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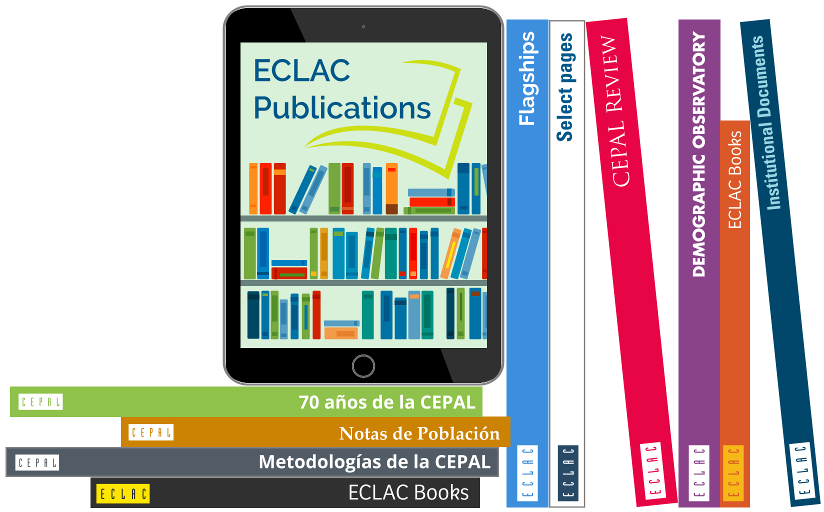

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Contents

Explanatory notes

- Three dots (...) indicate that data are not available or are not separately reported.
- A dash (-) indicates that the amount is nil or negligible.
- A full stop (.) is used to indicate decimals.
- The word “dollars” refers to United States dollars, unless otherwise specified.
- A slash (/) between years (e.g. 2013/2014) indicates a 12-month period falling between the two years.
- Individual figures and percentages in tables may not always add up to the corresponding total because of rounding.

Uncertainty and economic growth: evidence from Latin America

Daniel Aromí, Cecilia Bermúdez and Carlos Dabús

Abstract

This paper explores the effect of uncertainty on economic growth in Latin American from 1960 to 2016. Uncertainty is found to be positively correlated to inflation and the volatility of three macroeconomic variables: inflation rate, GDP and the real exchange rate. The empirical evidence indicates that uncertainty is detrimental for growth, particularly at higher levels. In line with existing consensus in the literature, the results appear to show that macroeconomic instability has been a major hindrance explaining the poor economic performance of the region. Economic policy recommendations include applying more stringent countercyclical policies to stabilize prices and output fluctuations.

Keywords

Economic conditions, uncertainty, economic growth, macroeconomics, inflation, gross domestic product, foreign exchange rates, Latin America

JEL classification

E32, O47, E31

Authors

Daniel Aromí is a Lecturer at the Faculty of Economic Sciences at the University of Buenos Aires, Argentina and at the Faculty of Economic Sciences at Pontificia Universidad Católica Argentina. Email: aromi.daniel@gmail.com.

Cecilia Bermúdez is a Category-V Researcher-Professor at the Department of Economics, National University of the South, Argentina. Email: cbermudez@uns.edu.ar.

Carlos Dabús is a Professor at the Economics Department, National University of the South, Argentina. Email: cdabus@criba.edu.ar.

I. Introduction

The determinants of economic growth have been widely studied in the literature. Since the key contribution of Levine and Renelt (1992), more recent evidence has been presented, inter alia, in Caporale and McKiernan (1996), Hall and Jones (1999), Doppelhofer, Miller and Sala-i-Martin (2000), Kneller and Young (2001), Crespo Cuaresma (2003), Bhattacharyya (2004), Hoover and Perez (2004), Minier (2007), Jones (2011), Bittencourt (2012), Kremer, Bick and Nautz (2013), Salahodjaev (2015), Brueckner and Kraipornsak (2016), Teixeira and Queirós (2016) and Vedia-Jerez and Chasco (2016). These works show several factors that can promote or damage growth processes. The factors that can promote growth include investment as a proportion of GDP, human capital accumulation, degree of economic openness and so forth. On the other hand, the main variables that can be harmful to economic growth include income inequality, volatility of output growth rate and high inflation.

In particular, the relationship between instability and economic growth is very relevant in a highly unstable region like Latin America. Along these lines, De Gregorio (2007) shows that macroeconomic instability was a limiting factor to sustained growth in Chile. The empirical literature also associates economic instability with output volatility. In a cross-country study, Ramey and Ramey (1995) show a strong negative relation between output growth variability and economic growth. Subsequently, Martin and Rogers (2000) presented evidence about countries and regions with higher standard deviations of the growth rate presenting lower economic growth. Hnatkovska and Loayza (2005) show a negative relationship between output growth rate volatility and long-term economic growth, particularly in developing countries. Similarly, Macri and Shina (2000) find a negative relationship between output variability and growth in the case of the Australian industrial sector. More recently, in a wide sample study of 93 countries, Fatás and Mihov (2013), state that policy volatility, proxied by government spending unrelated to business cycles, generates lower economic growth. Similarly, Bermúdez, Dabús and González (2015) find that high inflation and growth rate volatility are the main factors behind Latin American stagnation during the 1950-2009 period. In more general terms, Fanelli and Jiménez (2010) present a survey of the main stylized facts on economic volatility and economic performance in the region.

Predictably, the mechanism through which output growth rate fluctuations negatively affect economic growth is the adverse response of investors to future uncertainty related with those fluctuations. According to Fischer (1993b), the usual emphasis on the stability of the macroeconomic framework suggests that uncertainty is particularly harmful. There are two main channels through which uncertainty could affect negatively economic growth. First, policy-induced macroeconomic uncertainty reduces the efficiency of the price mechanism. This kind of uncertainty, associated with output growth rate variability, reduces the level of productivity, and then economic growth. In turn, temporary uncertainty about the macroeconomic context tends to reduce the rate of investment, because potential investors will wait for uncertainty to reduce before carrying out investment plans. This suggests that investment would be lower at higher uncertainty. Once again, lower investment can be expected to lead to a reduction in the economic growth rate.

Similarly, inflation is also a proxy for macroeconomic instability. Indeed, inflation is a useful indicator of general price level instability (Dabús, González and Bermúdez (2012)). A negative inflation-economic growth relationship can be found in Kormendi and Meguire (1985), Barro (1997), Fischer (1993a and 1993b), Bruno and Easterly (1998), and more recently in Bermúdez, Dabús and González (2015), who find that particularly high inflation has a strikingly damaging effect on long-term growth in Latin America. Moreover, according to Fischer (1993b), an increase in inflation and inflation variability, which create macroeconomic uncertainty and distort information, would adversely affect economic growth through at least three mechanisms. First, uncertainty reduces the efficiency of the price system, which brings down the level and the rate of productivity. Second, uncertainty also reduces the rate of private investment by increasing the option value of waiting, as potential investors wait for resolution before committing themselves, and reduces expected profits (Fischer, 1993b). In turn, this increases capital flight, which lowers capital accumulation and economic growth.

Finally, a rise in exchange rate variability creates higher uncertainty, which then brings down investment. In turn, it may also lead to a high degree of dollarization and hence result in a loss of seigniorage revenue, which reduces public capacity to carry out public investment expenditures, and once again harms economic growth. All in all, there seems to be a general consensus that higher variability of the real exchange rate is harmful for growth. Indeed Cottani, Cavallo and Khan (1990) present evidence for a sample of less developed countries indicating an inverse relationship between higher exchange rate instability and economic growth. Bleaney and Greenaway (2001), for a panel of 14 sub-Saharan African countries during the period 1980–1995, present evidence that economic growth is negatively affected by terms of trade instability, while exchange rate volatility reduces investment (and then growth). More recently, in a wide sample of the small open economies at the periphery of the European Monetary Union (EMU), Schnabl (2008) identifies a negative relationship between real exchange volatility and economic growth for countries in the economic catch-up process with open capital accounts. Similarly, Tarawalie (2010), Rapetti, Skott and Razmi (2012), Vieira and others (2013), Janus and Riera-Crichton (2015) and Bermúdez and Dabús (2018) find that real exchange rate volatility negatively affects economic growth.

The literature states that developed countries present less macroeconomic instability than developing countries. In fact, advanced economies show a history of lower inflation and a more stable output growth rate evolution. On the other hand, developing regions show greater economic instability, with periods of high inflation and a more erratic economic growth rate. In turn, the evidence indicates that both variables are detrimental for growth. The study of the relationship between economic instability and growth in unstable countries therefore deserves special attention. In this framework, the goal of this study is to determine the effect of uncertainty on economic growth in Latin America during the 1960-2016 period, for the total sample as well as at higher and lower uncertainty levels. These levels are obtained by using the k-median clustering algorithm. Regressions are then run on each uncertainty cluster to establish whether economic performance changes at different levels of the uncertainty index. The contribution of this paper is twofold. First, a measure of uncertainty is obtained by means of text mining techniques in a region that has historically experienced episodes of high uncertainty due to political and economic crises, high inflation and devaluation and significant output growth rate volatility. Second, the study determines the effect of uncertainty on economic growth at low and high uncertainty levels, which sheds some light on the relationship between the two variables in different macroeconomic environments.

Unsurprisingly, the evidence indicates that uncertainty, and particularly high uncertainty, was harmful for economic growth in Latin America during the period in question.

The following section presents the data and variables used in the study. Section III develops the methodology by means of the uncertainty index and the clusters of high and low levels of this index. Section IV characterizes the information captured by the uncertainty indices. Section V shows the empirical results. Finally, section VI presents the conclusions.

II. Data and variables

This study uses a sample of seventeen Latin American economies and nineteen consecutive and non-overlapping three-year periods from 1960 to 2016. The countries included in the sample are Argentina, Bolivarian Republic of Venezuela, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Honduras, Guatemala, Mexico, Nicaragua, Panama, Paraguay, Peru, Plurinational State of Bolivia and Uruguay.

Table 1 summarizes information about the variables of interest. Those that capture the volatility of a variable were calculated as the (rolling) standard deviation of three-year subperiods. In turn, for the uncertainty variable, this study uses text from the economic press to generate an index of uncertainty. More specifically, an uncertainty metric is calculated using a selection of text published in *The Wall Street Journal* between 1900 and 2011. For each article published in the newspaper, the website provides access to the headline, the lead and some of the text.[1]

Table 1
Variable definition and source

Variables	Definition	Source
gpd_pc	GDP per capita (constant 2010 US$)	World Bank - World Development Indicators [online] http://data.worldbank.org/data-catalog/world-development-indicators
vol_gdp	Standard deviation of GDP per capita (three-year average)	Authors' calculations based on World Bank gdp_pc data
ini_gdp	Initial GDP (of each three-year subperiod)	Authors' calculations based on World Bank gdp_pc data
gpd_pc_growth	Growth rate of GDP per capita	World Bank - World Development Indicators
vol_growth	Standard deviation of GDP per capita growth rate (three-year average)	Authors' calculations based on gdp_pc data
invest_gdp	Gross capital formation (% of GDP)	World Bank - World Development Indicators
Infla	Inflation, consumer prices (annual %)	World Bank - World Development Indicators
infl_vol	Standard deviation of Inflation (three-year average)	Authors' calculations based on inflation data
vol_rer	Standard deviation of real exchange rate (three-year average)	Authors' calculations based on nominal exchange rates (Penn World Table 9.0 (R. C. Feenstra, R. Inklaar and M. P. Timmer, "The next generation of the Penn World Table" *American Economic Review*, vol. 105, No. 10, 2015)) and inflation rates (World Bank)
Uncertainty	Uncertainty index	Authors' calculations

Source: Prepared by the authors.

It is important to mention that not all the above variables are used in the regressions, because the small panel size only allowed for the introduction of a few control variables. This study includes the control variables habitually used in the literature on economic growth: initial GDP and the investment-to-GDP ratio. In turn, in order to determine which social and economic variables are behind uncertainty, the rest of the variables are used to conduct two kinds of correlation approaches. The first is the classical Spearman or pairwise correlations, shown in table 2. Secondly, partial and semi-partial correlations between the uncertainty index and a set of variables that might also capture uncertainty are presented in table 3. These are inflation and the volatility of three macroeconomic variables: inflation rate, GDP, GDP growth rate and the real exchange rate. The results indicate that uncertainty is significantly correlated with the inflation rate (with the expected sign), as well as the volatility of inflation, GDP and the real exchange rate. These factors can therefore be seen as potentially causing the kind of uncertainty that discourages investment and reduces economic growth.

Table 2
Spearman correlations

Variables	gdp_pc_gr	vol_growth	vol_gdp	Infla	inf_vol	invest_gdp	vol_rer	uncertainty
gdp_pc_gr	1							
vol_growth	-0.0293	1						
vol_gdp	0.0849	0.074	1					
infla	-0.2642	-0.037	-0.0112	1				
inf_vol	-0.2463	-0.0322	-0.0139	0.9715	1			
invest_gdp	0.15	0.0848	0.1706	-0.0283	-0.0399	1		
vol_rer	-0.0985	-0.0382	-0.0405	0.0466	0.0368	0.0144	1	
uncertainty	-0.1506	-0.0308	0.2828	0.1406	0.1279	-0.0513	0.0931	1

Source: Prepared by the authors.

[1] The text was downloaded from a public website (http://pqasb.pqarchiver.com/djreprints/) using the "readLines" command in platform R. The website was unavailable at the time of writing.

Table 3
Partial and semi-partial correlations – uncertainty index and other uncertainty indicators

Variables	Partial correlations	Semi-partial correlations	Squared partial correlations	Squared semi-partial correlations	p-value
gdp_pc_gr	-0.0671	-0.0612	0.0045	0.0037	0.2776
vol_growth	-0.0570	-0.0520	0.0033	0.0027	0.3561
vol_gdp	0.3048	0.2913	0.0929	0.0849	0.0000
infla	0.1922	0.1783	0.0370	0.0318	0.0017
inf_vol	-0.1714	-0.1584	0.0294	0.0251	0.0052
invest_gdp	-0.0983	-0.0899	0.0097	0.0081	0.1110
vol_rer	0.1164	0.1067	0.0136	0.0114	0.0589

Source: Prepared by the authors.

III. Methodology: uncertainty index construction and the estimation method

1. The uncertainty index

The construction of the indicator is described as a two-step process. First, a large corpus is used to compute word vector representations. These representations allow for the identification of words related to uncertainty. In the second step, national uncertainty indices are computed using the list of uncertainty-related words indicated by word vector representations.

(a) Word vector representations

The first step involves representing words through vectors using an algorithm known as GloVe and presented in Pennington, Socher and Manning (2014). This type of representation has been shown to efficiently summarize semantic (and syntactic) information corresponding to each word. It can be understood as a linear structure of meaning. This quantitative representation can be used to measure relatedness between different words. For example, given the word "uncertainty", closely related words can be identified by computing the distance between the respective vectors. Also, information provided by multiple words can be aggregated by adding their respective word vector representations. While GloVe is not the only method that computes vector representations of words, it has been shown to perform better than alternative methods in multiple natural language processing tasks (see Pennington, Socher and Manning, 2014).

The inputs used to train the vector are a corpus (a collection of texts) and a list of words (a vocabulary). Given a window size parameter (such as +/- 5), the first computation involves counting the number of co-occurrences for each possible pair of words. In this way, a term co-occurrence matrix can be constructed. Next, a loss function that depends on word vector representations is proposed. The loss function is such that it decreases as the vector representations reflect more information contained in the term co-occurrence matrix. In this way, by minimizing the loss function, a rich set of information is reflected in a multidimensional portrayal.

More formally, let X represent a matrix of word co-occurrence counts. Its entries X_{ij} indicate the number of times word j occurs in the context of word i. The vectors w_i are computed to minimize the following loss function:

$$L = \sum_{i,j \in W} f\left(X_{ij}\right)\left(w_i^T w_j + b_i + b_j - log\left(X_{ij}\right)\right)^2$$

Where W is the vocabulary, $f(X_{ij})$ is an increasing concave weighting function and b_i is the bias of word i. This is the weighted least squares problem. The vector representations are formed using a stochastic gradient descent (Duchi, Hazan and Singer, 2011). More details can be found in Pennington, Socher and Manning (2014).

Typical vector dimensionality used in implementations is between 100 and 300. In the current implementation, the vector dimensionality is 100 and the window size used to compute term co-occurrence is 5. The vocabulary used in the implementation is made up of words with a frequency of at least 100 in the previously described corpus. Vector representations of words were computed using package text2vec in platform R. The same package was used in other related computations (such as tokenization and the term co-occurrence matrix).

The corpus used to train the vectors is a selection of text published in *The Wall Street Journal* between 1900 and 1989. For each article published in the newspaper, this website provides access to the headline, the lead and some of the text.

A small set of words is defined as unambiguously related to the topic of interest: uncertainty, uncertain and uncertainties. These three words are used as seeds to obtain a larger set of relevant words. With that objective, the "uncertainty vector", which represents the concept of uncertainty, is constructed by adding the vectors corresponding to the three seed words. The relatedness of a given word w with the concept of uncertainty is given by the cosine distance between the vector representation of w and the "uncertainty vector". The set of 500 closest words are selected to form the set of words U.

An informal inspection of the selected words indicates that the associations are mainly driven by semantic associations with the seed words. These are words describing adverse cognitive states (confusion, doubts, unclear), forward-looking terms (future, prospects) and related subjective responses (worries, nervousness, fear). In addition, there are some words that point to concepts that seem to be mentioned in times of high uncertainty. These concepts include: economy, political, inflationary and shortages.

(b) Indices of uncertainty

In the second step, given a set of words related to uncertainty (U), the index is constructed computing the frequency of these words for each period of the analysis. Let n_{wt} denote the number of times word w is observed on day t and let W denote the set of words in the vocabulary (or dictionary). Then, the value of the uncertainty index (UI) corresponding to day t is given as:

$$UI_t = \frac{\sum_{w \in U} n_{wt}}{\sum_{w \in W} n_{wt}}$$

That is, the index is given by the number of occurrences of words in U as a fraction of the total number of occurrences of dictionary words.

In this work, the previously described method is used to compute indices for each country in the panel. This requires selecting text associated to each country. In a straightforward approach, the selected text relates to portions of the corpus that are close to a keyword associated with the respective country. More specifically, country keywords are given by name of country, capital city and demonym. The text selected to compute country uncertainty indices is made up of the parts of the corpus that are located 50 words before or 50 words after a keyword for the corresponding country.

(c) Use of the uncertainty index

The uncertainty index is used to test for the presence of asymmetric effects of high and low uncertainty on the economic performance of Latin American economies. In order to determine the robustness of the results, the estimates of such effects are carried out by clustering the sample into two "categories" of uncertainty, namely "high" and "low", as well as by using a dummy of higher uncertainty levels. In relation to the clustering, the algorithm used is based on the median instead of the mean of each cluster, which avoids the effect of outliers that might be present in the sample.

The k-median algorithm used can be written as:

$$argmin \sum_{i=1}^{k} \sum_{x_j \in S_i} \| x_j - \mu_i \|$$

where μ represents the median of each cluster.[2] The inner sum represents the sum of squares of the difference between observation x (the uncertainty index) in cluster s and the median of cluster s. Meanwhile, the outer sum indicates that the sums of all clusters from i to k are totalled to obtain a single number that will be minimized.

The algorithm is composed of the following steps:

(i) Place k points into the space represented by the objects that are being clustered. These points represent initial group centroids.

(ii) Assign each object to the group that has the closest centroid. This study uses the Euclidean distance.

(iii) When all objects have been assigned, recalculate the positions of the k centroids.

(iv) Repeat steps 2 and 3 until the centroids no longer move. This produces a separation of the objects into groups to calculate the metric to be minimized.

Following these steps, two clusters are created with a satisfactory and similar number of observations, which allows separate regressions to be run for each one.[3]

Table 4 presents the descriptive statistics for the uncertainty index in each cluster. This shows that its mean value is considerably higher in the high uncertainty cluster.

Table 4
Descriptive statistics for the uncertainty index by cluster

Clusters	Observations	Mean	Standard deviation	Min.	Max.
High uncertainty	168	0.0593241	0.0100961	0.0448681	0.092615
Low uncertainty	154	0.0258786	0.0163166	0.0000000	0.0444065

Source: Prepared by the authors.

[2] This method was chosen over hierarchical clustering techniques because of the prohibitive computational burden of analysing 1,660 observations and at least two variables.

[3] Given the small size of the panel, it was decided to work with two distinct clusters, while the Calinski-Harabasz rule might determine a higher optimal number of clusters.

2. Estimation methodology

In line with the considerable literature on economic growth, a dynamic endogenous growth specification is estimated. The baseline model can be written as:

$$y_{i,t} - y_{i,t-1} = \propto y_{i,t-1} + \beta X_{i,t} + \gamma Z_{i,t} + \psi_{i,t}$$

where $y_{i,t}$ is the natural logarithm of output per capita for country i at time t (non-overlapping triannual averages), and $y_{i,t} - y_{i,t\text{-}1}$ is the growth rate of output per capita. In addition, $X_{i,t}$ and $Z_{i,t}$ are the vectors of two explanatory variables. The first contains the initial GDP per capita of each three-year subperiod and the investment level as a share of GDP. $Z_{i,t}$ is the vector of the uncertainty index.

A lagged dependent variable of the growth rate is also included, which makes the regression dynamic in nature. The generalized method of moments (GMM) estimator developed by Arellano and Bover (1995) and Blundell and Bond (1998) is used in its two versions: the difference GMM and the system GMM. These models use lagged values of regressors (in levels and in differences) as instruments for right-hand side variables, and also allow lagged endogenous (left-hand side) variables as regressors in short panels, as used in this study. The estimation of growth models using the GMM approach for linear panel data was introduced by Levine, Loayza and Beck (2000), and has now become common practice.

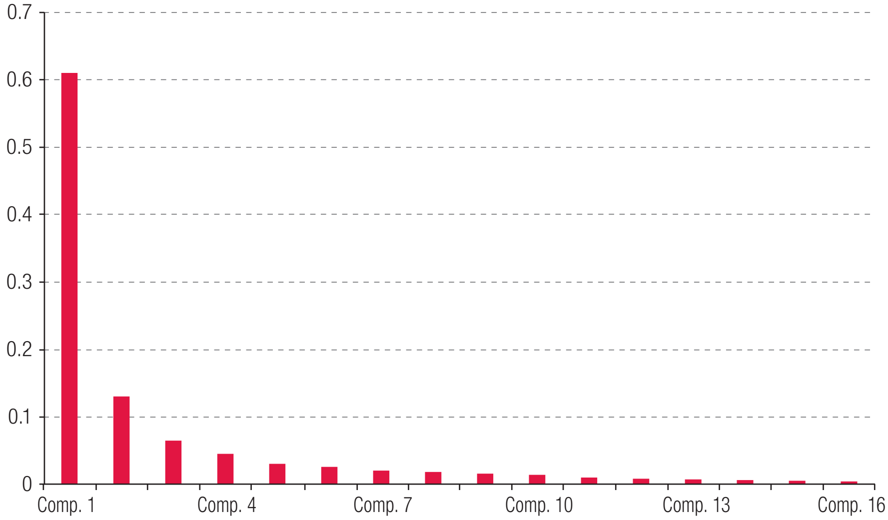
In order to address the issue of 'too many instruments' that can result in biased estimators, Roodman's (2009) approach is followed. This consists of limiting the lag depth to one or two instead of using all available lags for instruments. This strategy has been adopted by several researchers in the economic growth field (Levine, Loayza and Beck, 2000; Giedeman and Compton, 2009; Demir and Dahi, 2011). In addition, as the panel is small, this may produce a downward bias of the estimated asymptotic standard errors. Windmeijer's correction procedure (Windmeijer, 2005) avoids this inconvenience.

IV. Characterization of the uncertainty indices

The uncertainty indices are a novel metric proposed in this study. Considering its nontraditional nature, a characterization of the information captured by these indicators could be useful to interpret the results. Two exercises are implemented with this in mind. First, principal component analysis will be carried out to identify the fraction of the variation in the uncertainty indices explained by common factors. Second, this section evaluates the associations between the uncertainty indices and variables that describe the global economic environment.

Principal components were computed for the set of indices associated with each country. In the methodology used, the first principal component is the linear combination of the indicators that maximizes the fraction of the explained variability. Each subsequent factor then maximizes the fraction of explained residual variability. Figure 1 shows the fraction of the variance explained by each component. The first principal component explains approximately 60% of the variance of the indices. As expected, all loadings corresponding to this factor are positive and display similar absolute values. With just one exception, loadings are between 0.17 and 0.30. This substantial fraction of the variance explained by the first principal component can be linked to the existence of important common factors.

Figure 1
Fraction of variance explained by each component



Source: Prepared by the authors.

To understand the economic effects of these factors, a collection of economic variables associated with the global economic scenario is analysed. The set of variables are: real global GDP growth, a price index for commodities and real interest rate. Global real GDP growth corresponds to information provided by the World Bank (n.d.). The general price index for a broad group of commodities is from the United Nations Conference on Trade and Development (UNCTAD, n.d.). The real interest rate is the difference between the effective United States Federal Funds Rate minus the variation of the implicit deflator of United States GDP. This information is provided by the Federal Reserve Bank of St. Louis.

Table 5 gives the correlations between the uncertainty metric and the selected indicators of global economic environment. As expected, average country uncertainty indices are negatively associated with growth and commodity prices and positively associated with real interest rates. In a way that suggests these indicators can explain a substantial fraction of the variability of the uncertainty indices, the absolute value of the average correlations range between 0.3 and 0.64. The strongest association is found for commodity prices. A similar but stronger pattern is found for the correlations with the first principal component of the uncertainty index. Notably, the correlation between the first principal component and the commodity index reaches -0.84.

Table 5
Correlation between uncertainty indices and global economic indicator

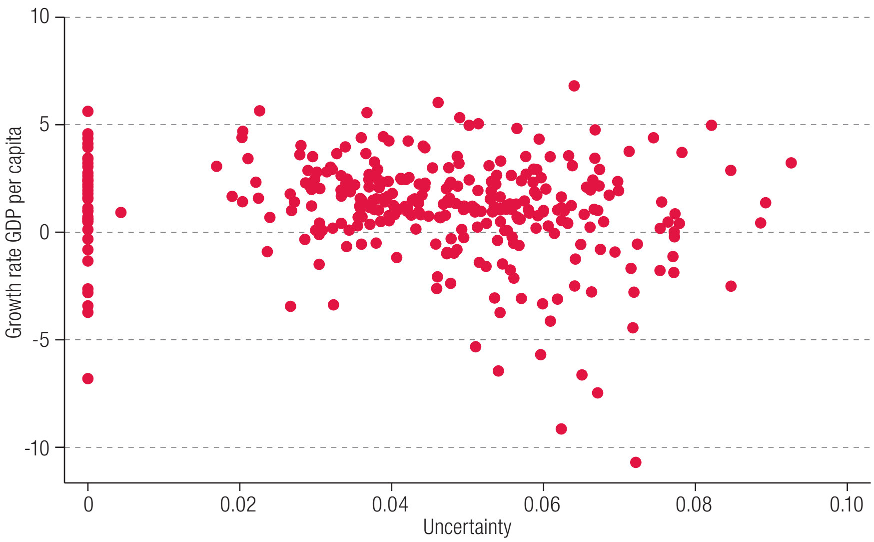
	Global GDP growth	Commodity price index	Real interest rate
Country uncertainty indices (Average correlation)	-0.32	-0.64	0.31
First principal component	-0.44	-0.84	0.35

Source: Prepared by the authors.

V. Uncertainty and economic growth in Latin America: empirical evidence

In order to assess the influence of uncertainty on economic performance more accurately, this section presents the empirical evidence between uncertainty and economic growth - both for the total sample and for the clusters of low and high uncertainty. To estimate the relationship between these variables, a dot graph is provided in Figures 2 and 3, while tables 6 and 7 show the estimation results. Figures 2 and 3 present these results for the total sample and for both the clusters of low and uncertainty, and tables 6 and 7 introduce a dummy variable for high uncertainty.

Figure 2
Economic growth and uncertainty, total sample, 1960–2016



Source: Prepared by the authors.

Figure 3
Economic growth and uncertainty by clusters, 1960–2016

Source: Prepared by the authors.

Table 6
Uncertainty and economic growth, total sample and clusters of low and high uncertainty levels

Variables	Total sample		Difference GMM by clusters		Sys GMM by clusters	
	(1)	(2)	(3)	(4)	(5)	(6)
	Diff Gmm	Sys GMM	High uncertainty	Low uncertainty	High uncertainty	Low uncertainty
Laggegdp_pc_gr	-0.218[a]	-0.0816	-0.209[b]	-0.199[b]	-0.0944	-0.0733
	(0.0189)	(0.376)	(0.0278)	(0.0339)	(0.514)	(0.749)
ini_gdp	-0.00115[a]	0.0000	-0.00146[a]	-0.00123[a]	0.0000	0.000124
	(0.000)	(0.291)	(0.000001)	(0.000001)	(0.825)	(0.278)
Invest_gdp	0.100[b]	0.359	0.150[b]	0.0283	0.0911	0.0116
	(0.0435)	(0.413)	(0.0219)	(0.641)	(0.246)	(0.878)
uncertainty	-123.6[a]	-60.73[a]	-98.43[a]	-70.63[a]	-63.35[c]	-48.71
	(0.000)	(0.0191)	(0.00162)	(0.00136)	(0.0640)	(0.151)
Constant		2.769[c]			2.708	2.405
		(0.0656)			(0.279)	(0.152)
Observations	275	291	155	120	160	133
Number of groups	17	17	16	16	16	16
Number of instruments	36	7	36	35	7	7
AR1 Test (p-value)	0.000	0.000934	1.97e-08	0.00754	0.0172	0.0522
AR2 Test (p-value)	0.945	0.918	0.407	0.0129	0.932	0.947
Hansen Test (p-value)		0.385			0.0512	0.0291

Source: Prepared by the authors.
Note: p-values are in parentheses.
[a] p<0.01.
[b] p<0.05.
[c] p<0.1.

Table 7
Uncertainty and economic growth, total sample with a dummy for uncertainty

Variables	Difference GMM	System GMM
Lagged gdp_pc_gr	-0.165[a]	-0.0613
	(0.0162)	(0.284)
ini_gdp	-0.00111[b]	0.0007
	(0.000)	(0.139)
invest_gdp	0.193[b]	0.0285
	(0.00013)	(0.359)
dummy_uncert	-3.65[b]	-2.96[a]
	(0.000000154)	(0.0113)
Constant		-1.290[c]
		(0.0863)
Observations	275	293
Number of groups	17	17
Number of instruments	36	7
AR1 Test (p-value)	0	0.00083
AR2 Test (p-value)	0.355	0.858
Hansen Test (p-value)		0.693

Source: Prepared by the authors.
Note: p-values are in parentheses.
[a] p<0.05.
[b] p<0.01.
[c] p<0.1.

At first glance, both figures suggest no clear link between the two variables at low uncertainty levels. Nonetheless, this relationship seems to be negative at higher uncertainty levels. In this sense, the regressions results presented below tend to confirm this evidence.

Table 6 shows that the control variables have the expected signs (in the differences estimates, both in the total and clusters samples). Initial GDP negatively affects economic growth, while the ratio of investment/GDP favours it. In turn, in table 1 the results presented for the total sample in regressions (1) and (2) indicate that the uncertainty index is very significant and negative for growth in Latin America in both difference and system GMM regressions. More interestingly, in order to determine if this index is more relevant to the economic performance of the region in different macroeconomic environments, the total sample was divided in two clusters of lower and higher uncertainty. In general, this reduces economic growth and, unsurprisingly, is more harmful at higher uncertainty. In fact, this has a higher and more significant coefficient into each estimation method at high uncertainty levels (regressions (3) and (5)), and is not only significant for the cases of lower levels when the system GMM method is applied (regression (6)).

In order to perform a robustness check of the empirical results obtained with the clustering technique, table 7 presents the estimation of the same model (using difference and system GMM) with the introduction of a dummy variable to capture both uncertainty levels (high and low), as defined by the k-median algorithm.

The main difference between running estimations for both clusters separately and the estimation model with a dummy is that the first implies that there are two different "structures" for groups of countries with high and low uncertainty, as the coefficients of the regressors are allowed to vary from one to the other. The use of a dummy variable is interpreted in the customary way: all countries in the sample are supposed to share the parameters that promote economic growth, and they only differ in the way it is affected by uncertainty. In this sense, the models estimated with the dummy variable show that countries with high uncertainty grow annually on average less than countries with low uncertainty by between 2.96% (with system GMM estimates) and 3.65% (with difference GMM estimates).[4] Hence, the results are robust for both cluster and dummy estimation techniques.

Tables 2 and 3 above indicate that uncertainty is significantly and positively correlated with inflation, as well as the volatility of inflation, GDP and the real exchange rate. As stated above, these factors therefore seem to cause higher uncertainty and also lower economic growth. In turn, uncertainty here seems to be an indicator that encompasses the behaviour of the variables usually associated with macroeconomic instability.

In short, the evidence presented above indicates that macroeconomic uncertainty, particularly at higher levels, is damaging for growth in the region. The suggestion is that higher inflation and volatility in real exchange rate, output and inflation are associated with higher uncertainty levels of the economic environment perceived by the society. This, in turn, discourages investment and then reduces economic growth.

These results are compatible with previous findings. In particular, they are similar to the evidence present in De Gregorio (2007), Bermúdez, Dabús and González (2015) and Fanelli and Jiménez (2010), who find that macroeconomic instability harms economic performance in the region. Economic policy recommendations must therefore contain measures destined to reduce overall macroeconomic uncertainty. According to the evidence from this study, this implies the need for tighter countercyclical policy to avoid sharp output fluctuations, as well as deeper and more effective price stabilization plans.

[4] The base category (with value zero) is "low uncertainty".

VI. Conclusions

This study examines the relationship between uncertainty and economic growth in Latin America from 1960 to 2016. This period was defined by periods of social unrest, as well as high political and economic instability. In general, these phenomena are associated with social uncertainty, approximated here by the uncertainty index. The aim of this study was to determine the impact on economic performance. In this sense, the results indicate that uncertainty is harmful for growth, and particularly at higher levels. Besides, the correlations suggest that factors like price and output instability seem to underlie uncertainty, which makes sense intuitively.

