of the price effect in subsequent periods reveal that this effect is present in a greater number of periods for the least liquid shares, meaning that, in Black's (1971) terms, they are less resilient.

Regarding the costs of executing an operation (the costs incurred by an investor to operate on the Lima Stock Exchange), the findings from the parameters estimated using the Newey and West (1987) methodology are that these costs are highest when trades are executed with the least liquid shares. Again, adverse selection costs (resulting from information asymmetry on the Lima Stock Exchange) can be interpreted as a better use of the new information that reaches the market (Stoll, 2000) via specialized investors, who obtain returns at the expense of non-specialized investors, i.e., those who do not use the new information in a correct and timely fashion.

Processing costs dominate the composition of these costs with an approximate share of 55%, the difference (45%) being made up by adverse selection costs. This cost composition changes at higher share trading volumes. For the most liquid share on the Lima Stock Exchange, VOLCABC1, adverse selection costs begin to account for a greater proportion. The situation is very different in the case of POMALCC1, with the composition remaining unchanged. Annex A shows that, generally speaking, the results are very different for each share.

The consequence for share prices of these processing and adverse selection costs is that they alter price distribution functions, enlarging or reducing distribution tails. Higher costs result in functions with fatter tails, and consequently larger spreads. Thus, the least liquid shares present larger spreads than the most liquid shares.

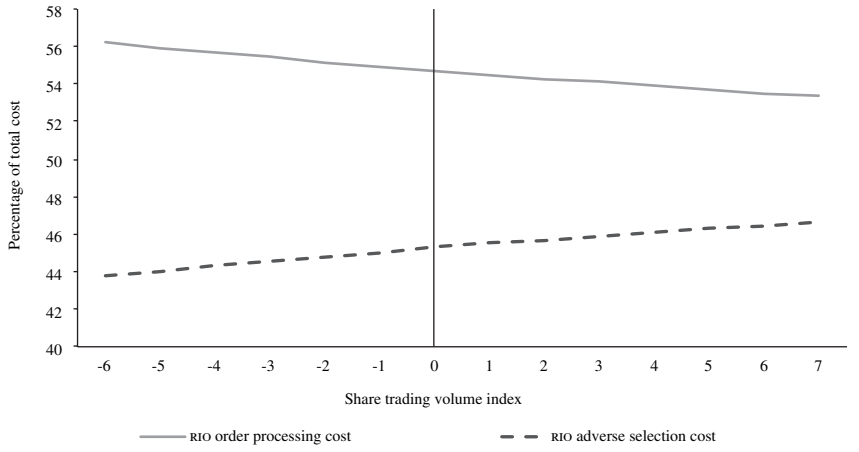
Lastly, parameters estimated by the Newey and West (1987) methodology were used to conduct an additional analysis for the calculation of the minimum number of shares needing to be traded to dilute processing and adverse selection costs. The least liquid shares have to be traded in larger numbers to dilute the costs defined in the theory presented here. It can be inferred from this finding that creating efficient portfolios with less liquid shares calls for more liquidity (cash), since a greater number of shares have to be traded for the equilibrium point to be reached. This situation could be contributing to the low liquidity presented by the share market of the Lima Stock Exchange.

ANNEX A

Figure A.1 shows the behaviour of the cost components for RIO shares. As the share trading volume index rises, the processing cost drops very slightly, so that the adverse selection cost increases slowly.

FIGURE A.1

Trading cost behaviour for RIO

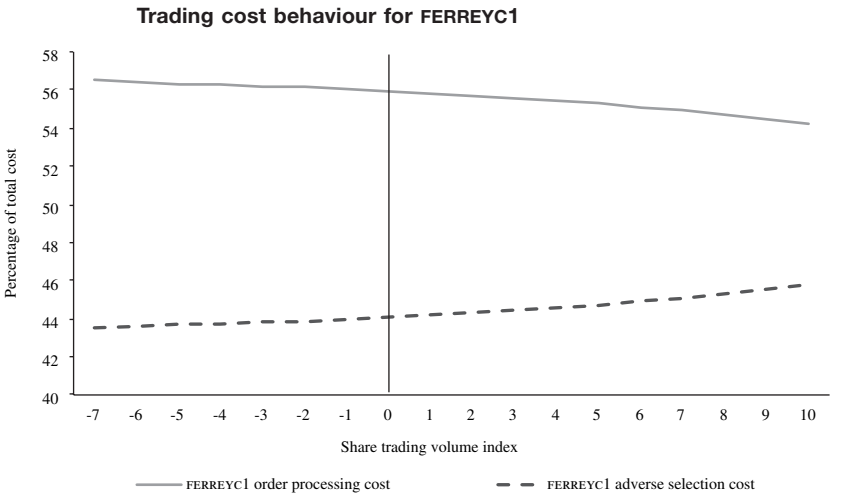


Source: prepared by the authors.

Figure A.2 shows the behaviour of the cost components for FERREYC1 shares. As the share trading volume index rises, the processing cost drops very slightly, so that the adverse selection cost increases slowly.

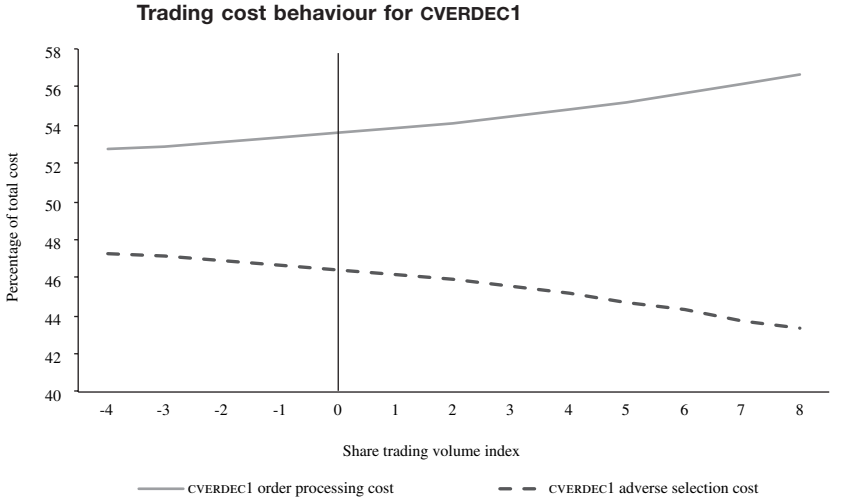
Figure A.3 shows the behaviour of the cost components for CVERDEC1 shares. As the share trading volume index rises, the processing cost increases very slightly, so that the adverse selection cost declines.

FIGURE A.2



Source: prepared by the authors.

FIGURE A.3

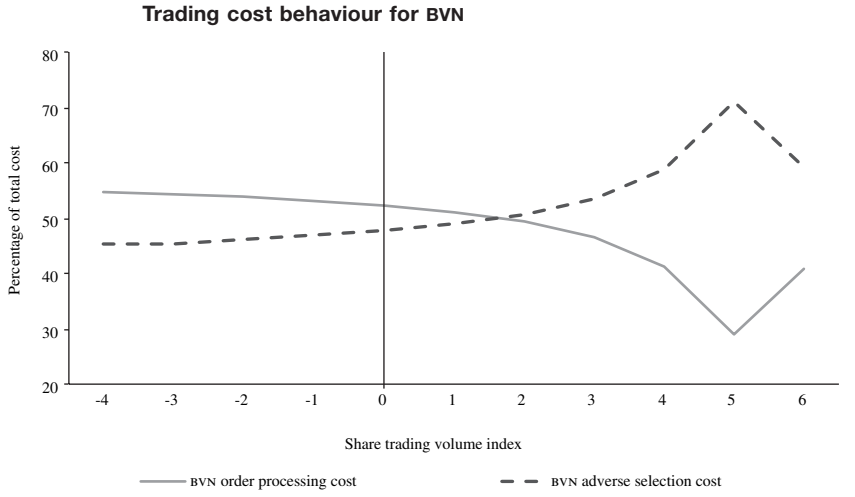


Source: prepared by the authors.

Figure A.4 shows the behaviour of the cost components for BVN shares. As the share trading volume index rises, the processing cost drops quickly, so that the adverse selection cost increases. An odd feature is that the trend is reversed once a certain level is reached, and it would be interesting to model these components using a non-linear methodology.

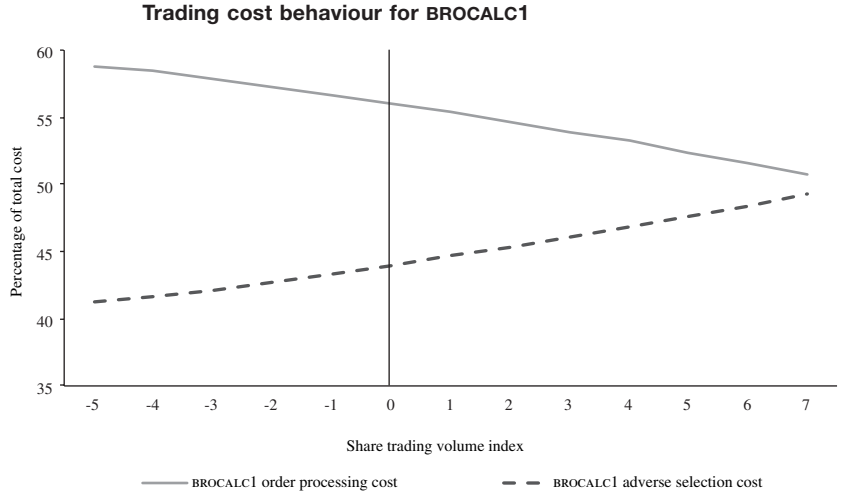
Figure A.5 shows the behaviour of the cost components for BROCALC1 shares. As the share trading volume index rises, the processing cost drops quickly, so that the adverse selection cost increases.

FIGURE A.4



Source: prepared by the authors.

FIGURE A.5

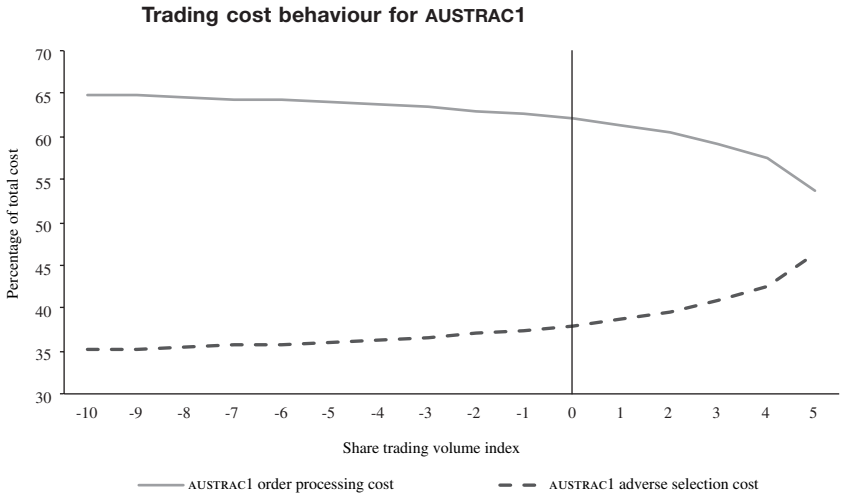


Source: prepared by the authors.

Figure A.6 shows the behaviour of the cost components for AUSTRAC1 shares. As the share trading volume index rises, the processing cost drops, so that the adverse selection cost increases slowly.

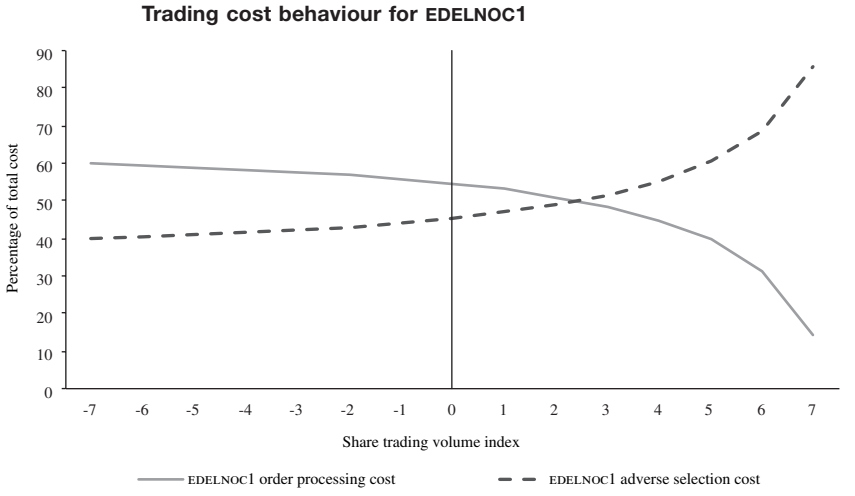
Figure A.7 shows the behaviour of the cost components for EDELNOC1 shares. As the share trading volume index rises, the processing cost drops quickly, so that the adverse selection cost increases.

FIGURE A.6



Source: prepared by the authors.

FIGURE A.7

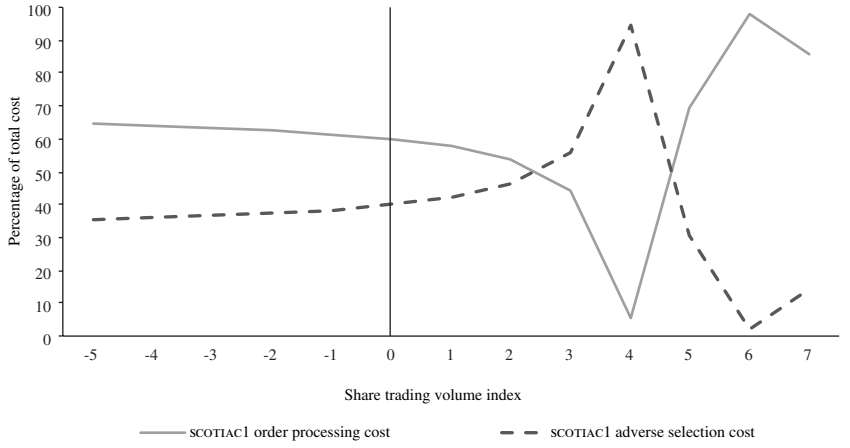


Source: prepared by the authors.

Figure A.8 shows the behaviour of the cost components for SCOTIAC1 shares. As the share trading volume index rises, the processing cost drops quickly, so that the adverse selection cost increases. An odd feature is that the trend is reversed once a certain level is reached, and it would be interesting to model these components using a non-linear methodology, as two possible turning points can be identified.

FIGURE A.8

Trading cost behaviour for SCOTIAC1

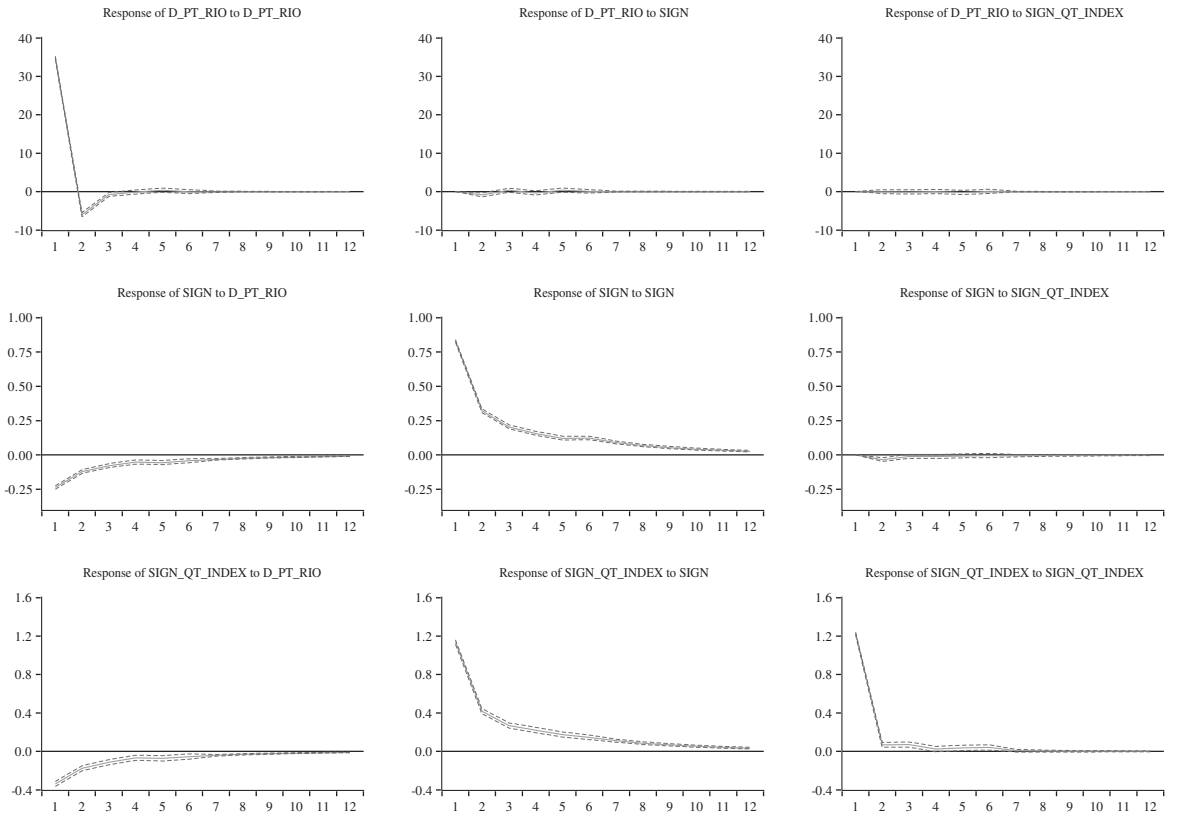


Source: prepared by the authors.

ANNEX B

FIGURE B.1

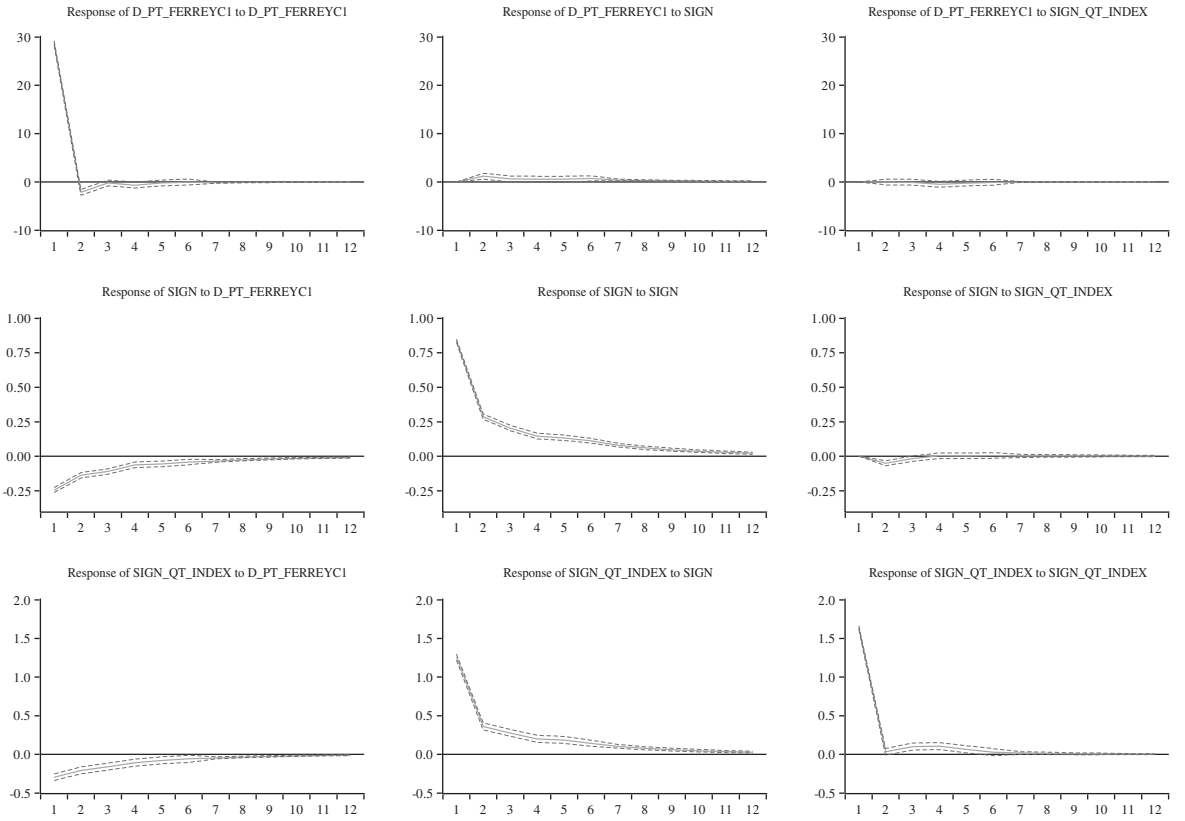
Impulse-response functions of the VAR econometric model for RIO



Source: prepared by the authors.

FIGURE B.2

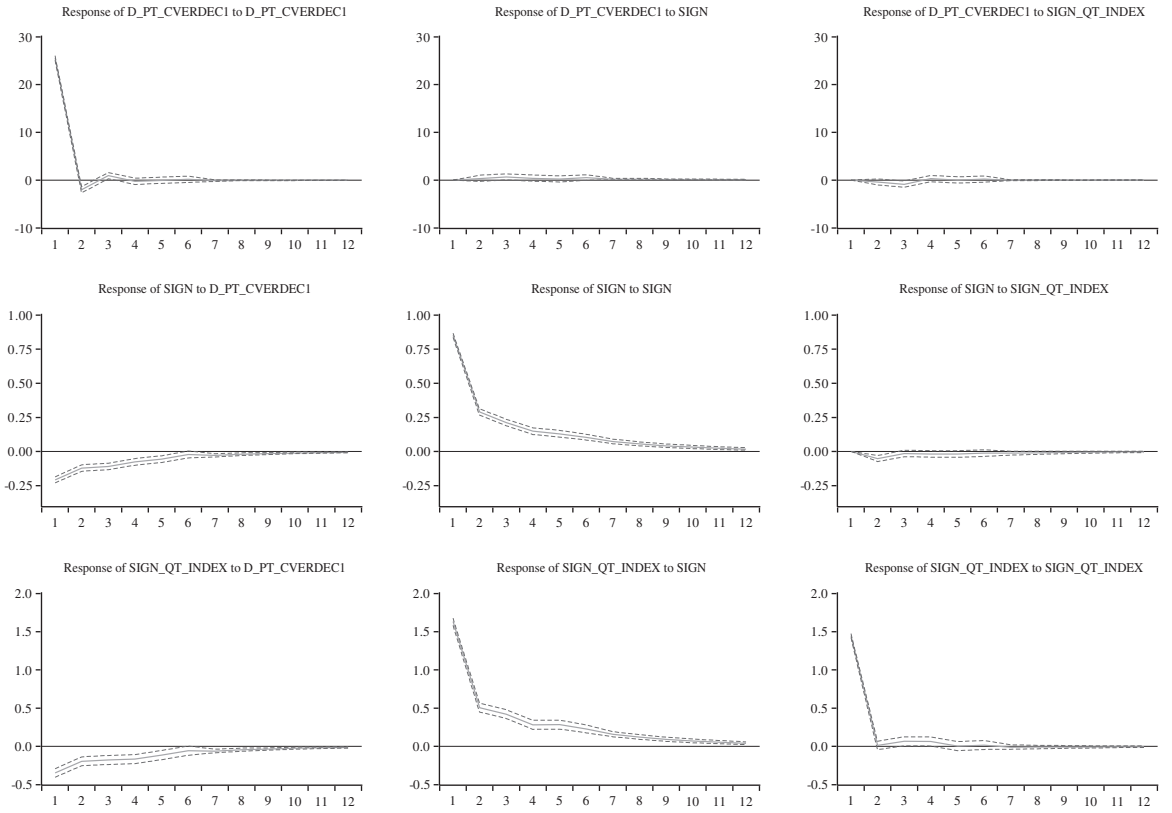
Impulse-response functions of the VAR econometric model for FERREYC1



Source: prepared by the authors.

FIGURE B.3

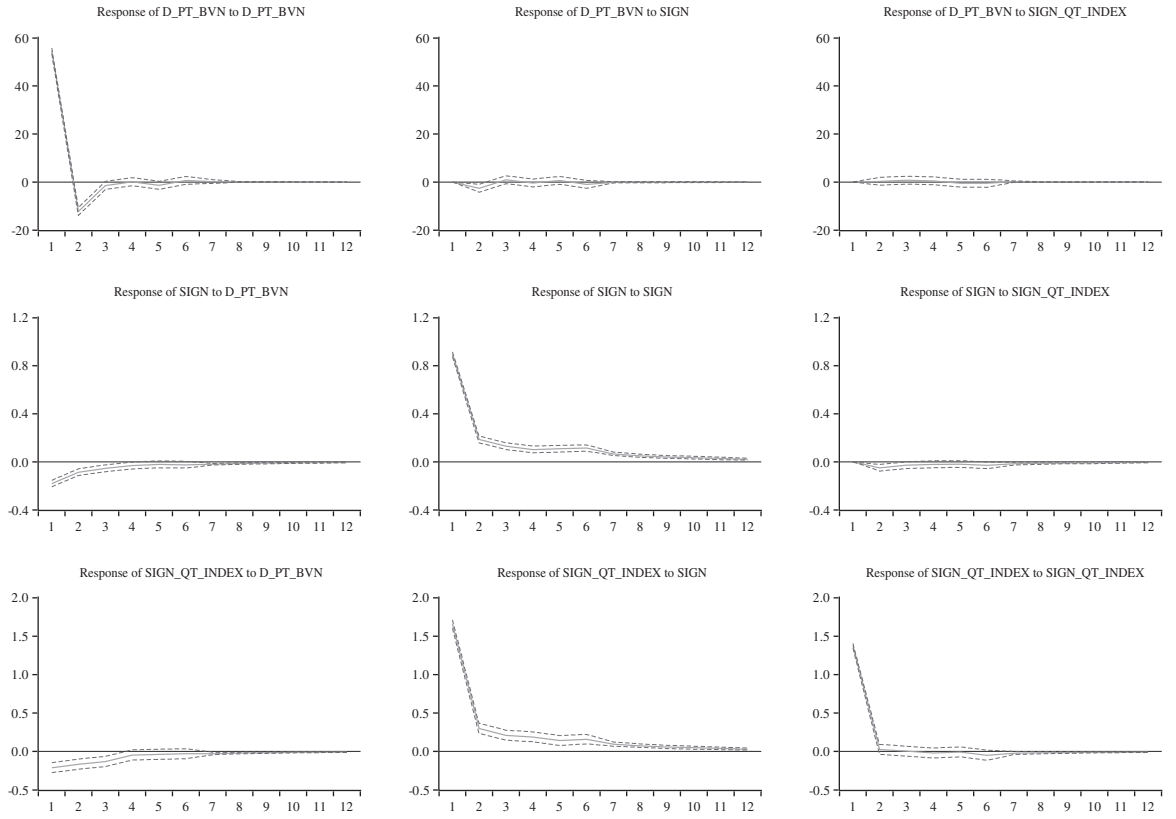
Impulse-response functions of the VAR econometric model for CVERDEC1



Source: prepared by the authors.

FIGURE B.4

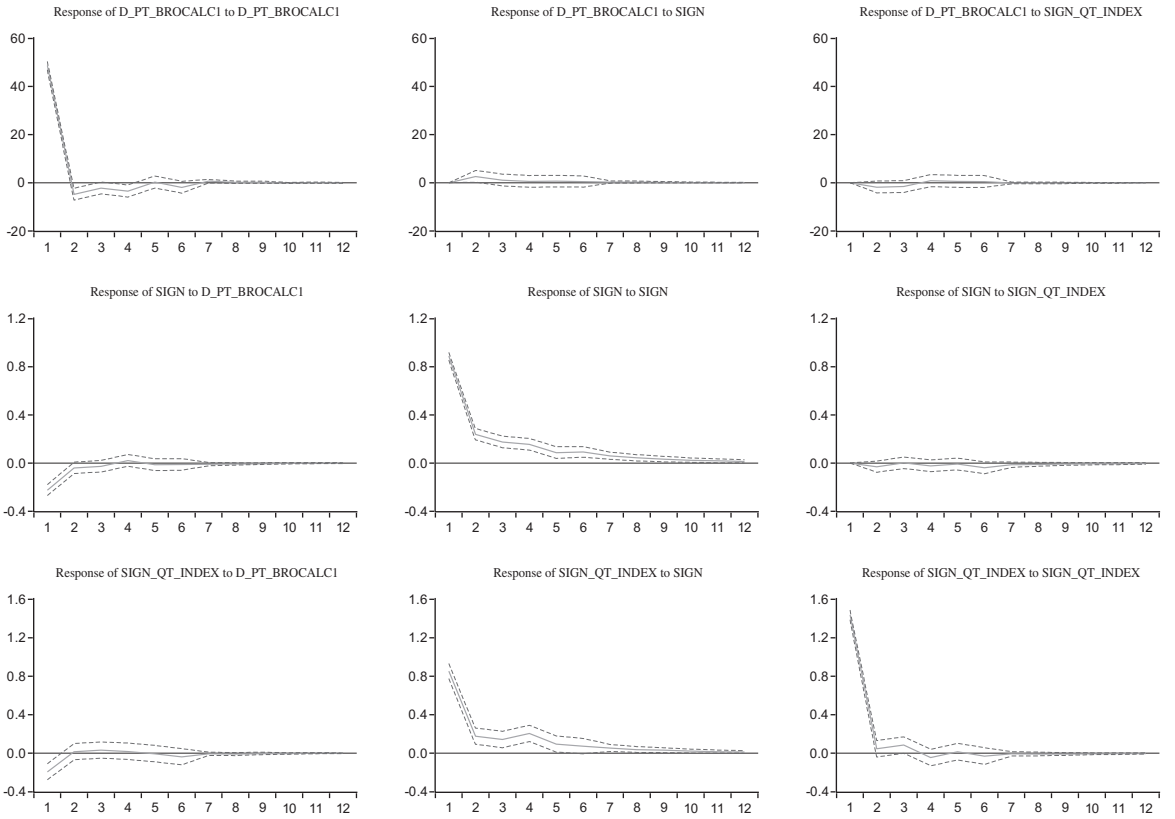
Impulse-response functions of the VAR econometric model for BVN



Source: prepared by the authors.