Therefore, higher inflation and volatility of output and inflation promote an atmosphere of uncertainty that discourages productive long-term investments, and then reduces economic growth. The evidence presented here seems to indicate that the perception of a social environment of uncertainty could reflect the existence of high macroeconomic instability. This is important for implementing economic policy. The evidence suggests that the region's policymakers could reduce instability and improve economic performance by implementing more stringent counter cyclical policies, in order to stabilize prices and output fluctuations more successfully.

This research could be expanded to explore other factors associated with uncertainty, or to build an index of uncertainty that includes social and political aspects, as well as external events that could cause instability in the region. This could allow for a more comprehensive measure that would explain the poor long-term economic performance of Latin America in relation to other more dynamic and successful emerging areas such as South-East Asia.

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Commodity prices and capital movement phenomena in emerging economies

Eliene de Sá Farias,[1] Leonardo Bornacki de Mattos[2] and Fabrício de Assis Campos Vieira

Abstract

The different fluctuations recorded in the balance of payments of emerging economies reflect the vulnerability of these economies, dependent as they are on the balance of capital and trade flows. This study analyses the relationship between commodity prices and some capital movement phenomena in a group of selected emerging economies. Probit and cloglog models are estimated to establish the likelihood of these phenomena occurring and their main determinants over the period from 1995 to 2016. The results allow us to identify the main global and country-level factors shaping the phenomena, as well as the importance of the contagion effect. The study concludes that countries which export large volumes of commodities, such as soybeans, minerals and oil, are subject to phenomena of reduction in foreign capital inflows.

Keywords

Commodities, commodity prices, capital movements, balance of payments, emerging markets, developing countries, mathematical models

JEL classification

F32, F21, F14

Authors

Eliene de Sá Farias holds a PhD from the Department of Rural Economics of the Federal University of Viçosa (Brazil). Email: eliene.farias@ufv.br.

Leonardo Bornacki de Mattos is an associate professor at the Department of Rural Economics of the Federal University of Viçosa (Brazil). Email: lbmattos@ufv.br.

Fabrício de Assis Campos Vieira is a level IV assistant professor at the Department of Rural Economics of the Federal University of Viçosa (Brazil). Email: fabriciodeacvieira@gmail.com.

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I. Introduction

Globalization has driven trade and financial relations between economies over the years, with the volume of commodity export and capital transactions increasing. Emerging economies' choice of sectors in which to concentrate their export structure, and likewise their approaches to managing capital inflows and outflows, have become crucial for their economic performance, financial stability and external competitiveness. After all, the inflow of large amounts of foreign capital into economies is associated with episodes of inflation and banking and currency crises (Forbes and Warnock, 2012). On the other hand, a reduction in the volume of foreign capital inflows can also harm nations via a worsening of the balance-of-payments current account and a decline in financing, investment and growth (Calvo, 1998; Calvo, Izquierdo and Mejía, 2004).

Emerging economies, especially those that have specialized in commodities, are vulnerable to commodity price fluctuations, a phenomenon that has been observed since the early 1970s. Notable in the past 15-year period in this regard was the impact of the favourable economic growth conditions of the 2000s, the "China effect" and the subprime crisis on commodity price fluctuations (Prates, 2007; Prates and Marçal, 2008; Veríssimo and Xavier, 2014; Bredow, Lélis and Cunha, 2016).

Similarly, emerging economies are very sensitive to the behaviour of foreign capital. Over time, various studies have sought to identify and characterize the determinants of capital movements. Calvo (1998) introduced the concept of the sudden stop, a phenomenon characterized by a large and unexpected slowdown in capital movements in emerging countries.[3] A number of studies have also addressed capital movement phenomena (Lane and Milesi-Ferretti, 2000; Caballero and Krishnamurthy, 2006; Reinhart and Reinhart, 2009). More recently, Forbes and Warnock (2012) studied four types of phenomena, namely non-resident capital surges (sharp increases in gross capital inflows) and stops (sharp decreases in gross capital inflows), and resident capital flight (sharp increases in gross capital outflows) and retrenchment (sharp decreases in net capital outflows).

The relationship between commodity prices and capital movements has been explored in the literature. For Reinhart and Reinhart (2009), higher commodity prices tend to improve domestic fiscal indicators, encourage domestic credit growth and attract more foreign investment. Frizo and Lima (2014) found that, in periods of global growth, higher commodity prices financed the domestic structural deficit in current transactions, owing to the higher volume of foreign direct investment (FDI) going to Brazil. Bredow, Lélis and Cunha (2016) considered that the commodity price boom cycle had a positive effect on portfolio investment inflows and, to a lesser extent, on FDI. Reinhart, Reinhart and Trebesch (2016) found that, in the period from 1815 to 2015, many emerging economies suffered a double bust involving a collapse in commodity prices and a sharp decline in capital movements.[4]

This study seeks to investigate phenomena related to non-resident capital (surges, stops, acceleration and deceleration) and resident capital (flight, retrenchment, acceleration and deceleration). When they occur, we seek to determine whether they are affected by commodity prices, in addition to domestic and external factors, in the period 1995 to 2016. The emerging economies analysed are Argentina, the Bolivarian Republic of Venezuela, Brazil, Chile, Colombia, Guatemala, Indonesia, Mexico, Nicaragua, Paraguay, Peru, the Plurinational State of Bolivia, the Russian Federation, South Africa and Uruguay. Economies such as Argentina, the Bolivarian Republic of Venezuela, Brazil, Colombia, Mexico, Peru, the Russian Federation and South Africa are part of the Emerging Markets Bond Index Plus (EMBI+) and are also included in EMBI Global. In terms of export potential, the commodity exports

[3] In methodological terms, this is defined as a period in which capital inflows fall one standard deviation below their mean and show a decline of two standard deviations at some point. The episode ends when capital inflows exceed one standard deviation below their mean.

[4] The authors argue that many emerging economies had to deal with a reversal of a double boom in commodity prices and capital inflows after the end of the last commodity boom.

of the above economies exceed 10% of their output (World Bank and others, 2016). While China is larger than the economies in the study, its commodity exports are equivalent to just 1.82% of its output, which is why it was not included.

This study differs from others because it: (i) includes commodity prices among the factors that may affect capital movement phenomena, (ii) disaggregates the prices of the different commodities (soybeans, oil and minerals) to increase the sensitivity of the results, (iii) methodologically introduces four phenomena that precede the major phenomena already studied (stop, flight, retrenchment and surge), and (iv) separates the capital controlled by domestic agents and external agents.[5] The main finding supports the evidence that commodity prices affect resident capital phenomena and that the dependence of emerging economies on a few commodities is indeed associated with phenomena of reduction in non-resident capital inflows.

This analysis contributes to policymaking by considering the relationship between the trade balance and the volatility of capital movements in the selected group of emerging countries and identifying the internal and external factors that drive capital movement phenomena. The results make it possible to visualize how economic vulnerability resulting from dependence on specific commodities is linked to weaknesses in respect of capital movement fluctuations.

The paper is divided into five sections including this introduction. The second section provides a theoretical exposition of commodity prices and capital movements, while the third identifies the way the phenomena are identified and the methodological procedures for estimating their relationship with commodity prices. The fourth section uses panel probit and cloglog models to detail the empirical results of the research. The fifth and final section presents the conclusions.

II. Commodity prices and capital movement phenomena

The model relating commodity prices to capital movements was developed by Frizo and Lima (2014) out of the assumptions of the new development economics, whose main exponent is Bresser-Pereira (2007).

The share of the services, primary income and secondary income categories in current transactions is assumed to be very low. For example, in the case of the balance of payments of Brazil (one of the economies in the sample), it is observed that 78.13% of income from current transactions in 2016 was provided by goods exports, 14.12% by services, 5.43% by primary income and 2.32% by secondary income. Since the shares of the services balance, primary income and secondary income accounts are of low significance, these categories are assumed to tend to zero owing to their lack of importance for the model.

Thus, the trade balance of commodity-exporting emerging countries is most affected by changes in the volume of commodities traded. The current transactions balance of the balance of payments can be expressed as follows:

$$CT = TB + SB + PR + SR \qquad (1)$$

Equation (1) indicates that the current transactions (CT) balance equals the sum of the trade balance (TB, exports and imports), the services balance (SB, services provided and received by residents), the primary income balance (PR, wages, salaries and investment returns) and the secondary income balance (SR, current unilateral transfers).

[5] See Alberola, Erce and Serena (2016) and Broner and others (2013) for more details on the implications of using gross capital to identify phenomena.

$$TB = TB(\theta, P_c, Y, Z) \quad (2)$$

From equation (2), it can be seen that the trade balance (TB) is affected by the nominal exchange rate (θ), commodity prices (P_c), income (Y) and control variables (Z). We shall now show how changes in the exchange rate (θ) and the trade balance (TB) are related to the movement of foreign capital (MFC):

$$\frac{d\theta}{dMFC} < 0, \frac{dTB}{dMFC} < 0 \quad (3)$$

The first derivative of equation (3) shows that, when foreign capital inflows (MFC) rise, there will be a larger supply of foreign exchange in the economy and a larger appreciation of the local currency (θ). The second derivative of (3) indicates that increased foreign capital inflows (MFC) into emerging economies prompt a decline in the trade balance (TB). The second relationship established will now be shown by using the aggregate consumption function to associate the exchange rate with foreign capital inflows.

$$CO = CO\left[Y, (\pi - r)\right] \quad (4)$$

In equation (4), aggregate consumption (CO) can be seen as a function of national income (Y) and the opportunity cost of investment ($\pi - r$), which refers to the differential between the rate of profit (π) and the rate of interest (r). While lower-income workers turn most of their wages into consumption, middle-class workers, who receive higher wages, and capitalists, who receive profits and interest, will choose to invest if the conditions for higher returns are in place. In an economy with a floating exchange rate, the inflow of foreign capital tends to cause the domestic currency to appreciate, with possible repercussions in the form of increased consumption of imported goods.

$$CO = CO\left[\theta, (\pi - r)\right] \quad (5)$$

Equation (5) shows that consumption can also be a function of the exchange rate (θ) and investors' opportunity cost ($\pi - r$). If a given economy grows through the foreign saving strategy and the current account deficit widens, the exchange rate will appreciate, leading to an increase in wages. With the wage bill at an artificially high level, profits are reduced.

$$CO = CO\left[MFC, P_c(\pi - r)\right] \quad (6)$$

Equation (6) shows consumption as a function of the movement of foreign capital (MFC), the price of commodities (P_C) and investors' opportunity cost ($\pi - r$). This equation highlights how the exchange rate appreciates with an increase in foreign capital inflows (MFC) and investors' opportunity cost ($\pi - r$) is weighted by the commodity price (P_C). Considering aggregate consumption (CO), the commodity price (P_C) and investors' opportunity cost ($\pi - r$), the following ratios are obtained from equations (5) and (6):

$$\frac{dCO}{dMFC} > 0, \frac{dCO}{dP_c} > 0, \frac{dCO}{d(\pi - r)} < 0 \quad (7)$$

The relationships in (7) reveal that an increase in the movement of foreign capital into the domestic economy will increase consumption, since people will increase their consumption of imported goods as the exchange rate appreciates. Higher commodity prices increase aggregate consumption. However, if the opportunity cost of agents investing increases, aggregate consumption decreases.

The assumption in the new development economics is that the inflow of capital into an economy can be determined by the ratio of external debt to exports, classified as a risk. An increase in this risk can reduce the inflow of foreign capital into the economy, prompting an exchange-rate devaluation and a balance-of-payments crisis.

$$MFC = MFC\left(dif\ f_i, \frac{D_e}{E}\right) \tag{8}$$

According to equation (8), the movement of capital into emerging economies (MFC) is a function of external debt (D_e) divided by commodity exports (E). This ratio is a proxy for country risk. The term $dif f_i$ captures the interest differential between the local economy (i) and the rest of the world.

The export of commodities depends directly on their price and the exchange rate. The model shows that capital inflows depend on the price paid for commodities, with a greater financial volume of exports reducing foreign investors' perception of risk in the economy concerned, which positively affects international capital inflows.

As the theoretical model outlined above highlights, an increase in commodity prices is expected to decrease the probability of stops, flights, liability deceleration and asset acceleration while at the same time increasing the probability of surges, retrenchments, liability acceleration and asset deceleration.

III. Methodology

1. Procedures for identifying capital flow phenomena

The analysis focused on the aggregate amount of the portfolio investment, FDI and other investment categories, represented by the sum of the values of the three categories. Derivatives were excluded owing to their small share in the total financial account of the balance of payments. Total gross capital inflows are the sum of portfolio investment, FDI and other investment inflows. Total gross capital outflows are the sum of the outflows of these three types of investment. These phenomena are determined following the procedures adopted by Forbes and Warnock (2012), with modifications of the standard deviations for the capital movement acceleration and deceleration phenomena.

The first step in recognizing these phenomena is to capture a pattern of capital movements. Initially, such a pattern was computed by considering the period from the first quarter of 1990 to the fourth quarter of 1994 (a total of 20 quarters), using the moving average method to average the series. The average moves quarter by quarter, with the data for the most recent quarter replacing those for the oldest quarter.

The identification of episodes is based on three criteria that must be met simultaneously. The first criterion is that the quarterly change in capital inflows (outflows) must be more than two standard deviations above (below) the mean for at least one quarter. The second criterion is that the duration of the episode in successive quarters must show a quarterly change of more (less) than one standard deviation from the mean. Lastly, the episode must last for more than one quarter.

The surge (flight) phenomenon occurred when the value of the capital entering (leaving) the country was equal to or greater than one standard deviation above the mean of the last 20 quarters and thereafter remained at least two standard deviations above the mean of the last 20 quarters for a period of at least one consecutive quarter.

Similarly, there was a stop (retrenchment) when the value of capital entering (leaving) the country was one or more standard deviations below the mean of the last 20 quarters and thereafter remained at least two standard deviations below the mean for a period of at least one consecutive quarter.

This study sought to identify the existence of two other phenomena, referred to as acceleration and deceleration. The first occurred when the value of capital entering the economy rose to a level one half or more standard deviations above the mean of the last 20 quarters and thereafter remained at least one standard deviation above the mean of the last 20 quarters for at least one consecutive quarter. The second was observed when the value of capital leaving the economy fell to a level of one half or more standard deviations below the mean and thereafter remained at least one standard deviation below the mean for a period of at least one consecutive quarter.

2. Estimating the likelihood of capital movement phenomena in emerging economies

The probit and cloglog models were used to establish the relationship between the likelihood of phenomena occurring and a set of factors. The cloglog model differs from the probit model in that it is asymmetric around zero and is more applicable when considering less frequently occurring phenomena. For more robust results (mainly for surge and flight phenomena, which occurred, respectively, 13 and 22 times in the period between the first quarter of 1995 and the fourth quarter of 2016), the model equation was also estimated using the cloglog model. In the case of the surge and flight phenomena, the value 1 appeared with a frequency of 5.23% and 4.55%, in that order. In the case of the stop, retrenchment, liability acceleration, asset acceleration, liability deceleration and asset deceleration phenomena, by contrast, the frequency was 36.67%, 25.23%, 10.45%, 12.73%, 50.61% and 41.06%, respectively.

To avoid problems of endogeneity between the dependent variables, the formulation of the structure of the equation in which the explanatory variables (global and domestic) were lagged by one period follows the studies of Calvo, Izquierdo and Mejía (2004 and 2008); Liesenfeld, Moura and Richard (2010); Forbes and Warnock (2012); Ghosh and others (2014); Silveira and Moreira (2014); and Ghosh, Ostry and Qureshi (2016). Eight models were estimated, as each phenomenon (surge, stop, flight, retrenchment, liability acceleration, asset acceleration, liability deceleration and asset deceleration) was estimated individually. For example, when the surge phenomenon was estimated, the "phenomenon" variable took a value of 1 if it was found to exist and a value of 0 otherwise. Equation (9) was used for all the phenomena separately, and all that changed was the dependent variable, which was estimated using the probit and cloglog models.

$$Phenomenon_{i,t} = \alpha_0 + \alpha_1 P_{i,t-1} + \alpha_2 GR_{i,t-1} + \alpha_3 GL_{i,t-1} + \alpha_4 GG_{i,t-1} + \alpha_5 GI_{i,t-1} + \alpha_6 pd_{i,t-1} + \alpha_7 edx_{i,t-1} + \alpha_8 fi_{i,t-1} + \alpha_9 GDP_{i,t-1} + \alpha_{10} CO_{i,t} + \alpha_{11} Crisis_{i,t} + \varepsilon_t \quad (9)$$

In equation (9), i represents the 15 emerging economies in the study, namely Argentina, the Bolivarian Republic of Venezuela, Brazil, Chile, Colombia, Guatemala, Indonesia, Mexico, Nicaragua, Paraguay, Peru, the Plurinational State of Bolivia, the Russian Federation, South Africa and Uruguay, while t represents each of the quarters in the period from 1995 to 2016.

In the composition of equation (9), the "phenomenon" variable took the value 1 if the phenomena (surge, stop, flight, retrenchment, liability acceleration, asset acceleration, liability deceleration and asset deceleration) existed in the i-th economy of the study in the t-th quarter and the value 0 otherwise.

α_0 is the constant.

The main variable of interest in equation (9) is the commodity price (P), which, by inducing an increase in exports, reduces investor risk and attracts greater foreign capital flows to emerging economies. Higher commodity prices can also change the direction of resident capital flows.

The determinants of the phenomena can be divided into global and domestic factors. The global factors taken included global risk (GR), global liquidity (GL, being the sum of the M2 monetary aggregate in the United States, Japan and the eurozone and M4 in the United Kingdom), global growth (GG) and the global interest rate (GI, being the average long-term rate on government assets in the United States, the eurozone and Japan).

The domestic factors used were public debt (pd), GDP per capita (GDP), the risk measure, represented by external debt/exports (edx), and financial integration (fi). The measure of financial integration used in this study is a proxy for capital controls, namely (assets + liabilities)/GDP, used by Forbes and Warnock (2012).

The regional contagion (co) variable is a dummy variable that takes the value 1 when the phenomenon under study also occurs in the other countries of the sample that are in the same region and 0 otherwise. This variable was constructed for all phenomena.

The subprime crisis ($Crisis$) variable is a dummy variable that takes the value 1 for the period from the second quarter of 2008 to the second quarter of 2009, as in the study by Forbes and Warnock (2012).

The series of the study are quarterly (first quarter of 1990 to fourth quarter of 2016), and all variables were transformed into index numbers, with 2014 as the base year. To standardize the unit of measurement, variables expressed in the tender of the country were converted into dollars at the average exchange rate for the period.

Table 1 shows the expected signs for the factors in relation to the phenomena.

Table 1

Expected signs for domestic and global factors explaining capital movement phenomena

Variable	*Surge*	*Stop*	*LA*	*LD*	*Retrenchment*	*Flight*	*AA*	*AD*
Commodity price (*P*)	+	-	+	-	+	-	-	+
Global risk (*GR*)	-	+	-	+	+	-	-	+
Global liquidity (*GL*)	+	-	+	-	+	-	-	+
Global growth (*GG*)	+	-	+	-	-	+	+	-
Global interest rate (*GI*)	-	+	-	+	-	+	+	-
Subprime mortgage crisis (*Crisis*)	-	+	-	+	+	-	-	+
Financial integration (*fi*)	+	-	+	-	+	-	-	+
Public debt (*pd*)	-	+	-	+	-	+	-	+
External debt/exports (*edx*)	-	+	-	+	-	+	+	-
GDP per capita (*GDP*)	+	-	+	-	-	+	+	-
Regional contagion (*co*)	+	+	+	+	+	+	+	+

Source: Prepared by the authors, on the basis of G. A. Calvo, L. Leiderman and C. M. Reinhart, "Inflows of capital to developing countries in the 1990s", *The Journal of Economic Perspectives*, vol. 10, No. 2, 1996; Y. Kim, "Causes of capital flows in developing countries", *Journal of International Money and Finance*, vol. 19, No. 2, April 2000; G. A. Calvo, A. L. Izquierdo and L. F. Mejía, "On the empirics of sudden stops: the relevance of balance-sheet effects", *NBER Working Paper*, No. 10520, Cambridge, National Bureau of Economic Research (NBER), 2004; G. A. Calvo, A. L. Izquierdo and L. F. Mejía, "Systemic sudden stops: the relevance of balance-sheet effects and financial integration", *NBER Working Paper*, No. 14026, Cambridge, National Bureau of Economic Research (NBER), 2008; G. M. Milesi-Ferretti and C. Tille, "The great retrenchment: international capital flows during the global financial crisis", *Economic Policy*, vol. 26, No. 66, April 2011; K. J. Forbes and F. E. Warnock, "Capital flow waves: surges, stops, flight, and retrenchment", *Journal of International Economics*, vol. 88, No. 2, November 2012; M. Fratzscher, "Capital flows, push versus pull factors and the global financial crisis", *Journal of International Economics*, vol. 88, No. 2, November 2012; M. A. C. Silveira and A. Moreira, "Paradas e flights súbitas dos fluxos de capital nos países emergentes: fatores globais e locais", *Texto para Discussão*, No. 1932, Rio de Janeiro, Institute of Applied Economic Research (IPEA), 2014; S. M. Bredow, M. T. Lélis and A. M. Cunha, "O ciclo de alta nos preços das commodities e a economia Brasileira: uma análise dos mecanismos externos de transmissão entre 2002 e 2014", *Economia e Sociedade*, vol. 25, No. 3, December 2016; P. Frizo and R. A. S. Lima, "Efeitos da flutuação dos preços das *commodities* no fluxo de investimento estrangeiro direto no Brasil", *Revista de Economia Contemporânea*, vol. 18, No. 3, September-December 2014; C. M. Reinhart, V. Reinhart and C. Trebesch, "Global cycles: capital flows, commodities, and sovereign defaults, 1815–2015", *American Economic Review*, vol. 106, No. 5, May 2016.

Note: LA = liability acceleration, LD = liability deceleration, AA = asset acceleration and AD = asset deceleration.

3. Data sources

The variables used to detect capital movement phenomena are the capital sub-account categories, namely foreign direct investment, portfolio investment and other investment. These variables are provided by the International Financial Statistics (IFS) database of the International Monetary Fund (IMF, 2017), in dollars.

The commodity price variable is the total commodity price index (PALLFNF). For the sensitivity analysis, use was made of the mineral price index (PMETA), the soybean price index, which is the average of (PSMEA+PSOIL+PSOYB), and the oil price index, which is the average of (PNRG+POILAPSP). The price variables were taken from the International Financial Statistics database of the International Monetary Fund (IMF, 2017), and were provided in index numbers.

Data on global factors were taken from a variety of sources. Global risk was based on the Chicago Board of Exchange (CBOE) VIX volatility index, which is derived from put and call option prices on the S&P 500 index (Cboe, 2017).

Global liquidity, the global interest rate and global growth (in dollars) were also taken from the International Financial Statistics database (IMF, 2017).

With respect to domestic factors, information from the World Economic Outlook database (IMF, n.d.) was used for financial integration (in dollars), the risk indicator (external debt/exports) and external debt, while data on free-on-board exports were taken from the International Financial Statistics database (IMF, 2017). Data on public debt as a share of GDP and GDP per capita, in dollars, were also extracted from the World Economic Outlook database (IMF, n.d.).

IV. Results and analysis

1. Identification and explanation of capital movement phenomena in the set of selected commodity-exporting countries

The 15 commodity-exporting emerging economies in this study experienced episodes of the phenomena studied (surge, stop, flight, retrenchment, liability acceleration, liability deceleration, asset acceleration and asset deceleration) in the period from 1995 to 2016. The number of episodes of these phenomena in the economies analysed is presented in table 2.

Failure to find many phenomena in capital inflows does not mean that large volumes of non-resident capital do not enter or even that the value of resident capital in other economies is small. However, it may signify that this upward trend in resident and non-resident capital occurs in a more concentrated and approximate way around the mean during the period analysed. The result is that not many episodes presenting a discrepancy with respect to the past mean of capital inflows into the economies have been detected.

Some unexpected shocks in the economies may explain a large part of the phenomena. For this reason, we sought to relate these episodes within a historical framework of different crises and financial weaknesses affecting emerging economies in the reference period.

Table 2
Capital movement phenomena in selected commodity-exporting countries
(Numbers)

Country	*Surge*	*Stop*	*LA*	*LD*	*Retrenchment*	*Flight*	*AA*	*AD*	Total
Africa									
South Africa	0	8	2	7	6	1	3	9	36
South America									
Argentina	1	5	1	5	5	0	3	11	31
Bolivia (Plurinational State of)	0	7	0	8	5	1	5	10	36
Brazil	1	7	2	7	9	0	0	13	39
Chile	0	9	0	12	8	1	4	11	45
Colombia	0	6	1	8	0	1	3	11	29
Paraguay	2	3	5	6	2	5	4	6	33
Peru	1	8	1	10	5	2	5	11	43
Uruguay	2	6	3	9	4	3	5	7	39
Venezuela (Bolivarian Republic of)	2	10	4	12	9	1	3	12	53
North America									
Mexico	0	10	2	10	6	1	2	8	39
Central America									
Guatemala	0	5	0	11	4	2	6	5	34
Nicaragua	3	1	4	5	3	1	7	5	29
Asia									
Indonesia	3	6	7	8	9	2	3	9	47
Eurasia									
Russian Federation	2	3	5	7	8	1	2	7	35
Total	17	94	37	125	83	22	55	135	568

Source: Prepared by the authors.
Note: LA = liability acceleration, LD = liability deceleration, AA = asset acceleration and AD = asset deceleration.

With the neoliberal reforms implemented from the second half of the 1980s, the Mexican economy exhibited an intermediate stage of financial openness (Freitas and Prates, 1998). According to Prates (2005), the Mexican crisis that broke out in 1994, unlike the other crises in Latin American countries at that time, was not the result of irresponsible behaviour stemming from government fiscal policies. According to the author, investment in the economy fell considerably because the country was not in a position to meet its short-term obligations. In fact, as can be seen in table 2, there were a total of 10 stop and 10 liability deceleration episodes in Mexico. The repercussions of the Mexican crisis were felt in the other emerging economies, as it represented an adjustment in the Latin American economies, and the increase in currency risk resulted in a sell-off of Latin American assets and, consequently, capital flight from those economies.

Countries whose fiscal and monetary fundamentals were considered sound were subjected to the 1997 Asian financial crisis, which mainly affected the countries in the south-east of that region (Prates, 2005). According to the author, as well as affecting exchange-rate regimes, this crisis led to a reversal of capital movements and to banking fragility, which even spread to other regions. During the crisis period, Indonesia experienced two episodes of capital inflow stops and one of liability deceleration, while there was one episode of resident capital flight, one of retrenchment and one of asset deceleration.

According to Johnson and others (2000), although the 1997 crisis started in Asia and some Latin American countries, its effects spread so far that in 1998 they reached the Russian Federation and Brazil. The authors state that in 1998 the Russian Federation went through a period of devaluation that caused the country's debt to increase. These events revealed the fragility of the economy in the face of default risk, and for this reason investor capital flight increased in a number of countries' financial markets. Between 1995 and 2016, the Russian Federation saw eight episodes of flight and seven of deceleration in the capital movements of residents, who, affected by contagion, avoided countries with similar structures. Specifically, stop, flight, liability acceleration and liability deceleration episodes were observed in the Russian economy during the crisis.

Subsequently, on top of the repercussions of the Asian, Russian and Brazilian crises, according to Batista Junior (2002), foreigners became increasingly distrustful over the 2000s of the financial system in Argentina, whose currency had been pegged to the dollar for nearly 10 years. This led to defaults by private debtors and a deterioration in the quality of bank assets. According to the author, the Argentine economy suffered several shocks from 1997–1998 onward, including a reduction in foreign capital. The results show that Argentina suffered five stop and five flight episodes between the first quarter of 1995 and the fourth quarter of 2016, in addition to a considerable deceleration in the movement of Argentine resident capital (giving a total of 11). During the crisis period, capital flowing into Argentina was subject to stops and liability deceleration, while Argentine investors' capital presented episodes of flight and deceleration.

Aldrighi and Cardoso (2009) stress that the external shocks suffered by Asia, the Russian Federation and Brazil in the periods mentioned led to a stop in foreign capital inflows. As justification for these effects, the authors point to the low degree of openness, dispersion in the public and private sectors and difficult fiscal situation of these economies. These factors increased their vulnerability and made them more susceptible to exchange-rate and financial crises.

The period between 2007 and 2008 was marked by the subprime mortgage crisis, which affected capital mobility between economies. This crisis began in the United States and had repercussions in other economies by changing agents' expectations, increasing global risk and reducing the volume of capital movements in emerging economies. The scale of the crisis is confirmed by the stop, flight, liability and asset deceleration phenomena that can be observed in almost all the countries of the sample during this period.

It should also be pointed out that periods of resident and non-resident capital acceleration and deceleration occurred prior to these crises. After all, despite the impact of the 2008 crisis, there was an upsurge in the movement of capital (especially short-term capital) to emerging economies, including Brazil, in mid-2009, owing to the large spread between domestic and external interest rates (Barbosa Filho, 2017).

2. The relationship between commodity prices and capital movement phenomena

The results of equation (9) using probit and cloglog models for episodes affecting non-resident capital (stop, surge, liability acceleration and liability deceleration) and resident capital (flight, retrenchment, asset acceleration and asset deceleration) are presented in table 3.

To ascertain the overall significance of the model, the result of the Wald test is presented in table 3. The null hypothesis is rejected at a significance level of 1%, so the models for each phenomenon are well specified.

The relationship between commodity prices and non-resident capital phenomena was not apparent. One justification for this result may be that the use of the total commodity price index does not reflect the reduction in emerging economy risk. Commodity prices did influence the flight and asset deceleration episodes in the case of resident capital, however. A reduction in emerging economy risk brought about by higher commodity prices influences domestic investors to invest more of their capital abroad.

Table 3

Results for the estimation of the likelihood of resident and non-resident capital movement phenomena

Variable	Non-resident capital								Resident capital							
	Probit				Cloglog				Probit				Cloglog			
	Stop	*Surge*	*LA*	*LD*	*Stop*	*Surge*	*LA*	*LD*	*Flight*	*Retr.*	*AA*	*AD*	*Flight*	*Retr.*	*AA*	*AD*
Commodity price	0	0	0	0	0	0	0	0	(-)*	0	0	(+)*	(-)**	0	0	0
Global variables																
Global risk	0	(-)**	(-)***	0	(-)*	(-)***	(-)***	0	0	0	0	0	0	0	0	0
Global liquidity	(+)***	0	0	(+)***	(+)***	0	0	(+)***	0	0	0	(+)**	0	0	0	(+)**
Global growth	(-)***	0	0	0	(-)***	0	0	0	0	0	0	0	(+)*	0	0	0
Global interest rate	0	0	0	0	0	0	0	0	(-)**	0	0	(+)**	(-)**	0	0	(+)*
Crisis																
Subprime mortgage crisis	0	0	0	(+)**	0	0	0	(+)**	0	0	0	0	0	0	0	0
Contagion																
Regional	(+)***	(+)**	(+)***	(+)**	(+)***	(+)*	(+)***	(+)**	0	(+)**	(+)***	(+)**	0	(+)***	(+)*	(+)**
Domestic variables																
External debt/exports	0	0	0	0	0	0	0	0	(+)**	0	0	0	(+)**	0	0	0
Public debt/GDP	0	0	0	0	0	0	0	0	(-)***	0	(-)*	(+)*	(-)***	0	(-)***	0
GDP per capita	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Financial integration	0	0	0	0	0	0	0	0	(+)*	0	0	0	0	0	0	0
Number of observations	1 305	1 305	1 305	1 305	1 305	1 305	1 305	1 305	1 305	1 305	1 305	1 305	1 305	1 305	1 305	1 305
X^2	148.27	246.39	234.80	152.16	183.55	646.61	462.40	166.35	269.85	493.25	144.54	39.55	284.32	732.88	116.71	32.42
Probability	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Likelihood ratio	34.60	45.21	114.27	31.85	41.68	40.41	113.73	37.50	7.14	102.47	34.71	43.64	8.12	97.52	35.73	38.91
Probability	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Prepared by the authors, on the basis of their research results.

Note: LA = liability acceleration, LD = liability deceleration, Retr. = Retrenchment, AA = asset acceleration, AD = asset deceleration. The "-" sign means that the variable was statistically significant and had a negative sign, "+" that the variable was statistically significant and had a positive sign and "0" that the variable was not statistically significant, with *** indicating significance at 1%, ** significance at 5% and * significance at 10%. Standard errors clustered at the country level were used.

Among the global determinants, contrary to expectations, the global liquidity variable affected the likelihood of stop and liability deceleration episodes occurring. Increased currency issuance internationally means a greater volume of capital to seek returns on. While emerging economies present risks, they also offer high yields. However, changes in domestic indicators can act as a disincentive to foreign investors, thus explaining the increase in stop episodes. Among the external factors, an increase in global liquidity was associated with an increase in resident capital deceleration. This result may be related to the ability of domestic economies to honour the commitments they have made, as this prevents domestic agents from opting for more liquid financial systems and thus rationing domestic credit (Silva and Resende, 2010).

The results point to global growth as a factor reducing the likelihood of disruptions to capital flows. Higher global growth suggests higher wages and greater purchasing power in the hands of agents who can allocate or maintain their investments, favouring emerging economies and preventing large reductions in foreign capital inflows.

The results also point to global growth as a factor driving flight episodes. Some conditions in foreign economies may attract migrant domestic capital, namely increases in domestic and private consumption and in investment, and decreases in the unemployment rate in economies that transact in the financial system.

Global risk was found to be important for the surge model, since when international uncertainty increases, investors are more likely to be sceptical about investing large amounts of capital. The same result is obtained for the phenomenon that precedes it: liability acceleration. According to these results, in periods of increased risk aversion, when financial fear or even panic can be perceived, foreign capital inflows into emerging economies decline.

A rise in the global interest rate was associated with a reduction in the likelihood of flight and asset deceleration episodes. These results ran counter to expectations, since if there is a greater prospect of returns in economies with greater investment security, domestic investors would be expected to increase the amount of capital invested abroad. No association between the interest rate and non-resident capital phenomena was found, however, and this response was likewise absent in the Forbes and Warnock (2012) study.

Another finding was that domestic factors were not related to non-resident capital phenomena. Other studies have also claimed that external factors are more important than domestic ones. Calvo, Leiderman and Reinhart (1996) highlighted the importance of external factors in explaining capital movements towards emerging economies in the 1990s. Munhoz (2013) noted that the vulnerability of emerging economies such as Brazil could be attributed to reversals in capital movements driven by exogenous forces. Similarly, Calvo, Izquierdo and Mejía (2004) argued that highly indebted countries tended to be more prone to capital flow reversals. The authors tested this claim for various approaches to measuring domestic public debt and found no clear evidence regarding the role played by public debt in sudden and sharp reductions of non-resident capital flows. The results of this study also confirm the limited significance of economies' public debt in determining non-resident capital movement phenomena.

With respect to the domestic factors driving phenomena, a rise in external debt/exports is associated with an increase in flight episodes. According to Silveira and Moreira (2014), sudden flight phenomena in different countries' capital movements have a more dispersed frequency and are more affected by domestic shocks. This explains the table 3 results, in which more domestic factors are found to determine the likelihood of flight episodes.

Higher domestic borrowing in an economy is associated with a reduction in the flow of domestic capital into the international financial system. If economic performance is weaker, this is also reflected in a lower volume of capital flowing into foreign investment.

The results show that the higher the degree of financial integration, the more likely flight episodes are to occur. If emerging economies increase their interaction with other economies, there is a possibility that the amount of domestic capital sent abroad will increase.

The subprime mortgage crisis was associated with episodes of some phenomena, such as capital movement stops and deceleration. The uncertainty in the international environment and the bankruptcy of a number of investors led to a sharp reduction of capital in several economies, especially emerging ones.

Moreover, geographical proximity increased the likelihood of all non-resident and resident capital movement phenomena except flight. This finding can be interpreted in two ways. In periods when economies inspire confidence in the financial market, this sentiment can be seen to extend to other economies with similar characteristics. Thus, an increase in capital in one economy is likely to spread to other economies in the same region as well. On the other hand, if the market loses confidence in a given country, there is a certain tendency for scepticism towards similar economies to increase. Thus, a reduction in capital in one economy may also occur in its peers. Contagion and a greater role for external than domestic factors in non-resident capital phenomena were also identified by Forbes and Warnock (2012).

To provide a stronger basis for the results, we attempt to ground them in pull and push factors as drivers of capital movements. First, we seek to understand whether capital investment in emerging economies is motivated by adverse forces in developed economies. This would mean that capital was somehow coming under pressure to migrate because of unfavourable conditions in developed economies (Fernández-Arias, 1996). The argument used about capital attracted by such forces is that it is highly volatile, owing to its distance from local policymakers.

We then consider foreign capital attracted by favourable conditions in emerging economies, i.e. foreign capital directed towards these economies because domestic policies are having an effect. In this case, domestic factors may act as a stronger force than external factors (Fernández-Arias, 1996). From the results presented in table 3 it can be seen that it is usually adverse conditions in developed economies that have led to massive increases or decreases in foreign capital inflows to emerging economies.

Differences in response between resident and non-resident capital phenomena were also identified. Calvo, Izquierdo and Mejía (2004) analysed differences in capital reversals, distinguishing between capital attributed to residents and non-residents. Analysing the case of the Chilean economy, Cowan and De Gregorio (2005) showed that much of the movement in the capital balance was due to fluctuations in residents' gross capital. This study also provides justifications for analysing the gross capital controlled by residents and non-residents, since the factors behind large inflows or outflows of capital are different, as can be seen in table 3.

The study also points out that commodity-exporting economies have advantages in certain production activities and therefore trade products on the international market that give them greater comparative advantages over other economies. The tendency of economies to expand the sectors in which they have comparative advantages, in this case natural resources, can trigger deindustrialization, a phenomenon known as Dutch disease (Sonaglio and others, 2010). This syndrome can also manifest itself in economies through appreciation of the domestic currency as capital inflows increase because of commodity exports (Bredow, Lélis and Cunha, 2016).

To perform a sensitivity test on these results, the sample was subdivided[6] on the basis of three specific commodities exported by the sample countries, namely minerals,[7] soybeans[8] and oil.[9] Equation (9) for the phenomena was estimated once again considering the new division of the sample. However, it was not possible to obtain consistent results for all phenomena, as some of them presented a frequency of 1 below 5% and some models were not well specified. Table 4 presents the results for the capital movement phenomena, considering the prices of minerals, oil and soybeans.

With respect to the main model, the results presented in the sensitivity test for disaggregated prices allow some observations to be made, namely:

(i) When the groups of economies specializing in three commodities (soybeans, minerals and oil) are distinguished, the results show an even more effective relationship between their prices and the likelihood of non-resident capital phenomena occurring, especially phenomena involving reduced capital inflows, such as stops and liability deceleration. This result clearly shows how dependent the economies analysed are on certain commodities and how changes in their prices can indeed affect capital movements particularly strongly.

(ii) In the case of disaggregated prices, domestic factors were also important (as determinants) for the likelihood of non-resident capital movements occurring.

(iii) As shown in the main model, the sensitivity test highlighted the role of higher prices for commodities (minerals and soybeans) in reducing domestic capital outflows, mainly through the asset deceleration phenomenon.

(iv) The global interest rate was found to be particularly sensitive.

(v) The analysis of disaggregated prices showed that the subprime mortgage crisis had a particularly strong impact in reducing capital inflows from foreign investors.

[6] This subdivision of economies considered the commodities that they exported the most and that appeared most frequently in order to obtain a larger number of countries in the sample.

[7] Brazil, Chile, Guatemala, Peru and South Africa.

[8] Argentina, Brazil, Paraguay, the Plurinational State of Bolivia and Uruguay.

[9] Brazil, Colombia, Indonesia, Mexico, Peru and the Plurinational State of Bolivia.

Table 4
Sensitivity test results for the prices of selected commodities

Variable	Minerals						Oil				Soybeans			
	Probit			Cloglog			Probit		Cloglog		Probit		Cloglog	
	Stop	*LD*	*AD*	*Stop*	*LD*	*AD*	*Stop*	*LD*	*Stop*	*LD*	*Surge*	*AD*	*Surge*	*AD*
Commodity price	(-)***	(-)***	(+)*	(-)***	(-)***	(+)*	(-)*	(-)**	0	(-)*	0	(+)**	(-)*	(+)*
Global variables														
Global risk	0	0	0	0	0	0	(-)**	0	(-)**	0	(-)**	0	(-)**	0
Global liquidity	0	(+)***	(+)***	0	(+)**	(+)***	0	(+)*	0	(+)**	0	0	0	0
Global growth	(-)**	0	0	(-)***	0	0	(-)**	0	(-)***	0	(+)***	0	(+)**	0
Global interest rate	0	(+)**	(+)***	0	(+)**	(+)**	0	0	0	0	0	0	0	0
Crisis														
Subprime mortgage crisis	(+)**	(+)**	0	(+)**	(+)***	0	0	(+)*	0	(+)*	(+)	(-)**	(+)***	0
Contagion														
Regional	(+)***	(+)**	(+)***	(+)***	(+)**	(+)**	(+)***	(+)***	(+)**	(+)***	0	(+)**	0	(+)***
Domestic variables														
External debt/exports	0	0	(-)***	0	(+)*	(-)**	0	0	0	0	0	0	0	0
Public debt/GDP	0	(+)*	(+)***	0	(+)**	(+)**	0	0	0	0	(+)***	0	(+)***	0
GDP per capita	(+)**	(+)***	0	(+)**	(+)***	0	(+)**	(+)***	(+)*	(+)***	0	(-)***	0	(-)***
Financial integration	(-)***	(-)***	0	(-)***	(-)***	0	(-)*	(-)**	(-)***	(-)**	0	0	0	0
Number of observations	522	522	522	522	522	522	522	522	522	522	348	348	348	348
X^2	93.08	92.84	56.49	96.64	86.26	58.12	87.34	72.95	94.66	68.28	21.06	21.94	20.89	20.33
Probability	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.03	0.04
Likelihood ratio	1.40	15.17	19.53	3.02	13.06	18.42	11.55	29.68	9.24	23.84	4.08	13.32	5.71	12.88
Probability	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.000	0.01	0.000

Source: Prepared by the authors, on the basis of their research results.

Note: The "-" sign means that the variable was statistically significant and had a negative sign, "+" that the variable was statistically significant and had a positive sign and "0" that the variable was not statistically significant, considering significance at 1%, 5% and 10%. LD = liability deceleration and AD = asset deceleration, with *** indicating significance at 1%, ** significance at 5% and * significance at 10%. Standard errors clustered at the country level were used.

V. Conclusions

This study has analysed phenomena associated with the movement of capital by non-residents (surge, stop, liability acceleration and liability deceleration) and residents (flight, retrenchment, asset acceleration and asset deceleration). In addition to investigating the role of global and domestic factors as drivers of these phenomena, the relationship with commodity prices in particular was tested.

The results show that emerging economies suffer a greater number of episodes of phenomena that reduce capital inflows or outflows than developed economies. These economies are more susceptible to reductions in financing, deterioration of the balance-of-payments current account and negative impacts on growth. At the same time, the results show that they are less likely to send large volumes of domestic wealth abroad.

The subprime mortgage crisis affected foreign capital inflows to emerging economies and had a dampening effect on domestic capital outflows. A prominent factor in the estimates was contagion at the regional level. This result shows that, if a situation produces fluctuations of capital movements in one economy, economies in the same region that perform similarly and are geographically close should prepare for the same trends.

A better understanding of the global factors related to the phenomena helps economies to implement macroeconomic policies that can limit the risk and instability caused by surges in capital inflows. After all, these phenomena affect the stability of capital movements, which is important for economic performance. Analysis of the determinants of capital movements points to the financial vulnerability of emerging economies to external factors, such as those occurring in the form of increased global risk, global liquidity and global growth. However, these variables do not influence the administration of those managing emerging economies, but knowledge of their influence on fluctuations in capital movements acts as a signal to these economies.

While external conditions put countries to the test, vulnerability is also driven by domestic factors. As noted in the previous section, all domestic factors (external debt, debt/GDP, GDP per capita and financial integration) influence the behaviour of resident and non-resident capital to some extent. This suggests that, if policymakers choose to increase external debt or even integrate more closely with other economies, a large amount of domestic capital may flow into the international financial system. On the other hand, if the policies adopted are reflected in an increase in the debt/GDP ratio, they act as a disincentive to capital outflows by domestic investors.

Over time, the performance of the external sector of countries' domestic economies has been influenced by both external financial cycles and fluctuations in the commodity cycle. The analysis conducted for all the countries in the sample allows us to conclude that there is indeed a relationship between commodity prices and episodes of resident capital movement phenomena. The results also show that this relationship becomes significant for non-resident capital when the study focuses on countries that export large volumes of commodities, such as soybeans, minerals and oil.

The study is limited by the availability of data on some domestic factors, such as indices of capital account openness. For future research, it is recommended that further work be done on differences in the responses of resident investors relative to non-resident investors.

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Effects of higher commodity prices on exports of manufactures: the case of Brazil

André Moreira Cunha, Marcos Tadeu Caputi Lélis, Sabrina Monique Schenato Bredow and Luciane Franke

Abstract

This study seeks to determine whether the increased earnings of Brazil's trading partners that benefited from the boom in commodity prices during the 2000s spurred Brazilian exports of manufactures to those countries. It begins with the hypothesis that there is a positive link between Brazil's exports of manufactured goods and the increased revenues of its trading partners derived from the robust performance of their exports of natural resources. A two-stage hierarchical statistical model based on a panel data structure is used to estimate a crosss-section data model. To our knowledge, this strategy has not been used before to study the behaviour of Brazilian manufactured exports during the economic boom of the 2000s fuelled by the commodity supercycle.

Keywords

Commodities, commodity prices, business cycles, industrial development, international trade, manufactures, exports, econometric models, Brazil

JEL classification

F14, F44, O14

Authors

André Moreira Cunha is a Professor of the Postgraduate Economics Programme of the Federal University of Rio Grande do Sul and a Research Fellow of the National Council for Scientific and Technological Development (CNPq). Email: andre.cunha@ufrgs.br.

Marcos Tadeu Caputi Lélis is an Associate Professor of the Postgraduate Economics Programme of the University of Vale do Rio dos Sinos and a Research Fellow of the National Council for Scientific and Technological Development (CNPq). Email: mlelis@unisinos.br.

Sabrina Monique Schenato Bredow holds a Ph.D. in Economics from the Federal University of Rio Grade do Sul and is an Economic Adviser to the Credit Division of the Banco do Brasil. Email: sabrinabredow@gmail.com.

Luciane Franke is a doctoral candidate in the Postgraduate Economics Programme of the Federal University of Rio Grande do Sul. Email: luciane.franke@hotmail.com.

I. Introduction

In a departure from the trend seen in the 1980s and 1990s, the prices of agricultural, mineral and energy commodities rose sharply during much of the first two decades of the twenty-first century in what has been described in the specialized literature as a "supercycle" (Sinnot, Nash and De la Torre, 2010; IMF, 2015; Fernández, González and Rodríguez, 2015; Alberola-Ila and others, 2016; World Bank, 2009; De la Torre, Filippini and Ize, 2016; UNCTAD/FAO, 2017; ECLAC, 2017). This appears to have been attributable to a combination of several different factors, including the expansion of global demand brought about by the rapid urbanization and growth of income in emerging countries, such as, in particular, China; insufficient investment in the production and distribution of some commodities, such as oil and petroleum products; and the "financialization" of prices, against a backdrop of expanding global liquidity.

The specialized literature suggests that this supercycle's positive impact on the terms of trade is what accounts for the strong macroeconomic and social performance of commodity-producing and commodity-exporting countries during this period. Throughout the 2000s and up to at least mid-2010 —but continuing at a somewhat slower pace until 2013— there was a widespread and quite unusual combination of accelerating economic growth, improving public accounts and balance of payments results, declining monetary poverty rates and increasingly positive human development indicators in such areas as education and health (ECLAC, 2018). This economic buoyancy apparently eased the widespread external and fiscal constraints that typically hold back emerging and developing countries, thus allowing them to step up investment in physical and social infrastructure. There was a partial break in this trend in 2008 and 2009 owing to the impact of the global financial crisis, followed by a reversal when commodity prices began to fall steeply in 2014.

This study looks at some of the effects that those years of strong growth may have had on Brazilian exports. There are at least two channels through which the favourable terms-of-trade effects generated by that period of robust growth could have been transmitted to external sales of goods: a direct one, via the rising prices and export volumes of commodities and commodity derivatives; and an indirect one, via the increase in exports of manufactured goods to economies specialized in the production and exporting of natural resources. This study will focus on that second channel in an effort to determine to what extent the increased revenues of Brazil's trading partners, which also benefited from the upswing in commodity prices, spurred Brazilian exports of manufactured goods to those countries. The study departs from the hypothesis that there is a positive link between Brazil's exports of manufactured goods and the increased revenues of its trading partners derived from the robust performance of their exports of commodities and natural resource-intensive goods.

As a first step in testing this hypothesis and pursuing the study's objective, a sample of 51 national markets for Brazil's manufactured exports was selected, which includes countries in Africa and Latin America known as producers and exporters of natural resources. During the study period (2001–2015), these countries bought approximately one third, on average, of the manufactured goods sold by Brazil on international markets. In order to establish the direct income effect of the upward swing in commodity prices, we used the value of exports of commodities and of resource-intensive goods, following the taxonomy of Pavitt (1984), as a proxy. In terms of the methodology, a dynamic panel data model was used to perform the empirical exercise. To our knowledge, this strategy has not been used before to study the behaviour of Brazil's exports of manufactures in the 2000s during the boom driven by the commodity supercycle (Castilho and Luporini, 2010; Bastos, 2012; Hiratuka and others, 2012; Jenkins, 2014; Medeiros and Cintra, 2015; Lélis and others, 2018; Lin, 2018).

Apart from this brief introduction, the study is divided into three sections: a review of the literature (section II) lays the groundwork for our presentation of the econometric exercise performed to provide input for the debate around this issue (section III). Conclusions (section IV) are then provided regarding the main results and their implications.

II. The commodity supercycle and exports of manufactured goods: a brief review of the literature

The recent upswing in commodity prices had a positive impact on the terms of trade for net commodity exporters (World Bank, 2009; De la Torre, Filippini and Ize, 2016; UNCTAD/FAO, 2017; ECLAC, 2017). Although this factor alone is not enough to reduce these economies' exposure to the problems associated with the unfavourable price structure and income elasticities of demand[1] described in the seminal works of Prebisch (1950) and Singer (1950), steeply rising commodity prices and dollar-denominated export earnings can diminish or even temporarily cancel out the negative pressure on such countries' balance of payments because the increased revenues generate a disproportionately large jump in the demand for manufactured goods. In the 2000s, these factors opened up an extraordinary opportunity for countries with commodity-based production structures to step up their pace of growth without having to deal with the external constraints that generally hold them back.

The growth of the income and domestic markets of commodity-exporting countries was not brought about solely by the increase in commodity prices, however. The domestic policies[2] adopted by these countries during this period were also influential. Nonetheless, while it is true that these economic policies drove the growth of aggregate demand, the fact remains that the increase in commodity prices[3] and improvement in the terms of trade were what ensured the viability of that growth and its compatibility with a balance-of-payments equilibrium. This translated into higher employment, higher income, an upswing in productive investment, improved solvency and more ample external liquidity thanks to greater inflows of foreign currency from exports, direct investment and portfolio investments, along with a reduction in physical vulnerabilities (World Bank, 2009; De la Torre, Filippini and Ize, 2016; Sinnot, Nash and De la Torre, 2010; IMF, 2015).

In Latin America, these conditions opened the way for greater trade integration among the countries of the region (Bastos, 2011 and 2012; ECLAC, 2017). Favourable external conditions and increased profitability in the primary export sector, combined with economic policies designed to promote internal market growth and income distribution, played a fundamental role in this process (IMF, 2015; De la Torre, Filippini and Ize, 2016). Brazil wielded a great deal of diplomatic influence during this period and proved to be one of the countries that gained the most from the economic boom (Bastos, 2011 and 2012; Alberola-Ila and others, 2016; De la Torre, Filippini and Ize, 2016). During the commodity supercycle, Latin America as a whole relied on its commodity export earnings to finance its intraregional imports of manufactures, and a substantial portion of those came from Brazil, which consequently amassed hefty trade surpluses. Bastos (2012) and Castilho and Luporini (2010) therefore point out that the Brazilian

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[1] A large and varied body of literature focuses on empirical evidence to back up the ideas espoused by Prebisch and Singer (Sinnot, Nash and De la Torre, 2010; UNCTAD/FAO, 2017). The empirical debate around whether or not there is a downward trend in the terms of trade for primary producers and about the normative implications of such a trend if it does exist continues to be quite animated. There is, however, a growing consensus around the outcomes of commodity price volatility. In addition, in balance-of-payments-constrained growth models such as those devised by Thirlwall (1979) —even without taking a downward trend in commodity prices into account— the structure of the income elasticity of demand for commodities and manufactured goods is enough in itself to block convergence between the economic growth of commodity exporters in the presence of the external constraints affecting them and the economic growth of exporters of manufactures (Nassif, Feijó and Araújo, 2015; Cimoli and Porcile, 2014; Lélis and others, 2018. Within a different framework, Gruss (2014) and IMF (2015) show that economies that specialize in the production and exportation of natural resources grow less over the long term.

[2] See, among others, Bastos (2011 and 2012), Castilho and Luporini (2010), Medeiros and Cintra (2015), Serrano (2013), Black (2015), World Bank (2009); De la Torre, Filippini and Ize (2016), UNCTAD/FAO (2017) and ECLAC (2017 and 2018). This literature suggests that there is no automaticity mechanism at work between variations in commodity prices and economic growth: transmission channels have to be reinforced in order for countries to tap into favourable external conditions.

[3] For further details, see Serrano (2013) and UNCTAD/FAO (2017).

economy benefited both directly (owing to the increased volume and prices of its commodity exports) and indirectly (owing to the increased volume of its manufactured exports to commodity-exporting countries) from higher commodity prices.

The competitive advantages of Brazil's industrial sector vis-à-vis other developing economies, and especially those in Latin America and Africa, enabled it to capitalize on this favourable set of conditions to expand its exports of manufactured items. Despite the difficulties experienced by the country in the 1980s (a sharp contraction of its domestic market and the breakdown of the import substitution process,[4] brought about by its external debt crisis) and 1990s (massive inflows of external capital, soaring imports and an atrophying industrial export sector), it continued to be in a different position than the rest of the Latin American countries, and a number of its economic sectors were more developed than those of the other countries in the region in terms of both scale and productivity (Medeiros and Serrano, 2001; Carvalho and Kupfer, 2011; Naudé, Szirmai and Haraguchi, 2016; Hiratuka and Sarti, 2017). As a result, even though a large part of its exports are commodities, Brazil's industrial sector is highly diversified and its production structure (especially in the case of processing industries) is technologically more complex than those of its trading partners in the region (Castilho and Luporini, 2010; Ferraz and Marques, 2014; UNIDO, 2015; ECLAC, 2017).

In the 2000s, and especially between 2003 and 2008, Brazil consolidated its position as a major exporter of commodities to China and as an important supplier of manufactured items to countries in its region, although the strength of that position was diminished somewhat by growing competition from Asian manufacturing, especially Chinese products. This competition intensified during the ensuing international economic crisis since, when developed-country demand began to slacken, China started to seek out emerging markets to sustain its export growth (Lélis, Cunha and Lima, 2012; Silva and Hidalgo, 2012; Black, 2015; Hiratuka and Sarti, 2017). Yet despite these competitive pressures and the loss of some regional market share by several Brazilian industrial sectors, the strong ties between Brazil and its resource-intensive trading partners can account for the upturn in Brazilian exports of manufactured products during the commodity price boom.

Studies by Black (2015), De la Torre, Filippini and Ize (2016), ECLAC (2017), UNCTAD/FAO (2017) and others indicate that the growth in manufactured export volume to these countries might have been a channel[5] for the positive effects of the recent upturn in commodity prices on Brazil's economic growth. This channel basically functioned through nominal price increases for commodities and improved terms of trade of commodity-exporting countries, which boosted the earnings of Brazil's trading partners and their ability to import manufactured goods to satisfy expanding aggregate demand. The gain in commodity prices in both absolute and relative terms improved the Latin American countries' terms of trade, and the more those countries exported commodities and imported manufactured items, the greater that improvement was.

Bearing in mind this overall context and the main objective of this study, the following discussion will address research that helps to explain what factors influenced Brazilian exports in the 2000s. This review, which is by no means exhaustive, will primarily focus on possible transmission channels between climbing commodity prices and trends in exports of manufactures. These studies have used differing approaches and theoretical frameworks to examine micro- and macroeconomic factors associated with export supply and/or demand on the basis of sector-specific or aggregate data. Increasing attention is

[4] For Medeiros and Serrano (2001), the more favourable levels of commodity prices relative to those of manufactured products, ample international liquidity and active public policies made it possible to intensify the import substitution process in the 1970s. This quickly led to the expansion and diversification of Brazil's industrial base that brought it to the fore among developing countries and enabled the country to increase its manufactures exports.

[5] Black (2015) identifies five such channels: (i) the price effect on commodity exports; (ii) the volume effect on exports of manufactures to commodity-exporting countries; (iii) increased employment in the commodity sector; (iv) the opportunity to boost imports to meet domestic demand; and (v) increased tax revenues.

being paid to the competitive position of Brazilian manufactured exports, especially in markets where Brazil has traditionally enjoyed advantages that are now being challenged more forcefully by China (Silva and Hidalgo, 2012; Lélis, Cunha and Lima, 2012; Pereira, 2014; Jenkins, 2014; Bichara and others, 2016).

In an effort to calculate the impact of the exchange rate on Brazilian exports and imports between 1996 and 2012, Carneiro (2014) estimated the elasticities of Brazil's exports using two different models: first, through cointegration tests to analyse both export supply and export demand variables at the same time; second, through a uniequational model with separate estimations of export demand and supply functions, although that method could risk biases in parameter estimates. In addition to analysing the determinants of aggregate exports, the author estimated models with the dependent variable of export volumes broken down into the categories of basic, semi-manufactured and manufactured products. In this case, the following explanatory variables were used: index of mean wages in the industrial sector (proxy for costs); total world imports (proxy for external income); relative export prices, calculated by dividing the Brazilian export price index by the global import index; the price of exports as calculated by dividing the real-denominated Brazilian export price index by the extended national consumer price index (IPCA); the industrial production index for estimates of manufactured items (a proxy for installed capacity), and the installed capacity utilization rate for the other categories; the London Inter-Bank Offered Rate (LIBOR) (a proxy for the financial cost); and dummies to control for the effects of the steep devaluation of the real in 1999, the 2002 elections and the failure of Lehman Brothers in 2008.

In general, over both the short and long term, the results for aggregate exports reflect a substantially greater response to external income (parameters between 1.024 and 1.049), while the price elasticity of demand is negative (-0.3). Supply-side factors proved to be insignificant. The results are similar to those obtained for semi-manufactured and manufactured items, except that, in the latter case, relative price variations also displayed a strong potential for influencing the demand for Brazil's exports. In sum, the main statistically significant parameters for the different models are as follows: income elasticity for semi-manufactures of between 0.409 and 0.817, with a greater potential for influencing exports than the other variables have, especially in the short run; an income elasticity for manufactured items of between 1.153 and 2.159; and a price elasticity of demand of between -0.93 and -1.819.

Using a similar econometric tool, Castilho and Luporini (2010) look into the income elasticity of Brazilian exports by country of destination, including Argentina, Chile and Mexico. These authors' research covers the period from 1986 to 2007 and is based on a single-equation distributed-lag model. The following variables were used: volume and price indices for Brazilian exports, by sector of activity; relative prices of exported products; GDP of the country of destination; the exchange rate for the Brazilian real and the currency of the destination market; and Brazil's installed capacity utilization rate. Their findings indicate that Brazilian exports of manufactured goods are more sensitive to demand conditions, especially in terms of variations in the incomes of their Latin American neighbours, particularly Argentina. The cointegration tests run as part of this study of Brazil's regional trade performance point to a long-standing link between Brazilian exports of manufactured products and domestic economic conditions in the various countries. They also indicate that all of these countries, including Brazil, rely on commodity price cycle upswings to spur economic growth.

A study conducted by Kawamoto, Santana and Fonseca (2013) that does not focus on the region is nonetheless useful for comparing the influence exerted by changes in prices and income on the demand for Brazilian exports. Their findings indicate that exports were more sensitive to changes in export earnings than to price changes between 2003 and 2010. Interestingly, they also find a negative and apparently spurious relationship between export volumes and the exchange rate. These authors used panel data and various estimators to gauge the scale of possible dynamic effects. They show that these effects were robust using a least-squares dummy variable corrected (LSDVC) estimator, with an increase of 10% in current exports leading to a 6.1% increase in exports in the following period. The dependent variables are indices of export volumes for 20 different processing industries. Among the explanatory variables, external earnings were calculated using industrial production indices for the United States, Japan, Canada, Mexico, the United Kingdom, France, Italy and the Republic of Korea and weighted by these countries' share of Brazil's exports of manufactured products.

In order to determine if Brazil's economic growth is constrained by its balance of payments, the estimates calculated by Lélis and others (2018) of the demand function of exports indicate that total external sales were highly sensitive to global income and to commodity price fluctuations between 1995 and 2013. The results for the real exchange rate, on the other hand, were spurious. One of the important contributions made by this study is its use of the general commodity price and the world income index as explanatory variables, which were estimated on the basis of the GDP of 46 countries representing 90% of world GDP. The authors of this study use vector auto regression (VAR), vector error correction (VEC) and structural state of space models, the latter being applied specifically to the estimated period of strong commodity prices (2001–2013).

The study conducted by Hiratuka and others (2012), which focuses on the effects of China's increasing economic power on Latin American trade between 2000 and 2009, is perhaps the one that is most closely aligned with the present study. In addition to investigating the possible crowding-out effect of stronger Chinese competition on regional trade in manufactured goods, the authors analyse the impact of the region's increased commodity exports to China on intraregional trade in manufactures among the member countries of the Latin American Integration Association (LAIA). The demand effect is investigated using a gravity model whereby the manufactured imports of country i from country j, which is a member of ALADI, are explained on the basis of the aggregate exports of country i to China and the GDP and per capita GDP of country i. The possible endogeneity between the exports of country i to China and GDP-related variables is controlled for by the independent variables traditionally used in models of this type, such as the geographic distance between China and country i. Another problem resolved by the study is the presence of null values for sectoral trade, which are replaced by a value close to zero (0.0001). The study's findings show that intraregional trade in manufactured goods was positively influenced by the increase in the region's commodities exports to China during the study period and that Brazil was the country that benefited the most from this demand effect.

In summary, the above studies of the sensitivity of Brazilian exports to price and income variations provide empirical support for the hypothesis that external revenue, and possibly the external revenue of Brazil's trading partners in the Latin American and Caribbean region as well, may have played an influential role in fuelling Brazil's exports of manufactures during the commodity price boom. Taking these contributions into account, the following section presents the econometric model used for the present study and our research findings.

III. Empirical evaluation of the link between the boom in commodity prices and Brazilian exports of manufactured goods

This section presents the sources, data treatment and estimated results for the statistical exercise undertaken in an effort to determine what impact commodity prices have had on Brazil's exports of manufactured products. To this end, the direct income effect of trading partners' commodity exports is analysed. The point of departure is the proposition that variations in commodity prices influence the income levels of the countries covered in this research by altering the value of their exports. The model we employ does not deal with the indirect or induced income effect, which is presumed to be the result of increases in private and public investment and domestic expenditure stemming from terms-of-trade shocks generated under the conditions analysed in the specialized literature (IMF, 2015;

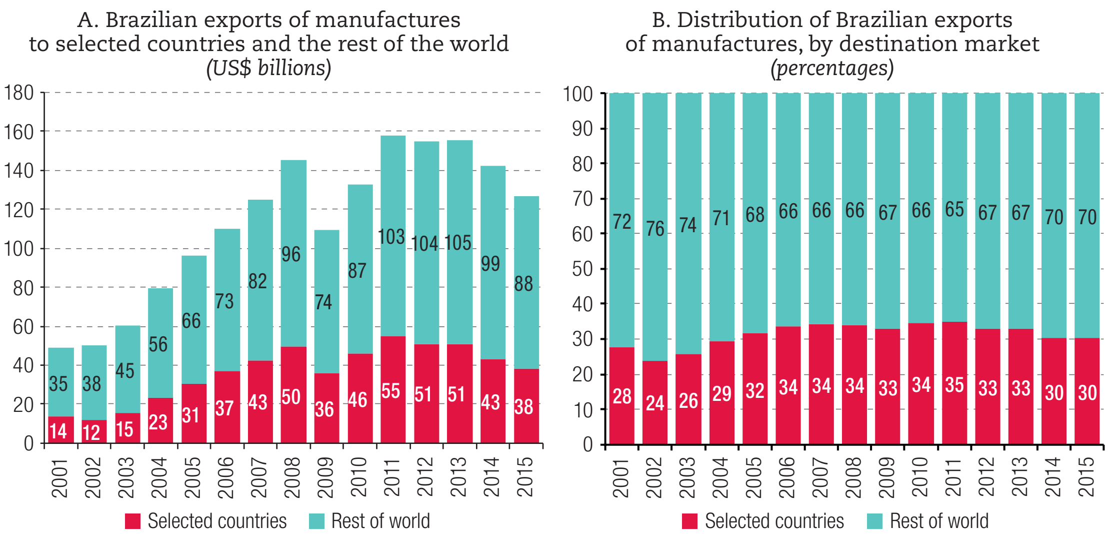
World Bank, 2009; De la Torre, Filippini and Ize, 2016; UNCTAD/FAO, 2017). The estimated model is used to establish the relationship between Brazil's exports of manufactured goods and their relative degree of dependence on trading-partner sales of natural resources and/or resource-intensive goods.

This exercise covers 51 African and Latin American trading partners.[6] These regions are heavily specialized in the development and exportation of natural resources and are major buyers of Brazilian manufactured items (purchasing five times more than the international average). More specifically, from 2001 to 2015,[7] an average of 3.8% of those countries' imports of manufactured goods came from Brazil, which accounted for only 0.7% of global exports of these products. Moreover, during that period, these markets absorbed a third, on average, of Brazil's total exports of manufactured goods.

This information is mapped out in figure 1, which shows, for example, that exports of manufactured items to the countries in the sample more than trebled between 2003 and 2008, jumping from US$ 15 billion to US$ 50 billion and then remaining at that level until 2013 (panel A). During that same period, total exports of manufactures doubled, and then rose to the equivalent of US$ 100 billion over the next five years. The share of those exports bought by the trading partners in the sample therefore climbed from 26% (2003) to 34% and then to 35% (2015) (panel B).

In 2014 and 2015 —when the upward phase in the supercycle of commodity prices gave way to a downturn, triggering a sudden slowdown in the growth of emerging and developing economies, especially those specializing in the development and exportation of natural resources— exports of manufactured goods to the markets in the sample and to the rest of the world plunged by 20% (De la Torre, Filippini and Ize, 2016; UNCTAD/FAO, 2017). While Brazil accounted for around 3.0% of the imports of manufactured products for the countries in the sample before the supercycle, that figure rose to 4.5%, on average, during the years when prices were booming (up to 2011). In other words, Brazil expanded its market share in those markets (panel C). This stands in contrast to what was occurring in the rest of the world, where its market share shrank (panel D).