FIGURE B.5

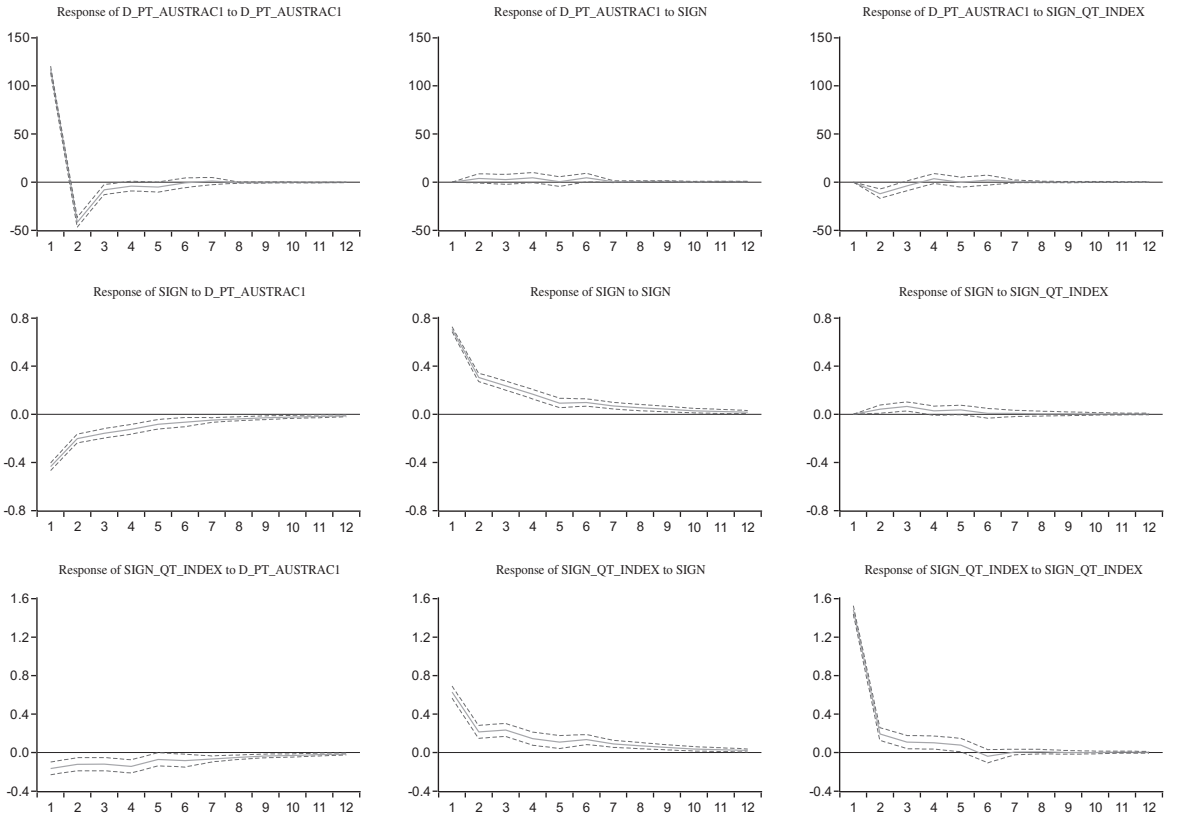
Impulse-response functions of the VAR econometric model for BROCALC1



Source: prepared by the authors.

FIGURE B.6

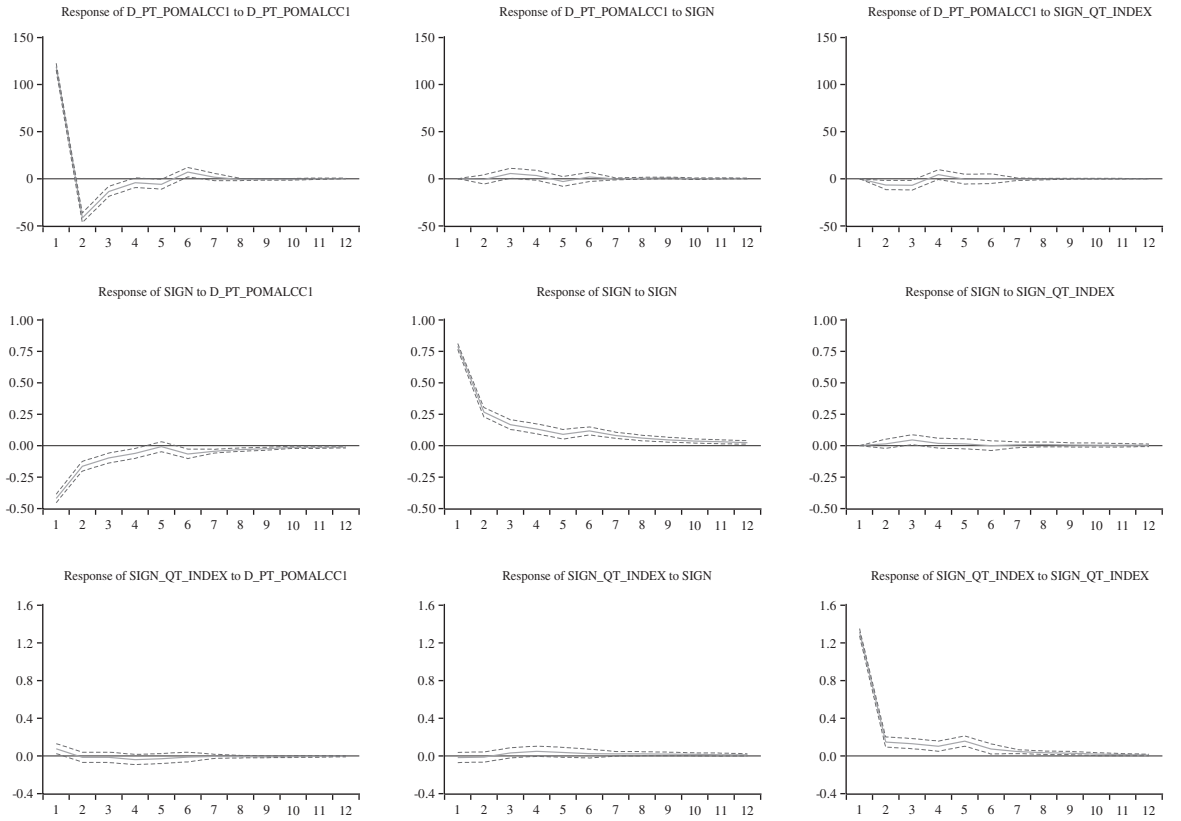
Impulse-response functions of the VAR econometric model for AUSTRAC1



Source: prepared by the authors.

FIGURE B.7

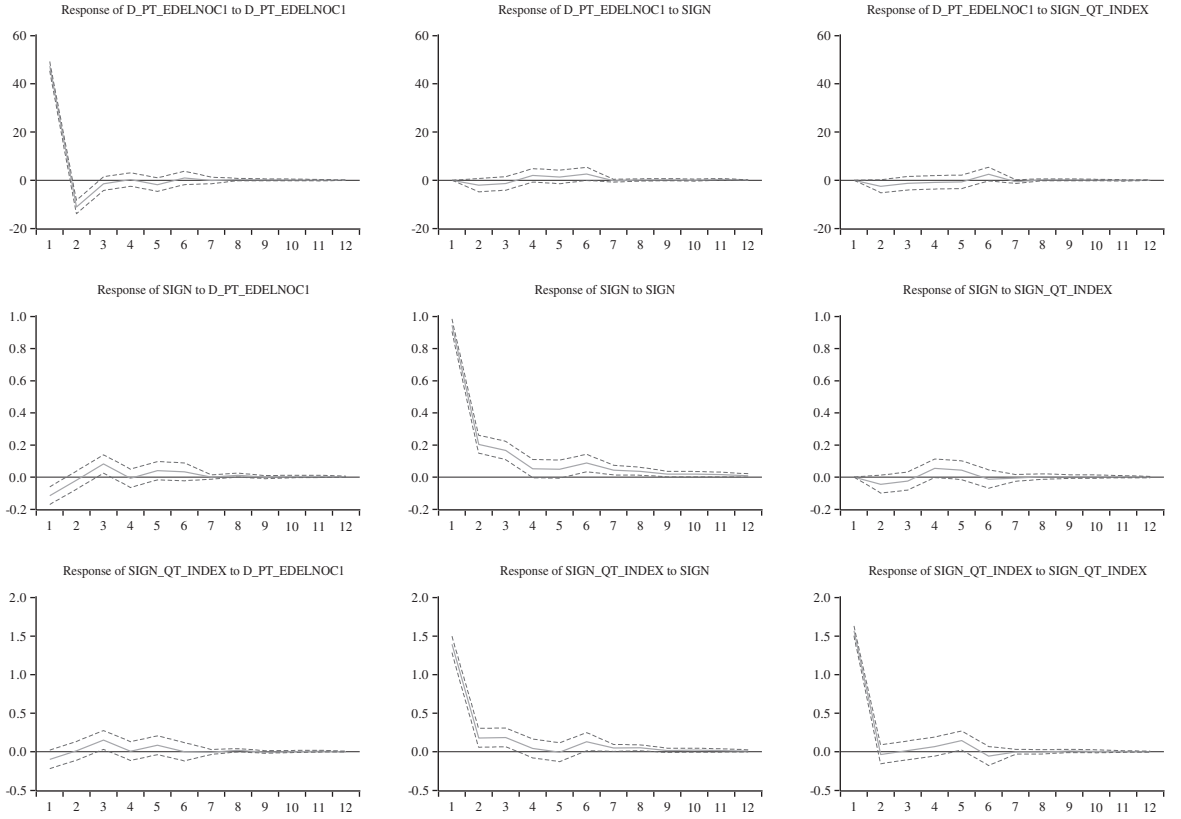
Impulse-response functions of the VAR econometric model for POMALCC1



Source: prepared by the authors.

FIGURE B.8

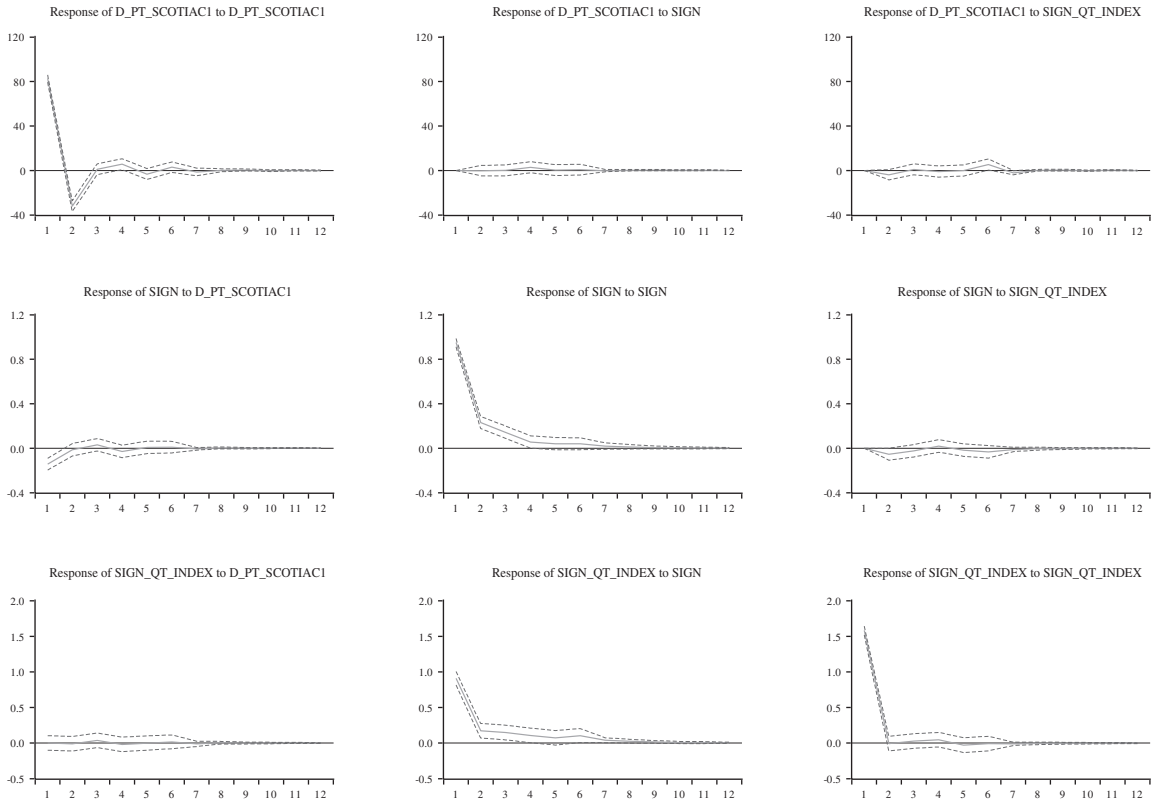
Impulse-response functions of the VAR econometric model for EDELNOC1



Source: prepared by the authors.

FIGURE B.9

Impulse-response functions of the VAR econometric model for SCOTIAC1



Source: prepared by the authors.

Bibliography

Black, F. (1971), "Toward a fully automated exchange, Part 1", *Financial Analysts Journal*, vol. 27, No. 4, CFA Institute.

Bolsa de Valores de Lima (2012), "Cartera del Índice General BVL" [online] http://www.bvl.com.pe/estadist/IndGral.htm.

Cochrane, J. (1988), "How big is the random walk in GNP?", *Journal of Political Economy*, vol. 96, No. 5, Chicago, University of Chicago Press.

Demsetz, H. (1968), "The cost of transacting", *Quarterly Journal of Economics*, vol. 82, No. 1, Oxford, Oxford University Press.

Easley, D. and others (2008), "Time-varying arrival rates of informed and uninformed trades", *Journal of Financial Econometrics*, vol. 6, No. 2, Oxford, Oxford University Press.

Foucault, T., O. Kadan and E. Kandel (2001), "Limit order book as a market for liquidity", *The Review of Financial Studies*, vol. 18, No. 4, Oxford, Oxford University Press.

Garman, M. (1976), "Market microstructure", *Journal of Financial Economics*, vol. 3, No. 3, Amsterdam, Elsevier.

Glosten, L. (1994), "Is the electronic open limit order book inevitable?", *Journal of Finance*, vol. 49, No. 4, Wiley.

Glosten, L. and L. Harris (1988), "Estimating the components of the bid/ask spread", *Journal of Financial Economics*, vol. 21, No. 2, Amsterdam, Elsevier.

Glosten, L. and P. Milgrom (1985), "Bid, ask and transaction prices in a specialist market with heterogeneously informed traders", *Journal of Financial Economics*, vol. 14, No. 1, Amsterdam, Elsevier.

Harris, L. (1986), "A transaction data study of weekly and intradaily patterns in stock returns", *Journal of Financial Economics*, vol. 16, No. 1, Amsterdam, Elsevier.

Hasbrouck, J. (1993), "Assessing the quality of a security market: a new approach to transaction cost measurement", *Review of Financial Studies*, vol. 6, No. 1, Oxford, Oxford University Press.

_____ (1991a), "Measuring the information content of stock trades", *Journal of Finance*, vol. 46, No. 1, Wiley.

_____ (1991b), "The summary informativeness of stock trades: an econometric analysis", *Review of Financial Studies*, vol. 4, No. 3, Oxford, Oxford University Press.

_____ (1988), "Trades, quotes, inventories and information", *Journal of Financial Economics*, vol. 22, No. 2, Amsterdam, Elsevier.

Heckman, J. (1978), "Dummy endogenous variables in a simultaneous equation system", *Econometrica*, vol. 46, No. 4, Econometric Society.

Jong, F., T. Nijman and A. Röell (1996), "Price effects of trading and components of the bid-ask spread on the Paris Bourse", *Journal of Empirical Finance*, vol. 3, No. 2, Amsterdam, Elsevier.

Kyle, A.S. (1985), "Continuous auctions and insider trading", *Econometrica*, vol. 53, No. 6, The Econometric Society.

Loaiza, C. (2013), "Relación entre liquidez y la microestructura del mercado de renta variable al contado, en la Bolsa de Valores de Lima", thesis [online] http://tesis.pucp.edu.pe/repositorio/handle/123456789/6.

Madhavan, A., M. Richardson and M. Roomans (1994), "Why do security prices change? A transaction level analysis of NYSE stocks", *The Review of Financial Studies*, vol. 10, No. 4, Oxford, Oxford University Press.

Markowitz, H. (1952), "Portfolio selection", *Journal of Finance*, vol. 7, No. 1, Wiley.

Newey, W. and L. West (1987), "A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix", *Econometrica*, vol. 55, No. 3, Econometric Society.

O'Hara, M. (1995), *Market Microstructure Theory*, Cambridge, Massachusetts, Blackwell Business.

Rosu, I. (2009), "A dynamic model of the limit order book", *Review of Financial Studies*, vol. 22, No. 11, Oxford, Oxford University Press.

Sharpe, W. (1964), "Capital asset prices: a theory of market equilibrium under conditions of risk", *Journal of Finance*, vol. 19, No. 3, Wiley.

Sims, C. (1980), "Macroeconomics and reality", *Econometrica*, vol. 48, No. 1, Econometric Society.

Stoll, H.R. (2000), "Friction", *Journal of Finance*, vol. 55, No. 4, Wiley.

_____ (1989), "Inferring the components of the bid-ask spread: theory and empirical tests", *Journal of Finance*, vol. 44, No. 1, Wiley.

_____ (1978), "The supply of dealer services in securities markets", *Journal of Finance*, vol. 33, No. 4, Wiley.

Exports from the Brazilian automotive sector to the Southern Common Market: Trade diversion or cost reduction?

André Filipe Zago de Azevedo and Angélica Massuquetti

ABSTRACT

The automotive sector is one of the sectors in which trade between MERCOSUR countries has grown most strongly. This article examines the possibility that trade diversion occurred in that sector during the period 1991-2010, assuming that product costs fell as a result of market expansion. The analysis is based on the concepts of "cost reduction" and "trade suppression" coined by Corden (1972), which capture the effects of economies of scale. Indices of regional orientation and revealed comparative advantages are used in combination to assess whether the trade bloc is evolving in line with comparative advantages. The results suggest efficiency gains for automotive-sector products, exports of which from Brazil to MERCOSUR grew more vigorously because the expanded and relatively protected market made it possible to exploit the economies of scale that are characteristic of the automotive industry.

KEYWORDS Automobiles, exports, Brazil, MERCOSUR, trade policy, intraregional trade, costs, trade statistics

JEL CLASSIFICATION F12, F13, F15

AUTHORS André Filipe Zago de Azevedo is a professor on the Postgraduate Programme in Economics at the University of Vale do Rio dos Sinos (UNISINOS), Brazil. aazevedo@unisinos.br

Angélica Massuquetti is a professor on the Postgraduate Programme in Economics at the University of Vale do Rio dos Sinos (UNISINOS), Brazil. angelicam@unisinos.br

I
Introduction

The Southern Common Market (MERCOSUR) was created with the aim of expanding the economic integration of its member countries, particularly by eliminating preferential trade barriers in intra-bloc trade. Through the Treaty of Asunción, signed by Argentina, Brazil, Paraguay and Uruguay on 26 March 1991, the four countries ratified their decision to expand the size of their domestic markets to enhance their integration into the increasingly regionalized international economic system. The automotive sector was one of the most important in the integration process: the flow of intra-bloc trade increased considerably, despite the absence of legal arrangements to ensure free trade between its member countries. In 1997, exports to MERCOSUR accounted for almost 50% of total exports from the Brazilian automotive sector.

From the outset of the integration process, a number of authors have claimed that the growth of trade in the automotive sector between the countries of the bloc would represent trade diversion (Yeats, 1997). As is well known, there is a propensity for economies of scale in the automotive sector (Senhoras, 2005; Casotti and Goldenstein, 2008) and the market expansion resulting from the formation of the trade bloc may have helped raise the competitiveness of production within the group of member countries. On that point, it is important to bear in mind other concepts used in the literature to review the effects of economic blocs in the presence of economies of scale, particularly the "cost reduction" and "trade suppression" effects proposed by Corden (1972).

The main objective of this article is to ascertain whether trade diversion occurred in the MERCOSUR automotive sector owing to the presence of economies of scale, and to propose an alternative analysis based on the concepts suggested by Corden (1972). For that purpose, the 76 six-digit products contained in Chapter 87 of the Harmonized System are analysed, to identify those for which trade flows were reoriented towards the interior of the trade bloc, and analyse the trend of their competitiveness in the period 1991-2010. The degree to which automotive-sector trade is redirected "intra-bloc" is evaluated through the regional orientation index (ROI), while competitiveness is measured according to the revealed comparative advantage (RCA) index. Thus, if the automotive-sector products that registered the greatest variation in trade towards the bloc become more competitive, this would imply a reduction in the costs of that sector's products, even when they are subject to a high level of protectionism compared to non- MERCOSUR countries.

The article contains six sections, including this introduction. Section II describes the main measures adopted by the bloc in relation to the automotive sector, both to regulate intra-zonal trade and to establish the level of protection with respect to imports from outside the zone. Section III discusses theoretical and empirical issues related to the effects of economic blocs in the presence of economies of scale; and section IV sets out the methodology used. Section V analyses the existence of cost reduction in MERCOSUR through the ROI and RCA indices; and section VI presents final thoughts.

II

MERCOSUR and the automotive regime legislation

The most notable product groups excluded from the MERCOSUR liberalization programme consist of the automotive sector and sugar.[1] In the initial phase of integration, trade in the automotive sector was regulated through Economic Complementation Agreement (ACE) No. 14, which aimed to establish the common market and promote economic complementation in industry to enhance the competitive capacity of the signatory countries. This agreement, which has been in force since 20 December 1990, was and remains one of the tools of dynamic equilibrium between Argentina and Brazil, and is subject to amendment through additional protocols. In 1994, Decision No. 29 defined three basic elements of the bloc's automotive regime, which were to be adopted in January 2000: (i) total liberalization of intra-zonal trade for automotive sector products; (ii) the common external tariff (CET), and (iii) the absence of domestic incentives that distort competitiveness in the region. The rules governing intra-zonal trade and with respect to imports from outside the bloc are two issues that warrant special attention.

Since its creation, commercial exchange between MERCOSUR members can be characterized as managed trade based on minimum regional contents, trade-balance requirements and conditional entry (IDB, 1996). The liberalization of automotive-sector trade between the MERCOSUR countries has been continually postponed owing to differences of opinion over the regime for this sector; and managed trade has been maintained in its place. In the early 2000s, the blocs Common Automotive Policy was inaugurated, establishing the regulation of intra-zonal trade through the exports deviation coefficient (flex), a mechanism that allows for a given imbalance between the exports of the sector. Between 1 August 2000 and 31 December 2005, trade in the sector's products was tariff free pursuant to the 30th Additional Protocol of ACE-14, which allowed for a maximum deviation of 3% of the volume of trade, which would be increased to 10% in 2003. Exports that exceeded the authorized limit would be taxed at 70% of the CET in the case of all types of vehicles and at 75% of the CET in the case of vehicle parts.[2]

Nonetheless, the rules were altered again in 2002 through the 31st Additional Protocol to ACE-14, which changed the limits on the volume of trade into dollar values. In 2002, for every dollar exported from Argentina to Brazil, the latter could export two dollars to Argentina without paying the tax quotas, thereby maintaining the quotas specified above in the event of exceeding the defined limit. Little by little, the flex would converge to 2.6 in 2005, and trade would finally be tariff-free in 2006. Nonetheless, the Argentine authorities insisted on maintaining the limits on free trade through the flex regime, until a more balanced pattern of bilateral trade with Brazil became feasible. Accordingly, in July 2006, the 35th Additional Protocol to ACE-14 was published, and took effect between July 2006 and June 2008, amending the annual coefficient of diversion to 1.95 without the payment of taxes. The penalty for exports exceeding the limit was maintained at 75% and 70% of the CET rate in the case of vehicle parts and automobiles, respectively (IDB, 2008).

Following intensive negotiations, in June 2008, the 38th additional protocol to ACE-14 was approved, setting the start of free intra-bloc trade for July 2013, despite pressure from the Brazilian authorities who wanted a shorter deadline.[3] The novelty was the establishment of an asymmetric flex: the limit for the trade deficit in the sector was set at 1.95 in the case of Argentina and

[1] The products of the automotive regime include automobiles, light commercial vehicles of up to 1.5 tonnes, buses and trucks, agricultural and highway machines machines, vehicle parts, chassis with engines, trailers, semi-trailers and parts for production and for the spare parts market. In the case of sugar, a transition period was stipulated of up to 1 January 2001, in which intra-bloc trade will be liberalized, accompanied by measures aimed at eliminating public policies that distort production and the exportation of this product in the bloc. Nonetheless, as of early 2014, trade were still subject to import tariffs.

[2] The agreement also set a minimum regional content of 60% (of parts and pieces) for the product to be exempt from tariffs in bilateral transactions.

[3] The ending of managed trade in the automotive sector in MERCOSUR should benefit the Brazilian automotive industry more, the production of which is much larger than that of Argentina. Whereas the Brazilian production trend is upwards between 1991 and 2006, attaining a level of roughly 3 million vehicles in 2006, automobile production in Argentina was much more volatile, attaining a level of around 500,000 vehicles in that year.

2.5 in the case of Brazil. Assuming that the agreement this time will be fulfilled, it will have taken 22 years, from 1991 to 2013, for the provisions of the Treaty of Asunción to be fulfilled.

Apart from the absence of free intra-bloc trade, the degree of protectionism in relation to imports from the automotive sector from other countries has always been high within MERCOSUR. Apart from a short period immediately after its formation, when the limit was 20%, the upper limit of the blocs CET for most products has corresponded to the maximum value allowed by the World Trade Organization (WTO). Thus, since the decade of 2000, the CET was set at 35% of vehicles generally, and at 14% for agricultural machinery and vehicle parts.

Kume and Piani (2005) confirmed the high level of protectionism practised in the bloc's automotive sector, by calculating the nominal and effective protection of the MERCOSUR CET in all sectors of activity in 2006 (see table 1). Products of the automotive sector (automobiles, trucks and buses) enjoyed the highest degree of protection, in both nominal and effective terms. These sectors nominal tariff was 34%, far higher than the average tariff of just 12.4%. Effective protection was even greater, at 124%, whereas the average for all sectors was just 17.2%. Apart from enjoying very high effective protection, the sector has state level tax and financial incentives and, in particular, a federal-level automotive regime.

TABLE 1

MERCOSUR: nominal and effective common external tariff (CET), by activity, 2006
(Percentages)

Code	Activity	Nominal common external tariff	Effective common external tariff
1	Agriculture	3.78	2.93
2	Mining	3.95	1.72
3	Oil and coal	0.00	-1.82
4	Mineral and metallic products	11.47	13.29
5	Iron and steel	7.98	12.55
6	Non ferrous metallurgy	9.78	10.28
7	Other metallurgical products	15.80	21.25
8	Machines and tractors	13.85	14.22
9	Electrical Appliances	15.99	19.99
10	Electronic equipment	13.10	12.86
11	Automobiles, trucks and buses	33.97	123.96
12	Other vehicles and parts	13.81	14.22
13	Wood and furniture	10.97	13.10
14	Cellulose, paper and printing	11.94	12.71
15	Rubber	12.84	14.70
16	Manufacture of chemicals	12.83	13.91
17	Oil refining	4.58	5.33
18	Miscellaneous chemical products	8.80	10.62
19	Pharmaceutical and perfume products	10.00	9.95
20	Plastics	16.54	20.59
21	Textiles	16.39	21.77
22	Garments	19.58	22.28
23	Leather and footwear	14.23	15.75
24	Coffee industry	11.33	11.73
25	Processing of plant products	12.09	22.17
26	Slaughtering of animals	9.76	9.81
27	Dairy industry	15.57	16.57
28	Sugar	16.00	16.90
29	Manufacture of vegetable oils	8.72	9.90
30	Beverages and other food products	15.69	23.64
31	Miscellaneous products	14.38	16.10
	Simple average	12.44	17.19
	Minimum	0.00	-1.82
	Maximum	33.70	123.96
	Standard deviation	5.92	20.74

Source: H. Kume and G. Piani, "MERCOSUL: o dilema entre união aduaneira e área de livre-comércio", *Brazilian Journal of Political Economy*, vol. 25, No. 4, São Paulo, 2005.

MERCOSUR: Southern Common Market.

III

Trade diversion or cost reduction: theory and measurement

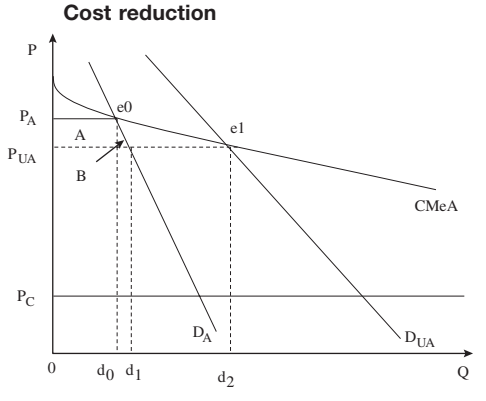
Studies on the effects of preferential trade liberalization agreements gained special importance in the 1990s, owing to the proliferation of this type of agreement worldwide. MERCOSUR was no exception, and several authors investigated the effects of the bloc on a series of variables using various methodologies (including Piani, 1998; Negri, 1999; Machado and Cavalcanti, 1999; Tigre and others, 1999; Sarti, 2001; Sica, 2005).

Even before the growth of disputes between MERCOSUR countries, Yeats (1997) compared the ROI and RCA indices in the period 1988-1994, and reached the conclusion that the structure of intra-bloc trade was distorted. The author found signs of trade diversion after the bloc had been formed, in the case of products displaying the fastest growth in the regional orientation of their trade, including those of the automotive sector; and he attributed this to the high tariffs imposed on imports from other countries, which would guarantee a protected market to MERCOSUR producers. This view coincides with the "this market is ours" syndrome proposed by Bhagwati (1993), which argues that the formation of a bloc in an environment in which producers play an important role in the determination of trade policies can lead to an increase in protectionism with respect to countries outside the bloc.

Nonetheless, the analysis performed by Viner (1950), based on the concepts of trade creation and trade diversion, is only applicable to sectors that have perfectly competitive market structures and no Economies of scale. Corden (1972) showed that, apart from the traditional effects described by Viner, the existence of economies of scale in sectors whose market structure involves imperfect competition would generate additional welfare effects. The first consists of "cost reduction" and happens when trade integration leads to an increase in the scale of production. Operating in an expanded market increases the firms' efficiency and lowers their average production costs, as shown in figure 1.