Figure 1
Brazilian merchandise exports in selected countries and worldwide, 2001–2015[a]



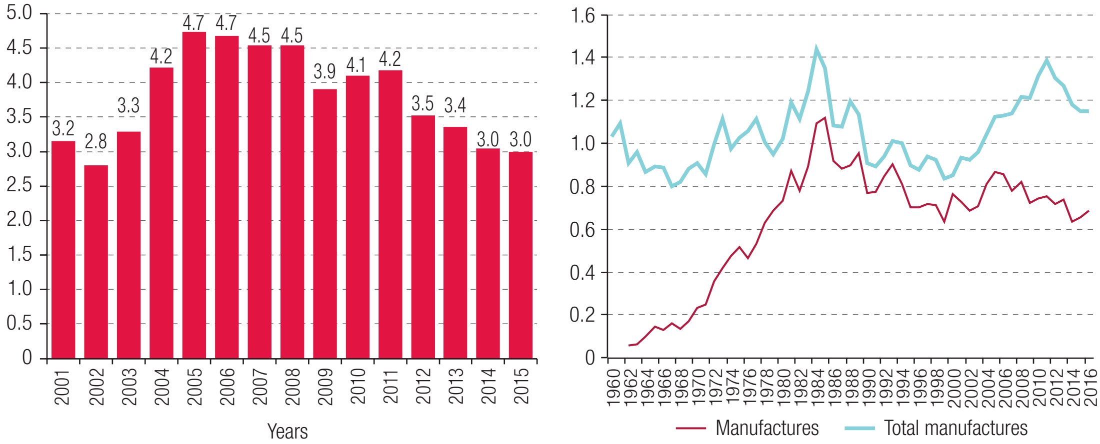
[6] Information was unavailable for the following countries, which are therefore not included in the figures shown: the Sudan, South Sudan, Cameroon, Eritrea and Cuba. Most of the countries in the sample are generally classified as low-income, middle-income or upper-middle-income countries.

[7] The study period starts with the first year of the upward cyclical trend in commodity prices and ends with the latest year for which information was available at the time of writing.

Figure 1 (concluded)

C. Brazil's share of the market for imported manufactures in selected countries
(percentages)

D. Brazil's share of world exports



Source: Prepared by the authors, on the basis of World Bank (2018 and United Nations, UN Comtrade Database, 2018.

[a] The data in panel D correspond to 1960–2016.

The use of 51 countries for the period 2001–2015 yielded 765 observations. The exercise was based on the following variables:

- **Brazilian exports of manufactured goods** – $\left(EX_{i,t}^{BR}\right)$: This is the main variable of interest for this study. The data source was the UN Comtrade Database.[8] The category of manufactured products corresponds to the category used in the National Classification of Economic Activities, version 2.0 (CNAE 2.0).[9]
- **Trading-partner commodity exports** – $\left(EX_{i,t}^{P-COM}\right)$: This is the main control variable for the direct income effect. The data source was the UN Comtrade Database.[10] The category of manufactured products corresponds to the classification developed by Pavitt (1984)[11] based on product specifications for primary and resource-intensive products.
- **Exchange rate for the Brazilian real against trading-partner currencies** – $\left(CA_{i,t}\right)$: Euromonitor[12] was the source for the gross data. To construct this variable, the nominal exchange rate for the currency of each country was converted into an index with 2001 as the base year. The index for Brazil was then divided by the index for the trading partner in question. An increase in the resulting ratio indicates a decline in value of the Brazilian real relative to the trading partner's currency.

[8] These data are for exports of manufactures in current dollars. Current values are preferred when working with volume indices for three reasons. The first is that there was little upward pressure on the prices of manufactures during the study period, owing mainly to the size of the exportable supply from Asian countries. The second has to do with the construction of the deflator for Brazilian exports of manufactures. A deflator would have to be used for each individual trading partner, since using a single deflator would skew the gross data. The third and final reason, which has been referred to previously, is that the commodity exports of Brazil's trading partners are measured in current dollars, so it is more logical for the comparison between this aggregate and Brazilian exports of manufactures to be made in current dollars as well. Thus, the estimated parameter for this ratio will partly capture the volume and partly the terms of trade. Accordingly, we chose to use the original data denominated in current United States dollars.

[9] The CNAE 2.0 classification is similar to the International Standard Industrial Classification of All Economic Activities (ISIC), Revision 4. The categories that were used were codes 10 to 33 of section C, which basically corresponds to processing industries.

[10] See [online] https://comtrade.un.org/.

[11] The classification developed by Pavitt (1984), as adapted by Guerrieri (1998), is used because this taxonomy provides a clearer picture of the competitiveness of the product itself as opposed to the corresponding technological standards.

[12] See [online] https://www.euromonitor.com/.

- **Brazil's gross domestic product** – $\left(GDP_t^{BR}\right)$: The International Monetary Fund (IMF) was the source for the gross data for this variable,[13] which denotes the size of the Brazilian economy as measured in terms of purchasing power parity (PPP) in United States dollars. This was used as a proxy for the economies of scale of Brazilian export production.
- **Trading-partner per capita gross domestic product** – $\left(GDPP_{i,t}^{P}\right)$: IMF was the source of the gross data. The $GDPP_{i,t}^{P}$ is measured in terms of purchasing power parity (PPP) in United States dollars and is used to gauge the standard of living in the region.
- **Share of commodities in trading partners' export profile** – $\left(COM_{i,t}^{P}\right)$: This measures the ratio between a trading partner's total exports and its commodity exports $\left(EX_{i,t}^{P-COM}\right)$, which ranges from 0 to 1.

All of these variables are expressed as natural logarithms. Trading partners' GDPs are not used in the model, however, because of the multicollinearity between this variable and $EX_{i,t}^{P-COM}$. Thus, as noted earlier, the model will only capture the direct effect through Brazil's trading partners' commodity exports.

Table 1 gives the descriptive statistics for the data.

Table 1
Descriptive statistics

Variables	Observations	Mean	Standard deviation	Minimum	Maximum
$EX_{i,t}^{BR}$ (US$/millions)	765	710.65	1 981.65	0.12	21 116.37
$EX_{i,t}^{P-COM}$ (US$/millions)	765	12 313.33	21 621.92	2.32	149 019.80
$GDP_{i,t}^{BR}$ (US$/millions)	765	2 495 180	572 684	1 638 286	3 306 570
$CA_{i,t}$	765	1.08	0.50	0.01	2.21
$GDPP_{i,t}^{P}$ (US$)	765	7 439.02	7 690.80	377.20	51 187.15
$COM_{i,t}^{P}$ (percentages)	765	67.37	26.24	5.58	99.80

Source: Prepared by the authors, on the basis of StataCorp, *Stata Statistical Software: Release 15*, College Station, StataCorp LLC, 2017.

The methodology is based on an estimated model represented by equation (1). This equation estimates the parameters for the variables exhibiting changes in dimensions i and t in a dynamic panel data model:[14]

$$Y_{i,t} = \left(\beta_0 + \mu_i\right) + \beta_1 + Y_{i,t-1} + \sum_{k=1}^{K} \gamma_k X_{k,i,t} + v_{i,t} \quad (1)$$

In equation (1), $Y_{i,t}$ represents the dependent variable of the hierarchical model, in this case $EX_{i,t}^{BR}$; the $X_{k,i,t}$ component indicates the regressors observed in country i in time t: $EX_{i,t}^{P-COM}$, $CA_{i,t}$, $GDP_{i,t}^{BR}$, $GDPP_{i,t}^{P}$, $\left\{COM_{i,t}^{P} + \left(COM_{i,t}^{P}\right)^2\right\}$. This defines a quadratic relationship between the trading partner's degree of commoditization and the $EX_{i,t}^{BR}$. This option was characterized by the units for each variable. The $EX_{i,t}^{BR}$ are measured in United States dollars and may vary between 0 and ∞.

[13] See [online] https://data.imf.org.

[14] For further details on the panel data methodology, see Baltagi (2005), Hsiao (2003) and Wooldridge (2002). On dynamic panels, see Arellano and Bover (1995), Blundell and Bond (1998) and Bond (2002). In choosing to work with a dynamic model, consideration was given to the time trend components of the dependent variable in the proposed model.

The $COM^{P}_{i,t}$ variable denotes a given share and so will vary only between 0 and 1.[15] In equation (1), μ_i and $v_{i,t}$, refer, respectively, to the individual effect of sectional units and the random residual $IID\sim N(0,\sigma^2)$.

As is usual, unit root tests —in the formalizations of Im, Pesaran and Shin (2003); Levin, Lin and Chu (2002); and Harris and Tzavalis (1999)[16]— and cointegration tests —Kao (1999) and Pedroni (1999 and 2004)— were performed. As shown in table 2, with the exception of the $EX^{BR}_{i,t}$ variable, which displayed a stationary pattern in all the tests, the other variables were non-stationary in at least one of the tests.

Table 2
Panel data unit root tests

Variables	Im, Pesaran and Shin test		Levin, Lin and Chu test		Harris and Tzavalis test	
	Statistical *W-t-bar*	*p*-value	Adjusted *t* statistic	*p*-value	*Rho statistic*	*p*-value
$EX^{BR}_{i,t}$	-8.5854	0.0000	-12.5917	0.0000	0.6700	0.0000
$EX^{P-COM}_{i,t}$	-3.2107	0.0007	-10.3147	0.0000	0.7719	0.1640
$GDP^{BR}_{i,t}$	-2.0505	0.0202	-12.8689	0.0000	0.9386	1.0000
$CA_{i,t}$	-4.3814	0.0000	-7.1470	0.0000	0.8878	0.9989
$GDPP^{P}_{i,t}$	-0.7701	0.2206	-10.8212	0.0000	0.9344	1.0000
$COM^{P}_{i,t}$	-0.8910	0.1865	0.9046	0.8172	0.6205	0.0000

Source: Prepared by the authors, on the basis of StataCorp, *Stata Statistical Software: Release 15*, College Station, StataCorp LLC, 2017; K. S. Im, M. H. Pesaran and Y. Shin, "Testing for unit roots in heterogeneous panels", *Journal of Econometrics*, vol. 115, No. 1, July 2003; A. Levin, C. Lin and C. J. Chu, "Unit root tests in panel data: asymptotic and finite-sample properties", *Journal of Econometrics*, vol. 108, No. 1, May 2002; R. D. F. Harris and E. Tzavalis, "Inference for unit roots in dynamic panels where the time dimension is fixed", *Journal of Econometrics*, vol. 91, No. 2, August 1999.

Given the results of the tests run by Kao (1999) and Pedroni (1999 and 2004) (table 3), the alternative cointegration hypothesis cannot be rejected in the five tests shown.

Table 3
Statistics of the tests applied by Kao and Pedroni for autocorrelation in panel data

Kao test	Statistic	*p*-value
Modified Dickey-Fuller test	-4.8740	0.0000
Dickey-Fuller test	-7.3621	0.0000
Augmented Dickey-Fuller test	-3.4027	0.0003
Unadjusted modified Dickey-Fuller test modificada no ajustada	-8.0738	0.0000
Unadjusted Dickey-Fuller test	-8.6640	0.0000
Pedroni test	**Statistic**	***p*-value**
Modified Phillips-Perron test	9.7229	0.0000
Phillips-Perron test	-9.1938	0.0000
Expanded Dickey-Fuller test	-7.5571	0.0000

Source: Prepared by the authors, on the basis of StataCorp, *Stata Statistical Software: Release 15*, College Station, StataCorp LLC, 2017; C. Kao, "Spurious regression and residual-based tests for cointegration in panel data", *Journal of Econometrics*, vol. 90, No. 1, May 1999; P. Pedroni, "Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis", *Econometric Theory*, vol. 20, No. 3, June 2004.

15 A number of comments are called for regarding the possibility of multicollinearity in the polynomial function. According to Gujarati and Porter (2011, p. 225), the polynomial models do not, strictly speaking, violate the multicollinearity assumption, since and are not perfectly linear. These same authors also state (2011, p. 330) that the potential estimation problem lies in the likelihood of incurring a large number of standard errors, which makes it more probable that the null hypothesis cannot be rejected. However, as we will see when examining our results, the purpose of the polynomial is to determine the relationship between the estimated parameters associated with . In other words, we apply a joint hypothesis test to these parameters, imposing that both are statistically significant at the same time. In addition, according to Hsiao (2003 and 2005), panel data involve at least two dimensions: a cross-sectional dimension and a time series dimension. This makes linear dependence between the regressors unlikely and minimizes the multicollinearity. Lokshin, Belderbos and Carree (2008), confirming Hsiao's suggestion, estimate a dynamic panel data model (with the same structure as proposed in equation (1)) using polynomial relations between the model's independent variables.

16 Generally speaking, the difference between the proposed tests lies in the asymptotic assumptions made with respect to the number of cross-sections in the dataset and the number of periods in each panel.

The statistical structure proposed in equation (1) can therefore be used to define a model with level variables. The Hausman test (table 4) for differentiating between fixed effects and random effects indicates that we must reject the null hypothesis and therefore can specify a fixed-effect model.

Table 4
Hausman test (fixed effects versus random effects): *within* estimators and generalized least squares (GLS) estimators

Estimators	χ^2 (5)	*p*-value
Within and GLS	40.79	0.0000

Source: Prepared by the authors, on the basis of StataCorp, *Stata Statistical Software: Release 15*, College Station, StataCorp LLC, 2017.

Table 5 shows the results of the following tests: (i) the Wooldridge test for autocorrelation in panel data;[17] (ii) the modified Wald test for heteroskedasticity for fixed-effect panel data models;[18] and (iii) the Hausman statistical endogeneity test[19] for the $GDP_{i,t}^{BR}$[20] variable. We observe that the proposed fixed-effect model displays autocorrelation and heteroskedasticity in the estimated residuals. However, based on the Hausman test, the statistical exogeneity of $GDP_{i,t}^{BR}$ is not rejected. This last result is corroborated by the fact that exports of manufactures represent such a small share of Brazil's GDP. This external component therefore does not play a significant role in determining Brazil's national income. The autocorrelation in the estimated residuals may be the result of the time trend in $EX_{i,t}^{BR}$. This opens up the possibility of working with a dynamic panel data model.

Table 5
Autocorrelation, heteroskedasticity and endogeneity tests

Test	F (1, 50)	*p*-value
Wooldridge test for autocorrelation in panel data	79.629	0.0000
	χ^2 (51)	*p*-value
Modified Wald test for heteroskedasticity in fixed-effect panel data models	7361.62	0.0000
	χ^2 (7)	*p*-value
Hausman test for statistical endogeneity of $GDP_{i,t}^{BR}$ – Arellano and Bond	0.98	0.9852

Source: Prepared by the authors, on the basis of StataCorp, *Stata Statistical Software: Release 15*, College Station, StataCorp LLC, 2017.

Table 6 shows the statistics calculated using the robust Arellano–Bond estimator (AB).[21] As the AB estimator specifies a dynamic panel data model (equation (1)),[22] it can be seen that the $EX_{i,t-1}^{BR}$ variable is statistically significant, since the Arellano and Bond (AB-AR) autocorrelation tests point to the presence of first-order autocorrelation, thereby rejecting the second-order autocorrelation hypothesis. This provides statistical corroboration of the dynamic panel specification. In addition, the Hansen test does not reject the hypothesis that the instruments are valid for the AB estimator.

[17] See Wooldridge (2002) and Drukker (2003).

[18] For further details, see Baum (2001).

[19] For the Hausman test, we estimated a fixed-effect model versus a model with a static Arellano and Bond estimator, where $GDP_{i,t}^{BR}$ is treated as endogenous.

[20] The possibility of the statistical endogeneity of $GDP_{i,t}^{BR}$ is determined on the basis of observations using the GDP demand approach, where exports of goods and services are treated as a component of this macroeconomic indicator.

[21] A dynamic panel data model was estimated on the basis of the approach espoused by Blundell and Bond (1998 and 2000). However, based on the statistical results and their economic interpretation, the Arellano and Bond estimator was selected for use in the presentation of our findings.

[22] For the dynamic panel data models, a robust two-step estimator was used.

Table 6

Estimated statistics: Arellano and Bond, Blundell and Bond, and fixed-effect estimators

Variables	Arellano and Bond	
$EX_{i,t}^{BR}$	Coefficients	*p*-value
$EX_{i,t-1}^{BR}$	0.5555822	0.000
$EX_{i,t}^{P-COM}$	0.3708294	0.004
GDP_{t}^{BR}	-0.2683318	0.515
$CA_{i,t}$	-0.2412565	0.075
$GDPP_{i,t}^{P}$	-0.0596441	0.877
$COM_{i,t}^{P}$	-6.0768460	0.015
$(COM_{i,t}^{P})^2$	0.8977919	0.013
_cons	-	-
Statistical test	m_1 - m_2	*p*-value
AB - AR (1)	-3.86	0.000
AB - AR (2)	0.09	0.928
	χ^2 (89)	*p*-value
Hansen test	49.17	1.000
Variables	Coefficients	*p*-value
$[COM_{i,t}^{P} + (COM_{i,t}^{P})^2]$	3.384329	0.000

Source: Prepared by the authors, on the basis of StataCorp, *Stata Statistical Software: Release 15*, College Station, StataCorp LLC, 2017, R. Blundell and S. Bond, "GMM estimation with persistent panel data: an application to production functions", *Econometric Reviews*, vol. 19, No. 3, 2000; R. Blundell and S. Bond, "Initial conditions and moment restrictions in dynamic panel data models", *Journal of Econometrics*, vol. 87, No. 1, November 1998.

The estimated statistics for the variables of interest in this study $\left(EX_{i,t}^{P-COM}, \left\{COM_{i,t}^{P} + \left(COM_{i,t}^{P}\right)^2\right\}\right)$ indicate that the direct income effect of commodity prices $\left(EX_{i,t}^{P-COM}\right)$ is statistically significant at 5%. The elasticity between $EX_{i,t}^{BR}$ and that income effect is low, however, which means that Brazil's exports of manufactures to countries in Africa and Latin America were not dynamic enough to take full advantage of the direct income effect of the changes in $EX_{i,t}^{P-COM}$.

The estimated results for the degree of specialization of trading partners in commodity exports $\left(COM_{i,t}^{P}\right)$ over $EX_{i,t}^{BR}$ were statistically significant at 5%. With the AB estimator, a quadratic relationship is obtained with at least one point. The AB estimator is characterized by at least one point where commodity exports represent a 29.5% share of the total exports of a Brazilian trading partner. The AB estimator yields a positive relationship between $EX_{i,t}^{BR}$ and the export specialization profile of Brazil's trading partners starting from that percentage and on up.

In summary, the statistical responses indicate that Brazil's exports of manufactures to countries in Latin America and Africa were buoyed by the recent cyclical rise in commodity prices. There were two possible channels for the transmission of these benefits. One of those channels would be the commodity exports of trading partners (a direct income effect). However, the elasticity for that relationship has been estimated at less than unit value, which means that it is quite low. The other channel is created by the degree of specialization in commodities of the trading partners' export profiles. Thus, the more specialized in commodities the Latin American and African countries are, the higher the level of Brazil's exports of manufactures will be (with a minimum point of between 24.7% and 29.5%). These positive effects notwithstanding, the share of Brazil's exports represented by commodities expanded rapidly during the recent upswing in commodity prices, perhaps owing to two different factors that are somewhat interrelated. One has to do with the fairly small impact on total demand of the Latin American and African countries when compared to that of advanced economies and China. The other stems from the competitive position of Brazilian industry in the international market, where it trades mainly with the emerging or developing economies analysed in the models used in this study.

IV. Conclusions

This study focuses on identifying the effects that the commodity supercycle had on exports of manufactured items produced in Brazil. Its point of departure is the hypothesis that Brazil's trading partners that develop and export natural resources benefited from those higher prices and that the resulting increase in their national income enabled them to expand their imports in general and their imports of manufactured products in particular. It also seeks to contribute to the literature on the determinants of Brazilian exports and especially its exports of manufactured goods, and to add to that literature by analysing Brazil's trade relations with low-, middle- and upper-middle-income countries in Latin America and Africa (Baumann, 2013; Medeiros and Cintra, 2015).

The study uses a sample of 51 countries, which purchased, on average, approximately one third of Brazil's exports of manufactures between 2001 and 2015. The econometric strategy adopted, which, to the knowledge of the authors, had not been used before in the literature, enabled the conclusion that the proxy used to determine the income effect of higher commodity prices was statistically significant and had the expected positive impact. In other words, the higher level of commodities exported by Brazil's trading partners was associated with an expansion of Brazil's exports of manufactures to those same markets. The effect tended to be stronger when the share of commodities in trading partners' export profiles passed a certain threshold. These findings dovetail with the conclusions of earlier, more general studies on this subject, such as those of the World Bank (2009), De la Torre, Filippini and Ize (2016), Sinnot, Nash and De la Torre (2010), Alberola-Ila and others (2016), UNCTAD /FAO (2017), ECLAC (2017), and with studies focusing on Brazil, notably those of Castilho and Luporini (2010), Bastos (2012), Hiratuka and others (2012), Medeiros and Cintra (2015) and Lélis and others (2018).

The data used in this econometric exercise and its results indicate that Brazil's total and manufactured exports were buoyed by both the direct effect of the commodity price supercycle (higher volume and prices for commodities and natural resource-intensive goods exported by Brazil) and the indirect effect associated with the more rapid economic growth of its trading partners. Thus, in the 2000s, Brazil regained part of the global market share that it had lost during years of economic decline. To provide some perspective, between 1981 and 1985, Brazil's exports represented, on average, 1.5% of the global total, and its exports of manufactured goods accounted for 0.8% of the total. In the second half of the 1990s, when the country's monetary stabilization process was anchored in the overvaluation of its currency, the corresponding figures were, respectively, 0.9% and 0.7%. But with the advent of the supercycle in the 2000s, its total exports rebounded to some extent, peaking at between 1.2% and 1.3% of the global total, while the market share of manufactured exports remained between 0.6% and 0.7%.

These indicators, which are graphed in panel D of figure 1, show the general outlines of one of the Brazilian economy's structural problems, which is its regressive pattern of specialization (Nassif, Feijó and Araújo, 2015; Naudé, Szirmai and Haraguchi, 2016; Gala, Rocha and Magacho, 2018). From the time of the external debt crisis onward, the economy's growth consistently fell below the world average (by one percentage point per year); its production structure, and especially its processing industries, began to decline in terms of density and complexity; and its export profile began to reflect an increasing reliance on sales of commodities and natural resource-intensive manufactures. Thus, although the rise in commodity prices helped to drive the relative improvement of Brazil's total and manufactures exports, it did not significantly alter the country's position in the international market. Furthermore, the weak income elasticity detected in our study suggests that the greater economic buoyancy of Brazil's trading partners was not enough to bring about a lasting or robust increase in the market share of Brazilian manufactures in those countries. The subsequent decline in commodity prices was enough to cause the market share of Brazilian manufactures in those countries to retreat once again. Future studies may look into the reasons for its loss of competitiveness on external markets. The existing literature suggests that, to some degree, this may be the result of various structural determinants, including the following:

(i) the long-standing decline in the dynamism of processing industries in Brazil; (ii) China's ascendancy to its present position as the world's leading producer and exporter of manufactures; and (iii) the difficulties encountered by the country in establishing robust, long-lasting development strategies (Jenkins, 2014; Nassif, Feijó and Araújo, 2015; Hiratuka and Sarti, 2017; Lélis and others, 2018; Lin, 2018).

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Economic complexity and human development: comparing standard and slack-based data envelopment analysis models

Diogo Ferraz, Herick Fernando Moralles, Naijela Silveira da Costa and Daisy do Nascimento

Abstract

Several studies have argued economic complexity is an alternative way to understand well-being. There is a growing literature using standard data envelopment analysis (DEA), but we did not find studies comparing them with more advanced models, such as slack-based measure (SBM), or considering economic sophistication as an input in human development. To fill the gap, this article aims to compare standard models with SBM DEA models as tools for measuring countries' efficiency in converting economic complexity into human development. We developed the Composite Index of Human Development and Economic Complexity (CIHD-EC) and used it to analyse 50 countries with data from 2013, finding that the standard models overestimated countries' efficiency, especially that of developed and prosperous countries. In contrast, the SBM model provides a better ranking. Lastly, the CIHD-EC shows that Singapore is the only economy in the world that is efficient at transforming economic complexity into human development.

Keywords

Economics, economic growth, human development, development models, development indicators, measurement, econometric models

JEL classification

O14, O15, O3

Authors

Diogo Ferraz[1] is a professor with the Department of Economics of the Federal University of Ouro Preto (Brazil). Email: diogoferraz@alumni.usp.br.

Herick Fernando Moralles is a professor with the Department of Production Engineering (DEP) of the Federal University of São Carlos (Brazil). Email: herickmoralles@dep.ufscar.br.

Naijela Silveira da Costa is a PhD student at the Department of Production Engineering (DEP) of the Federal University of São Carlos (Brazil). Email: naijelajanaina@gmail.com.

Daisy Aparecida do Nascimento Rebelatto is a professor with the Department of Production Engineering (DEP) of the Federal University of São Carlos (Brazil). Email: daisy@usp.br.

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I. Introduction

Economic growth cannot provide a full understanding of human development and well-being. Sen (2001) developed the human capabilities approach, prompting the creation in a number of studies of new indicators for understanding human development (Despotis, 2005a and 2005b; Zhou and Zhou, 2010; Morais and Camanho, 2011; Toffalis, 2014; Mariano and Rebelatto, 2014). For example, the transformation of wealth into human development was dubbed social efficiency (a structural literature review can be found in Mariano, Sobreiro and do Nascimento Rebelatto, 2015) in an approach that aims to show how countries can use their wealth to improve several aspects of quality of life, such as education, health, sanitation and employment. However, the social efficiency approach has many gaps (Mariano, Sobreiro and do Nascimento Rebelatto, 2015). For example, different models have to be compared to measure social efficiency, and there is a need to understand which variables apart from economic growth can explain human development (Mariano, Sobreiro and do Nascimento Rebelatto, 2015).

A new theoretical approach argues that economic sophistication influences several dimensions of human capabilities, since technological goods depend on available knowledge for their production (Hidalgo and Hausmann, 2009; Hausmann and others, 2014; Hartmann, 2014; Guevara and others, 2016; Hartmann and others, 2017; Hidalgo and others, 2007). Thus, on the one hand, economic complexity requires more human capabilities, and on the other, it affects living conditions such as education levels, health systems, infrastructure (ports, roads and airports), the labour market and wages (Hartmann, 2014; Hartmann and others, 2017). Economies are capable of generating useful knowledge through a network of people producing a variety of high-technology products, which can be translated into human development (Hausmann and others, 2014; Hartmann and others, 2017).

The literature demonstrates that economic complexity can improve the production structure, creating better conditions and more opportunities for people to develop their capacities and increase the social progress of a nation. A sophisticated country creates new sectors and generates better-quality jobs, and the country becomes more resilient to economic crises. Thus, the literature has shown the importance of economic complexity to economic development and well-being (Hartmann, 2014; Hartmann and others, 2017; Antonelli, 2016; Ferrarini and Scaramozzino, 2016; Guevera and others, 2016).

Despite the growing literature, these studies have not analysed how efficient any country is at transforming economic complexity into human development. A simple way to do this is to create an indicator using the data envelopment analysis (DEA) technique. DEA can help to address this difficult question because it allows economic complexity and human development to be measured in a single indicator. DEA uses methods from linear mathematical programming to measure how efficient decision-making units (e.g., in our case countries) are at translating inputs (e.g., economic complexity) into the highest possible levels of output (e.g., human development). DEA methods can be used to reveal the maximum number of social outputs that can be produced per unit of economic complexity by comparator countries or regions. Thus, DEA is ideally suited to measuring how efficient nations are at converting their economic structure into human capabilities. This permits better identification of inefficiencies and bottlenecks in countries as well as facilitating learning from more efficient regions that achieve higher levels of human development with an equally or less developed production structure. This indicator is relevant because it reveals best practices around the world, information that is crucial for policymakers. With it, authorities can compare regions and evaluate public and industrial policies.

A contribution of this paper is to compare standard DEA models, such as constant returns to scale (CRS) and variable returns to scale (VRS) models, with slack-based measure (SBM) models. Studies comparing DEA models in this field might show the importance of using models suited to the human development index approach, but we found none in the literature. To answer the questions raised, this study aims to compare standard and SBM DEA models, measuring how efficient countries are at converting economic complexity into human development by looking at 50 countries around the world with 2013 data available from a database developed by the World Bank (2018a). This information is used in a new indicator we have developed, the Composite Index of Human Development and Economic Complexity (CIHD-EC), to show how economic complexity is transformed into human development.

The remainder of this article is structured as follows. Section II reviews the literature on economic growth, human development and economic complexity. Section III introduces DEA models and presents our methodology. Section IV gives the results, discusses our models and findings, presents the Composite Index of Human Development and Economic Complexity (CIHD-EC) and provides some maps for illustration purposes. Lastly, section V provides concluding remarks.

II. Literature review

1. Human development and economic growth

Inclusive growth is a global concern. According to the International Monetary Fund (IMF, 2017), both large and small countries with developed or advanced economies have struggled to provide employment for the entire labour force. Furthermore, countries need to equalize opportunities of access to markets and resources. This new concept of economic growth is aligned with the human development perspective presented by the United Nations Development Programme (UNDP, 2016). Economic growth is commonly regarded as the only way to achieve economic development and increase human capabilities. However, the United Nations has shown that the relationship between economic growth and human development is complex, meaning that suitable methods are required to understand this process (UNDP, 2000).

To better understand the relationship, Sen (1998) analysed the correlation between income and life expectancy in a number of countries. The author found that some countries with relatively low incomes achieved relatively high life expectancy. Furthermore, some low-income countries had similar life expectancy to high-income nations. This complex phenomenon shows that economic growth does not guarantee human development (Sachs, 2004; Schumpeter, 1982), so that an alternative or new interpretation of this process is required. Other studies have argued that economic sophistication can improve the ability of a nation to deal with social problems and promote better human development (López, Thomas and Wang, 2008; Hartmann, 2014; Guevara and others, 2016; Hartmann and others, 2017). Accordingly, a number of them have focused on analysing how economic sophistication affects human development through economic complexity. The next section discusses how economic complexity can improve human development.

2. Economic complexity: innovation and structural change

Many economic sectors have been created since the Industrial Revolution, changing the goods produced and the social actors involved in the economic development process (Saviotti and Pyka, 2013). This is important because, according to Prebisch (1962) and Furtado (1959), the limitations of the production structure were responsible for countries' problems with income distribution and employment. Structural factors such as the aggregate value of agriculture, industry and services, the size of the urban population, educational levels and demographic patterns in the form of fertility and mortality rates are associated with economic development and play an essential role in explaining inequality between countries (IMF, 2017). A new approach, called economic complexity, revisited this issue, analysing the importance of economic sophistication and the export basket to economic growth and social matters (Hidalgo and others, 2007; Agosín, 2009; Hidalgo and Hausmann, 2009; Hausmann and others, 2014; Hartmann and others, 2017).

The economic complexity argument is that countries with high per capita incomes are characterized by the diversification of their export agenda and ability to export technology-intensive products (Tacchella and others, 2013; Ferrarini and Scaramozzino, 2016; Tacchella and others, 2013; Gala, 2017; Gala, Camargo and Freitas, 2017). Thus, economic complexity is defined by the types of products a country develops, with the production of technological products perhaps involving the combination of multiple kinds of available knowledge. In a complex economy, individuals work in a variety of jobs (finance, marketing, technology, human resources, operations, law) and need to interact and combine their knowledge to make sophisticated and valuable products. In contrast, when a nation lacks human capital, it is not possible to create new sectors or technological products, increase wealth and improve living conditions (Hausmann and others, 2014).

Economic complexity generates wealth because competitive advantage increases exports of high-technology products. According to Tacchella and others (2013), countries with a more exceptional ability to produce sophisticated goods are likely to have higher incomes than less productive countries. This is because countries that rely on commodity exports face macroeconomic volatility due to unpredictable commodity prices and real exchange-rate volatility, which discourages investment in tradable goods and services (Agosín, 2009; Ferrarini and Scaramozzino, 2016; Nkurunziza, Tsowou and Cazzaniga, 2017).

The sophistication of an economy can be measured by the Economic Complexity Index (ECI), which is calculated with data from the United Nations (Hidalgo and Hausmann, 2009). However, the ECI has been criticized for its theoretical and mathematical formulation, which makes it difficult to ascertain the real importance of economic sophistication in a country (Tacchella and others, 2013). Another issue arises because the ECI presents positive and negative values, making its use in econometric and DEA models problematic.

An alternative way of understanding economic complexity is to use the elements that influence economic sophistication. Two main elements affect economic complexity: (i) the diversification of exports, i.e., the ability to export high-technology products, and (ii) research and development (R&D) expenditure. R&D is vital because diversification and the exporting of high-technology products require innovation. Companies carry out R&D to generate better-quality goods, create new procedures and make production more efficient. It is research that provides the knowledge necessary for the creation of innovations (Saviotti and Pyka, 2004). In addition, new sectors and product improvements compensate for the decreasing capacity of established sectors and provide new jobs for skilled workers (Saviotti and Pyka, 2013).

According to Saviotti and Pyka (2004), R&D is the most common but not the only example of the research and innovation activities that take place in companies. R&D is considered a non-standard input that determines a significant percentage of the efficiency and competitiveness of enterprises. In developed economies, it occurs primarily in the agricultural machinery and equipment industry, which is generally the core of the capital goods sector, serving as the first step towards the creation of new sectors (Moralles and Rebelatto, 2016).

The structural change caused by innovation does more than anything else to create new sectors and sustain economic development (Saviotti, Pyka and Jun, 2016). It requires technical and social changes, as well as the development of new skills useful to companies and society (Kruss and others, 2015). An economy focused on the export of technological products and R&D tends to grow and develop socially.

One example are the urban centres present in complex economies. They tend to have better infrastructure and require more capabilities from the agents operating there. Hartmann (2014) argues that the region where people live influences their abilities. The jobs generated in urban centres are generally technologically intensive, requiring more substantial technical training than jobs elsewhere and a network of knowledge shared by a number of individuals. This demonstrates the influence of economic complexity on human development.

3. Linking economic complexity and human development

According to Hausmann and others (2014), knowledge plays a crucial role in complex economies, leading to better living conditions. For example, Hartmann and others (2017) find a strong correlation between economic complexity, income equality, education and GDP growth. In other words, complex countries have higher GDP growth, greater human capital and better income distribution, providing local citizens with better labour market opportunities and adequate access to health and education systems.

For Ferrarini and Scaramozzino (2016), economic complexity requires a better education because it influences the development of new skills and human capital formation. A growing and modernizing economy requires public policies to provide the conditions for greater innovation, competitiveness and economic diversification. Mustafa, Rizov and Kernohan (2017) point out that advanced Asian economies such as Japan, the Republic of Korea and Taiwan have presented rapid human development, bringing them to levels similar to those of the advanced industrialized countries. As a result, these countries have achieved exceptionally high rates of economic growth over the past 30 to 40 years. For example, Japan has the highest life expectancy among the countries analysed, and South Korea presents increasing labour productivity, linked to the great improvement in accumulated human capital. In contrast, China still presents significant shortfalls in human capital, indicating that the Chinese government could stimulate economic growth by investing in education (Lee, 2016).