As can be seen, in the initial equilibrium situation (e_0), there is a precisely calibrated import duty ($t = P_A - P_C$) (in other words, a tariff that prevents imports), which diverts the consumption of a given product in country A towards point d_0, supplied by domestic production. With the formation of a customs union between country A and other countries that are less efficient in the production of that product, a common external tariff is established, also precisely calibrated, but below the tariff in force before the trade bloc was formed ($P_{UA} - P_C$). In the presence of economies of scale, the expansion of the market owing to the formation of a trade bloc leads to a reduction in the average cost of firms operating in country A, which enables it to lower the import tariff. This produces a new equilibrium (e_1), in which country A supplies the amount d_2 of the product to all countries of the bloc, and allocates the amount d_1 to domestic consumption. It should be noted that, although the foreign country C is more efficient than country A (P_C), in both situations the precisely calibrated import duty impedes imports. Nonetheless, the expansion of the market in the presence of economies of scale leads to an increase in economic efficiency, which makes it possible to lower the import tariff and the price charged to consumers in country A. The welfare gains are represented by areas A and B, which reflect the growth of consumer surplus caused by the drop in prices from P_A to P_{UA}. These aspects characterize the "cost reduction" situation proposed by Corden (1972).

FIGURE 1



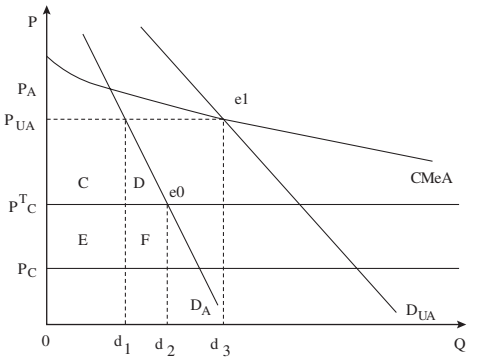
Source: W.M. Corden, "Economies of scale and customs union theory", *Journal of Political Economy,* vol. 80, No. 3, Chicago, University of Chicago Press, 1972; and A. Panagariya, "The regionalism debate: an overview", *World Economy,* vol. 22, No. 4, Wiley, 1999.

The second effect corresponds to "trade suppression", which occurs when the cost reduction arising from integration enables firms operating within the bloc to become more efficient, but not to the extent of supplanting their rivals outside the bloc. The latter happens only thanks to the protectionist measures that the bloc imposes on the more competitive imports from other countries. The new situation is shown in figure 2. In the initial equilibrium (e_0), the import tariff ($t = P_{TC} - P_C$) is lower than the precisely calibrated tariff, so country A can import d_2 from country C at price P_{TC}. In that setting, the good in question is not produced in country A and everything that is consumes is imported from country C, which is more efficient. Following the formation of a customs union, a new equilibrium (e_1) is produced: a precisely calibrated common external tariff is set ($P_{UA} - P_C$), at a level above the tariff in force before the formation of the bloc, which leads to an increase in the product's price. As a result of price P_{UA}, the country starts to produce d_1 for domestic consumption and to export d_1d_3. This generates losses owing to the suppression of trade caused by the displacement of an efficient external producer (country C) by a less efficient internal one (country A). In this case, there are welfare losses in terms of both consumer surplus (areas C and D) and government revenues (areas E and F).

The literature refers abundantly to the presence of economies of scale in the automotive sector, characterized by its organization in a global oligopoly, with high gains from economies of scale (Casotti and Goldenstein, 2008; Senhoras, 2005). The presence of economies of scale and agglomeration leads large firms to concentrate in specific geographic regions (Gabriel and others, 2011). The automotive sector is one of the few sectors that display those characteristics in MERCOSUR (Giordano and Santiso, 1999).

FIGURE 2

Trade suppression



Source: W.M. Corden, "Economies of scale and customs union theory", *Journal of Political Economy,* vol. 80, No. 3, Chicago, University of Chicago Press, 1972; and A. Panagariya, "The regionalism debate: an overview", *World Economy,* vol. 22, No. 4, Wiley, 1999.

One way to establish the presence of the two additional effects of economies of scale suggested by Corden (1972) consists of a joint review of the regional orientation index (ROI) and the revealed comparative advantage (RCA) index. A rise in both indices after the formation of the bloc, combined with an increase in the RCA index from a value below one to a value above one, would indicate a situation of "cost reduction". A rise in both indices, without the RCA index reaching the level of 1, would signal "trade suppression". In both cases, given the prerogative of the existence of economies of scale stemming from an increase in production, the value of exports needs to have increased throughout the period under analysis.

IV

Methodology

This article analyses the 76 six-digit-code products contained in Chapter 87 of the Harmonized System, to establish the existence of cost reduction or trade suppression in the MERCOSUR automotive sector in the period 1991-2010.[4] To that end, the indicators suggested by Yeats (1997) are used, but with an interpretation modified by the presence of economies of scale. The analysis of trade orientation uses the ROI, whereas competitiveness is analysed according to the RCA index. The most dynamic products exported by Brazil are identified on the basis of two criteria: (i) the largest absolute variation in the ROI throughout the period analysed, and (ii) a flow of exports to the bloc of at least US$ 50,000 at the start of

[4] The products in HS Chapter 87 are described in the annex.

the reference period.[5] Unlike the analysis by Yeats, this article examines the effects of the automotive sector on intra-bloc trade in the framework of a dynamic rather than a static environment, which allows for the influence of economies of scale. Data on Brazilian and world exports of automotive-sector products listed in Chapter 87 of the Harmonized Commodity Description and Coding System (HS) at the six-digit code level, are obtained from the Brazilian Trade and Investment Promotion Agency (Apex-Brasil).

The ROI is a ratio between two proportions, obtained by dividing the share of a given product in a country's total exports to the trade bloc, by that product's share in the total amount exported outside the bloc. The index takes values from zero to infinity, where a value of 1 indicates an equal tendency to export the product in question to countries inside and outside the bloc, whereas rising values and values above one observed through time indicate a propensity to export more to countries inside the bloc. The ROI is defined as follows:

$$\text{ROI} = (Xrj / Xtr) / (Xoj / Xto)$$

where:
Xrj = value of Brazilian automobile exports within MERCOSUR;
Xtr = value of Brazilian exports within MERCOSUR;
Xoj = value of Brazilian automobile exports outside MERCOSUR;
Xto = value of Brazilian exports outside MERCOSUR.

The RCA index, originally proposed by Balassa (1965), is based on the principle of comparative advantages. It aims to identify the products that a given country "a" produces more competitively than the rest of the world, based on past trade flows of a given product "i" with respect to the total exports of country "a" —in other words, the percentage of product "i" in the country "a" export basket, compared to the total worldwide exports of product "i" in relation to total global exports—. If the RCA index is above 1, the country has a revealed comparative advantage in exports of the product in question, whereas if it is below 1, the country displays a revealed comparative disadvantage. A rising index indicates an increase in the competitiveness of the product in country "a" through time. The index is obtained from the following equation:

$$\text{RCA } j = (Xij / Xi) / (Xwj / Xw)$$

where:
Xij = value of Brazilian automobile exports;
Xi = value of Brazilian exports;
Xwj = value of global automobile exports;
Xw = value of global exports.

Using the two indices together makes it possible to judge whether the trade bloc evolves according to the comparative advantages of its members after its formation. If the products that are most dynamic in intra-bloc trade (measured through the ROI) are competitive, the bloc would specialize in products in which it is competitive internationally. Nonetheless, if the products that display the fastest growth in ROI are not competitive, the bloc could be diverting trade, probably based on a high protection structure with respect to the rest of the world. When examining sectors characterized by the presence of economies of scale, however, it is necessary also to analyse the trend of the RCA index through time, because market expansion stemming from the creation of a trade bloc could have a positive effect on the production scale of those sectors, thereby increasing their efficiency.[6]

[5] The minimum level was set to prevent the results being biased towards products with a low share in the export basket at the start of the period under analysis.

[6] According to Yeats (1997), the RCA index has a number of defects. When it is applied to agricultural products, the result of the index could be distorted because it is a sector that is highly influenced by governments, either through export incentives and subsidies or through high tariff and nontariff barriers. In addition, this index does not capture the influence of cyclical factors that could affect the level of exports of the countries at certain times, so sometimes it may be overestimated or underestimated.

V
Results and analysis

This section evaluates the orientation and competitiveness of exports from the Brazilian automotive sector to MERCOSUR between 1991 and 2010. Figure 3 reveals the presence of three distinct phases.[7] The first, from 1991 to 1998, is marked by a vigorous increase in Brazilian exports to the bloc, which attained a 49% share of the total in 1997. In the second phase, from 1999 to 2008, was a sharp fall in trade flows, explained by the macroeconomic instability prevailing in the bloc's leading trading partners (Brazilian exchange rate and devaluation and Argentine crisis), which would have a significant effect on the sector. By the end of the period, in 2002, the sector's share in exports to the bloc had dwindled to just 8%. In the last phase, spanning 2003 to 2010, the growth of Brazilian exports to MERCOSUR revived to attain a 56.2% share, the largest throughout the period analysed.

The methodology described in the foregoing section was used firstly to review the performance of exports to MERCOSUR from the Brazilian automotive sector in the period 1991-2010. Table 2 lists the 24 products in this sector with six-digit HS codes that display the greatest reorientation of trade towards the bloc according to the ROI and RCA indices.[8] Comparing these two indicators makes it possible to determine whether the products that showed the greatest reorientation of intra-bloc trade were also competitive.[9] It should be noted that even at the start of the formation of MERCOSUR, in 1991, the average ROI of those products was above 1. In other words, Brazilian exports were already biased towards the bloc, and this bias increased thereafter, rising from 2.8 to 11.9 between 1991 and 2010.

Most of the products reporting the greatest variation in the ROI (8) were competitive both in 1991 and in 2010. In the latter year, over half of the products (13) displayed an RCA index above 1 and accounted for 78%

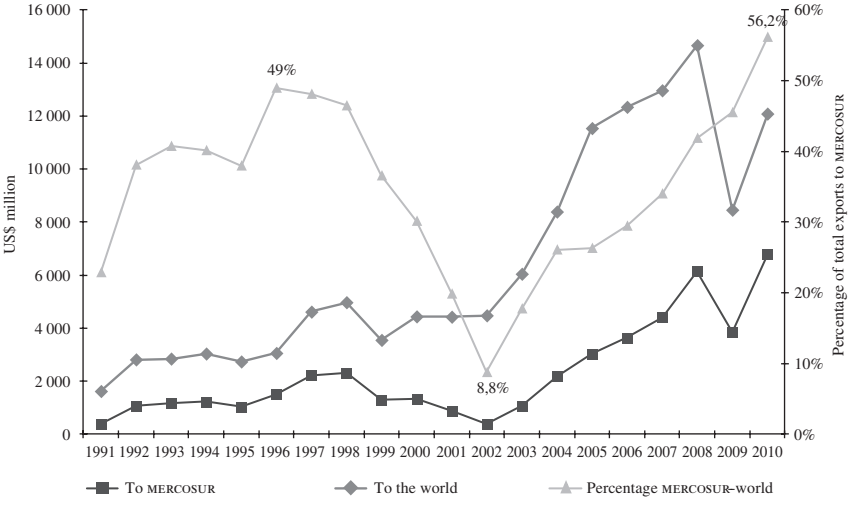
[7] The article only analyses Brazilian exports to the bloc, because these represent the sector's largest bilateral trade flow.

[8] It should be noted that, between 1991 and 2010, 39 of the 76 products of chapter posted an increase in the ROI. Nonetheless, just 24 of them also achieve the minimum level of US$ 50,000 set for Brazilian exports to MERCOSUR in 1991.

[9] Ten of these products belong to the "Vehicle parts and accessories" heading (HS Code 8708) and four belong to "Automobiles for the transport of goods" (HS Code 8704).

FIGURE 3

Brazil: trend of automotive sector exports to MERCOSUR and the world, 1991-2010



Source: Brazilian Trade and Investment Promotion Agency (APEX-Brasil).

MERCOSUR: Southern Common Market.

of Brazilian exports of this group of products to the bloc. In other words, when account is taken of the relevance of the sector's products in MERCOSUR internal trade, most of them are considered internationally competitive. For example, the two products with the highest value of exports to the bloc in 2010, namely "Other Vehicles, Spark-ignition Engine of a cylinder capacity exceeding 1,500 cc but not exceeding 3,000 cc for more than six passengers" (HS Sub-heading 870323) and "Other Vehicles, Spark-ignition Engine of a cylinder capacity exceeding 1,000 cc but not exceeding 1,500 cc for up to six passengers" (HS Sub-heading 870322) not only had an RCA index above 1 in that year, but the index also rose between 1991 and 2010. The table also shows that the aggregate RCA index of all products for which regional orientation increased rose significantly in the period analysed, from 0.59 in 1991 to 1.17 in 2010.

Accordingly, in contrast to the conclusions reached by Yeats (1997) for the period 1988-1994, the vigorous growth of the automotive sector trade in MERCOSUR between 1991 and 2010 does not seem to have been the result of a trade diversion process. As noted above, in terms of the quantity of products and the representativeness of their trade value, most of the fastest growing Brazilian exports towards the bloc were already internationally competitive or became so during the period reviewed.

Moreover, there was an increase in the RCA index for 14 of the 24 most dynamic products in intra-bloc trade between 1991 and 2010, which suggests that they had become more competitive. That phenomenon, characterized by the increasing competitiveness of automotive sector products could be related to what Corden (1972) called "cost reduction," as discussed in section III.

When the sector is divided into final products and vehicle parts and accessories, there is a significant difference in their importance and trend. Large volumes of Brazilian exports to the bloc consists of final products, particularly in HS headings 8703 and 8704. Those two groups of products alone accounted for almost two thirds (65.4%) of Brazil's exports to MERCOSUR in 2010. Moreover, there was an increase in the RCA index for most of those products over the period reviewed. Although numerous products in the parts and accessories group,

TABLE 2

Regional orientation index and revealed comparative advantage index, 1991-2010

HS 6-digit code	Exports to MERCOSUR *(US$ thousand)*		Regional orientation index (ROI)			Index of revealed comparative advantage (RCA)			Common external tariff
	1991	2010	1991	2010	Variation	1991	2010	Variation	2010
870333	979	931	436.7	738.5	301.8	0.04	0.00	-0.03	35
870421	16 967	411 482	1.6	82.2	80.6	1.99	0.91	-1.08	35
870850	4 017	265 597	1.5	25.5	24.1	2.49	1.61	-0.88	14
870892	124	18 365	0.6	22.8	22.2	0.20	0.28	0.09	18
870422	13 835	305 734	2.6	23.1	20.4	1.40	1.87	0.47	35
870829	3 117	401 315	2.7	15.4	12.7	0.13	0.95	0.83	18
870130	56	313	0.2	12.1	11.9	0.41	0.03	-0.38	14
870323	59 002	2 127 537	6.9	18.6	11.6	0.17	1.06	0.89	35
870894	2 429	91 891	2.1	13.7	11.6	1.22	0.79	-0.43	18
870870	1 960	115 689	0.5	10.8	10.3	2.26	1.09	-1.16	18
870891	1 321	40 945	2.8	12.7	9.9	0.80	0.84	0.04	18
870840	13 095	289 995	3.5	12.1	8.7	0.71	0.83	0.12	18
870120	1 347	276 281	1.2	9.1	7.9	0.59	1.90	1.31	35
870880	4 904	117 744	3.1	9.8	6.7	1.76	1.35	-0.41	18
871419	59	5 767	0.8	7.3	6.6	0.11	0.17	0.06	16
870893	3 145	68 214	1.8	6.5	4.7	1.77	1.41	-0.36	18
870810	501	15 803	1.7	6.1	4.4	0.26	0.51	0.24	18
870431	24 945	214 821	2.8	6.7	3.8	0.80	1.71	0.91	35
870600	5 641	218 081	1.1	4.1	3.1	4.71	13.24	8.53	35
871640	653	100	6.7	8.8	2.1	1.31	0.02	-1.29	35
870322	57 267	668 818	11.3	13.0	1.7	0.41	1.27	0.86	35
870423	1 829	62 248	0.6	1.8	1.3	1.32	1.99	0.68	35
871120	2 286	50 561	4.6	4.9	0.4	0.59	1.46	0.87	20
870210	6 148	27 139	0.7	0.8	0.1	4.96	1.99	-2.97	35
Total	225 627	5 795 371	2.81	11.94	9.1	0.59	1.17	0.58	25.5

Source: prepared by the authors, on the basis of data from the Brazilian Trade and Investment Promotion Agency (APEX-Brasil).
MERCOSUR: Southern Common Market.

which include the heading 8708, posted an increase in their ROI, they only represented 24.6% of the sector's exports in 2010. Apart from a smaller share in the Brazilian sectoral export basket, the RCA index of most of those products decreased. Thus, given the smaller volume exported and their loss of competitiveness, a reduction in protectionism with respect to those products could stimulate imports at lower prices, thereby further increasing the competitiveness of the sector in terms of final products.

As noted above, 14 of the products reviewed displayed an increase in the RCA index between 1991 and 2010, and consequently could be the subject of the analysis. According to the established criteria, five of them could be characterized as cases of "cost reduction". The total exports of those products grew by 2,204% in the reference period, with a value rising from US$ 144.8 million in 1991 to US$ 3,338 million in 2010. As a result, those categories alone accounted for 57.6% of the exports of the most dynamic products in intra-bloc trade in 2010. The CET of four of them was 35% in 2010, the maximum permitted by MERCOSUR, whereas the CET for fifth product (20%) also was above average. Apparently, high protectionism with respect to those products may be the main cause of the increase in Brazilian exports to MERCOSUR. Nonetheless, given the economies of scale and consequent increase in efficiency, the "cost reduction" could have generated welfare gains for the population, which would not occur in the case of trade diversion. The data on the other six products, for which exports amounted to US$ 772.2 million in 2010 (equivalent to 13.3% of the total), would suggest cases of "trade suppression".[10] Thus, the Brazilian automotive sector subsectors that most increased their exports to the bloc (around 70% of the value exported by the sector to the bloc in 2010) would have benefited from the existence of economies of scale, which led to an increase in their competitiveness (measured by the RCA) over the period.

Consequently, although the creation of MERCOSUR could be one of the reasons for the greater competitiveness of the most dynamic products in intra-bloc trade, it is not sufficient to do away with a high CET. On that point, Tigre and others (1999) make a more in-depth analysis of the performance of the automobile industry after the entry into force of the first version of the automotive regime. They argue, for example, that MERCOSUR played a decisive role in the restructuring of the sector, particularly in Argentina and Brazil. According to those authors, the regional agreement enabled multinational firms, already present in the two countries, to adopt regional specialization strategies that increased intra-bloc trade in final products and inputs. The foregoing analysis shows that the increase in trade could be the result of greater efficiency of the firms operating in MERCOSUR (particularly in the case of final products), which benefited from a wider and relatively protected market to exploit the economies of scale characteristic of the automotive sector.

Apart from analysing the period 1991-2010 globally, this article also examines the trend of intra-bloc trade and the competitiveness of the automotive sector products that grew most in that trade during three subperiods, corresponding to each of the main phases of trade between members of the bloc. As shown in the foregoing analysis, between 1991 and 1998 there was a major expansion of Brazilian exports from the automotive sector to MERCOSUR, owing to the preferential elimination of the high tariff barriers in force in previous years. As trade within the bloc became more open, there was a sharp trend towards an increase in trade between member countries. Table 3 shows the products at the HS six-digit level for which the regional orientation index (ROI) increased in absolute terms over that period, along with their revealed comparative advantage (RCA) index and their common external tariff (CET). For all products bar one, the CET is above 15%, and in most cases it attains the upper limit of 35%. These percentages are one of the reasons for the accentuated regionalization.

Over the reference period the ROI trended upwards in the case of 25 products, with an average increase of between 1.5 and 6.0. Most of those products also saw their RCA index rise, which reached a level of 20. This reveals a close relation between the growth of trade and the competitiveness of the products in question, which again indicates the presence of economies of scale related to "cost reduction." The average RCA index also rose considerably, from 1.1 in 1991 to 4.9 in 1998. Moreover, apart from not being able to identify the preponderance of products with a propensity to trade diversion in the sector, most of them became more competitive between 1991 and 1998. In 1998, 12 products displayed an RCA index above 1 and represented 80.8% of Brazilian exports to the bloc from that group. Accordingly, as in the period 1991-2010, the share of the automotive sector's products in intra-bloc trade increased above all in the case of products that were already competitive internationally or which became more so.

[10] The three remaining products (of the 14 mentioned) already had an RCA index above one in 1991, so they do not apply to either of the two situations.

TABLE 3

Regional orientation index and revealed comparative advantage index, 1991-1998

HS 6-digit code	Exports to MERCOSUR *(US$ thousand)*		Regional orientation index (ROI)			Index of revealed comparative advantage (RCA)			Common external tariff
	1991	1998	1991	1998	Variation	1991	1998	Variation	1998
871200	3 165	1 447	20.4	177.7	157.3	0.77	0.08	-0.69	16
870422	13 835	310 424	2.6	25.5	22.9	1.40	4.33	2.93	35
871620	51	1 764	10.1	30.0	19.9	0.13	1.16	1.03	19
870120	1 347	83 495	1.2	15.4	14.2	0.59	0.96	0.37	35
871639	433	35 413	3.3	13.8	10.5	0.28	1.75	1.48	35
870831	1 056	1 603	2.4	12.2	9.8	0.92	0.11	-0.80	0
870829	3 117	95 747	2.7	10.2	7.5	0.13	0.65	0.53	35
870421	16 967	279 568	1.6	8.0	6.4	1.99	2.46	0.47	35
870892	124	6 164	0.6	6.5	5.9	0.20	0.48	0.28	21
870894	2 429	20 135	2.1	6.0	3.9	1.22	1.09	-0.13	21
871680	129	813	4.1	7.4	3.3	0.15	0.25	0.10	19
871499	958	320	19.1	21.9	2.8	0.17	0.03	-0.14	21
870423	1 829	31 565	0.6	3.2	2.6	1.32	1.97	0.66	35
871640	653	900	6.7	9.0	2.4	1.31	0.40	-0.90	19
870893	3 145	18 433	1.8	3.6	1.8	1.77	1.85	0.08	21
870860	1 678	9 482	12.7	14.3	1.6	0.24	0.61	0.37	35
870870	1 960	38 326	0.5	1.9	1.4	2.26	2.54	0.29	35
870850	4 017	39 652	1.5	2.9	1.4	2.49	3.44	0.95	17
871419	59	1 557	0.8	2.1	1.3	0.11	0.26	0.16	35
870130	56	1 165	0.2	1.3	1.1	0.41	0.60	0.19	17
870839	4 616	44 177	0.9	1.9	1.0	1.57	1.99	0.42	35
871690	214	2 371	11.1	11.9	0.8	0.04	0.14	0.10	35
871120	2 286	15 479	4.6	5.0	0.5	0.59	1.31	0.72	35
870600	5 641	47 639	1.1	1.4	0.4	4.71	8.56	3.85	35
870810	501	4 933	1.7	2.0	0.2	0.26	0.75	0.49	35
Total	67 101	1 091 125	1.53	5.97	4.4	1.06	4.94	3.87	27.2

Source: prepared by the authors, on the basis of data from the Brazilian Trade and Investment Promotion Agency (APEX-Brasil).
MERCOSUR: Southern Common Market.

Despite the postponement of the automotive regime agreements, in this period there was a certain degree of optimism about the growth prospects for intra-bloc trade. Although full liberalization of the sectors in intra-bloc trade had been put off several times, the government had provided for free trade (31st Protocol to ACE-14) so that the firms in the two largest members of the bloc would benefit from the economies of scale provided by regional protectionism in many automotive-sector products.

Nonetheless, the macroeconomic instability caused by external crises (Mexico in 1995, South-east Asia in 1997, Russian Federation in 1998), or domestic problems (Brazilian exchange rate devaluation in 1999 and the Argentine moratorium in 2001) interrupted the most prosperous phase of intra-bloc trade.[11] The years between 1999 and 2002 were notoriously the most critical period for MERCOSUR, owing to the disturbances caused by the international financial crises and consequent losses in the regional trade flow. Table 4 calculates the competitiveness and regional orientation indices in this period, which reflect the consequences of the adverse macroeconomic scenario on the Southern Cone automotive sector.

The fact that fewer products saw their ROI rise than in the previous period (1991-1998) and very few of them were competitive, contributed to the shrinking of intra-bloc trade. Only 13 articles displayed an increase in the ROI in the second period, denoting slower growth of regional trade. In turn, 10 of those articles displayed an RCA index below 1 in 2002. The average of this index fell from 1.2 to 0.6 in the reference period, revealing a joint loss of competitiveness among the most dynamic products in intra bloc trade. Production scale is once again important, because Brazilian exports of the products with the greatest trade orientation towards the bloc declined in absolute terms, and total exports shrank from US$ 366.5 million in 1999 to US$ 164.3 million in 2002.

[11] For a more detailed analysis of trade bloc's advances and reversals see Preusse (2001).

TABLE 4

Regional orientation index and revealed comparative advantage index, 1999-2002

HS 6-digit code	Exports to MERCOSUR *(US$ thousand)*		Regional orientation index (ROI)			Index of revealed comparative advantage (RCA)			Common external tariff
	1999	2002	1999	2002	Variation	1999	2002	Variation	2002
871494	51	8	159.5	184.1	24.6	0.02	0.00	-0.02	16
870540	272	269	2.1	7.6	5.5	0.55	0.30	-0.25	35
870421	110 487	49 601	3.6	9.0	5.4	2.01	0.74	-1.27	16
870840	35 243	27 760	1.9	5.5	3.6	1.10	0.69	-0.41	35
870332	86 755	29 681	2.5	3.9	1.4	0.80	0.28	-0.51	18
870810	4 510	1 140	2.0	3.2	1.2	0.92	0.30	-0.61	14
871492	144	22	3.0	4.0	1.0	0.25	0.06	-0.19	35
870850	34 712	12 098	3.0	3.8	0.8	3.87	2.37	-1.49	18
870322	67 821	19 781	1.7	2.5	0.8	1.30	0.57	-0.73	20
870892	3 405	2 014	6.9	7.6	0.6	0.31	0.23	-0.08	16
870880	9 197	3 462	1.2	1.5	0.3	2.88	1.73	-1.16	35
870190	13 760	18 394	2.2	2.5	0.3	0.82	1.92	1.10	18
870590	148	140	0.5	0.5	0.0	0.12	0.24	0.12	18
Total	366 506	164 369	2.42	4.12	1.7	1.21	0.60	-0.61	22.6

Source: prepared by the authors, on the basis of data from the Brazilian Trade and Investment Promotion Agency (APEX-Brasil).
MERCOSUR: Southern Common Market.

Consequently, the reorientation of trade that occurred would have been due largely to protectionism. The CET of 12 of the 13 products analysed was above 15% and attained 35% in most cases. Moreover, only four of the products with the greatest trade orientation were among most dynamic in the period 1991-1998, which reveals a far-reaching changes in Brazilian exports to MERCOSUR in that crisis period.

As from June 2000, managed trade entered into force between MERCOSUR countries, characterized by the flex system. Moreover, also in this integration phase and owing to the crisis it was going through, the Argentine market was unable to absorb more products manufactured by its own industry and increased its exports to Brazil, even beyond the flex, thereby generating taxed trade as provided for under the established rules.

Once the worst phase of the crisis had passed, the recovery of intra-bloc trade also benefited the automotive sector. As shown in table 5, in the period 2003-2010, 36 products from the automotive sector at the HS six-digit level increased their ROI. Four of those products recorded an absolute variation in the index of more than 100. While the average ROI of these products grew significantly, from 2.3 in 2003 to 10.9 in 2010, the RCA index remained stable around 1.1. Most of those products (16) saw their RCA index rise, and all of them sharply increased their value exported to the bloc in the period analysed. This indicates a close relationship between the growth of trade and the competitiveness of the products, which in turn signals the exploitation of economies of scale. Three products showed signs of "cost reduction" and eight of "trade suppression." The other products were competitive in 2003 and their RCA indices had risen even more in 2010. Thus, in addition to being unable to identify the preponderance of products with a propensity to trade diversion in the sector, most of them became more competitive between 2003 and 2010.

To summarize, the methodology applied showed that in none of the periods in which trade grew were there clear signs of the predominance of trade diversion; but there were gains associated with the exploitation of economies of scale, particularly in the most protected sectors. In other words, over the period analysed, most automotive-sector products became more competitive, possibly owing to the economies of scale (characterized by an increase in the RCA index). This would represent a situation of "cost reduction" or "trade suppression" according to the concepts defined by Corden (1972) for studying the effects of the formation of country blocs on products that are subject to economies of scale. That intra-bloc performance is partly explained by the fact that the CET of those products is above average. In other words, the high preferences enjoyed by the automotive sector seem to be the main reasons for the reorientation of trade that occurred with respect to the sector's products after the formation of MERCOSUR. Nonetheless, owing to the efficiency gains seen in the products with the greatest reorientation of trade towards the bloc, there are signs of welfare gains for the population from this which contradict the analysis of Yeats (1997). That author established the presence of trade diversion in relation to most of the products whose intra-bloc trade increased, including the automotive sector.

TABLE 5

Regional orientation index and revealed comparative advantage index, 2003-2010

HS 6-digit code	Exports to MERCOSUR *(US$ thousand)*		Regional orientation index (ROI)			Index of revealed comparative advantage (RCA)			Common external tariff
	2003	2010	2003	2010	Variation	2003	2010	Variation	2010
870120	42 303	276 281	4.2	9.1	4.9	1.21	1.90	0.68	35
870210	2 011	27 139	0.2	0.8	0.6	1.88	1.99	0.11	35
870321	18 892	72 707	14.0	187.4	173.4	0.54	0.50	-0.03	35
870322	73 296	668 818	7.3	13.0	5.7	0.58	1.27	0.69	35
870323	262 516	2 127 537	1.6	18.6	17.0	1.39	1.06	-0.33	35
870331	23 760	65 872	36.6	46.0	9.4	0.49	0.29	-0.20	35
870333	7 842	931	60.4	738.5	678.1	0.06	0.00	-0.06	35
870410	235	513	0.1	0.2	0.1	1.89	0.28	-1.62	14
870421	128 669	411 482	14.0	82.2	68.2	1.00	0.91	-0.08	35
870422	64 601	305 734	16.1	23.1	6.9	1.03	1.87	0.84	35
870423	4 650	62 248	0.4	1.8	1.5	2.04	1.99	-0.05	35
870431	8 147	214 821	0.8	6.7	5.9	0.74	1.71	0.97	35
870600	20 720	218 081	1.0	4.1	3.2	12.01	13.24	1.23	35
870710	56	33	0.2	1.1	0.9	0.28	0.01	-0.28	35
870790	10 994	69 288	0.8	2.3	1.5	6.45	6.29	-0.16	35
870810	1 569	15 803	1.6	6.1	4.5	0.42	0.51	0.09	18
870821	1 132	36 876	10.6	117.7	107.1	0.09	1.09	1.00	18
870829	34 291	401 315	4.1	15.4	11.3	0.39	0.95	0.56	14
870840	27 639	289 995	3.4	12.1	8.7	0.63	0.83	0.20	18
870850	19 197	265 597	4.3	25.5	21.3	2.49	1.61	-0.88	14
870870	14 129	115 689	1.3	10.8	9.5	1.86	1.09	-0.76	14
870880	5 436	117 744	1.4	9.8	8.4	1.55	1.35	-0.20	18
870891	4 397	40 945	1.6	12.7	11.1	1.33	0.84	-0.49	18
870892	707	18 365	2.2	22.8	20.7	0.14	0.28	0.14	18
870893	7 066	68 214	2.4	6.5	4.0	1.16	1.41	0.24	18
870894	4 544	91 891	3.3	13.7	10.4	0.40	0.79	0.39	18
870899	61 882	268 284	1.3	4.6	3.3	0.98	0.63	-0.36	18
871120	5 193	50 561	0.5	4.9	4.5	4.33	1.46	-2.87	20
871130	59	4 910	0.7	8.2	7.5	0.14	0.82	0.68	20
871419	787	5 767	2.2	7.3	5.2	0.16	0.17	0.01	10
871491	80	109	9.2	26.7	17.5	0.03	0.01	-0.02	16
871495	1 187	707	45.0	166.2	121.2	1.08	0.22	-0.86	16
871496	691	568	249.2	300.5	51.3	0.26	0.06	-0.20	16
871500	77	21	1.0	19.0	18.0	0.11	0.00	-0.11	20
871640	201	100	4.5	8.8	4.3	0.16	0.02	-0.15	35
871690	786	13 589	1.8	9.4	7.6	0.19	0.37	0.18	16
Total	859 740	6 328 535	2.29	10.90	8.6	1.12	1.08	-0.04	24.4

Source: prepared by the authors, on the basis of data from the Brazilian Trade and Investment Promotion Agency (APEX-Brasil).
MERCOSUR: Southern Common Market.

VI
Final thoughts

The implementation of the common external tariff (CET) in 1995, based on the common MERCOSUR nomenclature (NCM), was a major step towards a common trade policy among the member countries of the bloc. Nonetheless, the degree of protection increased for many products compared to the previous situation, particularly in the automotive sector. Several studies (for example Kume and Piani, 2005) reveal the high level of protectionism of the automotive sector, measured both on the basis of nominal import tariffs, and in terms of effective tariffs. In reality, this sector is one of the most protected in MERCOSUR through the CET. Given the sector's high level of protectionism with respect to countries outside the bloc, there is a possibility that intra-bloc trade grows

even with respect to non-competitive products, thus raising fears of trade diversion.

Nonetheless, when the possibility of economies of scale is included, the formation of the bloc could be one of the reasons for the greater competitiveness of the automotive sector that are most dynamic products in internal trade, although this is still insufficient to forgo a high CET. The analysis, based on the ROI and RCA indices showed that the growth of trade seems to stem from greater efficiency of firms operating in the bloc, which would benefit from a broader and relatively protected market to take advantage of the economies of scale characteristic of the automotive sector.

Accordingly, an analysis of Brazilian exports to the bloc shows that most of those products seem to have actually suffered from "cost reduction" or "trade suppression" —the concepts coined by Corden (1972) to establish the effects of blocs on sectors in which there are economies of scale—. Although it is true that the dynamism of Brazilian exports to MERCOSUR is partly explained by an above-average CET, the automotive sector was already protected before the trade bloc was created. Although the high preferences of the sector seem to be the main reasons for the regional reorientation of the trade of its products following the formation MERCOSUR, the existence of economies of scale shows the real possibility of welfare gains.

Accordingly, owing to the economies of scale obtained from the expansion of exports from the automotive industry, an intensification of the tariff escalation process already existing in the sector is suggested. Consequently, a high level of protection would be maintained for the final products, particularly those in Headings 8703 and 8704. Those two groups of products alone represented 65.4% of Brazilian exports from the automotive sector to MERCOSUR in 2010. In the case of parts and components, particularly those in Heading 8708, a reduction in import tariffs could be allowed, which would stimulate imports at lower prices and further increase the competitiveness of the sector in final products. To conclude, it would be appropriate not only to maintain but also to intensify the tariff escalation process in the MERCOSUR automotive sector.

ANNEX

Description of the products contained in Chapter 87 of the MERCOSUR Common Nomenclature

CHAPTER 87

87.01	**TRACTORS (OTHER THAN TRACTORS OF HEADING 87.09)**
8701.10.00	Pedestrian controlled tractors
8701.20.00	Road tractors for semi-trailers
8701.30.00	Track-laying tractors
8701.90.00	Other tractors
87.02	**MOTOR VEHICLES FOR THE TRANSPORT OF TEN OR MORE PERSONS, INCLUDING THE DRIVER**
8702.10.00	With compression-ignition internal combustion piston engine (diesel or semi-diesel)
8702.90	**Other**
8702.90.10	Trams
8702.90.90	Other
87.03	**MOTOR CARS AND OTHER MOTOR VEHICLES PRINCIPALLY DESIGNED FOR THE TRANSPORT OF PERSONS (OTHER THAN THOSE OF HEADING 87.02), INCLUDING STATION WAGONS AND RACING CARS**
8703.10.00	Vehicles specially designed for travelling on snow; golf cars and similar vehicles
	Other vehicles, with spark-ignition internal combustion reciprocating piston engine:
8703.21.00	Of a cylinder capacity not exceeding 1,000 cc
8703.22	**Of a cylinder capacity exceeding 1,000 cc but not exceeding 1,500 cc**
8703.22.10	With capacity to transport up to six persons seated, including the driver
8703.22.90	Other
8703.23	**Of a cylinder capacity exceeding 1,500 cc but not exceeding 3,000 cc**
8703.23.10	With capacity to transport up to six persons seated, including the driver
8703.23.90	Other
8703.24	**Of a cylinder capacity exceeding 3,000 cc**
8703.24.10	With capacity to transport up to six persons seated, including the driver
8703.24.90	Other
	Other vehicles, with compression-ignition internal combustion piston engine (diesel or semi-diesel):
8703.31	**Of a cylinder capacity not exceeding 1,500 cc**
8703.31.10	With capacity to transport up to six persons seated, including the driver
8703.31.90	Other
8703.32	**Of a cylinder capacity exceeding 1,500 cc but not exceeding 2,500 cc**
8703.32.10	With capacity to transport up to six persons seated, including the driver
8703.32.90	Other
8703.33	**Of a cylinder capacity exceeding 2,500 cc**
8703.33.10	With capacity to transport up to six persons seated, including the driver
8703.33.90	Other
8703.90.00	Other
87.04	**MOTOR VEHICLES FOR THE TRANSPORT OF GOODS**
8704.10.00	Dumpers designed for off-highway use
	Other, with compression-ignition internal combustion piston engine (diesel or semi-diesel):
8704.21	**Gross vehicle weight (g.v.w.) not exceeding 5 tonnes**
8704.21.10	Chassis with engine and cabin
8704.21.20	With tipper
8704.21.30	With refrigeration or isothermic chamber

Annex (continuation)

8704.21.90	Other
8704.22	**g.v.w. exceeding 5 tonnes but not exceeding 20 tonnes**
8704.22.10	Chassis with engine and cabin
8704.22.20	With tipper
8704.22.30	With refrigeration or isothermic chamber
8704.22.90	Other
8704.23	**g.v.w. exceeding 20 tonnes**
8704.23.10	Chassis with engine and cabin
8704.23.20	With tipper
8704.23.30	With refrigeration or isothermic chamber
8704.23.90	Other
	Other, with spark-ignition internal combustion piston engine:
8704.31	**g.v.w. not exceeding 5 tonnes**
8704.31.10	Chassis with engine and cabin
8704.31.20	With tipper
8704.31.30	With refrigeration or isothermic chamber
8704.31.90	Other
8704.32	**g.v.w. exceeding 5 tonnes**
8704.32.10	Chassis with engine and cabin
8704.32.20	With tipper
8704.32.30	With refrigeration or isothermic chamber
8704.32.90	Other
8704.90.00	Other
87.05	**SPECIAL-PURPOSE MOTOR VEHICLES, OTHER THAN THOSE PRINCIPALLY DESIGNED FOR THE TRANSPORT OF PERSONS OR GOODS (FOR EXAMPLE, BREAKDOWN LORRIES, CRANE LORRIES, FIRE FIGHTING VEHICLES, CONCRETE -MIXER LORRIES, ROAD SWEEPER LORRIES, SPRAYINGLORRIES, MOBILE WORKSHOPS, MOBILE RADIOLOGICAL UNITS)**
8705.10.00	Crane lorries
8705.20.00	*Mobile drilling derricks*
8705.30.00	*Fire fighting vehicles*
8705.40.00	Concrete-mixer lorries
8705.90	**Other**
8705.90.10	Vehicles equipped to determine the characteristic physical parameters (profiling) of oil wells (R. 942/98 MEOSP)
8705.90.90	*Other*
8706.00	**CHASSIS FITTED WITH ENGINES, FOR THE MOTOR VEHICLES OF HEADINGS 87.01 TO 87.05.**
8706.00.10	*For the vehicles of heading 87.02*
8706.00.20	*For the vehicles of subheadings 8701.10, 8701.30, 8701.90 or 8704.10*
8706.00.90	*Other*
87.07	**BODIES (INCLUDING CABS), FOR THE MOTOR VEHICLES OF HEADINGS**
8707.10.00	*For the vehicles of heading 87.03*
8707.90	**Other**
8707.90.10	**For the vehicles of subheadings 8701.10, 8701.30, 8701.90 or 8704.10**
8707.90.90	**Other**
87.08	**PARTS AND ACCESSORIES OF THE MOTOR VEHICLES OF HEADINGS 87.01 TO 87.05.**
8708.10.00	Bumpers and parts thereof
	Other parts and accessories of bodies (including cabs):

Annex (continuation)

8708.21.00	*Safety seat belts*
8708.29	*Other*
8708.29.1	For the vehicles of subheadings 8701.10, 8701.30, 8701.90 or 8704.10
8708.29.11	Mud guards
8708.29.12	Radiator grilles
8708.29.13	*Doors*
8708.29.14	*Instrument panels*
8708.29.19	**Other**
8708.29.9	Other
8708.29.91	**Mudguards**
8708.29.92	Radiator grilles
8708.29.93	Doors
8708.29.94	Instrument panels
8708.29.99	Other
	Brakes and servo-brakes; parts thereof
8708.31	**Mounted brake linings**
8708.31.10	For the vehicles of subheadings 8701.10, 8701.30, 8701.90 or 8704.10
8708.31.90	Other
8708.39.00	Other
8708.40	**Gear boxes**
8708.40.10	*For the vehicles of subheadings 8701.10, 8701.30, 8701.90 or 8704.10*
8708.40.90	*Other*
8708.50	**Drive-axles with differential, whether or not provided with other transmission components, and non-driving axles; parts thereof**
8708.50.10	**For the vehicles of subheadings 8701.10, 8701.30, 8701.90 or 8704.10**
8708.50.90	Other
8708.60	**Non-driving axles and parts thereof**
8708.60.10	For the vehicles of subheadings 8701.10, 8701.30, 8701.90 or 8704.10
8708.60.90	*Other*
8708.70	**Road wheels and parts and accessories thereof**
8708.70.10	**Driving axles of for the vehicles of subheadings 8701.10, 8701.30, 8701.90 or 8704.10**
8708.70.90	Other
8708.80.00	Suspension systems
	Other parts and accessories:
8708.91.00	Radiators
8708.92.00	Silencers (mufflers) and exhaust pipes
8708.93.00	**Clutches and parts thereof**
8708.94	**Steering wheels, steering columns and steering boxes; parts thereof**
8708.94.1	*For the vehicles of subheadings 8701.10, 8701.30, 8701.90 or 8704.10*
8708.94.11	*Steering wheels*
8708.94.12	Steering columns
8708.94.13	**Steering boxes**
8708.94.9	Other
8708.94.91	Steering wheels
8708.94.92	Steering columns

Annex (continuation)

8708.94.93	*Steering boxes*
8708.99	**Other parts and accessories**
8708.99.10	Accelerator, break, clutch, steering, or gearbox mechanisms, including adaptations of pre-existing models of the type used by disabled persons (R.1497/98 MEOSP)
87.09	**WORKS TRUCKS, SELF-PROPELLED, NOT FITTED WITH LIFTING OR HANDLING EQUIPMENT, OF THE TYPE USED IN FACTORIES, WAREHOUSES, DOCK AREAS OR AIRPORTS FOR SHORT DISTANCE TRANSPORT OF GOODS; TRACTORS OF THE TYPE USED ON RAILWAY STATION PLATFORMS; PARTS OF THE FOREGOING VEHICLES**
	Works trucks:
8709.11.00	Electrical
8709.19.00	Other
8709.90.00	**Parts**
8710.00.00	**Tanks and other armoured fighting vehicles, motorized, whether or not fitted with weapons, and parts of such vehicles.**
87.11	**MOTORCYCLES (INCLUDING MOPEDS) AND CYCLES FITTED WITH AN AUXILIARY MOTOR, WITH OR WITHOUT SIDE -CARS; SIDE -CARS**
8711.10.00	*With reciprocating internal combustion piston engine of a cylinder capacity not exceeding 50 cc*
8711.20	**With reciprocating internal combustion piston engine of a cylinder capacity exceeding 50 cc but not exceeding 250 cc**
8711.20.10	*Motorcycles of a cylinder capacity not exceeding 125 cc*
8711.20.20	Motorcycles of a cylinder capacity exceeding 125 cc
8711.20.90	Other
8711.30.00	With reciprocating internal combustion piston engine of a cylinder capacity exceeding 250 cc but not exceeding 500 cc
8711.40.00	With reciprocating internal combustion piston engine of a cylinder capacity exceeding 500 cc but not exceeding 800 cc
8711.50.00	With reciprocating internal combustion piston engine of a cylinder capacity exceeding 800 cc
8711.90.00	**Other**
8712.00	**BICYCLES AND OTHER CYCLES (INCLUDING DELIVERY TRICYCLES), NOT MOTORIZED**
8712.00.10	**Bicycles**
8712.00.90	**Other**
87.13	**CARRIAGES FOR DISABLED PERSONS, WHETHER OR NOT MOTORIZED OR OTHERWISE MECHANICALLY PROPELLED**
8713.10.00	Not mechanically propelled
8713.90.00	**Other**
87.14	**PARTS AND ACCESSORIES FOR THE VEHICLES OF HEADINGS 87.11 TO 87.13**
	Of motorcycles and motorized tricycles (including mopeds):
8714.11.00	Saddles (seats)
8714.19.00	Other
8714.20.00	*Of carriages for disabled persons*
	Other:
8714.91.00	*Frames and forks, and parts thereof*
8714.92.00	*Wheel rims and spokes*
8714.93.00	*Hubs, other than coaster braking hubs and hub brakes, and free-wheel sprocket-wheels*
8714.94	**Brakes, including coaster braking hubs and parts thereof**
8714.94.10	*Coaster braking hubs*
8714.94.90	*Other*
8714.95.00	*Saddles (seats)*
8714.96.00	*Pedals and pedal mechanisms, and parts thereof*
8714.99.00	*Other*

Annex (conclusion)

8715.00.00	**BABY CARRIAGES (INCLUDING STROLLERS) AND PARTS THEREOF**
87.16	**TRAILERS AND SEMI-TRAILERS FOR ANY VEHICLE; OTHER VEHICLES NOT MECHANICALLY PROPELLED, AND PARTS THEREOF**
8716.10.00	*Trailers and semi-trailers for housing or camping, of caravan type*
8716.20.00	*Trailers and semi-trailers, self loading or self unloading trailers for agricultural purposes*
	Other trailers and semi-trailers for the transport of goods:
8716.31.00	*Tanker trailers*
8716.39.00	*Other*
8716.40.00	**Other trailers and semi-trailers**
8716.80.00	Other vehicles
8716.90	**Parts**
8716.90.10	**Tanker trailers and tanker semi-trailers**
8716.90.90	Other

Source: Common MERCOSUR Nomenclature.

Bibliography

Balassa, B. (1965), "Trade liberalization and 'revealed' comparative advantage", *The Manchester School of Economic and Social Studies*, vol. 33, No. 2.

Bhagwati, J. (1993), "Regionalism and multilateralism: an overview", *New Dimensions in Regional Integration*, J. De Melo and A. Panagariya (eds.), New York, Cambridge University Press.

Casotti, B.P. and M. Goldenstein (2008), "Panorama do setor automotivo: as mudanças estruturais da indústria e as perspectivas para o Brasil", *BNDES Setorial*, No. 28, Rio de Janeiro, Brazilian Development Bank (BNDES).

Corden, W.M. (1972), "Economies of scale and customs union theory", *Journal of Political Economy*, vol. 80, No. 3, Chicago, University of Chicago Press.

Gabriel, L.F. and others (2011), "Uma análise da indústria automobilística no Brasil e a demanda de veículos automotores: algumas evidências para o período recente", *Anais do 39° Encontro Nacional de Economia*, Rio de Janeiro, National Association of Centers for Post-graduation in Economics (ANPEC).

Giordano, P. and J. Santiso (1999), "La course aux Amériques. Les stratégies des investisseurs européens en Argentine et au Bresil", *Études du CERI*, No. 52, Paris, Centre for Educational Research and Innovation (CERI).

IDB (Inter-American Development Bank) (1996), *Informe Mercosur*, No. 1, Buenos Aires [online] http://www.iadb.org/intal/.

_____ (2008), *Informe MERCOSUL*, No. 1/12, Buenos Aires [online] http://www.iadb.org/intal/.

Kume, H. and G. Piani (2005), "MERCOSUL: o dilema entre união aduaneira e área de livre-comércio", *Brazilian Journal of Political Economy*, vol. 25, No. 4, São Paulo.

Machado, J.B. and M.A. Cavalcanti (1999), "Determinantes do comércio bilateral Argentina-Brasil: uma avaliação dos impactos estáticos do processo de integração no MERCOSUL", XXVII Encontro Nacional de Economia, Rio de Janeiro, National Association of Centers for Post-graduation in Economics (ANPEC).

Negri, J.A. (1999), "O custo do bem-estar do regime automotivo brasileiro", *Pesquisa e Planejamento Econômico*, vol. 29, No. 2, Institute of Applied Economic Research (IPEA).

Panagariya, A. (1999), "The regionalism debate: an overview", *World Economy*, vol. 22, No. 4, Wiley.

Piani, G. (1998), "Medidas antidumping, anti-subsidios e de salvaguardas: experiência recente e perspectivas no MERCOSUL", *Texto para Discussão*, No. 541 [online] www.ipea.gov.br/pub/td.

Preusse, H. (2001), "MERCOSUR: another failed move towards regional integration?", *The World Economy: The Leading Journal on International Economic Relations*, vol. 24, Wiley.

Sarti, F. (2001), "Internacionalização comercial e produtiva no mercosul nos anos 90", thesis, Campinas, State University at Campinas.

Senhoras, E.M. (2005), "A industria automobilistica sob enfoque estático e dinâmico: uma análise teórica", VIII SEMEAD, São Paulo, School of Economics, Business and Accounting/University of São Paulo.

Sica, D. (2005), "La realidad de la industria automotriz ¿en el camino hacia la consolidacion?", Buenos Aires, International Motor Show.

Tigre, P. and others (1999), "Impacto del MERCOSUR en la dinámica del sector automotor", *Impacto sectorial de la integración en el MERCOSUR*, J.J. Taccone and L.J. Garay (orgs.), Buenos Aires, Inter-American Development Bank/Institute for Latin American Integration (IDB/INTAL) [online] www.iadb.org/Intal/aplicaciones/uploads/.

Viner, J. (1950), *The Customs Union Issue,* New York, Carnegie Endowment for International Peace.

Yeats, A. (1997), "Does MERCOSUR's trade performance raise concerns about the effects of regional trade arrangements?", *Policy Research Working Paper*, No. 1729, Washington, D.C., World Bank.

Determinants of unfair inequality in Brazil, 1995 and 2009

Ana Claudia Annegues, Erik Alencar de Figueiredo and Wallace Patrick Santos de Farias Souza

ABSTRACT

This article analyses the trend of unfair inequality in Brazil (1995-2009) using a non-parametric approach to estimate the income function. The entropy metrics introduced by Li, Maasoumi and Racine (2009) are used to quantify income differences separately for each effort variable. A Gini coefficient of unfair inequality is calculated, based on the fitted values of the non-parametric estimation; and the robustness of the estimations, including circumstantial variables, is analysed. The trend of the entropies demonstrated a reduction in the income differential caused by education. The variables "hours worked" and "labour-market status" contribute significantly to explaining wage differences imputed to individual effort; but the migratory variable had little explanatory power. Lastly, the robustness analysis demonstrated the plausibility of the results obtained at each stage of the empirical work.

KEYWORDS Economic conditions, income distribution, income, education, employment, statistical data, statistical methodology, Brazil

JEL CLASSIFICATION C14, D63

AUTHORS

Ana Claudia Annegues is a doctoral student in the Graduate Programme in Economics at the Federal University of Rio Grande do Sul (UFRGS), Brazil. annegues.ana@gmail.com

Erik Alencar de Figueiredo is a professor with the Department of Economics of the Postgraduate Programme in Economics at the Federal University of Paraíba, Brazil. eafigueiredo@gmail.com

Wallace Patrick Santos de Farias Souza is a doctoral student in the Graduate Programme in Economics at the Federal University of Rio Grande do Sul, Brazil. wpsfarias@gmail.com

I
Introduction

The Brazilian economy, which endured a long period of rising inequality from the 1960s onwards, has seen an improvement in its social indicators since the mid-1990s (Azevedo, 2007). This has resulted from a macroeconomic environment favouring the transformations caused by the stabilization of inflation and Brazil's integration into the international market. Government income transfer programs also increased substantially in that period, which led to a rise in income and a consequent reduction in poverty levels (Figueiredo and Netto Júnior, 2014).

Nonetheless, although those indicators might lead one to believe that Brazil became a fairer country, the bibliography has questioned the way income inequality is usually treated, in which perfect equality is considered the ideal of social justice. Authors supporting this line of thought are highly diverse, ranging from the followers of the Rawlsian tradition, such as Dworkin (1981) and Arneson (1989), who support income differences related to individual preferences, to authors such as Roemer (1998), who propose the concept of inequality of opportunities.

Following the latter approach, individual economic outcomes depend partly on responsibility variables (defined as effort) and partly on variables that are beyond the scope of individual responsibility (defined as circumstantial). Following that line of reasoning, several researchers argue that only unfair inequality, or inequality caused by variables beyond the scope of responsibility, is socially undesirable.

Some studies have attempted to measure inequality of opportunities and its contribution to total inequality. For that purpose, direct and indirect parametric techniques have been used based on a defined functional form —as in Bourguignon, Ferreira and Menéndez (2007)— where the determinants of the counterfactual income distribution are considered by assuming that all individuals are in the same circumstances; and in Salvi (2007), which uses panel data to distinguish circumstances and effort in time-variant and time-invariant variables.

Applying the concept of sensitivity to responsibility, Devooght (2008) measures income inequality and a fairness criterion calculated on the basis of an income function g, approximated through log-linear regression. The author only uses responsibility variables, because it is not always possible to obtain a well-defined set of variables, particularly with respect to family background (the educational level and profession of the parents); so the component of inequality that is explained by the non-responsibility variables are included in the stochastic term.

Nonetheless, that methodology raises a number of problems; in particular the endogeneity generated by the degree of relation between the effort and circumstantial variables. Moreover, in many studies, assuming a functional form for individual incomes can result in specification bias, given the random nature of the relations between the variables.

This article attempts to bridge that gap by adopting a non-parametric approach (without a functional form defined for g), with the aim of answering the following questions, based on the hypothesis that incomes essentially reflect responsibility variables: which of variable has the greatest explanatory power? Have effort variables being losing their influence in the determination of income differentials over the period analysed? Does the suppression of variables beyond the individual's control expose the results to some degree of bias?

For that purpose, the following four-step empirical strategy is used. Firstly, a specification analysis is undertaken to justify the use of the non-parametric method for estimating the income equation. The second step consists of dividing the sample into two groups of individuals, classified on an ad hoc basis as "high-effort" and "low-effort", according to each responsibility variable, and then estimating incomes in relation to each of the determinants of effort (while holding the others constant) and observing their capacity to explain income inequality in the period analysed. The curves are compared on the basis of the entropy metrics discussed in Racine (2006). In the third step, Gini coefficients of unfair inequality are produced to measure the repercussion of the non-parametric inferences on the calculation of indices of fairness, and to verify whether the traditional parametric approach tends to overestimate those measures or not. To make inferences on the results obtained, the fourth and last procedure makes an analysis of robustness using data from the 1996

☐ The authors gratefully acknowledge financial support from the National Scientific and Technological Development Council (CNPq) (Project 470202/2012-2).

National Household Survey (PNAD). That year was chosen because the PNAD published a social mobility supplement that summarizes data on the education, schooling and occupation of the parents of the selected individual (family background).

The period between 1995 and 2009 is analysed using data from the annual PNADs. The effort variables used are education level, the decision to emigrate, hours worked, and labour-market status.[1] The logarithm of nominal wages is used as the dependent variable (proxying for individual income).

Following this introduction, the rest of the article is organized as follows: section II includes the methodological procedures, and presents the empirical strategy which is divided into the analysis of the relation between inequality and effort, estimation of the variable without a defined functional form, and the non-parametric model. Section III is devoted to the presentation of results and discussion, along with a comparison of the distributions for each responsibility variable used and for determining the entropy metric. Section IV presents debates on the topic, and section V sets out final thoughts.

[1] Those variables are presented in greater detail in subsection 1.c of section II, which describes the databank.

II
Methodological procedures

The objective of this section is to present the key methodological procedures of the study. It firstly highlights the theoretical concepts related to the bibliography on unequal opportunities, or unfair inequality; then, the steps in the empirical analysis are described, to clarify the study's analytical procedures (see subsection 1.a of this section). The methods involved in each step are described in subsection 1.b of this section. Lastly, the databank is presented.

1. Inequality of opportunities: theoretical and technical procedures

The traditional approach to unequal opportunities considers that an individual's economic outcome stems from circumstantial factors, such as family background, race or gender, among others, combined with effort, which is associated with variables that can be controlled by the person in question, including years of schooling or hours worked, for example (Roemer, 1998).[2] In short, unlike the modern egalitarian vision,[3] a society is considered fair if it guarantees the same access to social benefits to all of its members, irrespective of their circumstances, such that effort turns access to those benefits into real gains for individuals. Put another way, only inequality the results from circumstantial variables is socially undesirable. Accordingly, equalizing opportunities means correcting unequal circumstances while keeping effort differences unchanged.[4]

Nonetheless, although the concept of equal opportunities is quite simple, implementing it raises a number of significant challenges, not least the definition of the effort variable. Fleurbaey (1998) considers that effort is not observable, and uses a non-parametric approach to identify it, based on the Roemer identification assumption that multi-dimensional effort variables can be distributed independently of the individuals' circumstances. In contrast, Bourguignon, Ferreira and Menéndez (2007) believe effort is observable; and they develop a parametric model in which effort endogenously depends on circumstances. In short, effort can be considered either a latent (non-observable) variable, or not.[5] When a structure is adopted in which this is an observable factor, the traditional parametric representations are based on the fact that an economic outcome, such as the wage,

[2] Alternatively, inequality of opportunities can be studied by comparing economic outcomes in relation to the sets of opportunity variables. See Pattanaik and Xu (1990) and Kranich (1996) for more detailed information. Ooghe, Schokkaert and Van de Gaer (2007) provide a summary of the different approaches.

[3] See, for example, Dworkin (1981) and Arneson (1989).

[4] Discussion on the social norm of fairness is complex and involves a series of mutually conflicting perspectives. For a synthesis, see Thomson (2011) and Fleurbaey and Maniquet (2011).

[5] Bourguignon, Ferreira and Menéndez (2007), for example, approach effort variables on the basis of years of education, the decision to migrate and the worker's labour-market status. Checchi and Peragine (2009) consider effort as a non-observable factor, thereby adopting the Roemer axiom (Roemer, 1996); and they assume that individuals with different opportunity sets, but who are in the same percentile of the corresponding distribution, make the same level of effort.

is a function of the variables of circumstances (C_i) and effort (E_i) following an additively separable structure:

$$Y_i = \alpha C_i + \lambda E_i + u_i \quad (1)$$

Equation (1), however, requires the two sets of variables (effort and circumstances) to be available, which is generally not possible in most international surveys. In view of this, a variety of studies assume that the economic outcome can be determined from a series of effort variables, together with assumptions concerning the random term.

Devooght (2008), for example, applies a normative criterion under which the error term is included in the set of circumstantial variables (C_i). Following the same line of reasoning, Almås (2008), and Almås and others (2011), devise a criterion of fairness that is sensitive to responsibility; and they propose a Gini coefficient of unfair inequality that is applied to data from Norway. Figueiredo and Netto Júnior (2014) use a similar strategy to calculate unfair inequalities in Brazil between 1995 and 2009.

The results for the Brazilian economy are striking, because the country shows a significant reduction in total income inequality (Gini coefficient), without any alteration in unfair inequality. As the coefficients of unfair inequality are calculated on the basis of effort variables (education, hours of work, decision to migrate, and labour-market status), the maintenance of their values means that the importance of those co-variant variables in explaining the income equations have remained constant over the years. In fact, the equations contained in Figueiredo and Netto Júnior (2014) showed that the goodness of fit of the regressions (R^2) has deteriorated. In view of this, the authors postulate the following:

(i) given that the construction of the fairness rule considers that the unobservable factors (error term) are the non-responsibility variables, a decrease in R^2 implies that these factors have a heavier weight in 2009 than in 1995. In other words, earnings density in 2009 depends much more on variables related to origin, color, and family background than on factors related to effort; or

(ii) such a pattern would for instance occur if, with the quantitative expansion in the access to education, differences in the quality of education tend to matter more over time (Figueiredo and Netto Júnior, 2014).