Hartmann and others (2017) compared income inequality and economic complexity between Latin America and some Asian countries (China, Malaysia, the Republic of Korea and Singapore). Although Latin American economies showed social improvements due to rising commodity prices during the 2000s, the region did not diversify economically, and this was reflected by the lack of better job opportunities. On the other hand, Asian countries invested in human capital and technological innovation, which changed the region's export basket, increased its competitiveness and put it in a stronger position to face economic crises (Lee, 2017).

Structural change is essential because new technological sectors raise average wages and the demand for skilled labour, which requires higher educational levels (Antonelli, 2016). Vocational education increases per capita incomes and consumer purchasing power, as well as improving the quality of goods produced by skilled workers. This virtuous cycle plays a fundamental role in transforming societies with an abundance of low-skilled workers (Saviotti, Pyka and Jun, 2016).

Ferrarini and Scaramozzino (2016) showed that increasing complexity had increased the accumulation of human capital by promoting the acquisition of skills and learning. There was a positive coefficient between education and per capita output. The labour force participation coefficient was negative owing to the low rate of substitution between the factors of production and the employed labour force in weaker economies. Furthermore, Asian countries showed sustained growth, while France, Germany, Italy, Spain, the United Kingdom and the United States showed slow growth.

4. Structural change and public policies

Studies have discussed how structural change and public policies influence countries' development. In Japan, agricultural mechanization freed the labour force to enter the industrial sector, raising wages and generating urbanization. This process lasted more than 15 years and occurred because productivity grew in all economic sectors. In non-agricultural activities, productivity increased because of the adoption, imitation and assimilation of the technical knowledge flows of the advanced nations, which depended on the level of human capital (Esteban-Pretel and Sawada, 2014).

This structural change occurred because the Japanese government subsidized prices and investments with a view to mechanizing agriculture. To promote industrial development, the government lowered the interest rate and raised the level of loans and investments for the sector. These investments financed public enterprises involved with infrastructure. Low interest rates allowed the development of strategic sectors such as maritime transport, electric power, shipbuilding, automobile and machinery manufacturing, iron and steel, coal mining and petroleum refining (Esteban-Pretel and Sawada, 2014).

Another example is South Korea, where development policy is based on exports. According to Lee (2016), trade liberalization allowed intermediate goods to be imported more cheaply and provided access to advanced technologies, contributing to the rapid growth of industrial productivity. An industrialization-oriented export policy encouraged exporters, generating comparative advantages for Korean companies in international trade. Labour-intensive industries gave way to capital-intensive ones in the fields of electronics, machinery, automobiles, ships, and information and communications technology. As a result of this strategy, Korean per capita income rose to the level of developed countries, providing better living conditions for the country's citizens.

China has been growing at an average of 9.5% per year, although the Chinese economy still lags behind those of other Asian countries (Lee, 2016). For example, China's GDP per capita in 2011 (US$ 8,850 at purchasing power parity) was comparable to that of Korea in 1988 (US$ 9,137 at purchasing power parity) and Japan in 1968 (US$ 9,527 at purchasing power parity). Furthermore, China's relative productivity (44%) in 2010 was lower than Korea's in 1980. Lee (2016) states that the Chinese economy is more than 20 years behind Korea and more than 40 years behind Japan. For China to move from a low-income to a high-income economy, it needs to develop more technologically sophisticated industries (Lee, 2017), and its technological progress depends on policies to promote technological innovation, increase R&D investment and upgrade the industrial sector.

Singapore is a high-income economy and provides an excellent environment for business, with friendly regulatory conditions for local entrepreneurs, so that the country ranks among the world's most competitive economies. Singapore industrialized quickly during the 1960s (World Bank, 2018b), and the manufacturing sector drives its economic growth. For example, Singapore grew by 3.2% in 2018, with growth concentrated in value added manufacturing products such as electronics and precision engineering, information and communications industries, and finance and insurance (IMF, 2017). Furthermore, the Singaporean government has applied strong public education and human capital policies (Gopinathan, 2007), so that, according to the World Bank Human Capital Index (2018), it is the best country in the world for human capital development: the average Singaporean child will be 88% as productive when they grow up as if they enjoyed a full education and perfect health.

In contrast, Latin America adopted a much-criticized development model in which the productive modern sector competes with the primary production sector. The availability of land for cultivation absorbs rural workers and migrants, displacing skilled labour from other sectors of the economy. The region is susceptible to so-called Dutch disease, because when commodity prices increase, production and employment growth centre on the commodity export basket it specializes in (Barbier and Bugas, 2014). For example, data from the World Bank (2018a) show that 55.3% of total exports are commodities. Moreover, only 20.8% of the workforce is allocated to the industry sector. From a social perspective, 41.2% of the Latin American population is poor, and there are a number of problems with transport systems, infrastructure and the international competitiveness of the region's products.

Brazil is the biggest country in Latin America, and the Brazilian government still needs to improve its industrial development strategy. One successful example is the adoption of biotechnology for soy production, which has reduced labour intensity in agriculture and expanded employment in industry (Bustos, Caprettini and Ponticelli, 2016). Another example is the mechanization of sugar cane cultivation, which has virtually eliminated migratory flows in the poorest regions and has generated employment opportunities for skilled labour in the country (Moraes, Oliveira and Diaz-Chavez, 2015). On the other hand, there are examples of the adoption of technology being detrimental to local industry, such as the development of a technology that increased the area planted with maize, leading to an increase in the agricultural workforce and a contraction in industrial employment (Bustos, Caprettini and Ponticelli, 2016).

Technological specialization in specific sectors, such as agriculture in Brazil, is due to the adaptation of appropriate technologies to the inputs available in the local economy. Antonelli (2016) argues that technologically backward countries adapt the technological resources of the advanced countries, which reduces technological congruence and total factor productivity. Industrial policies in developing countries should favour structural changes that reinforce the supply of the region's main factors of production, together with a training policy that supports the creation of skills and capabilities for the region's human capital, generating social and economic development.

III. Methodology

1. The database

To evaluate the transformation of economic complexity into human development in 2013, we collected data on 50 countries available from the World Bank database.[2] This database covers four main dimensions of human development: education, health, sanitation and employment. We also selected two variables to represent economic complexity, namely exports of high-technology products and R&D expenditure.

The inputs used in this study are exports of high-technology products as a proportion of GDP (EHTP/GDP) and R&D expenditures (R&D-E) as a proxy for economic complexity. According to the literature, a country must export products with high value added to benefit from comparative advantage and international competitiveness, while R&D is essential because it allows new sectors and products to emerge (Chen, Chen and He, 2014; Waelbroeck, 2003; Caminati, 2006; Amsden and Tschang, 2003). Our outputs are: (i) life expectancy at birth (LEB); (ii) mean years of schooling (MYS); (iii) the sanitation rate (SR) and (iv) the employment rate (ER). Table 1 summarizes the selected variables.

Table 1
Variables used in the data envelopment analysis model

Variable	Source	Type	Literature
EHTP/GDP	World Bank	Input	Chen, Chen and He (2014); Waelbroeck (2003); Caminati (2006); Amsden and Tschang (2003); Hartmann (2014); Hartmann and others (2017)
R&D-E	World Bank	Input	Chen, Chen and He (2014); Waelbroeck (2003); Caminati (2006); Amsden and Tschang (2003); Hartmann (2014); Hartmann and others (2017)
LEB	World Bank	Output	Despotis (2005a); Reig-Martínez (2013)
MYS	World Bank	Output	Despotis (2005b); Mariano and Rebelatto (2014)
ER	World Bank	Output	Morais and Camanho (2011); Reig-Martínez (2013)
SR	World Bank	Output	Mariano and Rebelatto (2014); Reig-Martínez (2013)

Source: Prepared by the authors, on the basis of Amsden, A. H. and F. T. Tschang (2003), "A new approach to assessing the technological complexity of different categories of R&D (with examples from Singapore)", *Research Policy*, vol. 32, No. 4; Chen, X., G. Chen and Y. He (2014), "Trade on high-tech complex products", *Information Technology Journal*, vol. 13, No. 15; Caminati, M. (2006), "Knowledge growth, complexity and the returns to R&D", *Journal of Evolutionary Economics*, vol. 16, No. 3; Despotis, D. K. (2005a), "A reassessment of the human development index via data envelopment analysis", *Journal of the Operational Research Society*, vol. 56, No. 8; Despotis, D. K. (2005b), "Measuring human development via data envelopment analysis: the case of Asia and the Pacific", *Omega*, vol. 33, No. 5; Hartmann, D. (2014), *Economic Complexity and Human Development: How Economic Diversification and Social Networks Affect Human Agency and Welfare*, London, Routledge, Taylor & Francis Group; Hartmann, D. and others (2017), "Linking economic complexity, institutions, and income inequality", *World Development*, vol. 93; Mariano, E. B. and D. A. D. N. Rebelatto (2014), "Transformation of wealth produced into quality of life: analysis of the social efficiency of nation-states with the DEA's triple index approach", *Journal of the Operational Research Society*, vol. 65, No. 11; Morais, P. and A. S. Camanho (2011), "Evaluation of performance of European cities with the aim to promote quality of life improvements", *Omega*, 39, No. 4; Reig-Martínez, E. (2013), "Social and economic wellbeing in Europe and the Mediterranean Basin: Building an enlarged human development indicator", *Social Indicators Research*, vol. 111, No. 2; Waelbroeck, P. (2003), "Innovations, production complexity and the optimality of R&D", *Economics Letters*, vol. 79, No. 2.

Note: EHTP/GDP: exports of high-technology products as a proportion of GDP; R&D-E: research and development expenditure; LEB: life expectancy at birth; MYS: mean years of schooling; ER: employment rate; SR: sanitation rate.

[2] The countries analysed are listed in table 3.

Since our analysis measures the efficiency of economic complexity in bringing about human development, we only analyse economic complexity inputs. We do not analyse public expenditure, even though it is relevant, since it would yield a different kind of efficiency ranking. Future studies can use DEA models to compare the efficiency of social expenditure in different regions.

Following collection of the data, the variables were analysed using a correlation matrix and linear regression. Econometric validation was carried out, then the standard DEA models (CRS and VRS), the slack-based measure (SBM) model and the inverted frontier were estimated. The models are output-oriented, on the basis that each country will seek to maximize outputs (human development) without reducing inputs (economic complexity).

2. Econometric validation

DEA is a non-parametric technique requiring econometric validation to prove causality (Charnes, Cooper and Rhodes, 1978; Cook and Zhu, 2014; Mariano, Sobreiro and do Nascimento Rebelatto, 2015). For this reason, we validate our data with eight econometric panel fixed-effect models (from 2010 to 2013). Although several studies have used DEA to measure human development without presenting a statistical validation (Murias, Martínez and De Miguel, 2006; Somarriba and Pena, 2009; Martín and Mendoza, 2013; Mariano, Sobreiro and do Nascimento Rebelatto, 2015), our study uses econometric models to show the correlation between at least one input and one output. This is in line with previous DEA approaches, with Mariano and Rebelatto (2014), for example, using a correlation matrix to validate inputs and outputs. Our validation shows that most of the variables are statistically significant, proving the impact of economic complexity on human development, which validates the DEA procedure. The estimates are presented in annex A1.

The matrix of correlation between inputs and outputs shows that all social variables except mean years of schooling and the employment rate have a statistically significant correlation. All variables present the expected sign. R&D expenditure shows the highest correlation with life expectancy (16.71%), followed by the sanitation rate (12.12%). This means that more R&D expenditure increases life expectancy, access to basic sanitation, education and employment. Exports of high-technology products (EHTP/GDP) show positive and statistically significant correlation with all social variables. Life expectancy (23.94%) is the social variable presenting the highest correlation, followed by the employment rate (22.11%), the sanitation rate (15.87%) and mean years of schooling (12.41%). In other words, a country that exports technological products increases human development through education, basic sanitation, employment and life expectancy.

Regarding mean years of schooling, econometric model 5 shows that R&D-E is statistically significant at the 5% level and has the expected (positive) sign. It should be noted that spending on R&D (0.0114%) explains more years of study than GDP (0.0084%). This result shows that investment in innovation has a 0.0114% impact on mean years of schooling.

For life expectancy, econometric model 1 shows that R&D-E is statistically significant at the 1% level. It also explains more of the variation in life expectancy (0.0113%) than the economically active population (0.0041%). Furthermore, the EHTP/GDP variable shows a sign expected only in model 6.

Regarding the sanitation rate, model 3 proves that R&D-E has positive and statistically significant impacts on sanitation (0.0047%). Regarding the employment rate, both R&D-E and EHTP/GDP show a positive impact. In addition, EHTP/GDP impacts the employment rate by 0.010% in model 3.

In summary, the econometric analysis shows that the inputs selected for this study are correlated with the social variables (outputs) and that this correlation is statistically significant, confirming the theoretical assumptions previously discussed (Hidalgo and Hausmann, 2009; Hartmann, 2014; Hausmann and others, 2014; Hartmann and others, 2017; Antonelli, 2016).

3. Data envelopment analysis

Data envelopment analysis (DEA) is based on linear programming developed by Charnes, Cooper and Rhodes (1978).

The method presents different kinds of models and assumptions such as (i) returns to scale, (ii) orientation and (iii) input and output combinations. According to Mariano and Rebelatto (2014), the type of returns to scale distinguishes the two principal DEA models: constant returns to scale (CRS) and variable returns to scale (VRS). Table 1 shows the formulations of the CRS and VRS models in their two possible orientations. Table 2 shows the mathematical formulation of the VRS model in its two orientations.

Table 2
Main data envelopment analysis radial models in the form of multipliers

Model	Input-oriented	Output-oriented
Constant returns to scale (CRS)	$MAX\sum_{i=1}^{m} u_i \cdot y_{i0}$ Subject to: $\sum_{j=1}^{n} v_j \cdot x_{j0} = 1$ $\sum_{i=1}^{m} u_i \cdot y_{ik} - \sum_{j=1}^{n} v_j \cdot x_{jk} \leq 0 \quad \text{for } k = 1, 2, ..., h$	$MIN\sum_{i=1}^{n} v_j \cdot x_{j0}$ Subject to: $\sum_{j=1}^{m} u_i \cdot y_{i0} = 1$ $\sum_{i=1}^{m} u_i \cdot y_{ik} - \sum_{j=1}^{n} v_j \cdot x_{jk} \leq 0 \quad \text{for } k = 1, 2, ..., h$
Variable returns to scale (VRS)	$MAX\sum_{i=1}^{m} u_i \cdot y_{i0} + w$ Subject to: $\sum_{j=1}^{n} v_j \cdot x_{j0} = 1$ $\sum_{i=1}^{m} u_i \cdot y_{ik} - \sum_{j=1}^{n} v_j \cdot x_{jk} + w \leq 0 \quad \text{for } k = 1, 2, ..., h$	$MIN\sum_{i=1}^{n} v_i \cdot x_{j0} - w$ Subject to: $\sum_{j=1}^{m} u_i \cdot y_{i0} = 1$ $\sum_{i=1}^{m} u_i \cdot y_{ik} - \sum_{j=1}^{n} v_j \cdot x_{jk} + w \leq 0 \quad \text{for } k = 1, 2, ..., h$

Source: E. B. Mariano and D. A. D. N. Rebelatto, "Transformation of wealth produced into quality of life: analysis of the social efficiency of nation-states with the DEA's triple index approach", *Journal of the Operational Research Society*, vol. 65, No. 11, 2014.

Note: x_{jk} represents the amount of input j of decision-making unit (DMU) k; y_{ik} represents the amount of output i of DMU k; x_{j0} represents the amount of input j of the DMU under analysis; y_{i0} represents the amount of output i of the DMU under analysis; v_i represents the weight of input j for the DMU under analysis; u_i represents the weight of output i for the DMU under analysis; θ means the efficiency of the DMU under analysis; λ_k is the contribution of DMU k to the goal of the DMU under analysis; m is the quantity of outputs analysed; n is the quantity of inputs analysed; and w represents the scale factor (without sign restriction).

The hypothesis of the CRS model assumes that outputs vary proportionally to inputs in all regions of the frontier (Charnes, Cooper and Rhodes, 1978). However, this model does not consider the scale gains of a system, which is a limitation (Mariano, Sobreiro and do Nascimento Rebelatto, 2015). The VRS model, on the other hand, assumes that outputs do not necessarily vary proportionally to inputs, with the frontier having three regions: increasing, where outputs grow by more than inputs; constant, where there is proportionality; and decreasing, where outputs grow by less than inputs (Banker, Charnes and Cooper, 1984).

Tone (2001) developed a non-radial model called the slack-based measure (SBM) model. This additive model is invariant as regards the units of measurement used for inputs and outputs (Cooper, Seiford and Tone, 2006) and attains the same efficiency value regardless of the units of measurement adopted for each variable when dealing with gap variables, i.e., with excess inputs and scarce outputs. The SBM model projects the observations to the point farthest from the efficiency frontier in order to minimize the objective function with regard to the maximum clearance amounts (Choi, Zhang and Zhou, 2012). However, the SBM model has been little used in the literature on human development and social efficiency.

DEA has been used for a number of research problems and fields, such as the energy sector (Schuschny, 2007), innovation management (Aguilar-Barceló and Higuera-Cota, 2019), total factor productivity in ports (Guerrero and Rivera, 2009), production efficiency and technical change (Sotelsek and Abarca, 2010) and agrarian reform (Sobreiro Filho and others, 2016). There is also a growing literature in which DEA is used to create social indicators and measure human development (Despotis, 2005a and 2005b; Mariano, Sobreiro and do Nascimento Rebelatto, 2015).

For example, DEA can be used to measure social efficiency and thereby analyse the capacity of a country to transform wealth into human development (Mariano Sobreiro and do Nascimento Rebelatto, 2015). The pioneer in calculating countries' social efficiency was Despotis (2005a), using GDP per capita as the input and education and life expectancy as the outputs in the DEA VRS model. Morais and Camanho (2011) also measured the social efficiency of 284 European cities, using GDP per capita as the input and 29 indicators of quality of life as outputs. Mariano and Rebelatto (2014) developed the application of weight restriction and tie-breaking methods in a global analysis. Reig-Martínez (2013) used a DEA SBM model for 42 countries in Europe, North Africa and the Middle East. However, Mariano and others (2015) pointed out that there were a number of gaps to be filled in this field; e.g., there was no study comparing measured efficiency between standard and SBM models. Nor could we find studies that treated economic complexity as an input generating human development or quality of life. Thus, the main contributions of this paper are: (i) to remedy the lack of studies comparing DEA models, (ii) to remedy the lack of studies measuring efficiency around the world, (iii) to compare economic complexity and human development and (iv) to remedy the lack of studies applying the inverted frontier technique.

4. The inverted frontier technique

When ranked using DEA, many regions are tied in the same position, which is a problem because it does not present decision-makers with useful information. This was solved by developing tie-breaking techniques such as the inverted frontier (IF) method (Angulo-Meza and Lins, 2002). The IF method, originally proposed by Yamada, Matui and Sugiyama (1994) and used by Leta and others (2005) as a tie-breaking function, measures efficiency by changing the allocation of inputs and outputs in the DEA model. This technique yields two interesting results: (i) an indicator of regional weaknesses and (ii) a frontier of worst practices.

We used the IF tie-breaking method to create the Composite Index of Human Development and Economic Complexity (CIHD-EC). Leta and others (2005) recommended the use of a composite index, such as the average between the indicator obtained at the standard frontier ($E_{standard}$) and the number 1 minus the indicator obtained with the IF method ($E_{inverted}$) (expression 1).

$$\text{CIHD} - \text{EC} = \gamma * E_{standard} + (1 - \gamma) * (1 - E_{inverted}), \text{ with } 0 \leq \alpha \leq 1 \quad (1)$$

The use of a composite index for the standard and inverted frontiers means that two situations can be considered for both: when countries are compared by their strongest points and when they are compared by their weakest points. We computed a value of 0.5 for γ to aggregate the standard and inverted frontier results (expression 1), i.e., we used the average of the two boundaries. This value was chosen because it is the most commonly used in the literature, being generally considered a neutral value. However, other values of γ could be even more appropriate for this problem. It would be consistent with the capability approach if the inverted frontier (which highlights the worse performance) had a higher weight than the standard frontier (which highlights the factors on which the region performs best). The reason for this is that the capability approach places great emphasis on setting minimum standards, so it is more important for the region not to perform very poorly on some variable or variables than for it to perform excellently only on a restricted number of variables. Ascertaining the most appropriate γ value, however, is beyond the scope of this paper and also requires further in-depth theoretical discussion.

IV. Results and discussion

We use standard models and slack-based measure (SBM) models to compare differences in countries' efficiency at converting economic complexity into human development. This section presents a discussion of the discrepancies found between our DEA models, such as the number of efficient countries and the descriptive statistics (average, standard deviation and the coefficient of variation) for the world, developed and developing economies and high- and low-income nations.

Our findings show that the standard CRS model has a smaller number of efficient DMUs (six countries). The SBM CRS model shows the same number of efficient units (six countries). The averages of the CRS model (0.3594) and the SBM CRS model (0.3374) are close, as are their standard deviations, at 0.3537 for the CRS model and 0.3435 for the SBM CRS model. As expected, we also found similar coefficients of variation for the CRS (0.9842) and the SBM CRS (1.0181) models. This means that we did not find significant divergences between the standard and SBM CRS models when it came to the transformation of economic complexity into human development.

Table 3 summarizes the efficiency of each model, scale efficiency and the returns to scale for the countries.

Table 3
Estimates of the efficiency of standard and slack-based measure models

Country	Standard models						Slack-based models					
	CRS	VRS	IF VRS	CIHD-EC	Scale efficiency	Return	SBM CRS	SBM VRS	IF SBM VRS	CIHD-EC	Scale efficiency	Return
Argentina	0.0841	0.9580	0.9094	0.5243	0.0878	Decreasing	0.0773	0.8977	0.7696	0.5641	0.0861	Decreasing
Armenia	1.0000	1.0000	0.9314	0.5343	1.0000	Constant	1.0000	1.0000	0.7975	0.6013	1.0000	Constant
Australia	0.1440	1.0000	0.8410	0.5795	0.1440	Decreasing	0.1384	1.0000	0.6783	0.6609	0.1384	Decreasing
Austria	0.3807	1.0000	0.8565	0.5718	0.3807	Decreasing	0.3572	0.9997	0.7250	0.6374	0.3573	Decreasing
Belarus	0.3520	0.9461	0.9686	0.4888	0.3721	Decreasing	0.3407	0.9066	0.8093	0.5487	0.3758	Decreasing
Belgium	0.3301	1.0000	0.8889	0.5556	0.3301	Decreasing	0.3086	0.9999	0.7895	0.6052	0.3086	Decreasing
Bosnia and Herzegovina	1.0000	1.0000	1.0000	0.5000	1.0000	Constant	1.0000	1.0000	1.0000	0.5000	1.0000	Constant
Brazil	0.0173	0.9540	0.9212	0.5164	0.0181	Decreasing	0.0124	0.8346	0.7848	0.5249	0.0149	Decreasing
Bulgaria	0.9926	0.9926	0.9618	0.5154	1.0000	Constant	0.9272	0.9272	0.8632	0.5320	1.0000	Constant
Canada	0.0903	1.0000	0.8437	0.5782	0.0903	Decreasing	0.0867	1.0000	0.6793	0.6604	0.0867	Decreasing
Chile	0.1955	0.9900	0.8567	0.5667	0.1975	Decreasing	0.1783	0.9113	0.7403	0.5855	0.1957	Decreasing
China	0.0024	0.9787	1.0000	0.4894	0.0025	Decreasing	0.0017	0.8939	1.0000	0.4470	0.0019	Decreasing
Colombia	0.0728	0.9116	0.9282	0.4917	0.0799	Decreasing	0.0547	0.7776	0.8213	0.4782	0.0703	Decreasing
Costa Rica	0.7256	0.9887	0.8755	0.5566	0.7339	Decreasing	0.6284	0.8854	0.7763	0.5546	0.7097	Decreasing
Croatia	0.8567	1.0000	0.9451	0.5275	0.8567	Decreasing	0.7757	1.0000	0.8561	0.5720	0.7757	Decreasing
Czech Republic	0.3104	0.9910	0.8895	0.5508	0.3132	Decreasing	0.3006	0.9553	0.7389	0.6082	0.3147	Decreasing
Denmark	0.5778	1.0000	0.8639	0.5681	0.5778	Decreasing	0.5687	1.0000	0.7096	0.6452	0.5687	Decreasing
Egypt	0.0530	0.9470	1.0000	0.4735	0.0560	Decreasing	0.0411	0.7372	1.0000	0.3686	0.0558	Decreasing
El Salvador	0.9536	0.9536	0.9463	0.5037	1.0000	Constant	0.8243	0.8243	0.8758	0.4743	1.0000	Constant
Ethiopia	0.1432	1.0000	1.0000	0.5000	0.1432	Decreasing	0.0427	0.9999	1.0000	0.5000	0.0427	Decreasing
Finland	0.6127	0.9972	0.8654	0.5659	0.6144	Decreasing	0.5624	0.9547	0.7583	0.5982	0.5891	Decreasing
France	0.0555	0.9946	0.8753	0.5597	0.0558	Decreasing	0.0511	0.9203	0.7826	0.5689	0.0555	Decreasing

Table 3 (concluded)

Country	Standard models						Slack-based models					
	CRS	VRS	IF VRS	CIHD-EC	Scale efficiency	Return	SBM CRS	SBM VRS	IF SBM VRS	CIHD-EC	Scale efficiency	Return
Georgia	1.0000	1.0000	0.9275	0.5363	1.0000	Constant	1.0000	1.0000	0.7712	0.6144	1.0000	Constant
Germany	0.0392	1.0000	0.8633	0.5684	0.0392	Decreasing	0.0387	0.9963	0.7199	0.6382	0.0388	Decreasing
Greece	0.4347	1.0000	0.9257	0.5372	0.4347	Decreasing	0.3655	1.0000	0.8788	0.5606	0.3655	Decreasing
Hungary	0.3676	0.9800	0.9383	0.5209	0.3751	Decreasing	0.3403	0.8852	0.8218	0.5317	0.3844	Decreasing
Indonesia	0.0148	0.9121	1.0000	0.4561	0.0162	Decreasing	0.0099	0.7364	1.0000	0.3682	0.0134	Decreasing
Ireland	0.7608	1.0000	0.8834	0.5583	0.7608	Decreasing	0.7130	1.0000	0.7676	0.6162	0.7130	Decreasing
Israel	0.4620	1.0000	0.8449	0.5776	0.4620	Decreasing	0.4499	1.0000	0.6967	0.6517	0.4499	Decreasing
Italy	0.0647	0.9970	0.8989	0.5491	0.0649	Decreasing	0.0565	0.9377	0.8474	0.5452	0.0603	Decreasing
Japan	0.0260	1.0000	0.8880	0.5560	0.0260	Decreasing	0.0246	1.0000	0.8149	0.5926	0.0246	Decreasing
Korea (Republic of)	0.0651	1.0000	1.0000	0.5000	0.0651	Decreasing	0.0627	0.9667	1.0000	0.4834	0.0649	Decreasing
Lithuania	1.0000	1.0000	0.9378	0.5311	1.0000	Constant	1.0000	1.0000	0.7753	0.6124	1.0000	Constant
Mexico	0.0307	0.9293	0.9032	0.5131	0.0330	Decreasing	0.0256	0.8267	0.8006	0.5131	0.0310	Decreasing
Netherlands	0.1915	1.0000	0.8508	0.5746	0.1915	Decreasing	0.1814	1.0000	0.7016	0.6492	0.1814	Decreasing
Norway	0.6655	1.0000	0.8418	0.5791	0.6655	Decreasing	0.6225	1.0000	0.6767	0.6617	0.6225	Decreasing
Panama	1.0000	1.0000	0.8906	0.5547	1.0000	Constant	1.0000	1.0000	0.7604	0.6198	1.0000	Constant
Philippines	0.0404	0.8999	0.9903	0.4548	0.0449	Decreasing	0.0320	0.8079	0.8330	0.4875	0.0396	Decreasing
Poland	0.0874	0.9815	0.9113	0.5351	0.0890	Decreasing	0.0839	0.9327	0.7856	0.5736	0.0900	Decreasing
Portugal	0.3053	1.0000	0.8819	0.5591	0.3053	Decreasing	0.2591	1.0000	0.8276	0.5862	0.2591	Decreasing
Romania	0.2385	0.9401	0.9445	0.4978	0.2537	Decreasing	0.2226	0.9096	0.8289	0.5404	0.2447	Decreasing
Russian Federation	0.0224	0.9593	0.9702	0.4946	0.0234	Decreasing	0.0189	0.8591	0.7998	0.5297	0.0220	Decreasing
Singapore	0.6143	1.0000	0.8322	0.5839	0.6143	Decreasing	0.5282	1.0000	0.6660	0.6670	0.5282	Decreasing
Spain	0.0708	1.0000	0.8936	0.5532	0.0708	Decreasing	0.0608	0.9998	0.8508	0.5745	0.0608	Decreasing
Sweden	0.3316	0.9978	0.8469	0.5755	0.3323	Decreasing	0.3207	0.9806	0.7052	0.6377	0.3270	Decreasing
Turkey	0.0553	0.9410	0.9558	0.4926	0.0588	Decreasing	0.0464	0.7890	0.9214	0.4338	0.0588	Decreasing
Ukraine	0.0696	0.9732	0.9655	0.5039	0.0715	Decreasing	0.0656	0.9258	0.7781	0.5739	0.0709	Decreasing
United Kingdom	0.0514	1.0000	0.8587	0.5707	0.0514	Decreasing	0.0507	1.0000	0.7119	0.6441	0.0507	Decreasing
United States	0.0105	1.0000	0.8971	0.5515	0.0105	Decreasing	0.0103	0.9724	0.7461	0.6132	0.0106	Decreasing
Uruguay	1.0000	1.0000	0.8913	0.5544	1.0000	Constant	1.0000	1.0000	0.7467	0.6267	1.0000	Constant

Source: Prepared by the authors on the basis of World Bank, "Human Capital Project", 2018 [online] http://www.worldbank.org/en/publication/human-capital.

Note: CRS: constant returns to scale; VRS: variable returns to scale; IF VRS: inverted frontier variable returns to scale; CIHD-EC: Composite Index of Human Development and Economic Complexity; SBM CRS: slack-based measure constant returns to scale; SBM VRS: slack-based measure variable returns to scale; IF SBM VRS: inverted frontier slack-based measure variable returns to scale.

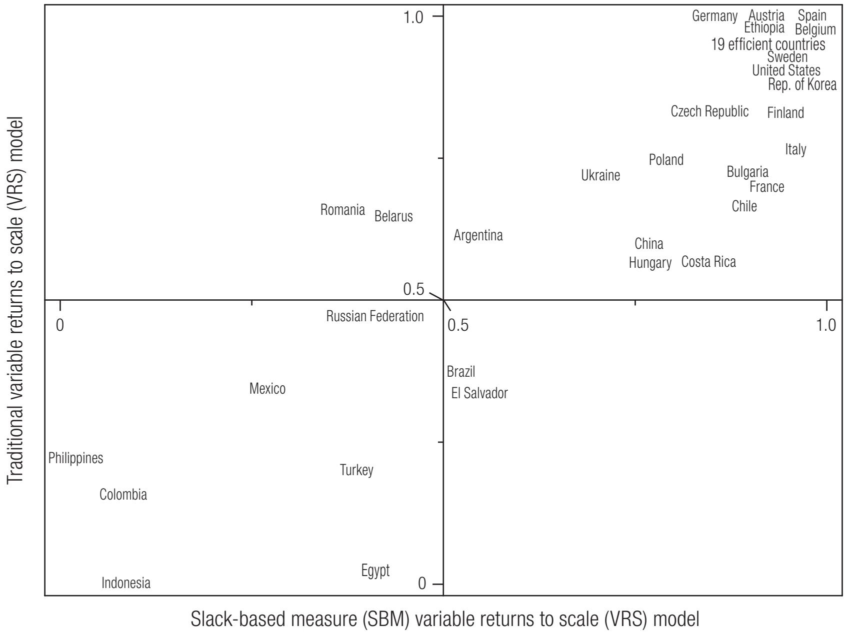
The efficient countries in the CRS and SBM CRS models are Armenia, Bosnia and Herzegovina, Georgia, Lithuania, Panama and Uruguay. With regard to scale efficiency, both the standard and the slack-based measure models presented 42 countries with decreasing returns to scale and eight countries with constant returns to scale. The countries with constant returns to scale are the six efficient countries in the CRS model plus Bulgaria and El Salvador. However, the previous literature has used VRS models.

The standard VRS model shows 26 countries as efficient at converting economic complexity into human development. The SBM VRS model shows only 19 countries as efficient. The change affects the discrepancy between averages. The VRS model average (0.9823) is slightly higher than the SBM VRS model average (0.9390). The standard deviation is lower for the standard VRS model (0.0509) than for the SBM VRS model (0.0770), showing that the latter has greater variability. Furthermore, the coefficient of variation of the VRS model (0.0279) is lower than that for the SBM VRS model (0.0820). Note that the SBM VRS model presents a coefficient of variation four times as high as that of the standard model. This is because the Philippines had the lowest efficiency in the VRS model (0.8322), while Indonesia had the lowest efficiency in the SBM VRS model (0.7364).

The seven countries found to be efficient with the standard VRS model but not with the SBM VRS model are Austria, Belgium, Ethiopia, Germany, the Republic of Korea, Spain and the United States.

Note that all except Ethiopia are developed, high-income countries. This is an important finding for the measurement of human development indicators by DEA. According to our empirical results, the standard models tend to overestimate the efficiency of some DMUs, especially in the case of developed, high-income countries. Figure 1 illustrates the discrepancies between the standard VRS model and SBM VRS model.

Figure 1
Benchmarking the standard and slack-based measure models with variable returns to scale



Source: Prepared by the authors on the basis of World Bank, "Human Capital Project", 2018 [online] http://www.worldbank.org/en/publication/human-capital.

When we use the standard VRS model, our findings are similar to those of Despotis (2005a and 2005b) and Reig-Martínez (2013), because many countries considered efficient at transforming economic complexity into human development are also efficient at converting wealth into human development, such as Austria, Belgium, Germany, the Republic of Korea and Spain. When we use the SBM VRS model, on the other hand, our empirical findings are that these countries cannot be considered efficient, which is not supported by previous studies (Despotis, 2005a and 2005b; Reig-Martínez, 2013).

The number of efficient units is high with the standard VRS model (52%) and SBM VRS model (38%). Models with variable returns to scale present many ties, and these have been solved with the inverted frontier technique. Accordingly, we created the Composite Index of Human Development and Economic Complexity (CIHD-EC). The advantage of this indicator is that it avoids ties by considering the best and worst practices of each country with regard to the transformation of economic complexity into human development. The CIHD-EC also allows policymakers to work out the best industrial policies (R&D expenditure and export of high-technology products) to generate human development.

The CIHD-EC has yielded a significant result: with both the standard VRS model and the SBM model, Singapore is the only efficient country among the 50 nations analysed. This is unexpected, since European and North American countries (i.e., Austria, Belgium, Germany, Spain and the United States) reach the highest-ranking position. However, the finding is supported by previous studies of Singapore's economic development (Gopinathan, 2007; World Bank, 2018a and 2018b).

In both the standard VRS and SBM VRS ranking, the top five countries are Singapore, Norway, Israel, Canada and Australia. The high position for Norway corroborates the findings of Reig-Martínez (2013). According to this author, SBM models showed the Nordic countries to be efficient at converting wealth into human development. In addition, our findings demonstrate that there is no clustering of efficient countries in the CIHD-EC, with the most efficient countries being spread across Europe, North America and Asia. Moreover, according to our empirical results, the inverted frontier technique avoids the discrepancies in efficiency rankings between standard models and the SBM model.

The bottom five countries in the standard VRS model are the Philippines, Indonesia, Egypt, China and Belarus, while the bottom five countries in the SBM VRS model are Indonesia, Egypt, Turkey, China and El Salvador. The standard model places a European country, Belarus, in the bottom five, while the SBM VRS model brings a Eurasian one, Turkey, into the bottom five. Furthermore, while the standard model places the Philippines, an Asian country, in the bottom five, the SBM VRS model includes a Latin American one, El Salvador, in the bottom five.

Table 4 summarizes the differences between the indicators calculated in this study. We analyse these differences for the 50 countries being evaluated by type of economy (developed as against developing) and income level (high-income and upper-middle-income as against low-income and lower-middle-income).

In the analysis by type of economy, we found that the standard VRS model benefited developed countries. While the SBM VRS model yielded only 14 efficient countries, the standard VRS model yielded 19 efficient countries. Among developing economies, in contrast, Ethiopia was the only efficient country with the VRS model. On the other hand, the SBM VRS model did not identify Ethiopia as an efficient nation. The CIHD-EC yields a better fit for developed and developing countries, identifying only Singapore as efficient and avoiding ranking ties.

Concerning income levels, the efficient units identified by the standard VRS model are mainly low-income and lower-middle-income economies (23 countries), while only 3 high-income and upper-middle-income economies are found to be efficient. The SBM VRS model reduces this discrepancy, finding there to be only two efficient high-income and upper-middle-income economies and 17 efficient low-income and lower-middle-income economies.

In summary, we consider that the SBM VRS model is better able to analyse how efficient countries are at transforming economic complexity into human development. It does not identify as efficient some developed countries that are so identified by the standard models. Also, the inverted frontier tie-breaker method was able to demonstrate a better fit among the five most efficient countries. Furthermore, the discrepancy of these models can be applied to the transformation of wealth into human development, bringing new insights to this problem.

Figure 2 shows four maps that illustrate the efficiency of simple indicators in the countries of the world when employing the standard CRS model, the standard VRS model, the SBM CRS model and the SBM VRS model. Figure 3 shows four maps that illustrate the efficiency of composite indicators (using the inverted frontier technique) in the countries of the world when employing the standard CRS model, the CIHD-EC based on the standard VRS model, the SBM CRS model and the CIHD-EC based on the SBM VRS model. More efficient countries are shaded dark green and less efficient countries light green.

Table 4
Comparison of regions using standard and slack-based models

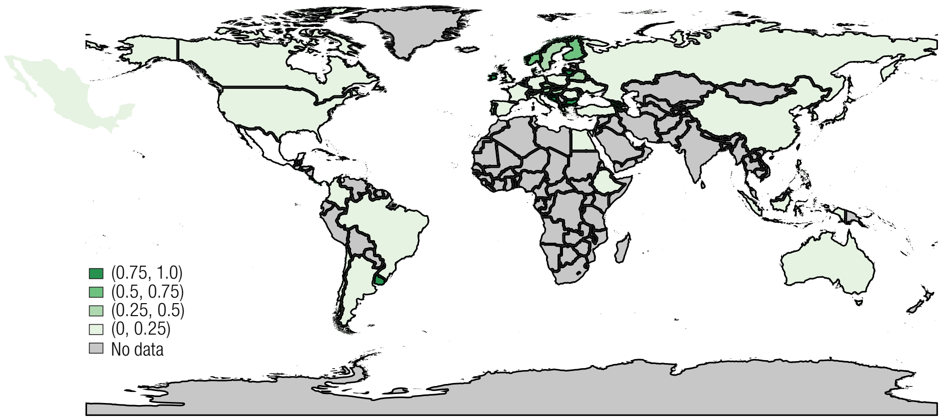
Region	Statistic	Standard models					Slack-based models				
		CRS	VRS	IF VRS	CIHD-EC	Scale efficiency	SBM CRS	SBM VRS	IF SBM VRS	CIHD-EC	Scale efficiency
World	Average	0.3594	0.9823	0.9120	0.5351	0.3623	0.3374	0.9390	0.8038	0.5676	0.3492
	Median	0.2170	1.0000	0.9011	0.5431	0.2256	0.2020	0.9765	0.7852	0.5742	0.2202
	Standard deviation	0.3537	0.0274	0.0509	0.0345	0.3552	0.3435	0.0770	0.0920	0.0721	0.3518
	Coefficient of variation	0.9842	0.0279	0.0558	0.0644	0.9804	1.0181	0.0820	0.1145	0.1269	1.0076
	Maximum value	1.0000	1.0000	1.0000	0.5839	1.0000	1.0000	1.0000	1.0000	0.6670	1.0000
	Minimum value	0.0024	0.8999	0.8322	0.4548	0.0025	0.0017	0.7364	0.6660	0.3682	0.0019
	Efficient countries	6	26	6	1	-	6	19	6	1	-
Developed	Average	0.3710	0.9955	0.8850	0.5552	0.3724	0.3465	0.9797	0.7637	0.6080	0.3537
	Median	0.3301	1.0000	0.8834	0.5583	0.3301	0.3086	1.0000	0.7583	0.6124	0.3147
	Standard deviation	0.2948	0.0121	0.0369	0.0219	0.2951	0.2788	0.0328	0.0653	0.0421	0.2847
	Coefficient of variation	0.7946	0.0121	0.0417	0.0395	0.7924	0.8046	0.0335	0.0855	0.0692	0.8048
	Maximum value	1.0000	1.0000	0.9618	0.5839	1.0000	1.0000	1.0000	0.8788	0.6670	1.0000
	Minimum value	0.0105	0.9401	0.8322	0.4978	0.0105	0.0103	0.8852	0.6660	0.5317	0.0106
	Efficient countries	1	19	0	1	-	1	14	0	1	-
Developing	Average	0.3458	0.9668	0.9438	0.5115	0.3504	0.3267	0.8913	0.8508	0.5203	0.3439
	Median	0.0728	0.9732	0.9463	0.5037	0.0799	0.0627	0.8977	0.8006	0.5249	0.0703
	Standard deviation	0.4119	0.0320	0.0464	0.0314	0.4144	0.4062	0.0861	0.0965	0.0711	0.4170
	Coefficient of variation	1.1912	0.0331	0.0492	0.0614	1.1826	1.2435	0.0965	0.1134	0.1367	1.2128
	Maximum value	1.0000	1.0000	1.0000	0.5667	1.0000	1.0000	1.0000	1.0000	0.6267	1.0000
	Minimum value	0.0024	0.8999	0.8567	0.4548	0.0025	0.0017	0.7364	0.7403	0.3682	0.0019
	Efficient countries	5	7	6	0	-	5	5	6	0	-
High-income and upper-middle-income	Average	0.4093	0.9607	0.9701	0.4953	0.4165	0.3770	0.8789	0.8820	0.4985	0.4028
	Median	0.1064	0.9634	0.9779	0.5018	0.1074	0.0542	0.8751	0.8544	0.4937	0.0633
	Standard deviation	0.4471	0.0372	0.0296	0.0296	0.4532	0.4404	0.1087	0.0965	0.0896	0.4628
	Coefficient of variation	1.0922	0.0387	0.0305	0.0598	1.0883	1.1683	0.1237	0.1094	0.1798	1.1491
	Maximum value	1.0000	1.0000	1.0000	0.5363	1.0000	1.0000	1.0000	1.0000	0.6144	1.0000
	Minimum value	0.0148	0.8999	0.9275	0.4548	0.0162	0.0099	0.7364	0.7712	0.3682	0.0134
	Efficient countries	2	3	3	1	-	2	2	3	1	-
Low-income and lower-middle-income	Average	0.3499	0.9864	0.9010	0.5427	0.3520	0.3298	0.9505	0.7889	0.5808	0.3390
	Median	0.2719	1.0000	0.8910	0.5538	0.2795	0.2409	0.9885	0.7795	0.5859	0.2519
	Standard deviation	0.3322	0.0230	0.0463	0.0298	0.3322	0.3211	0.0631	0.0832	0.0597	0.3254
	Coefficient of variation	0.9493	0.0233	0.0514	0.0549	0.9439	0.9737	0.0664	0.1055	0.1029	0.9601
	Maximum value	1.0000	1.0000	1.0000	0.5839	1.0000	1.0000	1.0000	1.0000	0.6670	1.0000
	Minimum value	0.0024	0.9116	0.8322	0.4888	0.0025	0.0017	0.7776	0.6660	0.4338	0.0019
	Efficient countries	4	23	3	0	-	4	17	3	0	-

Source: Prepared by the authors on the basis of World Bank, "Human Capital Project", 2018 [online] http://www.worldbank.org/en/publication/human-capital.

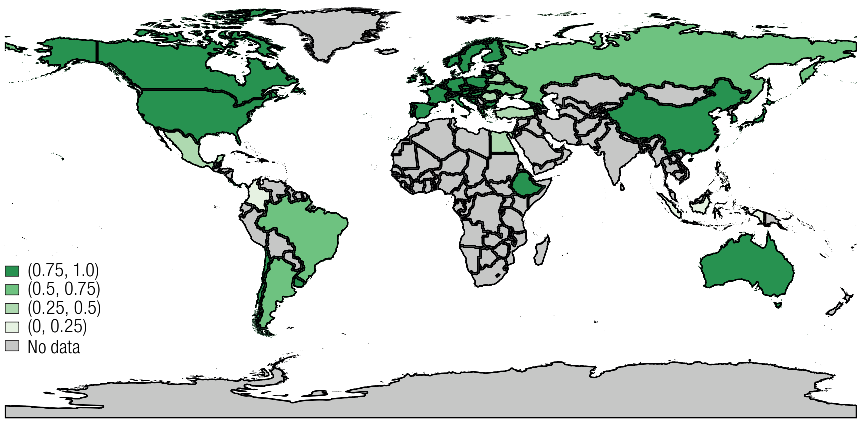
Note: CRS: constant returns to scale; VRS: variable returns to scale; IF VRS: inverted frontier variable returns to scale; CIHD-EC: Composite Index of Human Development and Economic Complexity; SBM CRS: slack-based measure constant returns to scale; SBM VRS: slack-based measure variable returns to scale; IF SBM VRS: inverted frontier slack-based measure variable returns to scale.

Figure 2
World: efficiency in converting economic complexity into human development as measured by simple indicators

A. Standard CRS model



B. Standard VRS model



C. SBM CRS model

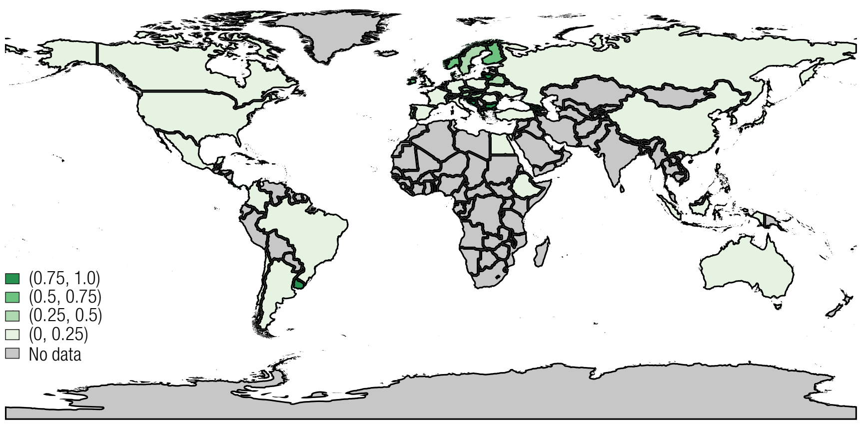
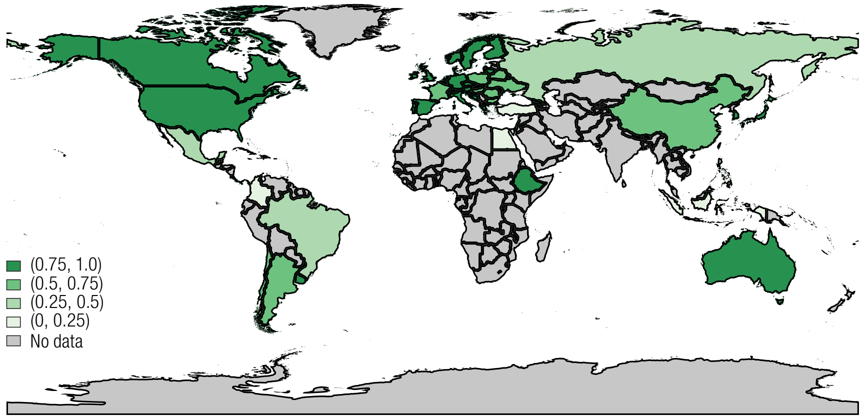


Figure 2 (concluded)

D. SBM VRS model



Source: Prepared by the authors on the basis of World Bank, "Human Capital Project", 2018 [online] http://www.worldbank.org/en/publication/human-capital.

Note: CRS: constant returns to scale; VRS: variable returns to scale; SBM CRS: slack-based measure constant returns to scale; SBM VRS: slack-based measure variable returns to scale.

Figure 3

World: efficiency in converting economic complexity into human development as measured by composite indicators (standard and inverted frontiers)

A. Standard CRS model

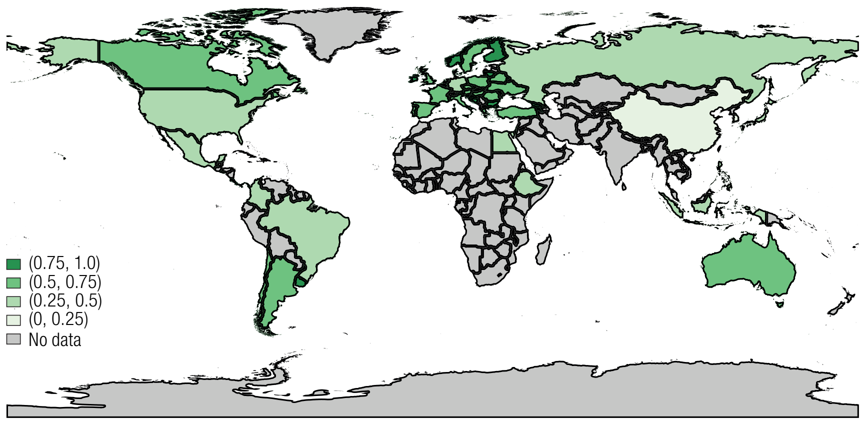
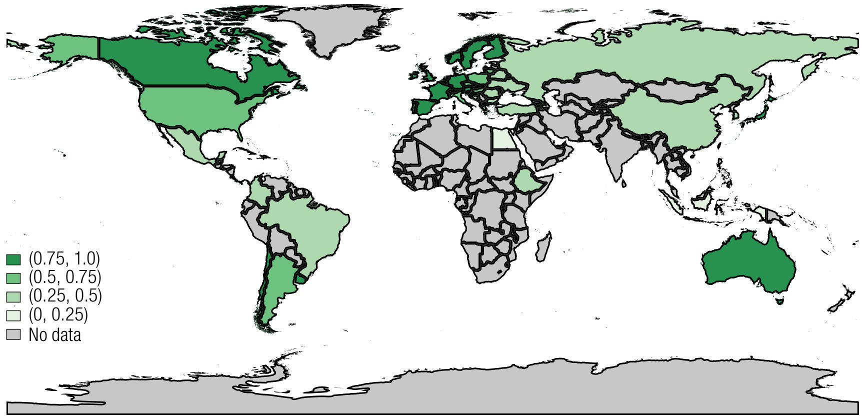
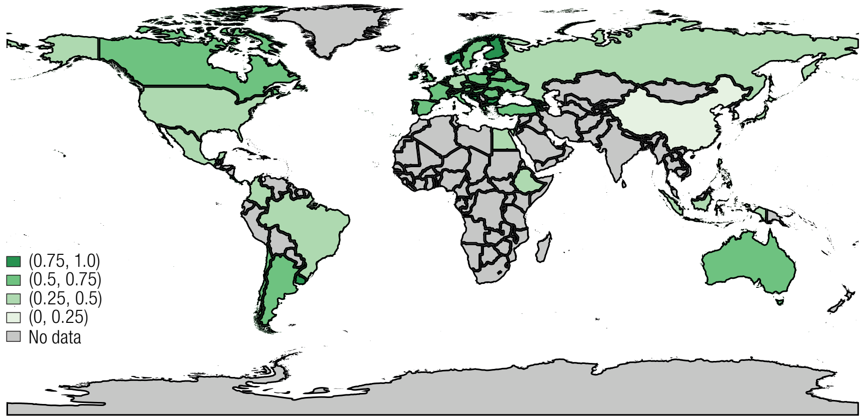


Figure 3 (concluded)

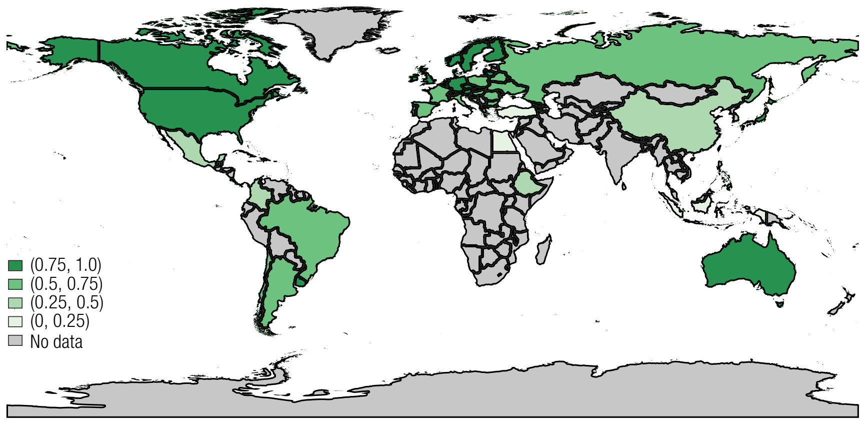
B. CIHD-EC (standard VRS model)



C. SBM CRS model



D. CIHD-EC (SBM VRS) model



Source: Prepared by the authors on the basis of World Bank, "Human Capital Project", 2018 [online] http://www.worldbank.org/en/publication/human-capital.

Note: CRS: constant returns to scale; CIHD-EC: Composite Index of Human Development and Economic Complexity; VRS: variable returns to scale; SBM CRS: slack-based measure constant returns to scale; SBM VRS: slack-based measure variable returns to scale.

V. Concluding remarks

This article contributes to the comparison of differences between standard and slack-based measure models for human development indicators. It also considers economic complexity as a new variable in the measurement of countries' efficiency at generating human development, since economic sophistication is an alternative perspective from which to analyse economic development.

We find that standard models tend to overestimate the number of efficient countries, especially in the case of developed and prosperous nations. In contrast, the slack-based measure model provides a better fit when measuring human development around the world because it yields a lower number of efficient countries and presents a better average and standard deviation than standard models.

The inverted frontier technique also provides a better understanding of the problem under analysis. Using this tie-breaking technique, we found that only Singapore was efficient at converting economic complexity into human development among the 50 countries under analysis. Furthermore, the inverted frontier technique ranks the same five countries as most efficient, which shows more synergy between the standard (IF VRS model) and slack-based model (IF SBM VRS). Using the inverted frontier, we found that North American, European and Asian countries had the world's best practices.

This study has some limitations, such as the lack of indicators for income inequality (Gini index) and the democratic environment. Although these variables are essential in Amartya Sen's approach, we did not find data available for all 50 countries. Also, we were using our econometric models to show correlation between inputs and outputs. Future studies can develop more advanced models and measure the impact of economic complexity on human development around the world. Another shortcoming of this study is that it did not evaluate efficiency over time, something that is vital for ascertaining how nations may have evolved (or not) during the last few decades.

Notwithstanding the limitations outlined above, our work reveals the need to use different data envelopment analysis (DEA) models to measure social indicators. Slack-based models can provide new rankings and identify different efficient countries, which affects how the human development approach is understood.

Lastly, our Composite Index of Human Development and Economic Complexity (CIHD-EC) sheds light on the economic complexity approach and its relationship with human development. These findings are essential for the production of new and improved social indicators and justify the need for complementary social and industrial policies to improve human capabilities. Furthermore, the CIHD-EC can provide policyholders, especially in developing economies, with straightforward aggregated information.

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Annex A1

Using data from 2010 to 2013, we measured a matrix of correlation and linear regressions between the inputs and each of the outputs. We proceeded with Cobb-Douglas functions adapted to the research problem (see expression 2).

$$\log y_{it}^{social\ variable} = \beta_0 + \beta_1 \log GFCF + \beta_2 \log EAP + \beta_3 \log GDP + \beta_4 \log EHTP + \beta_5 \log R\&D + \varepsilon \quad (2)$$

Where $y_{it}^{social\ variable}$ is one of the quality of life variables; β_0 is the intercept; $\beta_1 logGFCF$ is the logarithm of gross fixed capital formation; $\beta_2 logEAP$ is the logarithm of the economically active population; $\beta_3 logGDP$ is the logarithm of gross domestic product; $\beta_4 logEHTP$ is the logarithm of exports of high-technology products; and $\beta_5 logR\&D$ is the logarithm of R&D expenditure. A log-log regression is proposed since it is possible to interpret the parameters as elasticities (Greene, 2011). Table A1.1 presents the estimations of the correlation matrix.

Table A1.1
Matrix of correlation between input and outputs

Variable	MYS	LEB	SR	ER	EHTP/GDP	R&D-E
MYS	1					
LEB	0.3506*	1				
SR	0.4924*	0.5773*	1			
ER	0.0958	0.0342	-0.2224*	1		
EHTP/GDP	0.1241***	0.2394*	0.1587**	0.2211*	1	
R&D-E	0.1085	0.1671**	0.1212***	0.0998	0.1094	1

Source: Prepared by the authors.
Note: MYS: mean years of schooling; LEB: life expectancy at birth; SR: sanitation rate; ER: employment rate; EHTP/GDP: exports of high-technology products as a share of gross domestic product; R&D-E: research and development expenditure.
* significant at 1%; ** significant at 5%; *** significant at 10%.

Eight econometric models were estimated in order to analyse which variables best explained the variability of each social variable analysed. In addition to verifying the statistical significance of the parameters and the adjusted R^2, a comparative analysis of the Akaike information criterion (AIC) and the Bayesian information criterion (BIC) was used to select the best model (Greene, 2011). Table A1.2 summarizes the results arrived at in multiple linear regressions.

Regarding mean years of schooling, econometric model 5 was the one that yielded the highest adjusted R^2 (18.56%) and lowest BIC (-1672.5160), which shows the best fit among the models analysed. Regarding life expectancy, model 1 had the greatest explanatory power, with an adjusted R^2 (48.65) and BIC (-1994.7540) higher than those found in the other models. Regarding the sanitation rate, model 4 was the most robust, since it presented the highest adjusted R^2 (26.35%) and a BIC statistic equal to -1974.3780. All estimates can be found in table A1.2.

Table A1.2
Coefficients, p-values and R² of outputs relative to inputs

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Mean years of schooling								
EAP	0.1390*	0.1351*	0.1410*	0.1543*	0.1339*	0.1755*	0.1405*	0.1450*
GDP	0.0172	0.0089	-	0.0192***	0.0084	-	-	-
GFCF	-0.0065	-	0.0020	-	-	0.0061	0.0019	-
EHTP/GDP	0.0023	0.0023	0.0008	0.0121	-	0.0121	-	0.0001
R&D-E	0.0102***	0.0110**	0.0127**	-	0.0114**	-	0.0128*	0.0130*
Constant	-0.0221	-0.0363	-0.0712	-0.1416	-0.0269	-0.2720	-0.0675	-0.0792
Adjusted R^2	0.1875	0.1858	0.1829	0.1652	0.1856	0.1496	0.1829	0.1825
AIC	-1682.1770	-1683.7590	-1683.0560	-1680.7660	-1685.7090	-1677.0710	-1685.0500	-1684.9510
BIC	-1662.3870	-1667.2670	-1666.5640	-1667.5730	-1672.5160	-1663.8770	-1671.8570	-1671.7570
F test	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Life expectancy at birth								
EAP	0.0041	-0.0042	0.0090	0.0187	-0.0010	0.0572*	0.0145	0.0238
GDP	0.0432*	0.0253*	-	0.0376*	0.0266*	-	-	-
GFCF	-0.0140*	-	0.0073**	-	-	0.0131*	0.0085*	-
EHTP/GDP	-0.0062	-0.0061	-0.0099	0.0055	-	0.0059	-	-0.0124
R&D-E	0.0113*	0.0131*	0.0177*	-	0.0120*	-	0.0161*	0.0190*
Constant	1.7509*	1.7206	1.6278*	1.5948*	1.6963*	1.3476*	1.5812*	1.5982*
Adjusted R^2	0.4865	0.4603	0.3907	0.3627	0.4558	0.1750	0.3783	0.3712
AIC	-2014.5440	-2006.6110	-1982.3210	-1975.3470	-2006.9360	-1923.7130	-1980.2960	-1978.0240
BIC	-1994.7540	-1990.1200	-1965.8290	-1962.1540	-1993.7420	-1910.5200	-1967.1030	-1964.8310
F test	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Sanitation rate								
EAP	0.0527*	0.0532*	0.0548*	0.0564*	0.0561*	0.0674*	0.0587*	0.0749*
GDP	0.0185**	0.0196*	-	0.0213*	0.0208*	-	-	-
GFCF	0.0008	-	0.0100*	-	-	0.0115*	0.0108*	-
EHTP/GDP	-0.0055	-0.0055	-0.0071	-0.0039	-	-0.0030	-	-0.0104
R&D-E	0.0019	0.0018	0.0047***	-	0.0007	-	0.0035	0.0064*
Constant	1.5086*	1.5104*	1.4560*	1.4931*	1.4883*	1.3825*	1.4226	1.4156*
Adjusted R^2	0.2659	0.2658	0.2444	0.2635	0.2611	0.2261	0.2365	0.2000
AIC	-1984.2260	-1986.1950	-1980.4440	-1987.5710	-1986.9310	-1977.6750	-1980.3870	-1971.0460
BIC	-1964.4360	-1969.7030	-1963.9520	-1974.3780	-1973.7380	-1964.4820	-1967.1940	-1957.8530
F test	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Employment rate								
EAP	0.3395*	0.4191*	0.3288*	0.3980*	0.4022*	0.3041*	0.3058*	0.5048*
GDP	-0.0943*	0.0774*	-	0.0660*	0.0703*	-	-	-
GFCF	0.1340*	-	0.0874*	-	-	0.0845*	0.0826*	-
EHTP/GDP	0.0339	0.0323	0.0420***	0.0216	-	0.0338	-	0.0130
R&D-E	0.0048	-0.0121	-0.0091	-	-0.0059	-	-0.0022	0.0058
Constant	-1.7210*	-1.4307*	-1.4524*	-1.3144**	-1.3015**	-1.3086*	-1.2557**	-1.8058*
Adjusted R^2	0.4160	0.2712	0.3884	0.2661	0.2634	0.3849	0.3750	0.2204
AIC	-1428.1990	-1385.8940	-1420.9520	-1386.5080	-1385.7620	-1421.8280	-1418.6180	-1374.4270
BIC	-1408.4090	-1369.4020	-1404.4600	-1373.3150	-1372.5690	-1408.6350	-1405.4250	-1361.2340
F-test	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Observations				200				

Source: Prepared by the authors.

Note: EAP: economically active population; GDP: gross domestic product; GFCF: gross fixed capital formation; EHTP/GDP: exports of high-technology products as a share of gross domestic product; R&D-E: research and development expenditure; AIC: Akaike information criterion; BIC: Bayesian information criterion.
* significant at 1%; ** significant at 5%; *** significant at 10%.

The systemic nature of technological development: similarities between the neo-Schumpeterian school and Fernando Fajnzylber's approach

Andrey Hamilka Ipiranga and Pablo Felipe Bittencourt

Abstract

This article seeks to draw connections between Fernando Fajnzylber's approach and certain elements of the neo-Schumpeterian systemic approach to innovation, to show that there is longstanding discussion of many of the ideas underlying the development of both approaches in a variety of contexts. The results of the analysis revealed six similar features: the historical determinants of technological development; the similarity between the elements that sustain long-term technical progress; the relationship between technological development and the "non-economic spheres"; the relationship between technological development and the idiosyncrasies of each sociopolitical context; the proactive nature of government action; and the sector-level aspects of technical progress.

Keywords

Economic development, technological change, macroeconomics, industrial development, history, Fajnzylber, Fernando, economic analysis, industrialization, technological innovations, Latin America

JEL classification

B52, O11, O25

Authors

Andrey Hamilka Ipiranga holds a Master's degree in Economics from the Federal University of Santa Catarina. Email: andrey.ipiranga@yahoo.com.

Pablo Felipe Bittencourt is a professor in the Department of Economics and International Relations of the Federal University of Santa Catarina. Email: pablofelipe.bittencourt@gmail.com.

I. Introduction

Technological development is a prominent issue in the historical analysis of societal development and is addressed in the works of great economists who are renowned for their writing on production and distribution phenomena and how they are manifested in specific sociopolitical contexts.[1] It was Joseph Schumpeter who placed technological development at the centre of the analysis. "New combinations" of materials and forces were seen as the drivers of dynamic and structural economic system transformation, and hence of all qualitative transformations that occur over time (Schumpeter, 1934).

Technological development also takes centre stage in the contributions made by the Economic Commission for Latin America and the Caribbean (ECLAC) and associated theorists,[2] who hold that the incorporation of technology through capital accumulation —seen as stemming from a process of industrialization led by nation States— will enhance labour and capital productivity and ultimately improve social welfare (Welters, 2004). This is the basis of the importance of studying the specific ways in which technological progress is manifested and developed in each nation.

This article focuses on two approaches, one derived directly from Schumpeter's writings and the other from the ECLAC theoretical framework. To some extent, the first of these approaches is synthesized in the concept of national innovation systems, which establishes a frame of reference for analysing the modality and characteristics of (historically determined) innovation processes in each country. It emphasizes the way in which countries absorb, use and generate economically useful knowledge, taking into account the set of actors specific to each sociopolitical structure. The second approach is related to the writings of Chilean researcher Fernando Fajnzylber, who —based on ECLAC's "classical" structuralism— studied the Latin American industrialization process from a historical perspective. His analysis highlights elements that are clearly aligned with a systemic perspective (although this perspective did not yet exist formally at that time), which led to a normative agenda based on overcoming weaknesses to thus generate technical progress endogenously.

Both approaches emerged in the 1980s, a period characterized by the rise of neoliberal ideology and support for short-term recessionary macroeconomic adjustments. This formed the backdrop for the debate on long-term development policies, the focus of both Fajnzylber and the neo-Schumpeterian systemic perspective. The apparent simultaneous emergence of these two approaches shows Fajnzylber's affinity with Schumpeterian ideas in his analysis of the Latin American industrialization process. This article thus seeks to identify points of convergence between the two approaches that reveal Fajnzylber's systemic vision of innovation. To that end, sections II and III, respectively, address the positive and normative aspects of the concept of national innovation systems, while section IV provides a comparative synthesis of the points of convergence and divergence between this perspective and Fajnzylber's analysis. The fifth and final section presents the conclusions of the study.

II. The national innovation systems approach

In brief, the national innovation systems approach falls within the scope of neo-Schumpeterian economics and consists of a "means to learn about the impact of organizations and institutions on national innovative activity, understood as the result of interactive processes determined by various actors and framework conditions" (Balzat, 2002, p. 10).[3] The analytical and normative treatment of the concept is described below.

1 Examples include Smith (1776), Ricardo (1996) and Marx (1973).

2 These writings form the paradigm known in the literature as "Latin American structuralism" (Rodríguez, 2006).

3 Neo-Schumpeterian economics is concerned with the dynamic processes that generate qualitative transformation in economies, driven by innovation in its diverse and multifaceted forms and the related coevolutionary processes (Hanusch and Pyka, 2007, p. 280).

1. Origin of the concept and brief theoretical review

The concept of national innovation systems dates back to the 1980s, which saw the publication of seminal studies on technological development that diverged from conventional views. According to Sharif (2006), "The concept arose simultaneously in academia and policymaking spheres (with regard to the latter, specifically in the Organisation for Economic Co-operation and Development (OECD)), largely because its main proponents held positions in both universities and organizations that promoted economic policies.[4] At the time, the concept was a reaction to the minor role assigned to knowledge, technology and technological progress by the predominant neoclassical paradigm of the period. This "equilibrist" approach to economic growth ignores several factors that are considered determinants of technical progress or reduces them to excessively simplistic schemas. These include the formation and historical evolution of each country's specific socioeconomic structures; the role of government and institutions; the uncertainty inherent in the innovation process; interactive learning; and, mainly, the role of innovation as a driver of economic growth (Sharif, 2006; Cassiolato, de Matos and Lastres, 2014).