Nonetheless, at least one caveat needs to be raised: the authors use a linear parametric structure similar to that of equation (1). If, for example, that specification is not appropriate and the relation between income and the effort variables is non-linear, the values predicted by the estimated equations (used to calculate the unfair inequality coefficients) will not be valid; nor, consequently, will the degrees of fit of the regressions (R^2).[6]

In view of that limitation, the study proposes an alternative model which represents the economic outcome as follows:

$$ln\, Y_i = m\left(E_i\right) + g\left(\xi_i\right) \quad (2)$$

where $g\left(\xi_i\right) = s\left(C_i, u_i\right)$. Unlike equation (1), equation (2) does not impose a linear form to describe the link between the economic outcome and its covariant variables. Instead, it assumes that this relation arises from unknown functions $m(\cdot)$, $g(\cdot)$ and $n(\cdot)$. It also considers that $E_i \perp \xi_i$, in other words, it postulates that the two sets of variables are mutually independent.[7] This approach is inspired in the normative assumption of Devooght (2008) combined with the non-parametric structure widely adopted in economic studies.[8] The application of those methods follows the following empirical sequence.

(a) *Sequence of the empirical work*

The empirical strategy includes the following procedures:

(1) Specification analysis to compare the parametric and non-parametric alternatives for the income equations. This stage is necessary to avoid adopting the non-parametric structure on an ad hoc basis.

(2) Creation of high- and low-effort groups. Four divisions are considered, each linked to one dimension of effort, namely:

- Education: low-effort in the case of persons with less than four years' schooling and high-effort in other cases.
- Migration: low-effort for non migrants and high-effort for migrants.
- Hours of work: low-effort for persons who work less than 20 hours a week and high-effort for others.
- Labour-market status: low-effort for own-account and informal workers and high-effort for workers in the formal sector.

The idea is to measure the distance between the high- and low-effort groups in a period covering several

[6] See Maasoumi, Racine and Stengos (2007) for a discussion on the degree of fit in non-linear models and a presentation of alternatives to that parameter.

[7] This hypothesis is relaxed in the section on robustness analyses.

[8] For a synthesis see Li and Racine (2007).

years. The identification is based on the fitted regression values. This makes it possible to gauge whether effort is losing its influence in determining incomes among the Brazilian population.

(3) Using the fitted values of the non-parametric regressions, fairness criteria and Gini coefficients of unfair inequality are calculated.

(4) This procedure makes it possible to establish whether the gains obtained in applying a non-parametric method for the wage regressions is significantly reflected in the unfairness indices.

Lastly, a robustness analysis is performed based on a sample of effort and circumstantial variables.

The main lines of the analysis are the hypothesis of independence between the two sets of variables and the omission of circumstantial variables in procedures (1) to (3). The data used come from the social supplement of the 1996 PNAD.

The implementation of this sequence (procedures 1 to 4) is based on a non-parametric instrumental and the data set described in the next two subsections.

(b) *Inference*

Three non-parametric methods are used. The first is an analysis of specifications and relates to procedure (1) of the empirical strategy; in other words, the robustness of the non-parametric specification is tested against the parametric specification. The second method refers to the non-parametric estimations for the wage equations. The third, lastly, entails calculating the distances (entropies) between the low- and high-effort groups.

Specification analysis. This study chooses the kernel-based analysis developed by Racine (2006). To understand the structure of the Racine (2006) specification analysis, the following parametric representation should be considered:

$$y_i = q(x_i, \beta) + \eta_i,\ i = 1, ..., n$$

If the specification is correct, the expected error term η_i conditional on x_i will be equal to zero. Thus, the β estimator will be consistent. In contrast, if $q(x_i, \beta)$ was incorrectly specified, following the normal linear regression structure, for example, the β estimator would be inconsistent. Consequently, the correct specification would need to be considered as the null hypothesis:[9]

$$H_0: P\left[F\left(q\left(x_i, \beta\right)\middle| x_i\right)\right] = 1, \text{ for some } \beta \in \aleph \forall i \geq 1$$

where $q(x_i,\beta)$ is a known function, β is a factor of unknown parameters, and $\aleph$ is a compact subset of $\mathbb{R}^d$. The alternative hypothesis is as follows:

$$H_1: P\left[F\left(q\left(x_i, \beta\right)\middle| x_i\right)\right] < 1, \text{ for some } \beta \in \aleph \forall i \geq 1$$

The null hypothesis is true if $E\left(\varepsilon_i \middle| x_i\right) = 0$, and $I = E\left\{\left[E\left(\varepsilon_i \middle| x_i\right)\right]^2 f\left(x_i\right)\right\} \geq 0$, where $f(x_i)$ is the marginal density for X. In this case, $I = 0$ if and only if H_0 is true. Thus, I is a candidate for analysing H_0.

An observation is in order at this point. In general, kernel-based methods are appropriate for continuous data. Nonetheless, using a frequencies method (Li and Racine, 2007, chapter 3), it is possible to deal with discrete and continuous variables in the same dataset. Thus x_i^d can be considered as a vector of discrete variables of dimension $r \times 1$ and $x_i^c \in \mathbb{R}^d$ while the other variables are continuous. Accordingly, $x_i = \left(x_i^c, x_i^d\right)$.

The I sample is defined as:

$$I_n = n^{-2} \sum_i \sum_{j \neq i} \hat{\varepsilon}_i \hat{\varepsilon}_j K_{\gamma, ij}$$

where $K_{\gamma, ij} = W_{h, ij} L_{\lambda, ij}$, $\gamma = h$, φ are the bandwidths, $W_{h, ij}$ and $L_{\lambda, ij}$ are the multivariate kernel functions for the discrete and continuous data, respectively; and $\hat{\varepsilon}_i$ are the model's sample errors.

Racine (2006) recommends using the cross-validation method for selecting the bandwidths,[10] replacing $\left(h_1, ..., h_q, \varphi_1, ..., \varphi_r\right)$ by their estimators $\left(\hat{h}_1, ..., \hat{h}_q, \hat{\varphi}_1, ..., \hat{\varphi}_r\right)$. In this way, $\hat{I}_n$ is defined. Under certain assumptions the author shows that, with H_0,

$$\hat{J}_n = n\left(\hat{h}_1, ..., \hat{h}_q\right)^{1/2} \hat{I}_n \Big/ \sqrt{\hat{\Omega}} \rightarrow N(0, 1) \qquad (3)$$

and

$$\hat{\Omega} = \frac{2\left(\hat{h}_1, ..., \hat{h}_q\right)}{n^2} \sum_i \sum_{j \neq i} \hat{\varepsilon}_i^2 \hat{\varepsilon}_j^2 W_{\hat{h}, ij}^2 L_{\hat{\lambda}, ij}^2$$

[9] The null hypothesis is based on the consistent analysis definition. For further information, see Li and Racine (2007).

[10] See Härdle (1990) for further information on the cross-validation method.

The critical values are tabulated according to the *wild bootstrap* method. Racine (2006) presents and discusses details of the inference process, as well as the performance of the analysis in finite samples. Broadly speaking, the analysis $\hat{J}_n$ consists of several stages, including the estimation of regressions with combined or mixed data (Racine and Li, 2004), obtaining estimates for the bandwidths of the discrete and continuous variables.

Non-parametric estimations. Many empirical studies admit a specific functional form, generally log-linear, for measuring the inequality of opportunities. Examples include Bourguignon, Ferreira and Menéndez (2007); Devooght (2008), and Figueiredo and Netto Júnior (2014). Nonetheless, parametric modelling might not be appropriate, given the uncertainty in relations between the explained and the explanatory variables. Alternatively, a non-parametric estimation does not impose functional forms for the equation, so it is capable of revealing aspects of the data structure that are not captured by the traditional parametric approach.

This study uses the constant local kernel estimator for mixed data, suggested by Racine and Li (2004), bearing in mind that the regressions include categorical variables. The authors use a kernel function to smooth the discrete variables, which adopts the following forms:

$$l\left(X_{t,i}^{d}, x_{t}^{d}\right) = \begin{cases} 1 \; se \; X_{t,i}^{d} = x_{t}^{d} \\ \lambda \; se \; X_{t,i}^{d} \neq x_{t}^{d} \end{cases}$$

If $d_{xi,x} = \sum_{t=1}^{k} 1\left(X_{t,i}^{d} \neq x_{t}^{d}\right)$ is defined as the number of unequal components between $X_{t,i}^{d}$ and x_{t}^{d}, then the product kernel for discrete variables will be

$$L\left(X_{i}^{d}, x^{d}, \lambda\right) = \prod_{t=1}^{k} l\left(X_{t,i}^{d}, x_{t}^{d}\right) = 1^{k-d_{xi,x}} \lambda^{d_{xi,x}} = \lambda^{d_{xi,x}}.$$

Let W(.) be the kernel function associated with the continuous variables, and h its smoothed parameters. Using the notation $K_{h,ix} = W_{h,ix} L_{\lambda,ix}$, where $W_{h,ix} = h^{-p} W\left(\left(X_{i}^{c} - x^{c}\right)/h\right)$ and $L_{\lambda,ix} = L\left(X_{i}^{d}, x^{d}, \lambda\right)$, the kernel estimator for the joint density function of $\left(X_{i}^{c}, X_{i}^{d}\right)$ is given by:

$$\hat{f}(x) = \frac{1}{n} \sum_{i=1}^{n} K_{h,ix} \qquad (4)$$

In short, the true income function corresponds to the conditional average of the dependent variable, and its estimator is defined as:

$$\hat{g}(x) = \frac{n^{-1} \sum_{i=1}^{n} Y_i K_{h,ix}}{\hat{f}(x)} \qquad (5)$$

where Y_i is the dependent variable, and $K_{h,ix}$ satisfies the aforementioned definition. The results of this function are summarized in the form of partial regression graphs. The explained part of the multivariate regression is plotted in relation to each effort variable, holding everything else constant, in a series of bivariate graphs. In other words, $\hat{g}$ is plotted against the expected value of the regressors, keeping two of these at their respective averages; all of this for two different groups of individuals divided between low-effort and high-effort, according to each responsibility factor analysed. This procedure, used in Li, Maasoumi and Racine (2009), makes it possible to compare the curves of the two groups based on the distance between them, and thus observe the capacity of those regressors to explain income inequality over time. The distances are quantified through an entropy metric, which is explained in further detail in the next section.

Distance entropy metric. The entropy metrics represent a formal quantification of the distances between the distributions. An ideal metric of the distance between two random variables has a number of desirable properties, namely: (i) it is normalized on zero, if X and Y are identical; (ii) the modulus of the measure is equal to one, if there is an exact measurable (non-linear) relation between the variables $Y = g(X)$; (iii) it has a value close to the coefficient of linear correlation in the case of a bivariate normal distribution; (iv) it is a true metric of distance and not just of divergence between the distributions; (v) the ideal measure is well-defined for both continuous and discrete variables, and (vi) it is invariant to continuous and strictly increasing transformations such as $h(.)$. This is useful provided X and Y are independent, and if and only if h(X) and h(Y) are also independent.

Li, Maasoumi and Racine (2009) use entropy metrics to make inferences on the degree of fit of the models, measuring the distance between observed values and fitted values, because the traditional R^2 and other measures of correlation are inadequate if the estimated function is non-linear. The entropy used by the authors was suggested by Granger, Maasoumi and Racine (2004)

and consists of a normalization with the aforementioned properties, as well as an appropriate distance metric:

$$S_\rho = \frac{1}{2}\int \left(f_1^{1/2} - f_2^{1/2}\right)^2 dx \qquad (6)$$

where f_1 and f_2 are the marginal densities of the random variables. To improve the reliability of the results, the bootstrap method is applied to a new sample, refitting the joint distribution of X and Y.

As noted above, this study will use entropy metrics as an indicator of the inequality of effort between the groups (procedure 3). The fitted values of the dependent variable for low- and high-effort individuals will be plotted against each explanatory variable, holding everything else constant. The entropy metrics are used to calculate the distances between the curves, and an analysis of equality of univariate densities is immediately performed, based on the null hypothesis $S_\rho = 0$.

(c) *Data*

The data used in the study come from the PNAD for the period between 1995 and 2009. They cover male heads of family, of between 25 and 60 years of age, living in urban areas. Individuals with these characteristics were chosen so as to homogenize the sample used as far as possible, restricting the analysis to individuals of active age, while also avoiding the influence of gender factors, both in the selection and in the individual economic outcomes. Heads of families were chosen because they are the main source of family income. Income is represented by the hourly wage, expressed in reais at September 2009 prices, as in Bourguignon, Ferreira and Menéndez (2007).

The vector of effort variables is represented by: (i) the individual's years of schooling; (ii) a dummy variable for migration; (iii) the individual's labour-market status (formal work, without a work contract, or working on own account), and (iv) weekly hours of work. High-effort and low-effort categories were defined for each of the variables, as indicated in procedure 2 of the empirical strategy sequence (see subsection 1.a of section II).

The variables were selected following Bourguignon, Ferreira and Menéndez (2007) and Figueiredo and Netto Júnior (2014); and they include individual responsibility factors, since, despite being influenced by circumstances, they are ultimately determined by individual choices. In the case of years of schooling, it is reasonable to assume that individuals with higher levels of schooling are those that have tried to obtain higher qualifications, they have invested in human capital so have made a greater effort.

The variables "labour-market status" and "weekly hours worked" are included because they represent the pursuit of higher wages, since individuals who work more hours and in formal jobs tend to obtain higher income. In addition, formal jobs are generally held by individuals with a higher level of schooling.

In relation to the migratory factor, individuals who decide to migrate are selected by the labour market and, according to Assis, Costa and Mariano (2012), they display a higher level of human capital, in addition to being more productive than non-migrants, except in the southeast region. Bearing those characteristics in mind, migrants would have capacity to achieve a higher level of income, which makes it plausible to include this variable as a measurement of effort.

III
Results

This section sets out the results of each of the steps in the empirical strategy. Firstly, the income equation specifications are analysed; then, a graphical analysis is made of the non-parametric densities, comparing income differentials between the high- and low-effort groups over the period analysed, varying each responsibility factor separately. The formal quantification of those distances is obtained from the entropy metrics for the distances between the densities of the two groups. Lastly, robustness analyses are performed using data on the circumstances of the individuals, followed by measurement and comparison of the results related to non-parametric inequality of opportunities in Brazil.

Step 1. The analyses of the income equation specifications are summarized in table 1. As noted above, this involves comparing the parametric and non-parametric estimations of the income equations. This

procedure avoids making an ad hoc decision to adopt an estimation structure. In short, the analysis undertaken by Racine (2006) demonstrates the superiority of the non-parametric models in all years investigated.

Step 2. Once the superiority of the non-parametric models has been demonstrated, the study makes inferences based on the constant kernel estimator.[11] After obtaining the fitted values for each equation, the high- and low-effort groups are identified according to the categories indicated in section II. Figure 1 displays the estimations of the kernel densities for the fitted values by effort group in 1995 and 2009.

A visual analysis shows that the education curves moved closer together in terms of inequality, and there was less dispersion in the distribution of individuals in the high-effort category. In the case of migration, the difference between the groups, both in 1995 and in 2009, is relatively insignificant and hardly varies from one year to another.

In the case of labour-market status, the distance between the density functions increases, while the dispersion of the curve corresponding to the low-effort group decreases slightly. Analogously, the difference between the distributions attributed to the hours-worked factor grows in the period, without major alterations to the shape of the curves.

Nonetheless, the distances between the curves synthesized in figure 1 need to be formally quantified, and their trend during the period analysed needs to be identified. Figure 2 shows the evolution of the distances between the fitted values of a high and low effort groups, for each effort dimension, over the period considered.[12] Any measure of entropy is useful as an indicator of divergence between distributions and thus serves as a metric of their inequality or concentration.

When considering education as an effort factor, the values of the entropies decline during the period as a whole. From 1995 to 2009, the distance between the groups, which had been slightly more than 0.50 in 1997, dropped to a level close to 0.36 in 2009. This shows that effort, measured in terms of a higher educational level, has become less important in individual income differentials. In other words, years of schooling in 1995 (entropy = 0.41) involved a higher level of income than in 2009 (entropy = 0.35) relative to individuals who had a lower level of education.

In terms of migration, the values of the entropies are lower than those of the other effort variables, which suggests that this variable has little explanatory power. Thus, the fact that an individual is a migrant does not imply a significant improvement in his or her income.

An explanation for the weak effect of migration can be found in the study by Assis, Costa and Mariano (2012), which uses data on non-native migrants, returning migrants, and non-migrants in the states of São Paulo and Bahia, representing the south east and north-east regions, respectively. Their results show that migrants from the north-east region, particularly returnees, have higher income levels than non-migrants. The opposite is the case in São Paulo, however, because the migrants of this state are individuals who have failed to find a place in a more dynamic local market. Accordingly, as this study used data for Brazil as a whole, those effects may have cancelled each other out; and, migration has not been a factor associated with a significant wage difference between the groups at the national level.

Moreover, during the period, the distances (S_p) increased for the variables of labour-market status and weekly hours worked. The values of the entropies for hours worked were higher than those associated with labour-market status in all years, which shows that hours worked explains more of the income inequality between the groups than labour-market status. The trend of the entropies through time reveals a considerable variation in the distances for both variables with respect to the initial year.

[11] The results of the estimations were excluded from the text owing to space constraints. They can be requested from the corresponding author by e-mail.

[12] The values of the entropies for each year of the series are shown in table A.1 of the annex to this article.

TABLE 1

Analysis of parametric specifications

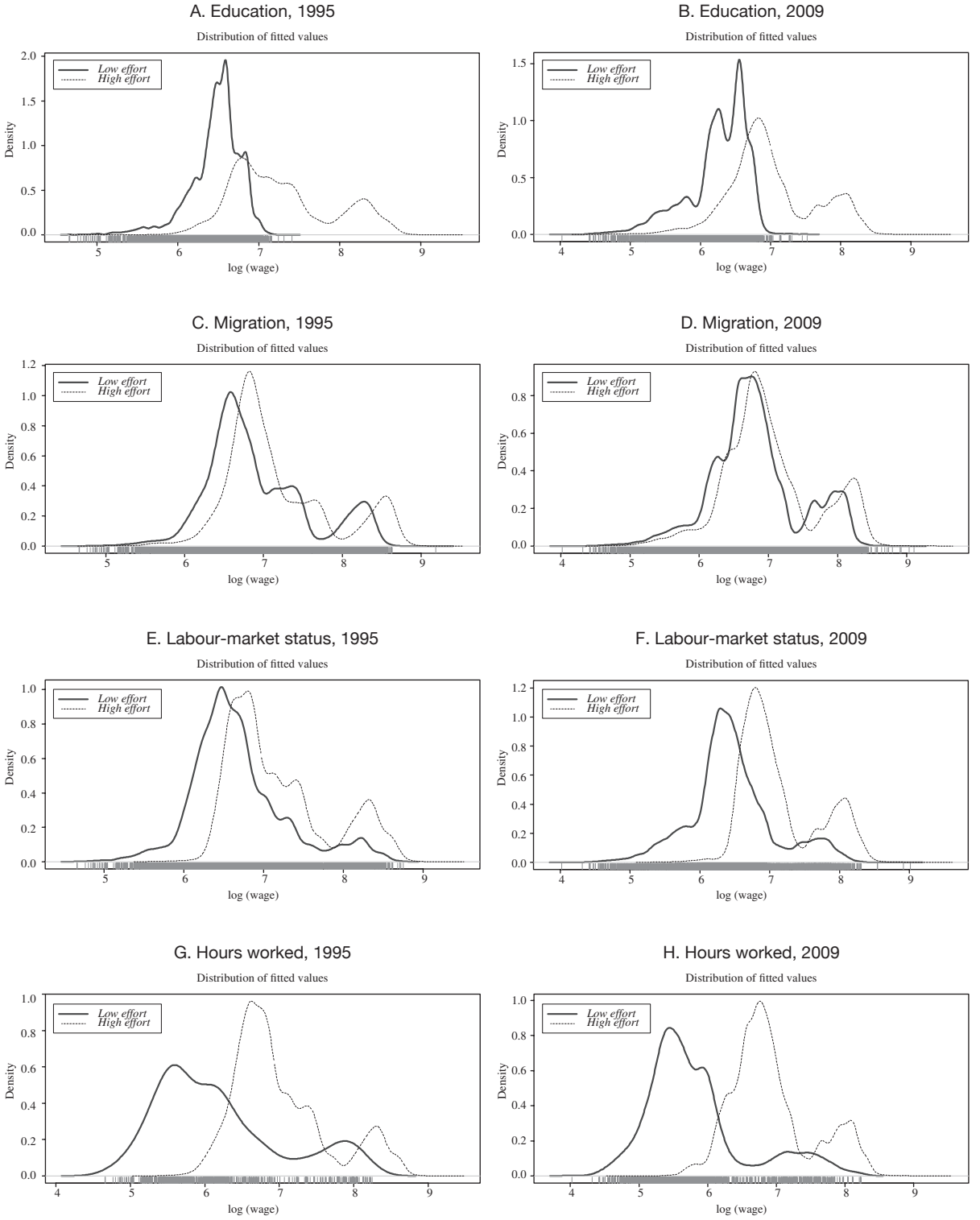
	H_0: perfect parametric specification													
Years	1995	1996	1997	1998	1999	2001	2002	2003	2004	2005	2006	2007	2008	2009
Statistic	34.45*	33.21*	47.62*	64.03*	66.43*	52.54*	66.76*	16.01**	32.43*	45.09*	45.06*	65.92*	15.43**	54.10*

Source: prepared by the authors.

Note: * and **represent rejection of the null hypothesis at the 1% and 5% significance level, respectively.

FIGURE 1

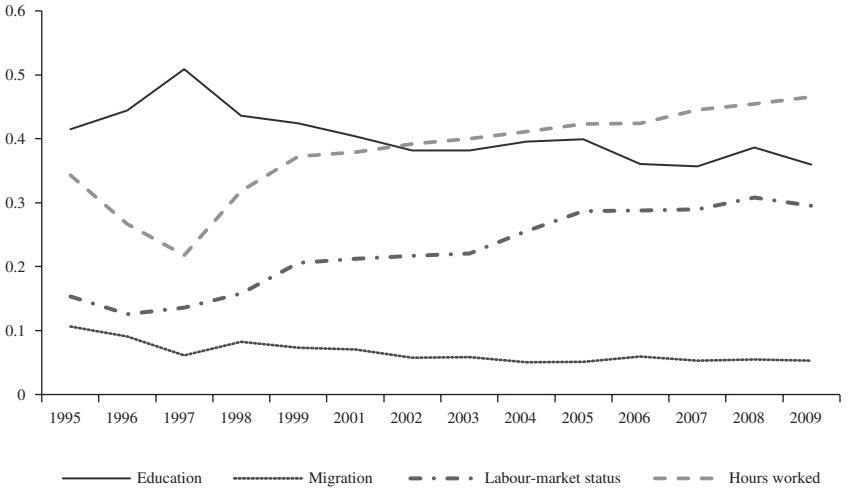
Brazil: non-parametric densities for the fitted values by effort factors, 1995 and 2009



Source: prepared by the authors.

FIGURE 2

Trend of the entropies, 1995-2009



Source: prepared by the authors.

Step 3. The main question in this stage is what impact does the use of non-parametric inferences have on the fairness indicators. Figueiredo and Netto Júnior (2014) propose a method for estimating the indices of unfair inequality in the period between 1995 and 2009. The authors basically use parametric models, although they address issues related to the endogeneity of the equations and the identification of the parameters. It is beyond the scope of this study to propose more robust estimations for the measures of unfair inequality, since topical inferences, parametric or otherwise, can have biases.

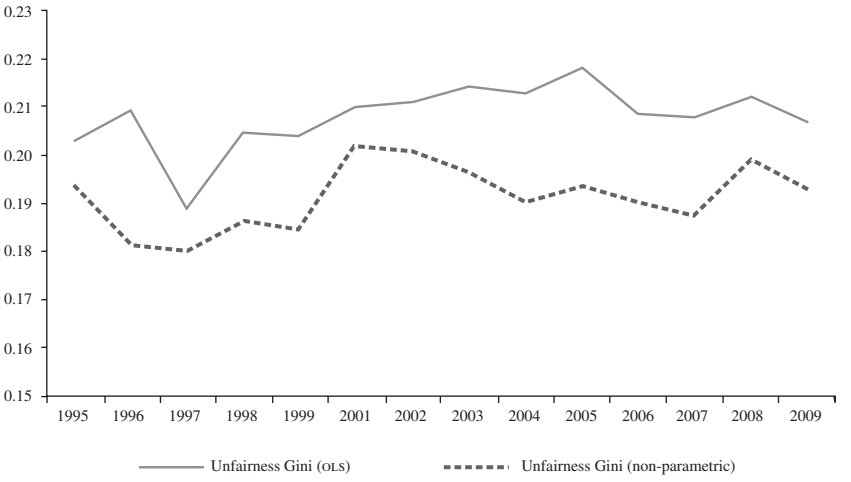
Accordingly, only the comparison of the unfair inequality indices is presented here (see figure 3), calculated on the basis of a parametric specification with these same indicators calculated using the non-parametric method.[13]

It should be noted that the unfair inequality index calculated from specification (2) is always lower than the

[13] See Almås (2008) and Almås and others (2011) for information on the development of the fairnesscriterion and the unfair inequality index.

FIGURE 3

Brazil: indices of unfair inequality, 1995-2009



Source: prepared by the authors.

value calculated by ordinary least squares (OLS), although its behaviour is similar. As there is an average difference of 10% between these inferences, the parametric method tends to overestimate the unfair inequality index.

Step 4. The results shown thus far depend on a fundamental assumption: independence between the responsibility and circumstantial variables. In other words, it is postulated that hours of work, education, the decision to migrate, and labour-market status are not affected by the circumstantial variables, such as family background, gender or race.

That assumption is often made in the bibliography on unequal opportunities (see O'Neill, Sweetman and Van de Gaer, 2001, and Checchi and Peragine, 2009). Nonetheless, recent developments in certain theories of justice alert to the possibility that responsibility factors and non-responsibility factors are not independent (Betts and Roemer, 2005). The study by Bourguignon, Ferreira and Menéndez (2007) is a key empirical reference for that hypothesis. With data on Brazil, these authors show that circumstances have direct and indirect effects on total inequality. The indirect effect reflects the influence of circumstances on effort. In short, circumstances are responsible for about 23% of total inequality: 13 percentage points through the direct effect and 10 percentage points through the indirect effect.

It is therefore possible that the results obtained up to that point in time, were affected by the hypothesis of independence between the two sets of variables. Accordingly, a robustness analysis needs to be performed, based on a simple procedure: the effect of circumstances on effort needs to be isolated, particularly in the years of the study; and whether the omission of circumstantial variables affects the entropies also needs to be analysed.[14]

For the robustness analyses, an equation is estimated in which years of schooling are explained by a set of variables that are outside the scope of individual responsibility. This provides the total number of years of schooling without the effect of circumstances (years of schooling minus years of study predicted by the variables); the entropy distances between the low- and high-effort groups are calculated, considering this new variable; and, lastly, a test is conducted to see whether the distance between the two groups is significant.

The data used in the estimations come from the social supplement of the 1996 PNAD, which summarizes information relating to the circumstances of the individuals, such as education, schooling, and the occupation of the parents of the selected persons (family background). For these years, the effort variables described above are used, along with a vector of circumstantial variables, defined by: (i) a dummy race variable, which takes the value 1 in the case of non-white persons (black, mixed race and indigenous) and zero for whites (including Asiatics); (ii) a dummy variable for the regions, which takes the value 1 if the individual lives in the most dynamic regions of the country (south, south-east and centre-west) and zero otherwise (north and north-east regions); (iii) the education of the father and mother, expressed in years of schooling, and (iv) the father's type of occupation, according to the six categories proposed by Pastore and Silva (2000).[15]

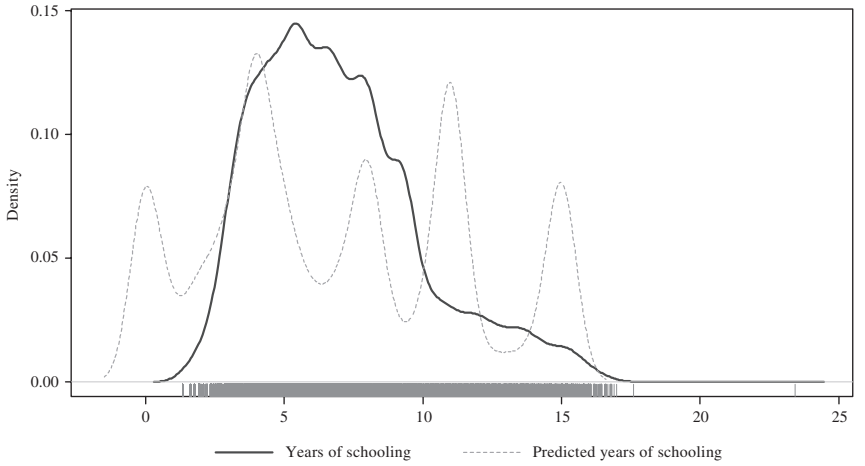
Figure 4 shows the difference between actual and predicted years of schooling (the latter defined as years of schooling controlled for the effect of circumstances). The entropy is calculated on the basis of the creation of the low- and high-effort groups in the variable "predicted years of schooling". Low-effort is assigned to individuals with less than five years of schooling predicted (including the two first modes of the discontinuous plot curve) and high- effort for other individuals. The result of the entropy (0.4023) shows that there has been no significant reduction, compared to the entropy for 1996, without considering the circumstantial variables (entropy = 0.4447). In that regard, while bearing in mind that the two sets of variables, effort and circumstances, are not independent, there is no clear change in the distance between the two effort groups, thereby demonstrating the plausibility of the results described in steps 1 to 3.

[14] This procedure was also used for the other effort variables. The results were similar to those of the "years of schooling" variable, and were eliminated owing to space constraints.

[15] Categories: (1) Lower low level: farm labourer, fisherman, or woodcutter, among others; (2) Upper low level: manual labourer, domestic employee, or security guard, among others; (3) Lower middle level: bricklayer, electrician or carpenter, among others; (4) Middle level: street trader, travelling salesperson or first level manager, among others; (5) Upper middle level; consultant, senior manager or director, among others, and (6) High level: large-scale proprietor, judge or other higher-level occupation.

FIGURE 4

Brazil: difference between years of schooling and predicted years of schooling, 1996



Source: prepared by the authors.

IV
Discussion of the results

As noted above, the entropy metrics represent a measure of the inequality of effort between individuals. By isolating the effect of each variable, the aim is to test its power to explain the income differentials between the groups, as quantified by the distance between the distributions.

Some of the results obtained should be highlighted for their theoretical and practical implications. One of these is the reduction in inequality when education is considered as an effort factor. The role of education in the income distribution can help expand or narrow gaps between individuals, depending on its rate of return and the composition of the population by education level. When describing the structure of income inequality in Brazil, Ferreira and others (2006) suggest that the reduction in total income inequality attributable to education differences reflects the rising education level of the labour force. The increase in the relative supply of individuals with primary and secondary education probably caused a reduction in the average rate of return to education, thereby reducing the wage differential between such persons and those with less education (Menezes-Filho, 2001).

Another factor that could explain that result is the expansion of social income-transfer programmes and the fact that these have targeted the poorest individuals. As many individuals in that segment of the population have few years of schooling, incomes in the low-effort group were raised during the period, so the distance from the high-effort group (higher level of schooling) narrowed. Another possible explanation for the narrowing of the distance between the curves could relate to a fall in the quality of education. Although educational policies have made it possible to increase the population's average number of years schooling, this does not necessarily guarantee higher skill or, therefore, significant wage increases.

The trend of labour-market status reveals an increase in income differentials between formal and informal workers. It is generally believed that the formal sector offers higher wages because of its intrinsic characteristics. Nonetheless, studies such as those of Menezes-Filho, Mendes and De Almeida (2004) provide clear evidence of an self-selection bias, suggesting that the reason why the formal sector offers better wages relates primarily to unobservable individual attributes of the workers themselves.

The results obtained can also be analysed in the light of a number of government policies, including those that have promoted social transfer programs, such as the *Bolsa Família* family subsidy program, and mechanisms for raising the minimum wage, used as tools to reduce income disparities and poverty. Nonetheless,

despite the reduction in inequality in Brazil in recent years, some studies question the effective influence of the succession of minimum wage hikes that have been implemented by the government (Barros, Carvalho and Franco, 2006) and the contribution made by the *Bolsa Família* program (Soares, 2006).

Since the implementation of the Real Plan, the minimum wage has been increased nearly every year. Nonetheless, these real increases have proven ineffective in terms of redistribution, since most individuals who earn the minimum wage are not considered poor under the Brazilian the poverty criterion (Saboia, 2006). An example of this situation is provided by the north-east region, where a large proportion of workers earn incomes below the minimum wage and, therefore, do not benefit when it is raised (Institute of Applied Economic Research-IPEA). According to Giambiagi and Franco (2007), the average real income of workers fell in that period.

Between 1995 and 2009, the minimum wage rose by more than productivity growth (increase in per capita GDP) nearly every year. In 1997, it was raised by 7%, whereas productivity grew by around 3%; and the entropy value with respect to hours worked, as an effort factor, was lowest in that year. That confirms the belief that, given the circumstances, there are few incentives to increase skills and improve labour-market status.

Nonetheless, the minimum wage policy does have a significant effect on the labour market, but most of all in the case of workers in the informal sector of the economy (Menezes-Filho, Rodrigues and De Souza, 2009). In short, while minimum-wage hikes can help reduce poverty, it is also possible to discern negative effects in the labour market when the increases outpace wage-earners' productivity. Maloney (2000) states that the minimum wage is also a significant determinant of employment and wages in the informal sector in most Latin American economies.

V
Final thoughts

This article has analysed the trend of the inequality of opportunities in Brazil between 1995 and 2009, in relation to a set of effort variables. For that purpose, data for the period from the National Household Surveys (PNADs) have been analysed, following a non-parametric approach presented in Racine and Li (2004), both to estimate the income function and to determine the distribution of income between individuals. Two groups were created, one of low effort and another of high effort; and inequality between the two groups was evaluated by using metrics of the entropy distance between the two income levels.

The results reveal a reduction in the explanatory power of years of schooling in the income differential between the groups, and a very weak participation by migration. The robustness analysis for 1996, based on information from that year's PNAD social supplement, revealed that the omission of circumstantial variables for other years, such as family background, did not significantly change the results, thereby corroborating the plausibility of the strategy used. Future improvements to this study could include: an analysis of the true reasons why the education has lost capacity to explain income inequality; an exploration of optimal policies for reducing inequality of opportunities and stimulating differences through effort; and more in- depth discussion of fairness criteria as applied to Brazil.

ANNEX

TABLE A.1

Entropies

Years	Effort factors			
	Education	Migration	Labour-market status	Hours worked
1995	0.4151*	0.1061*	0.1535*	0.3428*
1996	0.4447*	0.0905*	0.1253*	0.2664*
1997	0.5094*	0.0616*	0.1361*	0.2175*
1998	0.4358*	0.0825*	0.1580*	0.3179*
1999	0.4240*	0.0736*	0.2055*	0.3726*
2001	0.4039*	0.0701*	0.2122*	0.3795*
2002	0.3816*	0.0580*	0.2171*	0.3916*
2003	0.3814*	0.0588*	0.2210*	0.3999*
2004	0.3954*	0.0505*	0.2554*	0.4109*
2005	0.3994*	0.0510*	0.2874*	0.4234*
2006	0.3602*	0.0596*	0.2880*	0.4246*
2007	0.3567*	0.0534*	0.2898*	0.4456*
2008	0.3865*	0.0548*	0.3085*	0.4546*
2009	0.3594*	0.0530*	0.2955*	0.4654*

Source: prepared by the authors.

Note: * indicates values that are significant at 1%.

Bibliography

Almås, I. (2008), "Equalizing income versus equalizing opportunity: a comparison of the United States and Germany", *Research on Economic Inequality*, vol. 16, Emerald.

Almås, I. and others (2011), "Measuring unfair (in)equality", *Journal of Public Economics*, vol. 95, No. 7-8, Amsterdam, Elsevier.

Arneson, R. (1989), "Equality and equal opportunity for welfare", *Philosophical Studies*, vol. 56, No. 1, Springer.

Assis, R.S. de, E.M. Costa and J.L. Mariano (2012), "Impacto da migração de não naturais e da migração de retorno sobre a distribuição de renda dos estados da Bahia e de São Paulo: um olhar sobre a inserção desses indivíduos no mercado de trabalho local", *40º Encontro Nacional de Economia* [online] http://www.anpec.org.br/novosite/br/encontro-2012.

Azevedo, J. (2007), "Avaliando a significância estatística da queda na desigualdade no Brasil", *Desigualdade de renda no Brasil: uma análise da queda recente*, R. Barros, M. Foguel and G. Ullysea (orgs.), Brasilia, Institute of Applied Economic Research (IPEA).

Barros, R.P. de, M. Carvalho and S. Franco (2006), "A efetividade do salário mínimo como um instrumento para reduzir a pobreza no Brasil", *Boletim de Conjuntura*, No. 74, Institute of Applied Economic Research (IPEA).

Betts, J. and J. Roemer (2005), "Equalizing Opportunity for Racial and Socioeconomic Groups in the United States through Educational Finance Reform" [online] http://www. escholarship. org/uc/item/0gq4z4m9#page-3.

Bourguignon, F., F. Ferreira and M. Menéndez (2007), "Inequality of opportunity in Brazil", *Review of Income and Wealth*, vol. 53, No. 4, Wiley.

Checchi, D. and V. Peragine (2009), "Regional disparities and inequality of opportunity: the case of Italy", *Journal of Economic Inequality*.

Devooght, K. (2008), "To each the same and to each his own: a proposal to measure responsibility-sensitive income inequality", *Economica*, vol. 75, No. 298.

Dworkin, R. (1981), "What is equality? Part 2: equality of resources", *Philosophy and Public Affairs*, vol. 10, No. 4, Princeton, Princeton University Press.

Ferreira, F. and others (2006), "Ascensão e queda da desgiualdade de renda no Brasil", *Económica*, vol. 8, No. 1.

Figueiredo, E. and J.L. Netto Júnior (2014), "More equal but not so fair: an analysis of Brazilian income distribution from 1995 to 2009", *Empirical Economics*, vol. 46, No. 4, Springer.

Fleurbaey, M. (1998), "Equality among responsible individuals", *Freedom in Economics: New Perspectives in Normative Analysis*, J.-F. Laslier and others (eds.), London, Routledge.

Fleurbaey, M. and F. Maniquet (2011), "Compensation and responsibility", *Handbook of Social Choice and Welfare*, vol. II, K. Arrow, S. Sen and K. Suzumura (eds.), Amsterdam, Elsevier.

Giambiagi, F. and S. Franco (2007), "O esgotamento do papel do salário mínimo como mecanismo de combate à pobreza extrema", *Texto para Discussão*, No. 1290, Rio de Janeiro, Institute of Applied Economic Research (IPEA).

Granger, C., E. Maasoumi and J. Racine (2004), "A dependence metric for possibly nonlinear processes", *Journal of Time Series Analysis*, vol. 25, No. 5, Wiley.

Härdle, W. (1990), *Applied Nonparametric Regression*, Cambridge, Cambridge University Press.

Kranich, L. (1996), "Equitable opportunities: an axiomatic approach", *Journal of Economic Theory*, vol. 71, No. 1, Amsterdam, Elsevier.

Li, Q. and J. Racine (2007), *Nonparametric Econometrics: Theory and Practice*, Princeton, Princeton University Press.

Li, Q., E. Maasoumi and J.S. Racine (2009), "A nonparametric test for equality of distributions with mixed categorical and continuous data", *Journal of Econometrics*, vol. 148, No. 2, Amsterdam, Elsevier.

Maasoumi, E., J. Racine and T. Stengos (2007), "Growth and convergence: a profile of distribution dynamics and mobility", *Journal of Econometrics*, vol. 136, No. 2, Amsterdam, Elsevier.

Machado de Assis, J. (1891), *Quincas Borba*, Rio de Janeiro, B.L. Garnier, Livrero-Editor.

Maloney, W.F. (2000), "A note on minimum wages in Latin America", Washington, D.C., World Bank.

Menezes-Filho, N. (2001), "A evolução da educação no Brasil e seu impacto no mercado de trabalho", Instituto Futuro Brasil, São

Paulo, March [online] http://www.anj.org.br/pje/biblioteca/publicacoes/A%20Evolucao%20da%20educacao%20no%20Brasil%20e%20seu%20impacto%20no%20Mercado%20de%20trabalho.pdf.

Menezes-Filho, N., R. Fernandes and P. Picchetti (2006), "Rising human capital but constant inequality: the education composition effect in Brazil", *Revista Brasileira de Economia*, vol. 60, No. 4, Rio de Janeiro.

Menezes-Filho, N., M. Mendes and S.E. de Almeida (2004), "O diferencial de salários formal-informal no Brasil: segmentação ou viés de seleção?", *Revista Brasileira de Economia*, vol. 58, No. 2, Rio de Janeiro.

Menezes-Filho, N., E. Rodrigues and A. de Souza (2009), "Salário mínimo e desigualdade no Brasil entre 1981-1999: uma abordagem semiparamétrica", *Revista Brasileira de Economia*, vol. 63, No. 3, Rio de Janeiro.

O'Neill, D., O. Sweetman and D. Van de Gaer (2001), "Equality of opportunity and kernel density estimation: an application to intergenerational mobility", *Applying Kernel and Nonparametric Estimation to Economic Topics*, vol. 14, Stanford, JAI Press.

Ooghe, E., E. Schokkaert and D. Van de Gaer (2007), "Equality of opportunity versus equality of opportunity sets", *Social Choice and Welfare*, vol. 28, No. 2, Springer.

Pastore, J. and N. Silva (2000), *Mobilidade social no Brasil*, São Paulo, Macron Books.

Pattanaik, P. and Y. Xu (1990), "On ranking opportunity sets in terms of freedom of choice", *Recherches Économiques de Louvain*, vol. 56, No. 3-4, Catholic University of Louvain.

Racine, J. (2006), "Consistent specification testing of heteroskedastic parametric regression quantile models with mixed data", unpublished.

Racine, J.S. and Q. Li (2004), "Nonparametric estimation of regression functions with both categorical and continuous data", *Journal of Econometrics*, vol. 119, No. 1, Amsterdam, Elsevier.

Roemer, J. (1998), *Equality of Opportunity*, New York, Harvard University Press.

_____ (1996), *Theories of Distributive Justice*, Cambridge, Massachusetts, Harvard University Press.

Saboia, J. (2006), "Salário mínimo e combate à pobreza", *Valor Econômico*.

Salvi, A. (2007), "An empirical approach to the measurement of equality of opportunity", Milan, Università degli Studi di Milano, unpublished.

Soares, S. (2006), "Distribuição de renda no Brasil de 1976 a 2004 com ênfase no período entre 2001 e 2004", *Texto para discussão*, No. 1166, Rio de Janeiro, Institute of Applied Economic Research (IPEA).

Thomson, W. (2011), "Fair allocation rules", *Handbook of Social Choice and Welfare*, vol. 2, K. Arrow, A. Sen and K. Suzumura (eds.), Amsterdam, Elsevier.

A comparative analysis of productivity in Brazilian and Mexican manufacturing industries

Armênio de Souza Rangel and Fernando Garcia de Freitas

ABSTRACT

This article analyses productivity trends in Brazilian and Mexican manufacturing industries between 1995 and 2009, a period in which international competition intensified sharply. A total of 14 manufacturing industries are considered, using two methods based on: (i) the Leontief (1951) model to measure the consumption of intermediate goods used in production; and (ii) the analysis of total factor productivity (TFP). The studies performed show that manufacturing trends have diverged in the two countries. In Mexico, an increased need for imported goods and services was offset by a reduction in domestic goods and service requirements, and an increase in the TFP of production. In the case of Brazil, the fact that manufactured goods markets are more isolated from foreign trade seems to have contributed to a weak productivity performance.

KEYWORDS

Industry, industrial enterprises, manufactures, productivity, comparative analysis, input-output analysis, econometric models, Brazil

JEL CLASSIFICATION

C67, L60, O3, O40, O47

AUTHORS

Armênio de Souza Rangel, doctorate professor of the School of Communications and Arts (ECA) of the University of São Paulo (USP), Brazil. armenio@usp.br

Fernando Garcia de Freitas, economic director of the Brazilian Chamber of Services and economic adviser to the Brazilian Aluminium Association (ABAL). fernando.garcia.freitas@gmail.com

I
Introduction

Over the past two decades, the Mexican and Brazilian economies experienced profound transformations, largely driven by foreign trade. The reduction of import quotas, together with the elimination of non-tariff barriers and trade integration with neighbouring countries, radically changed the structure of the two countries' foreign trade. In manufacturing industry, Brazil and Mexico suddenly faced external competition, particularly from East Asian countries. As noted by Mesquita (2007), the emergence of China on the world industrial stage posed major challenges to the Latin American economies, because the static and dynamic productivity differentials of Chinese manufacturers place enormous constraints on the productive potential of Brazilian and Mexican manufacturing industries.

Following a lengthy growth period, the share of manufacturing industries in Brazilian and Mexican gross domestic product (GDP) fell sharply. According to the statistics and indicators database (CEPALSTAT) of the Economic Commission for Latin America and the Caribbean (ECLAC), manufacturing-industry GDP shares peaked in 1985 at 35.9% in Brazil, and in 1988 at 27% in Mexico. In 1996, manufacturing value added had declined to just 19.6% of Mexican GDP and 14.8% of Brazilian GDP. This loss of GDP share has continued since, albeit at a slower pace: in 2011, manufactured goods represented just 17.8% of Mexico's GDP and 12.4% of Brazil's.[1]

This result was due mainly to the slowdown in industrial growth. Katz (2000) found that manufacturing industry output grew by 3.8% per year in Mexico and by 2.8% per year in Brazil between 1970 and 1996, but growth was slower in the period 1996-2009. Figures from the World Input-Output Database (WIOD, 2012) show that the annual growth rate of manufacturing production fell to 1.2% in Brazil and 1.6% in Mexico, in that period.

Moreover, the slackening of manufacturing productivity growth was even more serious than the decrease in its share. According to the study by Katz (2000), between 1970 and 1996, labour productivity rose by 2.9% per year in Mexican manufacturing industry and by 1.9% per year in the same sector in Brazil. WIOD (2012) data report an increase in value added per worker of just 0.1% per year in the Mexican manufacturing industry between 1996 and 2009, and a much worse situation in Brazil, where value added per worker actually decreased by 1% per year, showing a sharply declining trend of labour productivity.

This study analyses the trend in productivity in Brazilian and Mexican manufacturing industries between 1995 and 2009, a period in which the two economies faced growing international competition. The analysis considers 14 sectors of manufacturing industry: food, beverages and tobacco; textile and textile products; leather and footwear; wood and products of wood; paper and pulp;[2] coke and refined petroleum; chemical products, plastics and rubber; non-metallic mineral products; metallurgy and metal products; machinery and equipment; electrical and optical equipments; transport equipment; and other industrial products.

The productivity trend is analysed in two ways: (i) using the Leontief (1951) model to measure the consumption of intermediate goods used in production, and (ii) through total factor productivity (TFP), which takes account of production factor requirements. The first measure of productivity defines the quantities of goods and services needed to produce one monetary unit of a given manufacture. The analysis allows for comparisons of productivity through time and space; and relative changes in productivities can be identified in the comparison between two countries over time.

Nonetheless, variations in production coefficients through time do not necessarily imply an improvement or worsening of technical and economic conditions in the industrial sector in question. Among other things, an industry's input expenses may rise because certain stages of production are outsourced. If this step is taken to enhance efficiency, the price of the goods may even fall, suggesting a reduction in output value and an apparent loss of productivity. Nonetheless, outsourcing saves on capital and labour in the final activity sector, involving an increase in TFP. In that case, a more detailed

☐ The authors are grateful to an anonymous referee and to professors Ana Lélia Magnabosco and Rogério Cesar de Souza for valuable comments and suggestions made on previous versions of this article.

[1] For further details, see Mesquita (2007).

[2] The paper and pulp sector includes production by the graphics and printing industry.

analysis of productivity should be complemented from the standpoint of the production factors used.

That aspect is highly relevant in the comparison between Brazil and Mexico, since both countries underwent trade liberalization which, in general, increased the share of imported goods and services in industry's intermediate consumption. Brazil also saw intensive outsourcing in manufacturing activities, owing to the rising costs of labour and social protection —processes that had been under way since the early 1990s—. Outsourcing dynamics were also impacted by the degree of economic integration, which was very different in the two countries.

This article is divided into three sections apart from this introduction. Section II compares the industrial productivity of the Brazilian and Mexican economies from the standpoint of the consumption of intermediate inputs, whereas section III analyses TFP. Lastly, section IV summarizes and comments on the results of the analysis and briefly evaluates the influence of economic liberalization on the trend of industrial productivity in the two countries.

II
Input productivity

1. The concept of productivity in input-output analysis

The literature on input-output analysis describes three widely used methods to evaluate technical change: (i) the direct comparison of technical coefficients; (ii) structural decomposition, and (iii) the "rowscaler" method.[3] All three techniques are based on the Leontief model, and their applications use national input-output tables as data sources.

The direct comparison of technical coefficients was suggested by Leontief himself (1951) as a way to evaluate technical change. Considering the basic equation of the Leontief model, $X = (I - A)^{-1}Y = BY$, in which X is the vector of production, Y is the vector of final demand and B is the Leontief matrix, defined as the inverse of the difference between the identity matrix (I) and the technical coefficients matrix (A), the method suggested by Leontief entails directly comparing the a_{ij} of two A matrices, which can differ in time or space.[4] When this is applied to matrices of physical coefficients, the method admits only partial conclusions, because it is impossible to aggregate quantities to identify the characteristics of a sector, for example. Although aggregation is possible in the case of monetary matrices, the method has shortcomings, because it supports evaluation of cost trends only, which could stem from technical changes or shifts in input prices, or both.[5]

Structural decomposition has also been widely used in evaluating technical changes.[6] This method consists of breaking down the sources of the variation in gross production value. Based on the production equation, $X = BY$, the total variation in gross production ΔX can be split into three parts, as shown in the following equation:

$$\Delta X = B\Delta Y + Y\Delta B + \Delta B\Delta Y \qquad (1)$$

According to that expression, differences in the value of production owing to changes in final demand can be estimated by setting the matrix of technical coefficients: $\Delta X = B\Delta Y$. Differences in output value resulting from changes in technical coefficients are obtained by setting the vector of final demand: $\Delta X = Y\Delta B$. With this method, technical change is estimated by the difference in the technical coefficients between the two matrices which, to obtain the same net output, use different amounts of intermediate inputs. The greater the quantity, or value, of those inputs, the lower productivity will be. It is also possible to identify the sectors of the economy which, in the aggregate, record the largest changes between two points in time,[7] and, in turn, the coefficients responsible for the change.

[3] Based on another study by Carter (1980), Feldman, McClain and Palmer (1987) proposed a method for comparing matrices with incomplete data. The study in question describes an adapted version of the original ideas for square matrices, taking account of the direct and indirect effects on the matrices.

[4] The first case would evaluate technical change, whereas the second would estimate the technological differences between two economies with different technologies.

[5] That aggregation reveals the production cost of products or sectors.

[6] On this point, see Lahr and Dietzenbacher (2001).

[7] This is possible only when the matrix is expressed in monetary values.

Structural decomposition can also be used to identify (approximately) the differences between two matrices in time and space. To specifically measure the impact of the technical changes, the vector of final demand of the economy must be set between two periods, allowing only the technical coefficients matrix to vary. Carter (1967) pioneered a study that analysed the technological changes that have taken place in the United States economy, comparing the matrices of 1947 and 1958. Given the vector of final demand for 1962 and the coefficients of the inverse matrices of 1947 and 1958, the author obtained the gross production vector for the sectors of the United States economy compatible with that demand and each period's Leontief matrices. The difference between the two gross production vectors determines the variation in production needed to satisfy the same final demand vector in the two periods. A positive variation would imply a productivity loss, because the same demand would require a larger amount of expenditure to produce the goods or services of the sector in question. In contrast, a negative variation would mean a reduction in expenditure and a consequent increase in productivity. All of the sectors of the economy can be aggregated to determine which of the two matrices is more productive.

Although this method allows for direct comparisons to be made between sectors of two technological matrices, comparing two economies poses a number of problems. This is because the aggregation depends on the composition of the gross production vector which, in turn, depends on the composition of final demand, a variable that is exogenous to the system. Differences in the composition of demand can produce different results. Whereas the share of low-productivity sectors in the economy as a whole tends to decline, the share of high-productivity sectors tends to increase. As a result, attributing the same share to the productive sectors of the two matrices could lead to distortions in the analysis. Carter (1967), for example, imposed the 1962 composition of final demand on the years 1947 and 1958.[8]

Feldman, McClain and Palmer (1987) proposed a "rowscaler" methodology. To explain it, the authors start with two different technological matrices (each one associated with a point in time), and a single vector of final demand. The values of gross output needed to obtain the final demand vector are given by:

$$X^t = A^t X^t + Y = \left(I - A^t\right)^{-1} Y = B^t Y, \quad t = 1, 2 \qquad (2)$$

[8] If Carter (1967) had used a final demand vector with different composition, the result would probably have been different.

The diagonalization of the production vectors obtained in each period generates the diagonal matrices $\hat{X}^t$, which have the values of the production vectors in the leading diagonal, and zeros in the other cells. Multiplying the diagonalized production vector obtained in the first period by that obtained in the second —both based on the same demand but with different technologies— gives expression (3):

$$\Gamma = \hat{X}^2 \left[\hat{X}^1\right]^{-1} \qquad (3)$$

where Γ Is the matrix[9] formed by the γ_{ij} elements. If $\gamma_{ii}^2 > 1$, sector *i* of matrix 2 is less productive than the same sector of matrix 1; if $\gamma_{ii}^2 < 1$, sector *i* of matrix 2 is more productive than the corresponding sector of matrix 1. Lastly, if $\gamma_{ii}^2 = 1$, the two matrices can be said to have the same productivity. In the specific case where the final demand vector is unitary, it is possible to directly compare the direct and indirect coefficients of the inverse Leontief matrix for the two countries. The sum of each of the rows of the Leontief matrix would indicate the direct and indirect quantity of goods and services needed to obtain one unit of good *i* to satisfy final demand.[10]

The foregoing method takes account of the production of all goods needed to satisfy a unitary demand vector, whose elements contain one unit of demand for each good and service in the economy, in other words a vector with unit values in each row. When the aim is to investigate the quantity of goods needed to satisfy the demand for one unit of a given good *i*, the method consists of summing the rows of the Leontief matrix corresponding to that good. That process aggregates the direct and indirect quantities of goods and services needed to produce one unit of the good or service being analysed.

In addition to the three methods described above, input-output analysis also developed a specific methodology to evaluate the trend of TFP, in the tradition

[9] In that matrix, the elements outside the leading diagonal are zero by construction.

[10] This procedure makes it possible to compare the same sectors of different matrices to ascertain whether a specific sector is more or less productive than the equivalent sector in the other economy. It is impossible to determine whether one economy is more or less productive than the other. Only the extreme case where all sectors of one of the matrices are more productive than the respective sectors of the other matrix, would it be possible to state, unequivocally, that one of the matrices is more productive than the other. To compare aggregate production, it would be necessary to set a vector of final demand or production, as proposed by Carter (1967).

of economic growth theories.[11] Nonetheless, the analysis cannot be applied to the international input-output matrix database, because this does not contain information on factor endowments (capital, labour and land) for all the economies. To determine the trend of TFP in the manufacturing sectors of the two countries, the following subsection uses another theoretical approach based on statistical methods.

2. Databases and methodology

The databases used in the analysis are the WIOD (2012) global input-output tables. The tables were constructed as a result of a huge task to make national input-output tables compatible with one another, undertaken by a group of research institutes around the world, coordinated by the University of Groningen.[12] The project, financed by the European Commission and published on the Internet in April 2012, will make a major contribution to deepening understanding of the world economy.[13]

The WIOD has data on national input-output tables for the years between 1995 and 2009, together with estimations of global input-output tables that show international flows of goods and services. The data cover a total of 40 countries, and estimations for the "rest of the world" —the regional grouping created to reconcile national foreign trade flows—. In addition to the national and international matrices, numerous other variables are provided per country, such as factor endowments, price indices, and the functional distribution of income.

This article uses the global input-output tables for 1995-2009 to calculate the productivity vector. These matrices abide by the original Leontief formulation, $X = (I-A)^{-1}Y$, where:

$$X=\begin{bmatrix} X^1 \\ \cdots \\ X^2 \\ \cdots \\ \vdots \\ \cdots \\ X^k \end{bmatrix}, Y=\begin{bmatrix} Y^1 \\ \cdots \\ Y^2 \\ \cdots \\ \vdots \\ \cdots \\ Y^k \end{bmatrix} \text{ and } A=\begin{bmatrix} A^{11} & \vdots & A^{12} & \vdots & \cdots & \vdots & A^{1k} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ A^{21} & \vdots & A^{22} & \vdots & \cdots & \vdots & A^{2k} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ A^{k1} & \vdots & A^{k2} & \vdots & \cdots & \vdots & A^{kk} \end{bmatrix} \quad (4)$$

In expression (4), $X^1, X^2, \ldots, X^k$ are (35 x 1) vectors of national production, each of which contains the output values of the 35 sectors of economic activity covered by the matrix. The vector Y denotes final demand and has the same interpretation. The matrix is formed by 1,681 matrices of technical coefficients (of dimension 35 x 35) which identify the origin (country and sector) and destination (country and sector) of intermediate consumption.[14] Matrix A is calculated by dividing the intermediate consumption matrix, of the same dimension as matrix A, by vector X.

Those data are used to obtain the global Leontief matrix for the years 1995 and 2009, which serves as a basis for calculating the production needed to satisfy one unit of final demand for a given good or service in a specific country. Expression 5 contains the definitions of that matrix, in which N and M indicate the countries, and B^{NM} the sub-matrix of technical coefficients of those two countries. In this system, when N is equal to M, the matrix B^{NM} designates the domestic coefficients of economy N, in other words the quantities of goods produced in economy N that are needed to produce one unit of the good in that economy. When N is different from M, the matrix B^{NM} denotes the external coefficients of economy N: the quantities of goods and services produced in the rest of the world that are needed to produce one unit of the good in economy N.

$$B=\begin{bmatrix} B^{11} & \vdots & B^{12} & \vdots & \cdots & \vdots & B^{1k} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ B^{21} & \vdots & B^{22} & \vdots & \cdots & \vdots & B^{2k} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ B^{k1} & \vdots & B^{k2} & \vdots & \cdots & \vdots & B^{kk} \end{bmatrix}$$

and

$$B^{NM}=\begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1j} \\ b_{21} & b_{22} & \cdots & b_{2j} \\ \vdots & \vdots & \ddots & \vdots \\ b_{i1} & b_{i2} & \cdots & b_{ij} \end{bmatrix}^{NM} \quad (5)$$

As noted above, the production needed to satisfy one unit of demand for a good in a given country is calculated by adding the values of the columns of the Leontief matrix. This can be done directly with respect

[11] On this topic, see Miller and Blair (2009).

[12] The editor in charge is Marcel Timmer of the University of Groningen.

[13] [Online] www.wiod.org/database.

[14] The number of A^{kk} matrices stems from the number of regions in the database (41).

to all economic sectors and countries of interest.[15] The resulting sum can be broken down into two elements representing domestic and external requirements. The domestic requirements are calculated as the sum of the b_{ij} values in the B^{NN} matrix, and the external requirements are calculated as the sum of bij values of the B^{NM} matrices, $N \neq M$. The ratio between the quantities needed in the two countries generates the matrix Γ, whose meaning and interpretation are identical to those presented in subsection 2 of section II. In the following analysis, two other matrices are calculated with those characteristics: Γ^d, which indicates the quantities of domestically produced goods and services that are needed to produce i goods in the two economies; and Γ^e, calculated as the ratio between the quantities of imported goods and services used in the production of *i* goods in the two economies.

This article only presents the values for the Brazilian and Mexican economies in the 14 activity sectors of manufacturing industry mentioned in its introduction. The values of the global input-output tables are expressed in millions of dollars at current prices each year. As the productivity indicators are expressed as monetary units of production of the goods, the inter-temporal comparisons contain variations in both quantities and relative prices, which restrict analysis possibilities. It should be remembered that the analyses do not consider differences in the purchasing power of currencies. In 2009, one dollar in Brazil was equivalent in purchasing power to US$ 1.32 at United States prices, whereas in Mexico, one dollar was worth US$ 2.19 in purchasing-power terms. That meant that a dollar of demand for a given good in Brazil was equivalent to a different amount of that good in Mexico. Nonetheless, relative production studies do not need adjustments for purchasing power parity, since they express relations between production values at a given place and time.