The systemic interpretation of technological development is the analytical cornerstone of the concept of national innovation systems. The first element of this interpretation is that technological progress, rather than being a linear process with stages determined and constructed sequentially through isolated research activities, is viewed in terms of the manner in which economic agents interact with each other in their innovation processes. From this perspective, the central factor is the manner in which interactions take place among the vast range of existing societal actors (researchers, firms, consumers and educational institutions, among others), from which new and economically useful knowledge emerges. In these processes, "formal" knowledge (through research and development (R&D), research centres and universities) is not the only determinant of technological development. Other knowledge, of a tacit and complex nature, may arise, for example, from professional and personal experiences and relationships, from organizational routines and in production lines (Balzat, 2002; Cassiolato, de Matos and Lastres, 2014).

The second element of this interpretation is that interactive processes of innovation are shaped by the institutional environment in which social actors are immersed.[5] As these interactions occur between a wide range of actors in a particular sociopolitical setting, technological development is likely to be influenced not only by interactions related directly to formal learning but also by the broad set of institutional domains present in that environment. These include the education system (which promotes creative capacity-building and formal learning); the legal system (which defines issues such as intellectual property rights and technology transfer); the financial system (which funds the development of new technologies); and the agencies that formulate economic policy (which define the development strategy and its parameters as embodied in the policies to be implemented). The national character of technological development is worth noting, since, as Lundvall (2016) notes, the geographical, cultural and linguistic features common to a nation, the actions of national governments, and the technological capacities developed over time in each country all have a positive effect on interactions between the agents present in a given system.

Three contributions to the concept of national innovation systems should be noted. The first is Christopher Freeman's "historical" approach to technological development.[6] Freeman argues that,

[4] For example, Christopher Freeman worked as a consultant at the Organisation for Economic Co-operation and Development (OECD) in the 1980s, and Bengt-Åke Lundvall served as Deputy Director of that organization's Directorate for Science, Technology and Industry (Sharif, 2006).

[5] The term "system", within the concept proposed by Nelson (2006, p. 40), consists of a group of institutional actors that jointly play the important role of influencing innovative performance.

[6] Christopher Freeman's analysis is directly influenced by List (1986), his research on German economic development in the nineteenth century and his studies on the "Japanese success" observable from the 1950s onwards (Freeman and Soete, 2008).

throughout history, the incentives that nation States deliberately promoted for technology assimilation and production, as well as technological learning and factors beyond formal R&D (such as incremental innovations in production lines and interactions between firms and the market) were fundamental for the technological and economic development of the countries analysed (Freeman and Soete, 2008; Bittencourt and Cário, 2017). The second contribution is the "narrow" approach of Richard Nelson (1993).[7] In this case, the emphasis is on the "explicit" factors that stimulate innovation in firms, represented by national science and technology policies. The elements that comprise each country's national innovation system include public research laboratories and the provision of funds for R&D in private firms and universities, for example (Nelson, 2006; Cassiolato, de Matos and Lastres, 2014; Bittencourt and Cário, 2017). The third and last contribution would be the "broad" approach, resulting from the writings of Bengt-Åke Lundvall. This approach sees the core of the national innovation system as the environment in which producers and users interact with knowledge infrastructure, through which information circulates beyond mere price and quantity.[8] This environment extends beyond the "narrow" dimension and encompasses the vast range of institutional spheres that exist (Lundvall, 2016; Bittencourt and Cário, 2017).

The national innovation system concept can thus be seen as an analytical construct for understanding the determinants of technological development. It transcends determinants directly related to the promotion of science and technology and encompasses all of the institutional spheres present in a given sociopolitical context and the relationships between the actors in that environment. According to Lundvall (2007), the concept becomes a "focusing device" for analysing the dynamics of contemporary production and innovation; in other words, a historically rooted analytical frame of reference that is capable of capturing how socioeconomic phenomena and the institutional framework present in each national context influence innovation and learning processes. These, in turn, help to explain a country's economic development.

2. Policies to promote technological development based on the systemic approach

The foregoing clearly shows the importance of the State as a promoter of policies aimed at stimulating a country's technological development.

More broadly, according to the typology proposed by Ferraz, de Paula and Kupfer (2013), from the standpoint of competency to innovate, industrial policy is closely aligned with the systemic perspective of innovation.[9] Government action involves fostering a competitive environment for firms, developing capacities (which encompasses the development of new technologies and the acquisition of formal and tacit knowledge), and stimulating interaction between firms through selective instruments targeting specific groups and general instruments affecting economic agents as a whole.

In terms of the characterization of a "technological agenda", Erber and Cassiolato (1997), authors who are aligned with the systemic perspective, define the neo-developmentalist agenda as one that

[7] The "narrow" approach is based on his work for *National Innovation Systems: A Comparative Analysis* (Nelson, 1993), which analyses the national innovation systems of 15 countries. These are classified into large industrialized high-income countries, small high-income countries with a strong natural resource matrix, and low-income newly industrialized countries.

[8] This information flow is related to the emergence of non-scientific knowledge and elements such as cooperation, loyalty, coordination, trust, power and codes of mutual respect, which are considered essential for overcoming the uncertainty inherent in the innovation process. Thus, in addition to "formal" learning (through R&D, research centres and universities), consideration is given to learning derived from the use of innovations that require long periods of use, or learning-by-using; learning through improvements implemented in production environments, or learning-by-doing; and product innovations that arise from interaction between users and producers, or learning-by-interacting (Lundvall, 2016; Bittencourt and Cário, 2017).

[9] On a preliminary basis, industrial policy is defined as the set of incentives and regulations associated with public actions, which can affect the inter- and intraindustry allocation of resources, influencing the production and capital structure, and the conduct and performance of economic agents in a given national space (Ferraz, de Paula and Kupfer, 2013, p. 313).

proposes the structural transformation of production matrices in favour of higher-tech sectors. Such agendas are government-directed, with actions that take into account the systemic nature of innovation, the set of agents involved and the strategic partnerships that exist between the state and civil society. To defend the efficacy of this agenda, these authors cited international examples and pointed out that the policies implemented by the key OECD countries (Germany, Japan, the United Kingdom and the United States), which were considered as advanced in terms of technology and manufacturing capabilities, were aligned with this neo-developmentalist agenda,[10] even though that was not the prevailing view in the 1980s and 1990s.[11]

Regarding the scope of more contemporary innovation policies, the following extract shows that this approach gained strength in the next decade, with emphasis on:

> [...] the tendency for policies to target sets of actors and their environments, in order to enhance, disseminate and increase the effectiveness of their results. The different contexts, cognitive and regulatory systems, and forms of articulation, cooperation and interactive learning among actors are recognized as fundamental for the generation, acquisition and dissemination of knowledge, particularly of the tacit kind. At the same time, instruments are being developed that encompass these collective actors, complementing the traditional emphasis on individuals (Cassiolato and Lastres, 2005, p. 39).

Under a neo-Schumpeterian approach, Suzigan and Furtado (2006) argue that industrial policy would be responsible for the following:[12]

(i) Setting targets for new technologies to become internationally competitive, ensuring that they attain the necessary levels of economies of scale and industrial efficiency;

(ii) Organizing instruments, rules and regulations (tax incentives, protecting competition, financing) in a synchronized and unambiguous manner, in line with the strategy to promote competitiveness and development;

(iii) Building and providing economic infrastructure services and developing education, science, technology and innovation systems, always in harmony with businesses, to enable them to benefit from the technological advances developed;

(iv) Coordinating actions, a very important issue given that coordination of industrial policy under this approach takes place before the fact rather than afterwards, as a reaction to market failures.[13]

The neo-Schumpeterian approach becomes more robust as an analytical framework for formulating technological development policy when the (supposed) contradiction between vertical and horizontal policies is placed at the centre of the debate over government actions aimed at improving and upgrading

[10] This shows the major influence of the historical analysis of the neo-developmentalist agenda. Examples include the following: the general reorientation of German industrial policy towards improving the national productive matrix, through stimulus measures targeting R&D investments in segments related to the “microelectronics paradigm”; the measures adopted in the United States to transfer the findings of military research to civil society (which in turn had a positive and direct influence on the development of higher-tech sectors, such as the semiconductor industry); and the work of the Japanese Ministry of Economy, Trade and Industry in formulating long-term technological and industrial policies on the basis of technology foresight systems, in which the main goal was to identify new technologies that could transform existing patterns of economic growth, such as recognition of the importance of information technology (Erber and Cassiolato, 1997, p. 56).

[11] Even during the heyday of neoliberalism, governments constantly intervened heavily to promote productive and technological development and the expansion of sectors that were strategic for the structural dynamic, even if these policies were camouflaged by strategic-military imperatives (Erber and Cassiolato, cited in Cassiolato and Lastres, 2005, p. 39).

[12] “According to this theory, industrial policy should be active and wide-ranging and should be aimed at industrial sectors or activities which foment technological change and at the economic and institutional environment as a whole, which conditions the evolution of business and industrial structures and the organization of institutions, including the establishment of a national innovation system” (Suzigan and Furtado, 2006, p. 77).

[13] As Ferraz, de Paula and Kupfer (2013) note, industrial policy from a market failure perspective would apply only when market mechanisms function suboptimally, where “market failures” (such as externalities and public goods) would be operating. Industrial policy would minimize the adverse effects of such phenomena.

production structure technology.[14] Based on this premise, Gadelha (2001) argues that government action should be both systemic and structural. The basis of this proposal is the interpretation that enterprises are immersed in a system, in other words, a locus of interactions between existing actors which also includes productive sectors undergoing structural and dynamic transformations in different ways. This implies a heterogeneous and idiosyncratic production structure, with nationally delineated characteristics. Its systemic nature is manifested in transformations of the business environment, and government actions should be structured to target sectors that "radiate" the effects of technological progress to the production structure as a whole; in other words, sectors that have a systemic impact. This gives rise to a new definition of industrial policy, which consists of targeting:

> [...] public intervention on the dynamic of industrial innovations, with the aim of promoting qualitative transformations in the production structure and the development of national economies, through systemic actions that selectively modify the competitive environments in which business strategies are formed (Gadelha, 2001, p. 161).

Thus, the formulation and implementation of policies aligned with a national innovation systems approach can promote national technological development, to the extent that they focus on the following: fostering the harmonized application of instruments to establish and regulate the competitive environment in which national enterprises operate; stimulating interaction and cooperation between social actors from the most varied institutional spheres, which in turn implies a symbiotic relationship between government and the private sector, focused on expanding technological capacity; creating innovative capacity by stimulating formal and informal learning, which in turn is directly related to building a knowledge infrastructure that is interconnected with the business environment (including science, technology and innovation systems and the education system, but also other elements, such as infrastructure, and even informal institutions based on relationships of trust between agents); and promoting dynamic sectors whose technological progress can have a ripple effect throughout production systems.

That said, what Fajnzylber has called "the truncated industrialization" of Latin America is described briefly below, in order to highlight elements that are aligned with the systemic perspective.

III. Truncated industrialization

Fernando Fajnzylber's writings are situated within the ECLAC theoretical framework, more precisely in "Latin American neo-structuralism", and they both criticize and complement the original contributions to this theoretical framework.[15] The basics of structuralist thought and its considerations and limitations with respect to technological progress are described below, followed by the positive and normative aspects developed by Fajnzylber.

1. Fundamentals of Latin American structuralism: the issue of technology at the centre of the debate

The industrialization process and its characteristics have always been a central part of the conception of Latin American structuralism. Based on the structural characteristics of the region's economies and

[14] Horizontal industrial policies seek to improve the performance of the economy as a whole, without favouring any industry specifically. In contrast, vertical industrial policies deliberately favour a specific industry. In other words, on the basis of strategic decisions, the government mobilizes part of the instruments described above, to benefit a targeted set of firms, industries or production chains (Ferraz, de Paula and Kupfer, 2013, p. 320).

[15] In short, neo-structuralism can be understood as the most recent phase in the evolution of Latin American structuralism, which originated in the 1990s and "regains the development analysis and policy agenda, by adapting it to the new era of openness and globalization" (Bielschowsky, 2016, p. 35).

the implications thereof, industrialization was seen as "the principal means at the disposal of those countries to obtain a share of the benefits of technical progress and progressively raise the standard of living of the masses" (Prebisch, 1950, p. 2).

From this standpoint, industrialization can be approached in two ways: as a historically determined process leading to the rise and leadership of the industrial sector in Latin American nations, which unfolded throughout the twentieth century and was known as the "import substitution process"; and as a model (import-substitution), in other words, an abstraction from the characteristics of materiality, which seeks to capture the essence and development rationale of the process, where improvement in the population's standard of living is based on productivity gains derived from an increase in the capital-labour endowment (through the adoption and efficient use of indirect production methods) and capital density (with accumulation driven by technical progress) (Fonseca, 2003; Rodríguez, 2006; Prebisch, 1950).[16] In short, the key feature of the import substitution model is its dynamic, characterized by a contradiction between the increase in substitutive production and the limits of import capacity. The continuity of substitutive production is constrained by external bottlenecks and the available technology (which is related to the structural characteristics of peripheral countries) (Tavares, 2011).[17]

The problem of technology in the import-substitution model stems from its limitations, which are manifested in the historical development of Latin American economies. Unlike the developed countries, which developed and then continued to dominate modern production techniques, peripheral countries were forced to use production techniques in their production systems that they had not developed or even adopted in the initial stages of development, when they were less distant from the technological frontier.[18] Moreover, the increasing complexity of production made it harder to level the production and technology playing field by scaling up production in key capital accumulation sectors, increasing the need for capital investment for those sectors to continue operating. In fact, they were considered as key sectors for both capital accumulation and for the generation and dissemination of technical progress.

In time, it became increasingly clear that merely introducing the most capital-intensive sectors into the production mix —as occurred in Brazil between 1956 and 1961 through the *"Plano de Metas"* [Targets Plan], later reinforced to some extent by the Second National Development Plan (II PND)— could not generate and propagate technical progress as hoped, and that major obstacles would remain. This was the main focus of Fajnzylber's vision, as described below.

2. Latin America's "truncated" industrialization: Schumpeterian elements in Fajnzylber's analysis

The economic development that Latin America enjoyed between the 1940s and 1970s collapsed for all intents and purposes in the wake of the Bretton Woods system crisis and the oil crises of the last quarter of the twentieth century. The global economic crisis worsened in the 1980s; its effects in Latin America were expressed through a sharp contraction in regional economic activity. Fernando Fajnzylber, Chilean economist and ECLAC researcher, contributed to the debate on the crisis through the diagnostic lens

[16] "Import substitution" can be defined as a domestic development process steered by external constraints and manifested mainly through the expansion and diversification of industrial production capacity (Tavares, 2011, p. 72).

[17] Given an initial external bottleneck situation, substitutive production starts with final consumption goods, given their lower technological content. From this, a derived demand for intermediate and capital goods is created, given the positive effect on the income multiplier and the fact that only part of the production value-added is fully internalized, considering the results of the initial stage.

[18] Viewed from a historical perspective, the development of these countries shows that the creation and mastery of modern techniques facilitated an increase in capital density and its standardization by the existing sectors. This was due to the mutual determination of innovations and incomes and also to the substitution of labour by capital, which was made possible by labour absorption in the newly created production processes. This reveals the harmonious relationship between accumulation, technical progress, wages and employment in the countries in which modern production techniques were developed (Rodríguez, 2006).

of a historical analysis of Latin American industrialization that focused on the distorted and "truncated" nature of the industrialization process, which departed from the neoliberal argument (and its claim that the economic crisis in the region had been caused by the fiscal irresponsibility of national governments).

Fajnzylber's analysis begins by noting the similarities and differences between the industrialization process in Latin America and in developed countries, as well as with respect to the productive restructuring that took place in those countries and in the "newly industrialized countries" of Asia during the twentieth century.

In short, major industrial powers and countries that experienced rapid and substantial industrial growth from the mid-twentieth century onwards (especially Japan) took steps to reorganize their production structures in response to the exhaustion of the prevailing industrial matrix, which was dominated by the capital goods and chemical sectors and whose consumption patterns centred around durable goods (including, in particular, the automotive sector). The reorganization was targeted towards new and emerging technologies, such as microelectronics, and, according to the neo-Schumpeterian perspective, it represented a shift from the "era of oil, automobiles and mass production" to the "era of information and telecommunications" (observable from the 1970s onwards) (Pérez, 2009).[19]

Broadly speaking, Fajnzylber's conclusion is that Latin American industrialization, framed by the import-substitution model, lacked creativity (a concept that will be discussed below), in contrast to the industrialization of the countries that served as comparators for his analysis.

It should be noted that Latin American industrialization reproduced the sectoral patterns of the developed countries; and, although the growth of manufacturing gross domestic product (GDP) and its share in the region's total GDP increased in most countries between 1940 and 1980 (both variables were drastically reduced thereafter), this replication was unsuited to the reality of these countries, both in "economic" terms (the production domain) and in "non-economic" terms (the social, political and cultural spheres). Its objective, rather than understanding the processes with a view to improving them, was to reproduce what already existed. Despite the industrial growth achieved, Fajnzylber argues that the socioeconomic structures of Latin American countries continued to be characterized above all by an abundance of labour and the predominance of natural-resource-intensive sectors. In contrast, external engagement through manufactured products was limited, since exports of industrialized products failed to keep pace with industrial GDP growth (Fajnzylber, 1983; Paiva, 2006).

In this context, Fajnzylber argues that industrialization should take into account each country's specific characteristics, and that results should be evaluated according to the "degree of functionality in responding to majority social needs, and creativity in developing the varied range of regional potentialities" (Fajnzylber, 1983, p. 163). On this basis, the author lists several unique features of the Latin American industrialization process that contrast its results with those of developed countries and newly industrialized countries (mainly observable between the 1950s and 1970s). These features are detailed below:

(i) The prevalence of transnational firms in the dynamic sectors of the economy, rather than the national public and private business sector; this makes the region's industrial future precarious, with no rules to guarantee the strengthening of the national technological innovation process;

(ii) The predominance of "frivolous protectionism", which can be defined as protecting both national and transnational firms, with few incentives for technological development and international competitiveness, and prioritizing final goods sectors over intermediate and capital goods sectors;[20]

[19] The emergence of a new technological pattern is known in the neo-Schumpeterian literature as a "technological revolution". It consists of a set of interrelated radical innovations that form a large constellation of interdependent technologies (Pérez, 2009, p. 8).

[20] The antithesis of this concept would be "protectionism for learning", which characterized Japanese industrial development in the post-war period (Fajnzylber, 1983).

(iii) The backwardness of the capital goods sector, considered to be the "bearer of technical progress" (given its positive effects on labour productivity and wages, and also on the manufacture and productivity of capital goods themselves); this is reflected in this sector's negligible participation in the region's manufacturing production. It should also be noted that the more complex capital goods were produced by transnational firms, while national firms were oriented towards less complex capital goods;

(iv) The external fragility of the region and of the industrial sector, which accounted for most of the structural deficit in Latin America's trade balance and revealed the "truncated" nature of its industrialization pattern. This reflects the weak technological development observed in those countries, owing to their inability to assimilate and create innovative capacities; and

(v) External engagement mainly through natural resources, which also contributed to the region's trade deficit, since the modernization of agriculture occurred mainly in the commodity-export sectors (the effects of which included the deterioration of relative prices), compounded by an increase in demand for food products driven by greater urbanization resulting from industrialization.

The specific features listed by Fajnzylber lead him to conclude that the Latin American industrialization pattern arose from the fact that the region's countries had been unable to build a production matrix that could promote technological development internally. This characterized the "truncated industrialization" observed between the 1930s and 1980s (an industrialization pattern that proved unable to overcome the contradiction in the import-substitution model with respect to technology). The factors that prevented the region's countries from assimilating the technologies of the major centres, given each one's internal shortcomings and potentialities (in other words their individual and specific characteristics), ultimately rendered them unable to form an "endogenous technology-energizing nucleus", which would foster the generation and assimilation of technical progress suited to the specificities of each nation.[21] This "endogenous technology-energizing nucleus" can be understood as an organized production structure in which creativity and learning provide mutual feedback, driving technological development in strategic sectors that propagates throughout the production structure through continuous waves of innovation (Paiva, 2006; Rodríguez, 2006). To form this endogenous nucleus, Fajnzylber proposes a "new industrialization" for Latin America, based on some of the fundamental categories of his analysis.

Fajnzylber argued that productive restructuring had to be "efficient" if it was to foster the long-term, sustained economic development of Latin America by overcoming each country's economic and social weaknesses. Fajnzylber's concept of "efficiency" was related to industrial development combining growth and creativity. Since "growth" is easy to quantify, his views on the concept of "creativity" need to be explored further.

Embedded in the concept of efficiency, creativity would basically entail overcoming social weaknesses and constructing a new technological pattern in the major centres, transcending the "strictly economic" domain to manifest in the political, cultural, artistic, scientific and productive spheres, which would ultimately drive the development of individual and collective capacities specific to each sociopolitical structure, thus evidencing the endogenous nature of creativity (Fajnzylber, 1983; Paiva, 2006). The link between creativity and industrial development can be examined in Fajnzylber's words:

> Creativity can therefore be associated with the establishment of social goals; with the deepening of understanding of man and social relations, as well as of the natural environment and the processes by which it is transformed. However, in the limited scope of these reflections on industrialization, attention is focused on discussion of some of the economic-institutional requirements of creativity and their link with the growth process (Fajnzylber, 1983, pp. 348-349).

[21] For Fajnzylber, the concept of technical progress consists in the accumulation of knowledge about a set of goods and how to produce them, and on existing production techniques.

Creativity is therefore viewed as the attitude that underlies learning and makes it effective, conditioned by the various actors that constitute the spheres of socio-materiality, taking into account each country's "economic" and "non-economic" idiosyncrasies so that individual and collective capacities can be developed (Rodríguez, 2006).[22] Growth alone would not be sufficient to stimulate creativity. The other factors needed for the development of domestic creativity include the organization of the relationship between economic agents and the degree of decentralization of economic life, which fosters greater autonomy for creativity to be unleashed through interaction between economic agents, both among those responsible for technological development and among those situated in the domain of production (Fajnzylber, 1983; Paiva, 2006).

It follows that Fajnzylber's "new industrialization" should promote creativity, which in turn would allow for both the domestic generation and external incorporation of modern production techniques, in addition to promoting external engagement through greater "real" competitiveness.[23] The main objective of development is to solve domestic shortcomings and promote each nation's potential (Paiva, 2006). Although Fajnzylber does not define a complete strategy for productive restructuring, he suggests prioritizing four sectors to form a productive and harmonized industrial matrix: the automotive industry, the capital goods sector, agriculture and the energy sector.

The government would play a strategic role in the new industrialization by setting targets based on social demands. This could include defining investment programmes to be implemented in specific sectors, along with the required conditions of "macroeconomic equilibrium". In addition, the social bases for sustaining this agenda would stem from the "new alliance", composed of the various agents of materiality and their convergence to enhance national value (Paiva, 2006; Rodríguez, 2006). In short:

> [...] according to Fajnzylber, it is the constitution of an "endogenous technology-energizing nucleus" that will determine the creation and harmonization of an industrial and productive matrix capable of generating technical progress, both by adapting technology acquired internationally and through innovation (Paiva, 2006, p. 195). Through this nucleus, the generation, adaptation and incorporation of technical progress is transformed into productivity; and it ultimately leads to enhanced competitiveness in international markets (Paiva, 2006, p. 195).

IV. Preliminary synthesis: convergent and divergent aspects between national innovation systems and Fajnzylber's contributions

The foregoing shows that there are similarities between Fajnzylber's analysis and the national innovation systems approach, in terms of both analytical categories and normative agendas. These similarities are elaborated further in this section.

Nonetheless, it should first be noted that analytical affinities are usually explained by their (at least partial) adherence to the same frame of reference. In this case, the reference is Joseph Schumpeter. Torres Olivos (2006) highlights that author's influence on the formation of Fajnzylber's thinking, emphasizing the role of the firm as an innovative economic agent. This influence was present throughout his writings beginning in the 1970s.

[22] Fajnzylber defines learning as the acquisition of new knowledge related to production techniques, arising from the activity of production itself and through R&D (Rodríguez, 2006).

[23] In other words, competitiveness strengthening through the generation and dissemination of technical progress and the consequent productivity increase. Such strengthening would be achieved through structural transformations in the various existing institutional domains, consciously employed through industrial policies, which would aim to form a solid basis for international engagement (Suzigan and Fernandes, 2004).

This helps to explain part of the process of analytically refining ECLAC's contributions in the fields of productive and technological development and international integration in the 1990s. The approximation of neo-Schumpeterian authors to Fajnzylber resulted in what Bielschowsky (2009) called a merger of neo-Schumpeterian and structuralist thought. In his words:

> The merger of the Schumpeterian and structuralist approaches is not surprising, given the priority both assign to the analysis of historical trends in the productive domain. The neo-Schumpeterian accent on knowledge formation and accumulation through the enterprise learning process, the effect of past decisions on the present (path-dependency), and changes in techno-economic paradigms enhance the historical-structural approach used by ECLAC in its attempt to understand changes in productive structures under conditions of underdevelopment and structural heterogeneity (Bielschowsky, 2009, p. 181).

With respect to Fajnzylber's diagnostic assessment of the weaknesses of Latin American industrialization, it is possible to view the specifics of this process from a neo-Schumpeterian perspective as described in the previous section. Thus, through the lens of national innovation systems, factors i and ii can be analysed as the inability to form an institutional framework that would enable the generation of economically useful knowledge, either by assimilating techniques originating in the central countries or by developing domestic innovation capabilities through learning-oriented activities. This would include the adoption of laws guaranteeing the transfer and appropriation by national enterprises of the technologies deployed by transnational firms, and the creation of a science, technology and innovation system aligned with production sectors to strengthen external competitiveness.

Factors iii, iv and v are related to the neo-Schumpeterian literature through the concept of "Schumpeterian efficiency" (Martins, 2008), a concept grounded in the prescription of a format for productive specialization and international engagement based on opportunity and the appropriable and cumulative nature of technology. Thus, international trade patterns should be defined on the basis of "innovative opportunities" (the possibility of improving and expanding the technological apparatus) in a technological paradigm; on expectations of extraordinary returns from investments in possible technological opportunities; and on the belief that existing patterns of productive specialization and trade mediate technological change through positive or negative externalities, and also, to a greater or lesser extent, mediate opportunities for the generation of technological learning. On this basis, the backwardness of the capital goods sector, which is considered strategic for the region's industrialization, and the repercussions of this backwardness on the fragile international integration of Latin American countries show that the industrialization pattern applied in the region was far from efficient in Schumpeterian terms.

In their analytical and normative aspects, both Fajnzylber's analysis and the systemic perspective actually emphasize the value of the presence of a broad set of social actors in the most varied institutional spheres of each specific sociopolitical context, together with their interactions, as key factors for technological progress. Moreover, this understanding serves as a basis for formulating specific policies to promote technological development. Points of convergence between the two perspectives include the following:

(i) *Historical determinants of technological development*. Both in Fajnzylber's analytical perspective and in that of national innovation systems, technological development is determined by the particular way in which the production and institutional structures of the different countries were articulated over time. Fajnzylber highlights a major difference between Latin American and central countries, noting that the way the industrialization process unfolded among the former restricted technical progress. After nearly half a century of substitutive production, not even the internalization of technology-intensive sectors (sectors in which leading companies were replaced, particularly after the last quarter of the twentieth century) was sufficient to promote a form of production that would generate continuous innovation. In other words, the way technical progress was promoted basically reproduced the contradictions existing in the import-substitution model. The contrast with developed countries is clear: throughout their history, they adopted regulatory agendas aimed at strengthening innovation capacity and policies aligned with the systemic approach to innovation. Their approaches were aimed at shifting production structures towards more technologically advanced sectors (in other words, facilitating participation in the technological revolution that has been under way since the 1970s). From the national innovation systems standpoint, the shortcomings of the production structure in implementing "sophisticated" innovation processes are analysed in Viotti (2002), for example. In analytical terms, these shortcomings stem from an inability to assimilate scientific and non-scientific knowledge by strengthening the interactions between the agents involved in production and innovation processes. This is a structural characteristic, stemming from the inability of the production structure to participate in technological revolutions.

(ii) *Elements that sustain technological development and technical progress over the long term*. For Fajnzylber, the generation and dissemination of technical progress goes beyond mere quantitative growth and involves stimulating creativity. Technological development would therefore involve the stimulation of individual and collective capacities related to each specific sociopolitical context, taking into account its shortcomings and potentialities. This, in turn, would enable learning or, in other words, the acquisition of knowledge of production techniques. In the national innovation systems approach, learning, both formal and informal, is seen as the key variable for promoting technological development. The creation of scientific and non-scientific knowledge streams, from processes such as learning by searching, learning by doing, learning by using and learning by interaction, which in turn are closely entwined with the interrelationships between actors in the social fabric, makes technological development not only possible but also effective.

(iii) *The "non-economic spheres" and technological development*. Fajnzylber emphasizes that technological development transcends the "strictly economic" domain. He argues that the cultural, artistic, political, scientific and productive spheres, as well as the interfaces between them, are factors that affect the stimulation of creativity, along with others such as the degree to which economic life is decentralized and the nature of the relationship between agents. The analysis of national innovation systems also encompasses a diverse set of non-economic elements capable of explaining technological development. This is revealed in specific studies on various countries, including Christensen and others (2008), who highlight the significance of the trust relationship between producers and users for the rapid dissemination of innovation in the Danish national innovation system; or Kim (2005), who considers the particular characteristics of the mindset of a country's workers.

(iv) *Technological development and the idiosyncrasies of each sociopolitical context*. Fajnzylber's analysis departs from the domestic shortcomings and potentialities of Latin American countries and the region as a whole, which are evident in specific aspects of the Latin American industrialization process, considering the whole set of specific actors and their characteristics. Fajnzylber posits that creativity and, ultimately, technological development, are directly related to each country's idiosyncrasies, which reveals the endogenous nature of the scope of his analysis of the determinants of technical progress. In addition, authors aligned with the national innovation systems perspective stress that some aspects defined at the "national" level have a positive influence on interactions between agents, and hence on technological development. These include a nation's shared geographical, cultural and linguistic features, and the development of technological capacities that are accumulated historically.

(v) *The proactive nature of government action*. For Fajnzylber, the role of the State is defined mainly in his "new industrialization" proposal. According to this view, government action entails construction of the national development strategy as a whole, for example by promoting investments in sectors considered strategic and maintaining “macroeconomic equilibrium” to implement that strategy. The “new alliance” would constitute the basis for sustaining that normative proposal, in which the defined strategy would be pursued on the basis of a connection between the agents of socio-materiality, such as business groups, government bureaucracy and the working class. Government action in the national innovation systems approach would consist, in short, of constructing a propitious habitat for interaction between agents (in other words, an environment conducive to learning) and for the creation of innovative capacities, both in terms of the assimilation and generation of new technologies and in terms of learning itself. In national innovation systems with numerous shortcomings, such as those of Latin America, government action would consequently need to be more prominent. Mazzucato (2014) discusses proactive action in the neo-Schumpeterian perspective. Based on the historical experience of technologically developed countries, she posits that it is the symbiotic relationship between the government and the private production sector that drives capitalism and development. This contradicts the commonly disseminated dichotomous view of the relationship between these two societal actors.

(vi) *Preferential treatment of a set of products and sectors, according to their technical-progress absorption and generation properties*. In this sense, Fajnzylber aligns with the Schumpeterian notion of efficiency, both in pointing out that external engagement continued to be based excessively on natural resource-intensive products, that is, products with little capacity to generate long-term productivity gains; and also in identifying a group of sectors that could constitute a productive and harmonized industrial matrix, which, by having relatively better conditions for inducing creative production processes, would receive government incentives. From the systemic standpoint, such conditions would include the possibility of appropriating the benefits of innovation, the cumulative nature of the technical knowledge base, and opportunities for improving and propagating existing technologies. They would also promote Schumpeterian efficiency. It is worth noting that, in terms of the policy agenda, the promotion of policies aimed at strengthening innovation capacity would be targeted at sectors that have potential systemic impact, in keeping with Schumpeterian efficiency.

Several observations regarding the similarity between Fajnzylber’s analysis and the national innovation systems perspective have been presented above. Although these approaches have different subjects of study (Fajnzylber deals with development in Latin American countries, while the systemic perspective considers technologically developed countries), the article has revealed clear similarities between the two. The importance of technological progress in historically constructed processes of economic development, and the fact that both arguments invoke the influence of non-economic factors and the centrality of the role of the state are clearly points of convergence. Affinities were also noted between Fajnzylber’s “creativity” and neo-Schumpeterian “learning”, with respect to their causes and specifics, especially the influence of non-economic factors. These, in turn, can be summarized as the institutional architectures constructed and delineated by the idiosyncrasies of each system (especially in terms of the “national” character of these institutional structures). Lastly, the “endogenous technology-energizing nucleus” synthesizes the existing similarities, by advocating symbiotic interaction between the production structure and the institutional environment, as does the national innovation systems perspective. These considerations are summarized in table 1.

Table 1
Synthesis of the points of convergence between the Fajnzylber and national innovation system approaches

	Analytical and normative aspects in Fajnzylber's thinking	Analytical and normative aspects in national innovation systems
Historical determinants of technological development	The historical diagnosis of the Latin American industrialization process evidences an inability to assimilate and generate technical progress, owing to the characteristics acquired by the industrial structure as a result of the import substitution process. Hence the need to promote creativity.	The cumulative nature of the knowledge acquired by the national innovation system is a decisive element in understanding its future potential. Development is path-dependent. Hence the desirability of strengthening interactions between agents over time, which can be seen in the agendas for promoting technological development in the most developed national innovation systems.
Elements underpinning technological development and technical progress in the long run	Creativity: related to the development of individual and collective capacities, which are reflected in a degree of mastery of the technologies deployed, so that the implementation of significant modifications is endogenously determined.	Capacity to innovate: related to the development of individual and collective capacities, which are reflected in a degree of mastery of the technologies deployed, so that the implementation of significant modifications is endogenously determined. The creation of scientific and non-scientific knowledge flows, derived from "formal" and "informal" learning processes, is decisive for developing the capacity to innovate.
Relationship between technological development and the "non-economic spheres"	Creativity is manifested in the cultural, political, artistic, scientific and production domains.	Set of institutions that directly or indirectly affect technological development and are closely related to knowledge creation (previous point).
Technological development and idiosyncrasies of each sociopolitical context	Endogenous aspect: based on domestic shortcomings for the development of the potential of each nation.	National aspect: a nation's shared geographical, cultural and linguistic features, and the action of nation States have a direct impact on technological development. The latter is necessary because systems have weaknesses.
Proactive nature of government action	Promote investment programmes in sectors considered strategic, preserve macroeconomic equilibrium. The theme of the "new alliance" is highlighted.	Provide a propitious environment for interaction between agents and the creation of innovative capacities. Instruments, standards and regulations are used in a coordinated manner.
Preferential treatment of a set of products and sectors, according to their technical-progress absorption and generation properties	Government action in the restructuring of key sectors (defined by their capacity to radiate technical progress), to constitute a productive and articulated industrial matrix: the automotive, capital goods, agriculture and energy sectors.	Government action aimed at promoting Schumpeterian efficiency, those sectors with the potential to "radiate" their technological progress throughout the production structure.