3. Results

Although Brazil's economy is much larger than Mexico's, their manufacturing industries display very similar structures. In 2009, the gross value of industrial output amounted to US$ 940,559 million in Brazil and US$ 470,853 million in Mexico (see table 1). In the Brazilian economy, 73% of gross production value was accounted for by five industries: food, beverages and tobacco; coke and refined petroleum; chemicals; metallurgy and metal products; electrical and optical equipment; and transport equipment. The equivalent share was even greater in the case of Mexico, at 80.5%. The structural change coefficient, which had a value of 0.89 in 2009, illustrates the similarity between the two industrial structures and between the two economies more clearly.[16]

It is also worth highlighting the importance of the food, beverages and tobacco industry in the two countries' industrial structure. This sector accounted for 19.8% of Brazil's gross industrial production value in 2009, and 24.6% in the case of Mexico. The greatest difference between the structures of the two countries corresponds to the electrical and optical equipment sector, which represented almost 15% of Mexican industry in 2009 compared to 6.6% in the case of Brazil.

Table 2 reports productivity indicators for 1995, in terms of the quantities of goods (domestic and imported) needed to produce one monetary unit of the goods of each industry in each country. The last three columns show the ratios between those amounts in the two countries. Taking the data for Brazil as an example, in 1995 the food, beverages and tobacco industry required US$ 2.27 for each dollar of output, representing US$ 0.12 in imported goods and services plus US$ 2.14 of goods and services produced domestically. In Mexico, to produce one dollar of food, beverages and tobacco required US$ 2.22 of production in all sectors of the economy —US$ 0.32 of imported goods and services, and US$ 1.90 of domestic production.

The ratio between the two coefficients of production in the food, beverages and tobacco sector was 1.02 in 1995, which shows that the Brazilian industry was slightly less productive than its Mexican counterpart. Table 2 also reports the values of the leading diagonal of the Γ^d matrix, which relates the quantities of domestically produced goods and services that are needed for the production of food and beverages in the two economies. In the case of the food, beverages and tobacco industry, the ratio was 1.13. This means that the Brazilian food and beverages industry required more monetary units of domestic production than its Mexican equivalent, and that the productive chain in Mexico also required more imports.[17]

[15] This is equivalent to calculating the value of *X* needed to satisfy a unit vector *Y*.

[16] Coefficient of correlation between the distribution (percentage) of gross production value between the two economies.

[17] Those calculations do not include imports of manufactured food and beverages by the two countries, but only the imports of raw materials (goods and services) needed to produce one monetary unit of the goods in question.

TABLE 1

Brazil and Mexico: gross industrial production value, 2009
(US$ million)

Sector	Brazil	Percentage	Mexico	Percentage	Total	Percentage
Food, beverages and tobacco	186 480	19.8	115 636	24.6	302 136	21.4
Textiles and textile products	42 162	4.5	14 380	3.1	56 546	4.0
Leather and footwear	14 037	1.5	4 511	1.0	18 549	1.3
Wood and products of wood	11 825	1.3	3 588	0.8	15 414	1.1
Paper and pulp	44 507	4.7	17 294	3.7	61 806	4.4
Coker and oil refining	92 996	9.9	39 495	8.4	132 502	9.4
Chemical products	111 678	11.9	45 287	9.6	156 977	11.1
Plastics and rubber	32 121	3.4	12 030	2.6	44 155	3.1
Nonmetallic mineral products	26 381	2.8	16 156	3.4	42 540	3.0
Metallurgy and metal products	113 573	12.1	46 327	9.8	159 912	11.3
Machinery and equipment	59 588	6.3	9 672	2.1	69 266	4.9
Electrical and optical equipment	62 065	6.6	70 421	15.0	132 493	9.4
Transport equipment	119 805	12.7	61 750	13.1	181 568	12.9
Other industrial products	23 341	2.5	14 306	3.0	37 650	2.7
Total	940 559	100.0	470 853	100.0	1 411 512	100.0

Source: prepared by the authors, on the basis of information from the World Input-Output Database (WIOD).

The data of table 2 show that, in 1995, 10 segments of Brazilian industry were more productive than their counterparts in Mexico, namely: textiles and textile products; wood and products of wood; paper and pulp; chemical products; plastics and rubber; metallurgy and metallic products; machinery and equipment; electrical and optical equipment; transport equipment; and other industrial products. Only in the leather and footwear, non-metallic mineral products, and coke and refined petroleum sectors did the productivity of Mexican industry greatly exceed that of Brazil. In the specific case of coke and refined petroleum, the productivity difference was largely due to the greater need for imports in Brazilian industry, which was not yet self-sufficient in oil production.

The data of figure 3 show a very different situation in 2009, because Mexico's industry had overtaken Brazil's in productivity terms. All industrial segments,

TABLE 2

Brazil and Mexico: input requirements and relative productivity, 1995

Industrial sectors	Production needed						Γ		
	Brazil			Mexico					
	Total	Domestic	External	Total	Domestic	External	Total	Domestic	External
Food, beverages and tobacco	2.2676	2.1436	0.1241	2.2244	1.8975	0.3269	1.0194	1.1297	0.3795
Textiles and textile products	1.9997	1.8188	0.1809	2.3634	1.8648	0.4987	0.8461	0.9753	0.3628
Leather and footwear	2.4597	2.2514	0.2084	2.3231	1.9371	0.3860	1.0588	1.1622	0.5398
Wood and products of wood	1.8489	1.7591	0.0898	2.1605	1.8841	0.2764	0.8558	0.9337	0.3249
Paper and pulp	2.0535	1.8796	0.1739	2.0616	1.6402	0.4214	0.9961	1.1459	0.4127
Coker and oil refining	2.5341	2.1945	0.3397	2.1276	1.9858	0.1418	1.1911	1.1051	2.3953
Chemical products	2.1038	1.8931	0.2107	2.1552	1.8632	0.2920	0.9762	1.0161	0.7215
Plastics and rubber	2.2005	1.9492	0.2513	2.3242	1.7562	0.5679	0.9468	1.1099	0.4425
Nonmetallic mineral products	1.9870	1.8371	0.1499	1.8275	1.5988	0.2287	1.0872	1.1490	0.6554
Metallurgy and metal products	2.1255	1.9193	0.2062	2.3187	1.7878	0.5309	0.9167	1.0736	0.3884
Machinery and equipment	2.1956	1.9914	0.2043	2.2692	1.5589	0.7104	0.9676	1.2775	0.2875
Electrical and optical equipment	2.3319	2.0319	0.3000	2.7552	1.4770	1.2782	0.8464	1.3757	0.2347
Transport equipment	2.4428	2.1795	0.2633	2.4756	1.6337	0.8419	0.9867	1.3341	0.3127
Other industrial products	1.9878	1.8411	0.1467	2.3174	1.6576	0.6598	0.8578	1.1107	0.2224

Source: prepared by the authors, on the basis of information from the World Input-Output Database (WIOD).

apart from the textile products, electrical and optical equipment, and other industrial products industries were less productive in Brazil than in Mexico. Those three sectors were already more productive in Brazil in 1995, and the advantages with respect to Mexico had diminished in two of them by 2009. In contrast, the four sectors of Mexican industry that were more productive in 1995 had actually increased their advantage by 2009.

In this situation, it is natural to ask how a team that won a match 10-4 can lose a second one 3-11? Table 4, which reports the rates of change of the indicators shown in the previous tables between 1995 and 2009, answers that question. Comparing the data for the two reference years, there are significant changes in the goods and services requirements in the two countries; and Brazilian industry recorded greater increases in all sectors, except electrical equipment.

In Brazil, requirements increased in all industrial sectors, except for the leather and footwear industry. This indicates a loss of productivity, which could represent both a physical decline and an adverse trend in relative prices. In the Mexican case, there were considerable productivity gains in eight of the 14 manufacturing industries between 1995 and 2009. The productivity loss in the other sectors was less than in Brazilian industry, except in the case of electrical equipment. Another important characteristic of Mexican industry is that the growth in imported goods and service requirements was offset by a reduction in requirements for domestic goods and services. Thus, compared to the Brazilian case, the productivity of Mexican industry evolved by replacing domestic raw materials with imports, in other words, that trade liberalization generated larger productivity gains in Mexico than in Brazil.[18]

[18] The only exception to that rule was the coke and refined petroleum industry.

TABLE 3

Brazil and Mexico: input requirements and relative productivity, 2009

Industrial sectors	Production needed						Γ		
	Brazil			Mexico					
	Total	Domestic	External	Total	Domestic	External	Total	Domestic	External
Food, beverages and tobacco	2.5257	2.3525	0.1732	2.1461	1.7900	0.3560	1.1769	1.3142	0.4864
Textiles and textile products	2.1539	1.9064	0.2475	2.2520	1.6807	0.5713	0.9564	1.1343	0.4332
Leather and footwear	2.3820	2.1767	0.2054	2.1947	1.7799	0.4148	1.0854	1.2229	0.4952
Wood and products of wood	2.1030	1.9517	0.1514	2.0346	1.7229	0.3117	1.0336	1.1328	0.4855
Paper and pulp	2.1271	1.9196	0.2075	2.0509	1.6050	0.4460	1.0371	1.1960	0.4653
Coker and oil refining	2.7676	2.3908	0.3768	2.2069	1.9969	0.2100	1.2541	1.1973	1.7941
Chemical products	2.5001	2.1684	0.3317	2.1988	1.7836	0.4152	1.1370	1.2157	0.7990
Plastics and rubber	2.4443	2.0914	0.3530	2.3837	1.6912	0.6925	1.0254	1.2366	0.5097
Nonmetallic mineral products	2.2249	2.0207	0.2042	1.8193	1.5656	0.2537	1.2230	1.2907	0.8049
Metallurgy and metal products	2.3269	2.0570	0.2700	2.2955	1.6944	0.6012	1.0137	1.2140	0.4491
Machinery and equipment	2.4189	2.1234	0.2955	2.3393	1.5334	0.8059	1.0341	1.3848	0.3667
Electrical and optical equipment	2.5327	2.0422	0.4905	3.0350	1.4594	1.5756	0.8345	1.3993	0.3113
Transport equipment	2.7291	2.3044	0.4246	2.4459	1.5720	0.8739	1.1158	1.4659	0.4859
Other industrial products	2.1408	1.9348	0.2060	2.3324	1.5828	0.7496	0.9178	1.2224	0.2748

Source: prepared by the authors, on the basis of information from the World Input-Output Database (WIOD).

TABLE 4

Brazil and Mexico: variation in input requirements and relative productivity, from 1995 to 2009
(Percentages)

Industrial sectors	Production needed						Γ		
	Brasil			México					
	Total	Domestic	External	Total	Domestic	External	Total	Domestic	External
Food, beverages and tobacco	11.4	9.7	39.6	-3.5	-5.7	8.9	15.4	16.3	28.2
Textiles and textile products	7.7	4.8	36.8	-4.7	-9.9	14.6	13.0	16.3	19.4
Leather and footwear	-3.2	-3.3	-1.4	-5.5	-8.1	7.5	2.5	5.2	-8.3
Wood and products of wood	13.7	10.9	68.5	-5.8	-8.6	12.8	20.8	21.3	49.4
Paper and pulp	3.6	2.1	19.3	-0.5	-2.1	5.8	4.1	4.4	12.7
Coker and oil refining	9.2	8.9	10.9	3.7	0.6	48.1	5.3	8.3	-25.1
Chemical products	18.8	14.5	57.5	2.0	-4.3	42.2	16.5	19.7	10.7
Plastics and rubber	11.1	7.3	40.4	2.6	-3.7	21.9	8.3	11.4	15.2
Nonmetallic mineral products	12.0	10.0	36.2	-0.5	-2.1	10.9	12.5	12.3	22.8
Metallurgy and metal products	9.5	7.2	30.9	-1.0	-5.2	13.2	10.6	13.1	15.6
Machinery and equipment	10.2	6.6	44.7	3.1	-1.6	13.4	6.9	8.4	27.5
Electrical and optical equipment	8.6	0.5	63.5	10.2	-1.2	23.3	-1.4	1.7	32.7
Transport equipment	11.7	5.7	61.3	-1.2	-3.8	3.8	13.1	9.9	55.4
Other industrial products	7.7	5.1	40.4	0.6	-4.5	13.6	7.0	10.1	23.5

Source: prepared by the authors, on the basis of information from the World Input-Output Database (WIOD).

III
Factor productivity

As it is impossible to apply input-output matrix analysis owing to the lack of data on factor endowments (capital, labour and land) in the set of countries forming the area referred to as "rest of the world" in the WIOD, factor productivity in the 14 industrial sectors of Brazil and Mexico was evaluated using a different approach.

In this case, TFP was calculated on the basis of the "Solow residual" (Solow, 1957). To improve the analysis of productivity trends, separating the effects of demand and supply crises on that indicator from longer-term trends (such as technological progress and economies of scale), a complementary statistical approach was used. This firstly involves fitting a production function and then using the estimated coefficients to calculate productivity by means of a decomposition. Under this approach, the productivity trend is the portion of GDP growth that is explained neither by factor accumulation —a concept present in the Solow (1957) approach— nor by specific random phenomena.[19]

1. Production frontier and decomposition of productivity

This study adopted the stochastic-frontier econometric approach to fit the production function. This approach

[19] It is not necessary to estimate a production function to calculate TFP. The calculation can be based on statistics of the trend of GDP, factor endowments and the factor shares in the functional distribution of income. Nonetheless, a strictly accounting approach accentuates the effects of supply and demand crises in the measurement of productivity trends. Econometric approaches, on the other hand, make it possible to remove random phenomena from the variations in GDP and factor endowments, and, depending on the technique, measurement errors. In general, those approaches produce more stable TFP estimations with more plausible economic interpretations.

has been, widely applied in microeconomic studies and was used with satisfactory results in recent studies for the international comparisons of factor productivity at more aggregate levels. On this point, see Kneller and Stevens (2003); Kumbhakar and Wang (2005); Garcia, Souza and Pires (2008), and Pires and Garcia (2012).

The first advantage of the approach is that the productivity difference between two economies is not restricted to technological differences. The stochastic production frontier admits the possibility of inefficiency in production and, therefore, that there may be productivity differences between two economies that operate at the same technological level. Another advantage is that, when panel data are used, the stochastic frontier produces better estimates then ordinary least squares (OLS) in the absence of heterogeneity controls.[20] This is because it is based on an error component model that makes it possible to separate random phenomena from those that can be attributed to omitted factors, such as the output gap caused by labour unemployment.

Expression (6) defines the stochastic production frontier as a production function fitted through a theoretical measure of technical inefficiency.

$$Y_{it} = F\left(B_t, K_{it}, H_{it}, L_{it}\right) \cdot exp\left(-u_i\right), \quad i = 1, 2, ..., N \text{ and } t = 1, ..., T \tag{6}$$

This expression uses the following definitions:

- Y_{it} is industrial value added in country i at time t;
- F is the production function;
- K_{it}, H_{it} and L_{it} are the quantities of capital, skilled labour and unskilled labour used by the industry of country i at time t;
- B_t is the level of productivity reflecting optimal practice at time t, and
- $u_{it} \geq 0$ is the measure of technical inefficiency of the industry of country i at a time t.

Based on the stochastic production frontier, the Bauer-Kumbhakar decomposition of the trend of TFP is performed (see Kumbhakar, Denny and Fuss, 2000), to identify four sources of productivity variation: technical progress, variation in technical inefficiency, variation of allocative inefficiency, and economies of scale. The decomposition also makes it possible to interpret the trend of TFP more precisely and to identify different patterns. For example, although two economies may display the same TFP growth rate, in one case the increase may stem from technological progress and in the other from economies of scale, which are very different economic processes.

In mathematical terms, the decomposition of the productivity trend under the production-frontier model is obtained by differentiating that frontier with respect to time. Following numerous algebraic manipulations, the time differential of the production frontier gives equation (7), which expresses the rate of growth of industrial value added in a given country i at a time t, as the sum, weighted by the respective elasticities (ε), of the rates of: (i) variation in optimal practice, also known as the rate of technological progress; (ii) factor accumulation (capital, skilled and unskilled labour), and (iii) variation in technical inefficiency.

$$\frac{\dot{Y}_{it}}{Y_{it}} = \varepsilon_B \cdot \frac{\dot{B}_{it}}{B_{it}} + \varepsilon_K \cdot \frac{\dot{K}_{it}}{K_{it}} + \varepsilon_H \cdot \frac{\dot{H}_{it}}{H_{it}} + \varepsilon_L \cdot \frac{\dot{L}_{it}}{L_{it}} - \dot{u}_{it} \tag{7}$$

Assuming Hicks-neutral technology which means that $\varepsilon_B = 1$, and using the TFP definition established by equation (8) —the Solow residual— in which S_j is the share of productive factor j in the functional distribution of income, it is possible to find a new decomposition for the variation of TFP.

$$\frac{\dot{A}_{it}}{A_{it}} = \frac{\dot{Y}_{it}}{Y_{it}} - S_K \cdot \frac{\dot{K}_{it}}{K_{it}} - S_H \cdot \frac{\dot{H}_{it}}{H_{it}} - S_L \cdot \frac{\dot{L}_{it}}{L_{it}} \tag{8}$$

Combining (7) and (8), gives:

$$\frac{\dot{A}_{it}}{A_{it}} = \frac{\dot{B}_{it}}{B_{it}} + \left(\varepsilon_K - S_K\right) \cdot \frac{\dot{K}_{it}}{K_{it}} + \left(\varepsilon_L - S_L\right) \cdot \frac{\dot{L}_{it}}{L_{it}} + \left(\varepsilon_H - S_H\right) \cdot \frac{\dot{H}_{it}}{H_{it}} - \dot{u}_{it} \tag{9}$$

A transformation can be applied to simplify the foregoing expression (9) and isolate the components of the rate of change of TFP. Defining:

$$RTS = \sum\nolimits_j \varepsilon_j \text{ and } \lambda_j = \frac{\varepsilon_j}{RTS}, \; j = K, H, L,$$

[20] As shown in Garcia, Souza and Pires (2008), aggregate production functions which control the heterogeneity produce estimations without economic meaning; for example, the African economies would show the highest rate of technological progress while the industrial economies would display regression or stagnation. This happens because there is a very close linear link between capital, technology and the quantity of labour used, because the technologies are embedded in the capital.

in which *RTS* denotes returns to scale, gives equation (10):

$$\frac{\dot{A}_{it}}{A_{it}} = \frac{\dot{B}_{it}}{B_{it}} - \dot{u}_{it} + \left(RTS - 1\right)\cdot\left[\lambda_K \cdot \frac{\dot{K}_{it}}{K_{it}} + \lambda_H \cdot \frac{\dot{H}_{it}}{H_{it}} + \lambda_L \cdot \frac{\dot{L}_{it}}{L_{it}}\right] + \left[\left(\lambda_K - S_K\right)\cdot\frac{\dot{K}_{it}}{K_{it}} + \left(\lambda_H - S_H\right)\cdot\frac{\dot{H}_{it}}{H_{it}} + \left(\lambda_L - S_L\right)\cdot\frac{\dot{L}_{it}}{L_{it}}\right] \quad (10)$$

which states that the rate of change of TFP can be broken down into four components:

(i) technical progress measured by $\dot{B}_{it}/B_{it}$;

(ii) change in technical efficiency approximated by $-\dot{u}_{it}$;

(iii) change in productivity owing to the effect of a change in the scale of production, calculated by

$$\left(RTS - 1\right)\cdot\left[\lambda_K \cdot \frac{\dot{K}_{it}}{K_{it}} + \lambda_H \cdot \frac{\dot{H}_{it}}{H_{it}} + \lambda_L \cdot \frac{\dot{L}_{it}}{L_{it}}\right],$$

(iv) change in allocative efficiency, measured by

$$\left[\left(\lambda_K - S_K\right)\cdot\frac{\dot{K}_{it}}{K_{it}} + \left(\lambda_H - S_H\right)\cdot\frac{\dot{H}_{it}}{H_{it}} + \left(\lambda_L - S_L\right)\cdot\frac{\dot{L}_{it}}{L_{it}}\right]$$

Under constant returns to scale, *RTS = 1*, so the third component of the productivity change is cancelled out; but if *RTS* differs from 1, part of the variation in productivity is explained by the change in the scale of production. Moreover, if the ratios between the elasticities and *RTS* (λ_j) are equivalent to the respective factor shares in the functional distribution of income (S_j), then the industry is efficient in terms of factor allocation. In that case, by definition, there are no productivity changes attributed to changes in the allocation of factors. Lastly, in this model, technical progress accounts for at least as much of the variation in productivity. Only when there are no technical or allocative inefficiencies, or increasing or decreasing returns to scale, is the measure of the variation of productivity, $\dot{A}/A$, identical to technical progress, $\dot{B}/B$. This approach thus covers a larger number of possible situations, without very arbitrary restrictions on the shape of the production function and its properties.

2. Databases and econometric model

The data used in the analysis also come from the WIOD and relate to the 14 manufacturing industries analysed above. For each industrial sector, a stochastic frontier is estimated based on the data from 40 countries with regard to value added (Y_{it}), capital endowment (K_{it}), hours of skilled labour employed (H_{it}) and hours of unskilled labour employed (L_{it}) between 1995 and 2009. Hours of skilled labour employed are equivalent to the sum of the number of hours worked by medium- and high-skilled workers. The monetary values are expressed in constant 1995 dollars.[21] As the analyses were conducted at the industrial-sector level, the data were not adjusted for purchasing power parity, as is more frequent in aggregate macroeconomic analyses.

The econometric model estimated is a translog function of the value added of the three factors of production and time (t), which captures the trend of the frontier. The function in question, described in equation (11), has 14 explanatory variables: the levels of factors of production and time (K_{it}, H_{it}, L_{it} and t), the squares of the factors of production and time (K_{it}^2, H_{it}^2, L_{it}^2 and t^2) and the interactions between them ($K_{it}.H_{it}$, $K_{it}.L_{it}$, $K_{it}.t$, $H_{it}.L_{it}$, $H_{it}.t$ and $L_{it}.t$). The variables u_{it} and v_{it} are the model's error components: the first of these measures technical inefficiency and has a distribution $u_{it} \sim i.i.d\ N^{+}\left(\mu, \sigma_u^2\right)$; and the second is the random error with distribution $v_{it} \sim i.i.d\ N\left(0, \sigma_v^2\right)$. The values of all variables (except time) are expressed in natural logarithms and are deviations from the mean of each series (including time), such that the estimated coefficients of each regression are fitted to the sample mean.

$$\begin{aligned} ln\, y_{it} = {} & \beta_0 + \beta_t.t + \beta_K ln\, K_{it} + \beta_L ln\, L_{it} + \beta_H ln\, H_{it} \\ & + 1/2\cdot\beta_{tt}.t^2 + 1/2\cdot\beta_{KK}\left(ln\, K_{it}\right)^2 \\ & + 1/2\cdot\beta_{LL}\left(ln\, L_{it}\right)^2 + 1/2\cdot\beta_{HH}\left(ln\, H_{it}\right)^2 \\ & + \beta_{Kt}\left[\left(ln\, K_{it}\right)\cdot t\right] + \beta_{KL}\left[\left(ln\, K_{it}\right)\cdot\left(ln\, L_{it}\right)\right] \\ & + \beta_{KH}\left[\left(ln\, K_{it}\right)\cdot\left(ln\, H_{it}\right)\right] + \beta_{Lt}\left[\left(ln\, L_{it}\right)\cdot t\right] \\ & + \beta_{LH}\left[\left(ln\, L_{it}\right)\cdot\left(ln\, H_{it}\right)\right] + \beta_{Ht}\left[\left(ln\, H_{it}\right)\cdot t\right] \\ & + v_{it} - u_{it} \end{aligned} \quad (11)$$

As proposed by Garcia, Souza and Pires (2008), no coefficients are included to control for heterogeneity between countries. Given the high correlation that exists between the dummy variables and the explanatory variables, that procedure generally distorts the estimates of technical efficiency and technological progress. It is

[21] Although the total number of observations is 585, owing to the lack of data on the capital endowment in some countries, the number of effective observations in the panels varies between 570 and 547.

therefore assumed that any heterogeneity in the industrial sectors of the sample countries can be captured through the model's explanatory variables and the technical inefficiency component.

The trend of TFP is estimated using equation (8). As there is no information on labour remuneration by skill level in the WIOD, the expression was simplified to encompass the total variation in hours worked, without prejudice to the concepts defined in the foregoing section. Technological progress and the elasticities of value added with respect to each factor of production are given by equations (12) and (13). By construction, the elasticities and technical progress of a given activity sector vary through time and across countries. The variation in allocative efficiency was obtained as a residual —by definition, that measure is the variation in TFP, having discounted technical progress, technical efficiency and economies of scale.

$$TC = \frac{\dot{B}_{it}}{B_{it}} = \beta_t + \beta_{tt} \cdot t + \beta_{tK} \cdot K_{it} + \beta_{tH} \cdot H_{it} + \beta_{tL} \cdot L_{it} \quad (12)$$

$$\varepsilon_j = \beta_j + \beta_{jK} \cdot K_{it} + \beta_{jH} \cdot H_{it} + \beta_{jL} \cdot L_{it} + \beta_{jt} \cdot t, \quad j = K, H, L \quad (13)$$

Table 5 reports on the estimations of the coefficients of the production frontiers of the 14 industrial sectors for the 40 countries in the sample between 1995 and 2009. In nine of the 14 sectors the variance of the error term u_{it} is significantly different from zero, which indicates productive inefficiency. In the other sectors, inefficiency is relatively minor, and random deviations from the production frontier predominate. As the variance of u_{it} tends to zero in the model of the machinery and equipment sector, it was estimated using OLS.

Most of the coefficients are significantly different from zero at the 10% significance level in all models, which shows that the translog model is appropriate as a generic specification of the frontiers. Moreover, the presence of non-significant coefficients is foreseen in this type of analysis, since the number of observations (maximum 570) is relatively small for the set of parameters to be estimated (14).

3. Results

Based on the foregoing estimations, the mean elasticities of the factors of production were firstly calculated in each of the 14 industrial sectors of Brazil and Mexico, along with the average rate of technological progress. Those data were augmented by the estimations of technical efficiency to evaluate the trend of TFP and its components in the two countries between 1995 and 2009. Table 6 shows the estimations for each of the industries in Mexico and Brazil.

As can be seen, the patterns of capital accumulation and the trend of productivity differ greatly between the two countries. In nearly all industrial sectors, capital accumulation rates are higher in Brazil than in Mexico. A similar pattern can be seen in the use of skilled labour, as employment growth is higher in Brazil. This trend is partly offset by a larger reduction in unskilled employment in Brazil than in Mexico, which indicates a more intensive rate of substitution of labour by capital and human capital in Brazil, probably reflecting the sharp rise in labour costs in that country. According to WIOD data, the average value of real wages[22] in Brazil grew by 3.1% per year between 1995 and 2009, compared to a reduction of 0.9% per year in Mexico.

The counterpart of the slower pace of factor accumulation in Mexico was more vigorous growth of TFP. Mexico's industries generally recorded higher TFP growth rates, except for the textile products, chemicals and machinery and equipment industries.

In terms of the components of TFP, the situation is quite varied. In Mexico, technological progress between 1995 and 2009 was positive in all industrial sectors except for five. In Brazil, however, eight of the 14 sectors posted negative rates of technological progress, probably owing to the recomposition of production within each sector, involving the retreat of higher value added product lines and specialization in products of lower technological content. The reduction in manufacturing industry value added per hour worked, mentioned in the introduction to this article, corroborates that idea. Also important is the influence of the general economic situation in 2009, the last year of the comparison, because the global recession hit the prices of several industrial products, with effects on industrial value added.

The trend of technical efficiency is also worse in Brazil than in Mexico in 10 of the 14 sectors analysed. The situation is even more serious in terms of economies of scale: as shown in table 6, Brazil lags behind Mexico in 11 out of the 14 industrial sectors. This is probably affected by Mexico's trade integration with the United States and Canada, which considerably expands the scale of businesses in the country. In the case of allocative

[22] Variation over and above the inflation rate (consumer prices).

TABLE 5

Brazil and Mexico: estimations of stochastic frontiers, 14 industrial sectors, coefficients and *p*-value

Industrial sectors	Translog coefficients														Statistics		
	K	L	H	t	KK	KL	KH	Kt	LL	LH	Lt	HH	Ht	tt	Lns^2v	lns^2u	log of MV
Food, beverages and tobacco	1.0165	-0.0843	0.1012	-0.0168	-0.1821	-0.1180	0.2036	0.0071	0.0170	0.0388	-0.0005	-0.1652	0.0001	-0.0002	-1.6480	-9.1544	
p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1640	0.5950	0.1360	0.9100	0.0000	0.9820	0.9420	0.0000	0.8930	-339.172
Textiles and textile products	0.9299	-0.0189	0.0706	-0.0136	-0.2966	0.0553	0.1797	0.0034	-0.0003	-0.0236	0.0018	-0.1318	0.0012	-0.0038	-2.8526	-2.4878	
p-value	0.0000	0.2870	0.0000	0.0000	0.0000	0.0000	0.0000	0.2950	0.9900	0.2480	0.5390	0.0000	0.7170	0.0230	0.0000	0.0000	-113.743
Leather and footwear	0.7813	0.0703	0.0428	-0.0116	-0.1854	-0.0319	0.1850	-0.0082	-0.0536	0.1015	0.0012	-0.2908	0.0091	-0.0016	-2.4084	-0.8007	
p-value	0.0000	0.0090	0.0970	0.0550	0.0000	0.2490	0.0000	0.1230	0.1760	0.0020	0.8040	0.0000	0.0910	0.5320	0.0000	0.0000	-393.624
Wood and products of wood	0.9257	-0.1046	0.1795	-0.0207	-0.2431	-0.0250	0.2325	0.0102	0.0661	-0.0168	-0.0101	-0.1817	-0.0009	-0.0031	-2.8903	-0.8582	
p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.1960	0.0000	0.0400	0.0260	0.4910	0.0060	0.0000	0.8590	0.1670	0.0000	0.0000	-341.101
Paper and pulp	0.8537	-0.0208	0.1417	-0.0100	-0.3205	-0.0162	0.2381	-0.0053	-0.0212	0.0206	0.0040	-0.2103	0.0063	-0.0015	-2.0437	-1.2604	
p-value	0.0000	0.3050	0.0000	0.0470	0.0000	0.4900	0.0000	0.3180	0.3890	0.4110	0.3400	0.0000	0.2170	0.5530	0.0000	0.0000	-388.657
Coker and oil refining	0.6201	0.3131	0.1780	0.0010	0.0758	-0.1653	0.1291	-0.0069	-0.1278	0.1182	-0.0083	-0.1870	0.0129	0.0012	-1.4531	0.0953	
p-value	0.0000	0.0000	0.0000	0.9070	0.0000	0.0000	0.0000	0.1810	0.0000	0.0000	0.1680	0.0000	0.0570	0.7670	0.0000	0.5160	-638.375
Chemical products	1.0143	-0.0226	-0.0082	-0.0001	-0.0589	-0.0747	0.1197	-0.0103	-0.0251	0.1030	0.0027	-0.2276	0.0102	0.0010	-2.2197	-2.2384	
p-value	0.0000	0.1160	0.6550	0.9880	0.0170	0.0000	0.0000	0.0070	0.1680	0.0000	0.4060	0.0000	0.0100	0.6140	0.0000	0.0000	-262.409
Plastics and rubber	1.0135	-0.1415	0.1173	-0.0069	-0.0294	-0.1010	0.1294	-0.0124	0.1343	-0.0221	0.0016	-0.1062	0.0115	-0.0028	-3.7165	-1.1710	
p-value	0.0000	0.0000	0.0000	0.0520	0.4470	0.0000	0.0000	0.0010	0.0000	0.2080	0.5580	0.0000	0.0010	0.0980	0.0000	0.0000	-211.317
Nonmetallic mineral products	1.0280	-0.0649	0.0742	-0.0065	-0.2005	0.0262	0.1353	-0.0031	-0.0206	-0.0236	0.0009	-0.0688	0.0022	-0.0037	-2.4167	-9.5583	
p-value	0.0000	0.0000	0.0000	0.0430	0.0000	0.1130	0.0000	0.4250	0.2990	0.2030	0.7220	0.0140	0.5460	0.0190	0.0000	0.8610	-120.106
Metallurgy and metal products	0.8969	-0.1358	0.1963	0.0000	-0.1545	-0.0283	0.1550	-0.0258	-0.0394	0.0576	-0.0002	-0.1848	0.0268	-0.0039	-2.9635	-0.9414	
p-value	0.0000	0.0000	0.0000	0.9920	0.0060	0.3740	0.0000	0.0000	0.1580	0.0260	0.9660	0.0000	0.0000	0.0920	0.0000	0.0000	-318.557
Machinery and equipment	0.8742	-0.0492	0.0827	0.0054	0.2018	-0.2467	0.0387	-0.0335	0.0550	0.1492	0.0077	-0.1812	0.0230	0.0003			
p-value	0.0000	0.0080	0.0000	0.2430	0.0000	0.0000	0.1250	0.0000	0.0360	0.0000	0.0540	0.0000	0.0000	0.8830			0.962
Electrical and optical equipment	0.9492	-0.1095	0.0674	-0.0013	0.3057	-0.3006	-0.0433	-0.0246	0.0161	0.2595	-0.0020	-0.2241	0.0280	-0.0029	-1.3952	-10.6632	
p-value	0.0000	0.0000	0.0020	0.8060	0.0000	0.0000	0.1010	0.0000	0.5470	0.0000	0.6550	0.0000	0.0000	0.2780	0.0000	0.9140	-411.175
Transport equipment	0.8715	-0.0388	0.0587	0.0143	0.3866	-0.2692	-0.1374	-0.0265	-0.0309	0.2291	-0.0100	-0.0444	0.0244	0.0054	-5.5180	-0.6306	
p-value	0.0000	0.0020	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1360	0.0000	0.0000	0.0530	0.0000	0.0010	0.0000	0.0000	-272.586
Other industrial products	0.7074	0.0076	0.2406	-0.0056	0.1167	-0.1757	0.0479	-0.0227	0.0656	0.0074	-0.0078	-0.0219	0.0302	-0.0015	-2.6278	-0.9075	
p-value	0.0000	0.6870	0.0000	0.2460	0.0000	0.0000	0.0940	0.0000	0.0310	0.7510	0.0520	0.5270	0.0000	0.5170	0.0000	0.0000	-360.393

Source: prepared by the authors, on the basis of information from the World Input-Output Database (WIOD, 2012).

Note: * estimation by ordinary least squares (OLS) reports adjusted R^2 instead of the log of maximum likelihood.

TABLE 6

Brazil and Mexico: growth, factor accumulation and productivity trend, 14 industrial sectors from 1995 to 2009
(Percentages, annual average)

Industrial sectors	Y	Factor accumulation			Productivity trend				
		K	L	H	PTF	TC	TE	SE	AE
Brazil									
Food, beverages and tobacco	2.1	6.3	-0.5	6.3	-2.1	-0.4	0.0	-1.4	-0.3
Textiles and textile products	-0.5	1.2	-2.3	4.5	-1.3	0.1	-0.8	0.1	-0.7
Leather and footwear	-2.0	6.9	-1.2	5.6	-4.8	0.2	-6.0	-0.8	1.8
Wood and products of wood	-1.7	11.8	-4.3	4.2	-7.1	-2.9	-8.9	0.6	4.1
Paper and pulp	2.7	19.1	-4.2	4.4	-6.6	-0.5	-4.9	-3.3	2.1
Coke and refined petroleum	5.5	18.4	-0.5	8.1	-10.8	-1.9	-6.8	-3.2	1.1
Chemical products	5.5	6.9	-4.1	4.5	1.7	0.8	-0.6	-0.3	1.8
Plastics and rubber	-0.6	7.8	-1.2	7.4	-5.4	-0.6	-7.6	0.1	2.6
Nonmetallic mineral products	1.7	2.2	-2.6	6.0	0.0	-0.5	0.0	0.1	0.5
Metallurgy and metal products	2.0	8.9	-2.0	6.6	-4.0	-1.0	-6.1	-0.8	3.9
Machinery and equipment	3.8	6.1	-0.8	7.8	-0.2	0.1	0.0	-1.5	1.1
Electrical and optical equipment	1.6	3.1	-1.5	6.0	-1.2	0.1	0.0	-0.9	-0.4
Transport equipment	5.1	13.0	-0.7	6.8	-0.4	-2.6	-5.9	-4.3	12.4
Other industrial products	2.3	2.9	-3.0	4.4	0.6	0.9	-1.0	-1.1	1.7
Mexico									
Food, beverages and tobacco	2.7	-0.4	1.6	2.8	2.4	-1.0	0.0	0.1	3.3
Textiles and textile products	-0.1	2.1	0.7	4.2	-2.1	-0.6	-0.6	0.2	-1.0
Leather and footwear	-0.6	-1.0	-1.5	1.3	0.1	-0.1	0.2	0.1	-0.1
Wood and products of wood	-0.2	-0.6	-1.9	1.4	0.2	-3.6	2.3	0.0	1.6
Paper and pulp	1.9	0.9	0.7	1.3	0.9	0.4	0.3	0.0	0.3
Coker and oil refining	-0.4	-0.3	-1.9	-1.1	-0.4	1.2	-0.7	0.0	-0.8
Chemical products	2.1	1.3	-2.0	1.3	1.0	1.8	-0.1	0.0	-0.7
Plastics and rubber	2.1	2.7	-0.5	2.8	-0.1	1.4	-1.4	0.0	-0.1
Nonmetallic mineral products	2.2	0.5	-1.3	3.0	1.7	-0.6	0.0	0.0	2.3
Metallurgy and metal products	2.2	0.4	-1.4	1.7	1.7	1.6	-0.1	0.0	0.3
Machinery and equipment	1.3	2.6	0.0	2.4	-0.8	5.7	0.0	-0.2	-6.3
Electrical and optical equipment	1.7	2.9	-1.9	4.0	-0.6	5.1	0.0	-0.1	-5.7
Transport equipment	4.0	4.0	2.2	2.2	0.8	1.8	-0.1	-0.3	-0.7
Other industrial products	3.0	-0.5	4.2	1.6	2.1	2.7	-0.3	-0.2	-0.1

Source: prepared by the authors, on the basis of information from the World Input-Output Database (WIOD, 2012).

efficiency, while Brazil recorded increases in nearly all manufacturing industries, there were decreases in nine sectors in Mexico.

The productivity indices of each country (Brazil and Mexico) in each of the 14 industrial sectors are shown in table 7, estimated in relation to the sample base year of 1995. The values for that year were subjected to the TFP variations estimated on the basis of table 6; so the resulting indices express the historical differences and recent trend of the 14 industrial sectors in the two countries.

The data of table 7 show that there were few productivity differences in 1995. In general, productivity levels in Brazilian industries were higher than those of their Mexican counterparts (in 10 of the 14 sectors). Only in the "wood and products of wood" and "plastics and rubber" sectors does Mexico surpass Brazil. In two other sectors (textile products and chemicals), the differences were small. By 2009, however, the situation had changed drastically. Only four sectors of Brazilian industry maintained factor productivity levels that were substantially above those of Mexican industries: textiles and textile products; chemical products; machinery and equipment, and transport equipment. In the other industries, Mexico's TFP greatly surpassed that of Brazil in 2009.

TABLE 7

Brazil and Mexico: productivity indices, 14 industrial sectors 1995 and 2009

Industrial sectors	1995			2009		
	Brazil (A)	Mexico (B)	(A/B)	Brazil (A)	Mexico (B)	(A/B)
Food, beverages and tobacco	99.2	99.2	1.000	99.2	99.2	1.000
Textiles and textile products	81.0	83.0	0.976	81.0	83.0	0.976
Leather and footwear	65.7	63.3	1.038	65.7	63.3	1.038
Wood and products of wood	51.1	57.8	0.885	51.1	57.8	0.885
Paper and pulp	68.7	64.7	1.062	68.7	64.7	1.062
Coker and oil refining	53.7	42.3	1.269	53.7	42.3	1.269
Chemical products	79.4	81.0	0.980	79.4	81.0	0.980
Plastics and rubber	77.6	83.1	0.934	77.6	83.1	0.934
Nonmetallic mineral products	99.3	99.3	1.000	99.3	99.3	1.000
Metallurgy and metal products	66.7	58.6	1.138	66.7	58.6	1.138
Machinery and equipment	100.0	100.0	1.000	100.0	100.0	1.000
Electrical and optical equipment	99.6	99.6	1.000	99.6	99.6	1.000
Transport equipment	78.8	61.6	1.279	78.8	61.6	1.279
Other industrial products	73.5	61.2	1.200	73.5	61.2	1.200

Source: prepared by the authors, on the basis of information from the World Input-Output Database (WIOD, 2012).

IV
Foreign trade and productivity

The analyses reported in the previous section show that the manufacturing-industry productivity trend was generally more favourable in Mexico than in Brazil, such that in a few years Brazil's relative advantage was reversed. The input requirements needed for production decreased in eight of the 14 manufacturing sectors in Mexico, while they increased in the case of Brazil. Apart from one sector, the growth of requirements was less in Mexico, indicating a considerable saving in the use of intermediate goods and services.

From the TFP standpoint, the results revealed a large increase in just three industrial sectors of the Brazilian economy (textiles, chemicals, and machinery and equipment). In the other 11 sectors, productivity growth was greater in Mexico.

In addition to the positive trend of TFP, in seven sectors of Mexican manufacturing industry (food and beverages, leather and footwear, products of wood, paper and pulp, nonmetallic minerals, metallurgy, and transport equipment) there was also a reduction in input requirements. These two processes combine to enhance industrial competitiveness. In the chemicals and other industrial products sectors, the greater input requirement is offset by an increase in TFP. In the case of Brazil, the productivity trend is quite negative: input requirements increased in all manufacturing sectors, except for leather and footwear; and TFP decreased in all of them, except for chemicals, nonmetallic minerals, and other industrial products.

A relevant fact revealed by the analyses is that the increase in imported goods and services requirements in Mexican manufactures was compensated for by a reduction in domestic goods and services requirements. This suggests that, at least in the case of Mexico, trade liberalization had a decisive influence on the productivity trend —as is frequently claimed in the literature on productivity in Latin America—. Bandeira and Garcia (2002), for example, suggest that trade liberalization in the Latin American economies had positive effects on investment and economic growth in the region in the 1990s. Hay (2001); Cavalcanti and Rossi (2003), and Schor (2004) use different methods to analyse the productivity of Brazil's manufacturing industry, and they report substantial TFP gains linked to the rapid reduction in import quotas in the 1990s. Moreover, the studies by Weiss (1992); İşcan (1998), and Guillermo and Tanka (2007) reveal the effects of trade liberalization on the efficiency of Mexico's manufacturing industry at different points in time, particularly in the 1980s and 1990s.

Statistics on the composition of the demand for manufactured products in Brazil and Mexico, and how this relates to the productivity trend, corroborate this

view. Table 8 shows the share of imports in total demand in the Brazilian in Mexican economies in 1995 and 2009, by manufacturing industry sector. The statistics, taken from the WIOD, indicate the degree of penetration of imports of industrial goods in domestic demand, considering its two components: (i) final demand, consisting of consumption and investment by families, public administrations and non-profit institutions, and (ii) intermediate consumption, consisting of demand for goods and services by firms and the government.

The data of table 8 show that, despite a considerable increase in Brazilian imports, the manufactured goods markets in that country were relatively little affected. Imports, which represented 11.1% of final demand for manufactured goods in 1996, were just 11.6% in 2009. Imports of manufactured goods to satisfy intermediate demand by firms in all sectors of economic activity, grew from 10.6% in 1995 to 12.7% in 2009. In other words, despite trade liberalization, imports satisfied a relatively small proportion of the final and intermediate demand for Brazil's manufactures.

In Mexico, the situation was very different. As a result of its accession to the North American Free Trade Agreement (NAFTA) in 1992, the share of imports in the composition of final and intermediate demand for manufactured goods grew by much more. That treaty between Mexico, the United States and Canada set a 15-year period for the total elimination of tariff barriers between the three countries; and this expired in 2007. In that context, the import content in the final demand for

TABLE 8

Brazil and Mexico: share of imports in final, intermediate and total demand, 1995 and 2009

(Percentages)

	Brazil			Mexico		
	Intermediate	Final	Total	Intermediate	Final	Total
			1995			
Food, beverages and tobacco	3.8	9.2	7.3	13.8	4.2	6.0
Textiles and textile products	9.7	2.6	5.8	26.9	51.0	37.4
Leather and footwear	6.0	4.1	4.7	3.9	18.2	12.2
Wood and products of wood	1.4	6.9	1.7	16.8	2.9	13.7
Paper and pulp	7.5	4.8	6.9	27.1	15.8	24.7
Coker and oil refining	7.5	7.0	7.3	11.9	6.9	9.4
Chemical products	22.3	7.8	17.5	39.6	9.2	26.6
Plastics and rubber	7.7	15.2	8.7	56.1	21.7	47.5
Nonmetallic mineral products	4.0	6.1	4.2	16.4	1.7	11.3
Metallurgy and metal products	6.8	9.0	7.1	41.8	11.7	35.2
Machinery and equipment	19.5	23.4	22.2	81.3	70.1	74.3
Electrical and optical equipment	20.5	19.1	19.7	79.4	58.4	72.4
Transport equipment	13.5	14.3	14.0	52.0	9.9	29.2
Other industrial products	4.3	5.6	5.3	22.5	8.5	12.7
Total manufactures	10.6	11.1	10.9	41.9	17.1	30.0
			2009			
Food, beverages and tobacco	3.2	4.0	3.7	94.0	8.0	23.5
Textiles and textile products	11.8	3.9	7.2	89.6	38.7	65.3
Leather and footwear	2.3	6.7	5.7	94.7	28.4	51.7
Wood and products of wood	1.5	3.3	1.6	60.4	6.8	49.8
Paper and pulp	5.0	2.1	4.3	65.3	16.9	55.7
Coker and oil refining	7.6	7.3	7.5	58.4	21.9	41.6
Chemical products	23.0	12.6	19.7	88.1	25.1	66.1
Plastics and rubber	9.5	22.3	10.6	86.6	58.3	81.6
Nonmetallic mineral products	4.1	10.8	4.4	35.9	2.8	27.4
Metallurgy and metal products	8.6	7.6	8.5	81.5	24.6	73.3
Machinery and equipment	23.6	19.0	20.2	95.6	86.0	88.9
Electrical and optical equipment	29.4	33.3	31.5	96.0	74.1	89.0
Transport equipment	18.4	11.6	14.3	88.8	55.1	68.4
Other industrial products	8.5	5.2	5.9	65.9	17.6	35.0
Total manufactures	12.7	11.6	12.2	81.9	29.6	57.0

Source: prepared by the authors, on the basis of information from the World Input-Output Database (WIOD, 2012).

manufactured goods grew from 17.1% in 1995 to 29.6% in 2009; and the penetration of imports in intermediate demand for manufactured goods increased by 40 percentage points, from 41.9% to 81.9% between 1995 and 2009. Most of that growth was based specifically on products originating in the NAFTA area, which includes two highly industrialized economies.

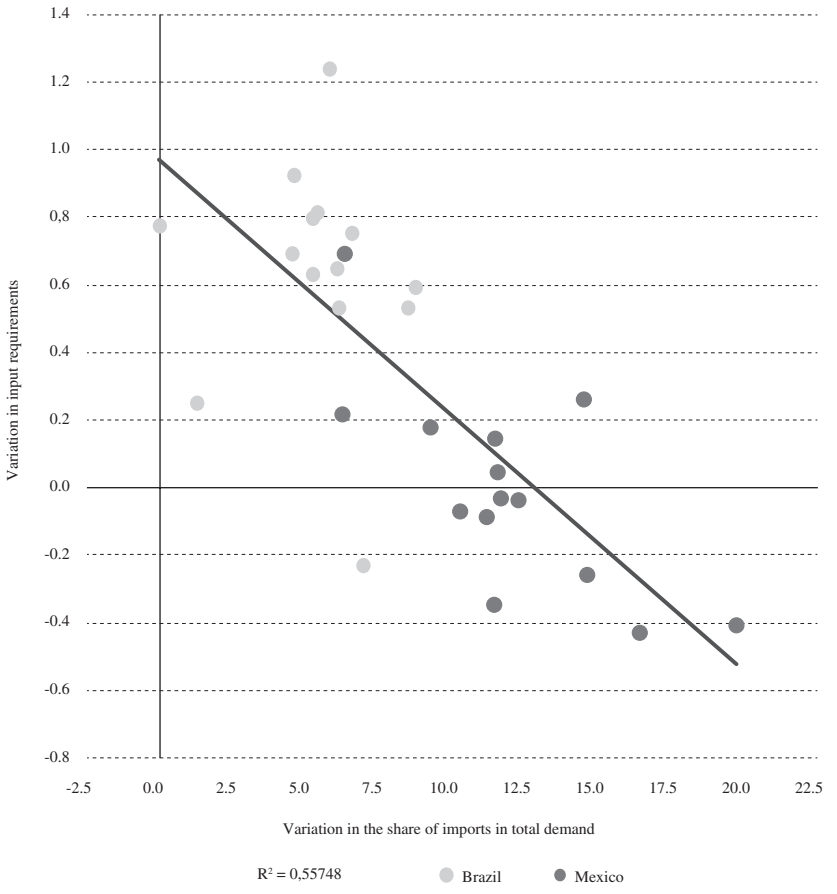
Considering the data from the 14 industrial sectors in Brazil and Mexico, the reduction in input requirements recorded between 1995 and 2009 seems to be negatively correlated with the increased share of imports in total demand, as shown in figure 1. Considering the average of the sectors, the larger the increase in imports in the total demand for manufactured goods, the relatively larger were the reductions in requirements to produce those manufactured goods in each of the two countries. This shows that the greater relative importance of imports could have contributed to the cost reduction and, hence, to the more efficient production of manufactured goods.[23]

The analyses performed in this article reveal the different paths followed by Brazilian and Mexican manufacturing industries between 1995 and 2009. While Mexican industry consolidated its position with a significant productivity increase, despite the reduction in the share of manufacturing in GDP and in the total demand for manufactured goods, Brazilian industry experienced an absolute and relative productivity loss,

[23] A similar relation exists between increases in the import share of demand between 1995 and 2009 and the trend of TFP in the 14 industrial sectors of Mexico and Brazil. The linear correlation coefficient between the two variables is 50.1%.

FIGURE 1

Brazil and Mexico: variation in the share of imports in total demand and trend of input requirements, annual averages, from 1995 to 2009
(Percentages)



Source: prepared by the authors, on the basis of information from the World Input-Output Database (WIOD, 2012).

along with a rise in costs. The fact that manufactured goods markets in that country are more isolated from foreign trade could have contributed to the weak productivity performance. As a counterpart, final demand for manufactured goods grew by 25.4 percentage points less in Brazil than in Mexico between 1995 and 2009.

Accordingly, the results reported in this article suggest a future need for more in-depth research into the pattern of consumption and foreign trade in manufactured goods in the two economies, and a study of the effects of the changes in industrial productivity on economic growth and welfare in the two countries.

Bibliography

Bandeira, A.C. and F. Garcia (2002), "Reforms and growth in Latin America", *CEPAL Review*, No. 77 (LC/G.2180-P), Santiago, Chile, August.

Carter, A.P. (1980), "Changes in input-output structures since 1972", *Data Resources Interindustry Review*.

_____ (1967), "Changes in the structure of the American economy, 1947 to 1958 and 1962", *The Review of Economics and Statistics*, vol. 49, No. 2, Cambridge, Massachusetts, The MIT Press, May.

Cavalcanti, P. and J. Rossi (2003), "New evidence from Brazil on trade liberalization and productivity growth", *International Economic Review*, vol. 44, No. 4, Wiley, November.

Feldman, S.J., D. McClain and K. Palmer (1987), "Sources of structural change in the United States 1963-78. An input-output perspective", *The Review of Economics and Statistics*, vol. 69, No. 3, Cambridge, Massachusetts, The MIT Press, August.

Garcia, F., R.C. Souza and J.O. Pires (2008), "Technical change: it should be positive and make sense!", *Economics Letters*, vol. 100, No. 3, Amsterdam, Elsevier.

Guillermo, S. and B. Tanka (2007), "Measuring total factor productivity growth in Mexican manufacturing: the story before and after trade liberalization", *Ensayos sobre Política Económica*, vol. 25, No. 53, Bogota, Bank of the Republic.

Hay, D. (2001), "The post-1990 Brazilian trade liberalization and the performance of large manufacturing firms: productivity, market share and profits", *The Economic Journal*, vol. 111, No. 473, Wiley, July.

İşcan, T. (1998), "Trade liberalization and productivity: a panel study of the Mexican manufacturing industry", *The Journal of Development Studies*, vol. 34, No. 5, Taylor & Francis.

Katz, J. (2000), "Structural change and labor productivity growth in Latin American manufacturing industries 1970-96", *World Development*, vol. 28, No. 9, Amsterdam, Elsevier.

Kneller, R. and A. Stevens (2003), "The specification of aggregate production function in the presence of inefficiency", *Economics Letters*, vol. 81, No. 2, Amsterdam, Elsevier.

Kumbhakar, S.C., M. Denny and M. Fuss (2000), "Estimation and decomposition of productivity change when production is not efficient", *Econometric Reviews*, vol. 19, No. 4, Taylor & Francis.

Kumbhakar, S.C. and H. Wang (2005), "Estimation of growth convergence using a stochastic production frontier approach", *Economics Letters*, vol. 88, No. 3, Amsterdam, Elsevier.

Lahr, M.L. and E.E. Dietzenbacher (eds.) (2001), *Input-Output Analysis: Frontiers and Extensions*, Houdmills, Palgrave.

Leontief, W. (1951), *The Structure of the American Economy*, New York, Oxford University Press.

Mesquita, M. (2007), "Fear of China: is there a future for manufacturing in Latin America?", *World Development*, vol. 35, No. 3, Amsterdam, Elsevier.

Miller, R. and P. Blair (2009), *Input-Output Analysis*, Cambridge, Cambridge University Press.

Moreira, M.M. (2007), "Fear of China: is there a future for manufacturing in Latin America?", *World Development*, vol. 35, No. 3, Amsterdam, Elsevier.

Pires, J. and F. Garcia (2012), "Productivity of nations: a stochastic frontier approach to TFP decomposition", *Economics Research International*, Hindawi Publishing Corporation.

Schor, A. (2004), "Heterogeneous productivity response to tariff reduction. Evidence from Brazilian manufacturing firms", *Journal of Development Economics*, vol. 75, No. 2, Amsterdam, Elsevier.

Solow, R.M. (1957), "Technical change and the aggregate production function", *Review of Economics and Statistics*, vol. 39.

Weiss, J. (1992), "Trade policy reform and performance in manufacturing: Mexico 1975-88", *The Journal of Development Studies*, vol. 29, No. 1, Taylor & Francis.

WIOD (World Input-Output Database) (2012), *The World Input-Output Database: Contents, Sources and Methods*, M. Timmer (ed.), April [online] www.wiod.org/database.

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.

Publicaciones recientes de la CEPAL
ECLAC recent publications

www.cepal.org/publicaciones

Informes periódicos / *Annual reports*

También disponibles para años anteriores / *Issues for previous years also available*

- Estudio Económico de América Latina y el Caribe 2014, 222 p.
  Economic Survey of Latin America and the Caribbean 2014, 214 p.
- La Inversión Extranjera Directa en América Latina y el Caribe 2013, 160 p.
  Foreign Direct Investment in Latin America and the Caribbean 2013, 152 p.
- *Anuario Estadístico de América Latina y el Caribe 2013 / Statistical Yearbook for Latin America and the Caribbean 2014, 238 p.*
- Balance Preliminar de las Economías de América Latina y el Caribe 2014, 92 p.
  Preliminary Overview of the Economies of Latin America and the Caribbean 2014, 92 p.
- Panorama Social de América Latina 2014, 296 p.
  Social Panorama of Latin America 2013, 284 p.
- Panorama de la Inserción Internacional de América Latina y el Caribe 2014, 148 p.
  Latin America and the Caribbean in the World Economy 2014, 140 p.

Libros y documentos institucionales / *Institutional books and documents*

- El desafío de la sostenibilidad ambiental en América Latina y el Caribe: textos seleccionados de la CEPAL 2012-2014, 2015, 148 p.
- *Panorama Fiscal de América Latina y el Caribe 2015: Dilemas y espacios de políticas, 2015, 130 p.*
- La economía del cambio climático en América Latina y el Caribe: paradojas y desafíos del desarrollo sostenible, 2014, 98 p
  The economics of climate change in Latin America and the Caribbean: Paradoxes and challenges. Overview for 2014, 2014, 76 p.
- Los pueblos indígenas en América Latina: avances en el último decenio y retos pendientes para la garantía de sus derechos, 2014, 410 p.
- Pactos para la igualdad: hacia un futuro sostenible, 2014, 340 p.
  Covenants for Equality: Towards a sustainable future, 2014, 330 p.
- Integración regional: hacia una estrategia de cadenas de valor inclusivas, 2014, 226 p.
  Regional Integration: Towards an inclusive value chain strategy, 2014, 218 p.
  Integração regional: por uma estratégia de cadeias de valor inclusivas, 2014, 226 p.
- Reflexiones sobre el desarrollo en América Latina y el Caribe. Conferencias magistrales 2013-2014, 2014, 100 p.
- *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.
  International trade and inclusive development: Building synergies, 2013, 200 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*

132 Neoestructuralismo y corrientes heterodoxas en América Latina y el Caribe a inicios del siglo XXI, Alicia Bárcena, Antonio Prado (eds.), 2014, 452 p.

131 El nuevo paradigma productivo y tecnólogico: la necesidad de políticas para la autonomía económica de las mujeres, Lucía Scuro, Néstor Bercovich (eds.), 2014, 188 p.

130 Políticas públicas para la igualdad de género: un aporte a la autonomía de las mujeres, María Cristina Benavente, Alejandra Valdés, 2014, 134 p.

129 Prospectiva y política pública para el cambio estructural en América Latina y el Caribe, Javier Medina Vásquez, Steven Becerra y Paola Castaño, 2014, 338 p.

128 Inestabilidad y desigualdad: la vulnerabilidad del crecimiento en América Latina y el Caribe, Juan Alberto Fuentes Knight (ed.), 2014, 304 p.

127 Global value chains and world trade: Prospects and challenges for Latin America, René A. Hernández, Jorge Mario Martínez-Piva and Nanno Mulder (eds.), 2014, 282 p.

126 Planificación, prospectiva y gestión pública: reflexiones para la agenda del desarrollo, Jorge Máttar, Daniel E. Perrotti (eds.), 2014, 250 p.

Copublicaciones / *Co-publications*

- *Decentralization and Reform in Latin America: Improving Intergovernmental Relations, Giorgio Brosio and Juan Pablo Jiménez (eds.), ECLAC / Edward Elgar Publishing, United Kingdom, 2012, 450 p.*
- Sentido de pertenencia en sociedades fragmentadas: América Latina desde una perspectiva global, Martín Hopenhayn y Ana Sojo (comps.), CEPAL / Siglo Veintiuno, Argentina, 2011, 350 p.
- Las clases medias en América Latina: retrospectiva y nuevas tendencias, Rolando Franco, Martín Hopenhayn y Arturo León (eds.), CEPAL / Siglo XXI, México, 2010, 412 p.

Coediciones / *Co-editions*

- Perspectivas económicas de América Latina 2015: educación, competencias e innovación para el desarrollo, CEPAL/OCDE, 2014, 200 p.
  Latin American Economic Outlook 2015: Education, skills and innovation for development, ECLAC,/CAF/OECD, 2014, 188 p.
- *Regional Perspectives on Sustainable Development: Advancing Integration of its Three Dimensions through Regional Action, ECLAC-ECE-ESCAP-ESCWA, 2014, 114 p.*
- Perspectivas de la agricultura y del desarrollo rural en las Américas: una mirada hacia América Latina y el Caribe 2014, CEPAL / FAO / IICA, 2013, 220 p.

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.

Documentos de proyecto / *Project documents*

- La economía del cambio climático en el Perú, 2014, 152 p.
- 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.

Cuadernos estadísticos de la CEPAL

42 Resultados del Programa de Comparación Internacional (PCI) de 2011 para América Latina y el Caribe. Solo disponible en CD, 2015.

41 Los cuadros de oferta y utilización, las matrices de insumo-producto y las matrices de empleo. Solo disponible en CD, 2013.

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.

Revista CEPAL / *CEPAL Review*

La Revista se inició en 1976, con el propósito de contribuir al examen de los problemas del desarrollo socioeconómico de la región. La *Revista CEPAL* se publica en español e inglés tres veces por año.

CEPAL Review first appeared in 1976, its aim being to make a contribution to the study of the economic and social development problems of the region. 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. 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. 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. 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. 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 la CEPAL están disponibles en:
ECLAC Publications are available in:

www.cepal.org/publicaciones

También se pueden adquirir a través de:
They can also be ordered through:

www.un.org/publications

United Nations Publications
PO Box 960
Herndon, VA 20172
USA

Tel. (1-888)254-4286
Fax (1-800)338-4550
Contacto / *Contact*: publications@un.org
Pedidos / *Orders*: order@un.org

ECONOMIC COMMISSION FOR LATIN AMERICA AND THE CARIBBEAN

ECLAC

United Nations Publication • E1420918 • April 2015 • ISSN 0251-2920 • e-ISBN 978-92-1-057220-0