Source: Prepared by the authors.

V. Final thoughts

This article set out to conduct a theoretical review and comparative analysis of Fernando Fajnzylber's writings on the Latin American economic development process, and of the neo-Schumpeterian analytical perspective represented by the concept of national innovation systems. Without creating a theoretical summary, the study was confined to highlighting similarities in the scopes of these analyses, while suggesting points of convergence and divergence which, in turn, reveal the systemic vision of innovation in Fajnzylber's contributions.

The innovation systems approach considers the development of innovative capacities as cumulative and historically constructed, determined by the broad set of actors existing in socio-materiality. It thus seeks to understand the influence of these actors and their interactions in the development of the capacities in question. Fajnzylber's analysis focuses on the specifics of the industrialization process, expressed through the concept of "truncated industrialization". Identification of the weaknesses of this process brought the neo-Schumpeterian authors closer to Fajnzylber and, consequently, to the systemic approach, although the term "national innovation systems" would only be coined at the end of the 1980s.

The article has shown this influence to have been decisive in defining the meaning of Fajnzylber's normative "new industrialization" agenda, especially the emphasis on "creativity" (limited in Latin America) as a key variable for assimilating and generating technical progress. The alignment between the two approaches was also seen by relating the causes of weakness to the historical aspects of the region's economic and institutional formation. It can also be seen that the new industrialization agenda aligns implicitly with the Schumpeterian concept of efficiency, by promoting production activities that offer a high degree of technological opportunity. Lastly, reflections on the role of government in promoting productive and technological development also suggest an alignment between the two approaches.

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Firm-level innovation, government policies and the middle-income trap: insights from five Latin American economies

Eva Paus and Michael Robinson

Abstract

Latin American economies need higher productivity to escape from the middle-income trap. This article analyses the drivers of innovation at the firm level, which is a critical driver of productivity growth. The article estimates a two-step-model where firm characteristics affect firm engagement with innovation inputs, and such engagement then generates innovation outputs. We use World Bank Enterprise Survey data to analyse this two-stage process for a pooled panel of matched firms in 2006, 2010 and 2017 for five Latin American economies (Argentina, Colombia, Ecuador, Peru and Uruguay). The findings indicate that here is no missing link per se between innovation inputs and outputs in Latin American firms to explain innovation underperformance at the aggregate level. However, a comparison with China's firms suggests possible differences in firms' innovation behaviour. The results support the use of horizontal and vertical government policies to advance firm-level innovation.

Keywords

Economic development, productivity, industrial enterprises, technological innovations, research and development, middle-income countries, comparative analysis, Latin America, China

JEL classification

O12, O31, O54, O57

Authors

Eva Paus is Professor of Economics at the Ford Foundation at Mount Holyoke College, United States. Email: epaus@mtholyoke.edu.

Michael Robinson is Professor of Economics at Mount Holyoke College, United States. Email: mirobins@mtholyoke.edu.

I. Introduction

With the end of the commodity price boom, economic growth in most Latin American countries declined considerably in the 2010s. For the region as a whole, growth in Gross Domestic Product (GDP) went from 6.3% in 2010, to 2.9% in 2013 and to 0.9% in 2018 (ECLAC, 2019 and 2010). The economic slowdown, dramatically exacerbated by the crisis induced by the coronavirus disease (COVID-19) in 2020, has highlighted the drastic ongoing structural challenges in the region. One critical challenge is persistently low productivity growth.

When productivity growth stays too low in relative terms, middle-income economies in Latin America and elsewhere become stuck in a middle-income trap with low economic growth (Paus, 2019, 2014 and 2012; Foxley, 2012; Ohno, 2009; Gill and Kharas, 2007). Middle-income economies, especially higher middle-income economies, can no longer compete internationally in standardized, labour-intensive goods, as their wages are too high compared with low-income economies. In order to advance, they have to be able to compete internationally based on productivity. In other words, the production structure has to shift to higher value added activities on an increasingly broader scale.

While increased productivity growth is the way out of the middle-income trap, innovation is the key to achieving it. At the aggregate level, Latin American economies lag behind other middle-income economies in important aspects of innovation, notwithstanding differences at country and sectoral levels (ECLAC, 2016; OECD, 2016). Advancing broad-based innovation is a complex, multifaceted and challenging undertaking aimed at increasing the innovation capabilities of domestic firms (Cimoli and others, 2009; Lundvall, 1992; Fagerberg, 1988; Nelson and Winter, 1982).

In this article, we study innovation at the firm level to shed light on innovation at the aggregate level. We test a two-step model of firm-level innovation based on Crepon, Duguet and Mairesse (1998). In a first step, we examine how firms' characteristics affect their engagement with innovation inputs. In a second step, we investigate how engagement with innovation inputs impacts the likelihood of a firm producing innovation outputs (in the form of new products or processes). We analyse this two-step process using a matched firm-level panel for Argentina, Colombia, Ecuador, Peru and Uruguay: the five Latin American countries for which the World Bank Enterprise Survey provides data for 2006, 2010 and 2017.[1]

This inquiry into firm-level innovation behaviour in Latin America is broader in scope and uses more recent data than existing studies, which tend to focus on the country level and use national innovation surveys from the early to mid-2000s (Chudnovsky, López and Pupato, 2006; Cimoli, Primi and Rovira, 2011; Crespi and Zuñiga, 2012; De Negri and Laplane, 2009). We use a random-effects model (controlling for country and year specifics) and a fixed-effects model, which controls for firm-specific characteristics. The pooled data analysis allows us to make broader statements about the links between the characteristics and innovation outcomes of innovating firms in Latin America, without ignoring the importance of country, year and firm contexts.

Most studies focus on research and development (R&D) spending as the main, if not only, channel for technological innovation. However, the heterogeneity of production capabilities among Latin American firms suggests that, for many, non-R&D elements of innovation remain important. We therefore consider two other possible channels for innovation inputs in addition to R&D expenditures: the use of licenses and investment in capital goods.

We compare the results for the pooled Latin American data with estimates of the model for China, the middle-income economy which has achieved very high levels of productivity growth (and economic

[1] The World Bank also has Enterprise Surveys with innovation-related questions for the Plurinational State of Bolivia, Chile, Mexico and Paraguay, but only for the years 2006 and 2010. There is no innovation-related World Bank Enterprise Survey for Brazil.

growth) for the past three decades. We also explore the impact of key aspects of the broader innovation ecosystem on firm engagement with innovation.

Overall, the results from this study suggest that there is no missing link per se between innovation inputs and outputs to explain the underperformance at the aggregate level. Exporting, internationally recognized quality certifications and virtual connectivity are firm characteristics that increase the likelihood of firm engagement with innovation inputs. Engagement with any of the innovation channels therefore raises the likelihood of a firm introducing a new product or process, although spending on R&D and investing in capital goods have a considerably stronger impact than holding a foreign-owned license.

Nonetheless, the findings suggest two possible links between micro and macro innovation performance. The first link is R&D spending by large firms. Controlling for other firm characteristics, engagement with innovation inputs increases in direct proportion with firm size. Most firms in Latin America are micro-sized, and few of them engage in innovation inputs. Large firms account for the bulk of spending on R&D, but their spending per firm is low compared with large firms in China. The second possible link is the translation of innovation inputs into innovation outputs. The comparison with model estimates for China suggests that the degree of translation is considerably lower for Latin American firms. We consider these results suggestive only, since different survey years and formulation of questions do not allow for a direct statistical comparison.

Under the market-led strategies of the past decades, Latin American governments welcomed foreign direct investment (FDI) with open arms in the expectation of substantial economic benefits. In the five economies analysed here, the share of foreign-owned firms that engage with innovation inputs and generate innovation outputs is significantly higher than the share of domestic firms. The estimates show that once we control for firm characteristics in the model, foreign ownership has no additional positive impact.

Our results support the case for active government policies to advance firm-level innovation. Based on the variables included in the analysis, the results highlight the efficacy of direct support for engagement with innovation inputs and possibilities for collaboration with other innovative institutions. They also suggest that policy measures with broader goals can have a positive indirect impact on firm innovation by facilitating: access to information and communication technology, the acquisition of internationally recognized quality certifications and the entry into foreign markets.

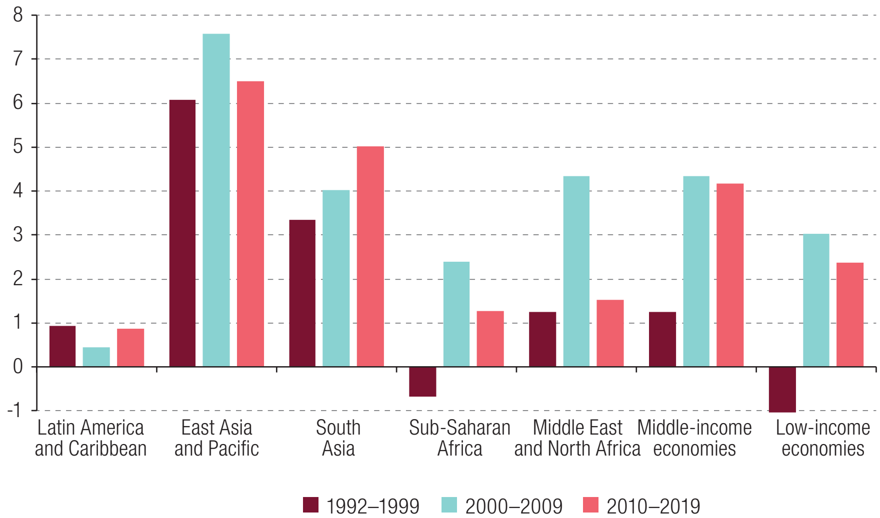
This article is structured as follows: following this introduction, section II provides a brief background on productivity and innovation performance in Latin America at the aggregate level, highlighting the challenges in the region. Section III presents the model and data sources for analysis of innovation characteristics and outcomes at the firm level. Section IV discusses the estimation results. The final section concludes with policy implications of the findings.

II. The middle-income trap, productivity growth and macro indicators of innovation

Moving from factor-driven to innovation-driven growth has always been the challenge for middle-income countries. However, it is only since Gill and Kharas (2007) first introduced the notion of the middle-income trap that economists and policymakers have become concerned with middle-income countries being trapped at their income level. That is a danger when producers can no longer compete internationally in standardized, labour-intensive goods because wages are relatively too high, but they are unable to compete in higher value added activities on a broad enough scale because productivity is relatively too low (Felipe, 2012; Foxley, 2012; Gill and Kharas, 2007; Lee, 2013; Ohno, 2009; Paus, 2019, 2014 and 2012).

Notwithstanding exceptions at the country and sectoral levels, Latin America's productivity performance at the aggregate level suggests that the region's countries are in a middle-income trap. Labour productivity in Latin America grew at an average annual rate of 0.93% during the 1990s, 0.46% during the 2000s and 0.88% between 2000 and 2019. These rates do not compare well with those of other developing economy regions (see figure 1).

Figure 1
Growth rate of GDP per worker employed, by developing country area, 1992–2019
(Average annual growth rate, based on constant 2017 purchasing power parity (PPP))



Source: Prepared by the authors, on the basis of World Bank, World Development Indicators [online database] https://databank.worldbank.org/source/world-development-indicators.

The Asian Development Bank (2017) finds productivity growth to be the differentiating factor between middle-income economies that graduated to high income levels and those that did not. To achieve higher and sustained productivity growth, Latin American producers need to innovate more, both by moving up the value chain within existing production areas and by creating new areas of competitive advantage.

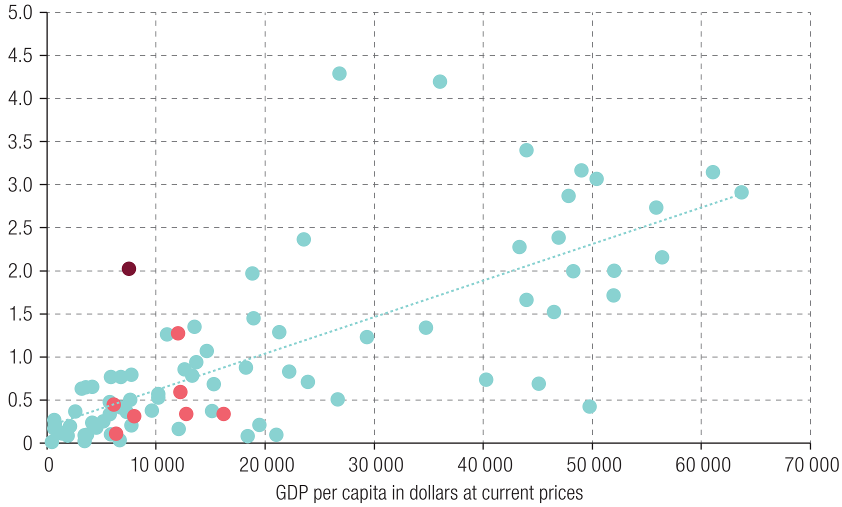
The innovation process is complex, and key factors at the micro, meso and macro levels have to co-evolve and complement each other to enable broad-based movement forwards. Aggregate innovation indices aim to capture this complexity by including a larger number of variables. The Global Innovation Index 2018, for example, includes 80 indicators on the different pillars underlying its two sub-indices of innovation inputs and innovation outputs. Latin American economies ranked in the bottom half of the 126 countries included, with the exception of Chile, Costa Rica, Mexico and Uruguay. China, in contrast, ranked seventeenth (Dutta, Lauvin and Wunsch-Vincent, 2018).

An examination of some of the common indicators of technological capabilities and innovation potential underscores Latin America's underperformance in innovation. The region's R&D intensity (R&D spending as a share of GDP) is lower than expected given countries' GDP per capita (see figure 2, in which the red dots indicate Latin American countries). The one exception is Brazil, which is just above the trend line.[2] China's R&D intensity (represented by a dark red dot), in contrast, was more than three times higher than predicted by its income level. The growth of resident patent applications over the last 15 years has also been much slower than in East Asia, especially compared to China. Access to

[2] Nonetheless, Brazil's R&D intensity over the past two decades has increased only slowly, from 1% in 2000 to 1.27% in 2016. See World Bank, World Development Indicators [online database] https://databank.worldbank.org/source/world-development-indicators.

education has increased across the region, but the quality of high school education, as measured by the results of the Programme for International Student Assessment (PISA), does not compare favourably with many Asian middle-income countries.

Figure 2
Research and development (R&D) as a share of GDP, 2014
(Percentages)



Source: Prepared by the authors, on the basis of World Bank, World Development Indicators [online database] https://databank.worldbank.org/source/world-development-indicators.
Note: The red dots in the figure represent Latin American countries; the dark red dot represents China.

The need to expand domestic innovation capabilities and increase productivity growth is particularly urgent in the current context of globalization. The rise of China, with the rapidly growing diversification and sophistication of its exports, has shifted the goalposts for other middle-income economies. They are now competing with products (and services) from China across the spectrum of technology intensities in domestic and third markets (Paus, 2019).

III. Firm-level innovation

1. General considerations

Economic theories about innovation, productivity and economic growth suggest that firm innovation on a broad level generates productivity growth, which then advances economic growth. Informed by the analytical framework of Crepon, Duguet and Mairesse (1998), we conceptualize innovation as a process where firm engagement in innovation activities (innovation inputs) leads to innovation outputs. With respect to innovation inputs, scholars typically distinguish R&D and non-R&D activities. The latter refer primarily to the incorporation of knowledge developed elsewhere, through licenses, investment in new equipment or a reorganization of the production process.

A key challenge for middle-income economies is to make the process of innovation increasingly more endogenous and to increase domestic R&D efforts. Nonetheless, focusing exclusively on R&D is too limiting in terms of innovation in middle-income economies, since many firms are nowhere near the technological frontier. Structural heterogeneity is a key characteristic of Latin American economies: there are a few large and internationally competitive firms and a large number of micro and small enterprises with much lower productivity levels.

The statistical offices of many countries and international organizations choose employment as the criterion for distinguishing firms by size. In Latin America, each country uses its own criteria for firm size. These often combine data on employment, sales and taxable units; sometimes employment does not figure at all.[3] Using the country-specific classifications of firm size, Dini and Stumpo (2020) find that, in 2016, micro firms accounted for 88.4% of all firms in Latin America, small firms for 9.6%, medium-sized firms for 1.5% and large firms for a mere 0.5%.[4] The same study shows that the productivity level of micro firms in Latin American countries is less than 10% that of large firms (see table 1). The distribution of firms across size brackets in the European Union is similar to that in Latin America.[5] However, the productivity gap between firms of different sizes is much smaller. In Spain, for example, the labour productivity of micro firms is 45% of that of large firms, and in France it is 74%.[6]

Table 1

Productivity of micro, small and medium-sized companies relative to large companies, 2016

(Percentages)

	Micro-enterprises	Small companies	Medium-sized companies	Large companies
Brazil	4.5	22.4	50.7	100
Chile	7.2	16.6	22.4	100
Ecuador	8.2	29.7	46.2	100
Mexico	8.1	23.9	48.3	100
France	73.6	76.0	85.4	100
Germany	62.5	64.3	83.4	100
Italy	40.4	69.2	91.1	100
Spain	45.2	69.9	96.1	100

Source: M. Dini and G. Stumpo (coords.), "Mipymes en América Latina: un frágil desempeño y nuevos desafíos para las políticas de fomento", *Project Documents* (LC/TS.2018/75/Rev.1), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2020.

Size is not the only factor behind structural heterogeneity. In a study of 4,000 Brazilian manufacturing firms (with more than 30 employees), Catela, Cimoli and Porcile (2015) use cluster analysis to separate firms into five groups based on productivity levels. In 2004, the average productivity level of firms in the lowest productivity group (group 1: 15.5% of total firms) was only 0.79% of that in the highest productivity group (group 5: 7.7% of all firms). In group 2 (25% of all firms), the average productivity level was 2.5% that of the top group. In group 3 (28.7% of firms), it was 8%. In group 4 (23% of firms), it was 23%. In light of such productivity differentials, knowledge developed elsewhere is likely to be an important avenue for innovation engagement for many Latin American firms.

Innovation outcomes include the introduction of a new product or process, a new organizational method in business practices or a new marketing method (UIS, 2015, p. 9). They may be new to the firm, the country or the world.

The theoretical links between innovation inputs, innovation outputs, productivity growth and economic growth are straightforward. Empirical studies, however, reveal greater complexity. They generally show a positive impact of innovation on productivity growth, as summarized in Ortega-Argilés, Piva and Vivarelli (2011). For example, based on panel data for 65 countries for 1965–2005, Bravo-Ortega and García (2011) estimate that a 10% increase in R&D per capita spending generates a 1.6% increase in long-term total factor productivity. Using data on R&D expenditures by United States and European

[3] For the criteria used in Central American countries, for example, see Monge-González (2019).

[4] The firm size shares are based on data for Argentina, Brazil, Chile, Ecuador and Mexico.

[5] Eurostat uses the following employment cut-offs in distinguishing between firms in member countries: micro (1–9 persons employed), small (10–49), medium (50–249) and large (250 or more). Based on this size classification, 92.9% of firms in the European Union are micro, 5.9% are small, 1% are medium-sized and 0.2% are large (Dini and Stumpo, 2020).

[6] The data for European Union countries are based on the Eurostat size definition.

manufacturing and services firms during 1990–2008, Ortega-Argilés, Piva and Vivarelli (2011) find that cumulative R&D expenditures have a significant impact on firms' productivity. Reviewing the literature on R&D and economic growth, Mazzucato (2013) concludes that empirical findings differ —a result she attributes to differences in the innovation ecosystem across countries.

Empirical analyses of the impact of innovation outputs on productivity growth in Latin American countries reveal a positive link, though there are exceptions. Arza and López (2010) show that product and process innovation are important determinants of labour productivity in Argentina. Crespi and Zuñiga (2012) find a positive impact of product innovation on productivity growth in Brazil and Mexico, but not in Argentina. Their results indicate that the introduction of a new process has a positive impact on productivity in Argentina, Chile, Colombia, Panama and Uruguay, but not in Costa Rica.

One reason for the different findings may be the measurement of productivity. Labour productivity is value added per employee, but analysts often use sales per employee as a proxy. We consider that a poor proxy, since the correlation between sales per employee and value added per employee probably varies across firms in an industry, and across industries, countries and time. The input intensity of a firm's sales is also likely to differ with firm size and the level of incorporation into global value chains. Another possible explanation for the differences in empirical outcomes is the lag time between the year when a firm engages in innovation and the year when productivity results materialize. In the case of Chile, for example, Álvarez, Bravo-Ortega and Navarro (2010) find that process innovation has a contemporaneous impact on labour productivity, while product innovation affects productivity with a lag of two years.

2. Model

This study of firm innovation behaviour focuses on two steps in the innovation sequence: innovation inputs and innovation outputs. We consider three channels for innovation inputs: R&D expenditures, use of a license and investment in capital goods. With respect to innovation outputs, the focus is on the introduction of a new product or process. Given that the analysis covers developing economies, the vast majority of these innovations will be new to the firm or country, but not to the world.

In the first step, we explore the characteristics of firms that engage in one of the three innovation channels. In a second step, we investigate whether engagement in one of the three channels increases the likelihood of firms introducing a new product or process. Due to data limitations, the impact of innovation outputs on productivity growth is not investigated. The Enterprise Surveys do not have data on value added, only on sales. Sales per worker are a poor proxy for labour productivity, especially given variations over time and the absence of deflators at the industry level.

Equation (1) specifies our hypotheses about the links between firms' characteristics and their use of innovation inputs.

$$Innovation_{it}^{k} = B_0 + \sum_{j=1}^{m} B_j X_{jit} + B_{2010} Year_t + B_{2017} Year_t + \sum_{c=1}^{4} C_i CD_i + \alpha_i + \varepsilon_{it} \quad (1)$$

where:

i: firm

t: 2006, 2010 or 2017

k: channel of innovation engagement

X_j: vector of firm characteristics

CD: country dummies

α_i: firm-specific individual effect

ε_{it}: normal error term.

The Enterprise Surveys include information on R&D spending and use of a license. They have data on investment in fixed assets, but not on investment in capital goods. We use the former as a proxy for the latter, well aware that this may not always be the best fit, since investment in fixed assets also includes investment in building structures. The vector X includes a set of firm characteristics. Following previous studies (Crespi and Zuñiga, 2012; Pires, Sarkar and Carvalho, 2008; Chudnovsky, López and Pupato, 2006; Crepon, Duguet and Mairesse, 1998), we include a dummy for 'size'. The underlying assumption is that larger firms are better able to absorb the fixed costs of innovation, shoulder the risks inherent in innovation and access necessary (internal or external) financial resources.

It would be straightforward to use the number of employees as the uniform criterion for firm size across the five economies. However, a company may be small in terms of employees, but medium or large in terms of sales or other criteria. A proxy for firm size was therefore constructed that combines information on employment as well as sales. Each firm is classified by employment size (1–9, 10–49, 50–199 and 200 or more) in each of the three years, and by its sales relative to the sales of all firms by year and country (lowest quartile, second lowest quartile, second highest quartile and highest quartile). A firm's size is then determined in each country and year by its highest ranking in the two groupings. There are four firm sizes: micro, small, medium and large. For example, a firm with eight employees and sales in the second lowest quartile is a small firm, and a firm with 220 employees and sales in the second highest quartile sales is a large firm. Micro firms are the omitted category in the regressions.

In addition to firm size, we include a set of variables to capture a firm's awareness of the need to be competitive. If a firm exhibits behaviour that indicates an interest in expanding markets or communicating virtually with customers and suppliers, it is more likely to engage with innovation inputs. The relevant firm characteristics are whether a firm exports, holds an internationally recognized quality certification (IRQC), is part of a multi-plant company (multi-plant) and has virtual connectivity (VC). The first three variables enter the regression as dummy variables. However, VC is an index composed of two indicators: 'email use to communicate with clients' and 'existence of a firm website'. If the firm has neither, VC = 0; if it has either, VC = 1; and, if it has both, VC = 2. The hypothesis is that the coefficient for each of these variables is positive.

We also investigate any differences in innovation behaviour between domestic and foreign-owned firms. Firm nationality is of interest because a sustained advance in innovation ultimately depends on increased technological capabilities of domestic firms. Furthermore, governments in Latin America and elsewhere have been keen to attract foreign direct investment in the hope that this would bring new investment and technological know-how to the country. In the regressions, 'foreign ownership' is a continuous variable of the share of foreign ownership of a company's assets. The minimum share is 10%, on the assumption that this gives a foreign owner some control over the firm.[7] Thus, 'foreign' ranges in value from 0.1 to 1.

Finally, we include dummies for years and countries. The year dummies capture the broader economic environment for growth. The year 2010 is close to the 'Great Recession of 2008', 2017 is a year in a period of low economic growth in the five countries and 2006 is the omitted year.[8] The country dummies account for country-specific characteristics, with Uruguay as the omitted country.

[7] A threshold of 10% is quite common. In the balance of payments statistics, for example, a foreign investment is only considered 'foreign direct investment' if it gives the investor control of more than 10% of the firm's assets.

[8] Between 2014 and 2017, GDP per capita (in constant local currency units) grew at an average annual rate of 0.04% in Argentina, 0.77% in Colombia, -1.28% in Ecuador, 1.74% in Peru, and 1.19% in Uruguay. See World Bank, World Development Indicators [online database] https://databank.worldbank.org/source/world-development-indicators.

In a second step, we analyse the likelihood that firms engaging in one of the three innovation channels introduce a new product or new process.

$$New\ product\ (Process)_{it} = B_0 + \sum_{k=1}^{3} \phi_k\, Innovation_{it}^{k} + \sum_{j=1}^{m} B_j X_{jit} + B_{2010} Year_t + B_{2017} Year_t + \sum_{c=1}^{5} C_i CD_i + \alpha_i + \varepsilon_{it} \quad (2)$$

We include all the variables from the innovation input model in the innovation output model to test whether these variables have an impact on introducing new products or processes that goes beyond their impact on R&D, licenses and capital investment.

3. Estimation, data and descriptive statistics

We use a linear probability model to estimate equations (1) and (2). The results of both random- and fixed-effects models are presented to harness the advantages of both models. The advantage of fixed-effects models is that they generate unbiased estimates, even where the individual company effects correlate with both ‘Y’ and ‘X’ variables in the model. However, the fixed-effects model estimates will be relatively inefficient, since this panel is short, with a maximum of three observations per company, and many of the variables do not change between years for a specific firm. For example, only 9% of the firms switch export status between years, and only 7.6% switch between having an IRQC or not.[9] Thus, significant coefficients in the fixed-effects estimates are particularly compelling because they are unbiased and significant in spite of the relatively small effective sample size. The random-effects model estimates, on the other hand, have the advantage of generating considerably more efficient estimates on the variables of interest (such as exports and IRQC). Even though the Hausman tests indicate that some model estimates are biased, the results of all the random-effects models are shown to avoid leaving out the very variables of interest for the step 1 estimates.

The empirical analysis uses data from the World Bank’s Enterprise Surveys. They offer innovation-related information for five Latin American countries (Argentina, Colombia, Ecuador, Peru and Uruguay) for three years (2006, 2010 and 2017). Annex A1 lists the survey questions and the definitions of the variables included in this model. The vast majority of the companies surveyed are in the manufacturing sector.

The five economies differ considerably in income level and population size (see table 2). Argentina and Uruguay have significantly higher income levels than the other three economies. Even though the World Bank classifies them as high-income economies based on their GDP per capita, both economies are more similar to upper middle-income economies when indicators of technological capabilities are considered. Population size varies from a low of 3.4 million in Uruguay to a high of 49 million in Colombia. However, the five countries do share an important common characteristic: they all have a relatively small manufacturing sector.

[9] If a variable for a firm does not change between years, that firm is not included in the coefficient estimate for that variable in the fixed-effects model.

Table 2
Latin America (5 countries): key economic indicators, 2014 and 2017

	Gross national income (GNI) per capita *(current US$)*	Population	Manufacturing value added as a share of GDP	R&D as a share of GDP
	2017	2017	2017	2014
Argentina	13 120	44 044 811	12.9	0.61
Colombia	5 930	48 901 066	11.4	0.20
Ecuador	5 860	16 785 361	14.4	0.34[a]
Peru	6 060	31 444 297	13.0	0.16[b]
Uruguay	15 150	3 436 646	11.7	0.33

Source: Prepared by the authors, on the basis of World Bank, World Development Indicators [online database] https://databank.worldbank.org/source/world-development-indicators.

[a] 2011.

[b] 2004.

The descriptive statistics in table 3 show the variable means for all firms in the five countries jointly, as well as by nationality of ownership and firm size. The number of observations for each variable changes with data availability.

Table 3
Latin America (5 countries):[a] variable means, 2006, 2010 and 2017
(Percentages)

	All	Nationality of ownership		Firm size			
		Domestic	Foreign[b]	Micro	Small	Medium	Large
Firm characteristics							
Foreign (%)	10.4	0.0	100.0	2.2	3.7	7.4	26.8
Exporting (%)	24.3	21.4	49.5	5.9	15.1	25.4	45.9
Virtual connectivity[c] (0-2)	1.6	1.6	1.8	1.2	1.5	1.7	1.8
Multi-plant (%)	15.8	13.5	35.6	5.5	9.9	14.5	29.2
Internationally recognized quality certification (IRQC) (%)	21.5	18.1	51.0	3.2	10.1	20.1	48.3
Micro (%)	14.9	16.5	2.9				
Small (%)	27.2	29.4	9.1				
Medium (%)	29.3	30.6	19.4				
Large (%)	28.6	23.5	68.6				
Innovation inputs							
R&D (%)	42.6	41.2	55.4	25.6	35.5	46.5	58.6
License (%)	12.7	10.5	33.2	4.9	7.8	13.3	23.5
Capital goods (%)	60.7	58.9	75.3	35.5	50.3	65.9	80.7
Innovation outputs							
New product (%)	68.3	67.4	76.8	58.7	67.1	70.3	76.2
New process (%)	57.8	57.3	61.7	48.5	54.8	60.3	65.2

Source: Prepared by the authors, on the basis of World Bank, "Enterprise Surveys" [online] https://databank.worldbank.org/source/enterprise-surveys.

[a] Argentina, Colombia, Ecuador, Peru and Uruguay.

[b] Foreign ownership of assets > 10%.

[c] This variable is not expressed in percentages, but in values from 0 to 2.

Domestic firms account for roughly 90% of firms in the sample: 16.5% of them are micro-sized, 29.4% are small, 30.6% are medium and 23.5% are large. Foreign firms, in contrast, are predominantly large (68.6%), followed by medium-sized (19.4%), small (9.1%) and micro-sized (2.9%). Compared to the above-mentioned country-specific data for Latin America, micro firms are very under-represented in the World Bank Sample, while the other size groups are over-represented. That is immaterial for this analysis, however, since the focus is on the behaviour of firms and not their absolute numbers.

Regarding the different channels of innovation inputs, spending on capital goods is the most frequently used channel (60.7%), followed by spending on R&D (42.6%) and use of a license from a foreign-owned company (12.7%).[10] Size and foreign ownership are distinguishing traits for all firm characteristics related to innovation inputs and the generation of innovation outputs. For each of them, variable incidence increases with firm size. For example, 48.3% of large firms hold an IRQC, compared to 3.2% of micro firms; and the share of large firms spending on R&D or capital goods is more than double the share of micro firms.

Comparing foreign-owned and domestic-owned firms, a larger proportion of foreign-owned firms demonstrates awareness of the need to be competitive, while a larger proportion also engages in each of the three innovation input channels. Relatively more foreign-owned firms introduce a new product (76.8% compared to 67.4% for domestic-owned firms), while the incidence of new process introduction is roughly similar for the two groups (61.7% versus 57.3%).

IV. Results

1. General model

When interpreting the regression results, two caveats must be kept in mind. First, this study primarily explores associations between firm characteristics and innovation engagement and outcomes, not causality. Nonetheless, the fixed-effects estimates do suggest causal relations, since they capture changes in firm behaviour from one of the three years to another. Second, with the exception of 'virtual connectivity' and 'foreign ownership', we use dummies, not absolute values for all the variables. We estimate the likelihood of firms engaging in particular innovation activities or not, and not the impact of the degree of engagement. For instance, the data capture whether firms spend on R&D or not, but not how much they spend. Similarly, the analysis captures whether a firm introduces a new product or process, but not the nature of that innovation. For example, it does not distinguish between minor adjustments to the production process and a major change.

Table 4 shows estimates of the first step: the impact of firm characteristics on engagement with innovation inputs. The results for spending on R&D are particularly strong, because the coefficients are unbiased in the random-effects model. All firm characteristics that indicate awareness of the need to be competitive have the expected signs and are statistically significant in the random-effects models for engagement with each of the three innovation input channels (with the exception of exporting for 'holding a license'). The coefficients on these firm characteristics are highest for spending on R&D. However, the results show that the other innovation input channels are also important particularly investment in capital goods. With the exception of IRQC and VC, the coefficients in the fixed-effects models are not statistically significant. That most likely reflects the fact that not enough firms switched between years to generate efficient estimates. Being part of a multi-plant corporation does not generally have a significant impact.

Firm size matters greatly for engagement with innovation inputs. The likelihood that a firm engages with the three innovation inputs increases in proportion with the firm's size. For example, compared to micro firms, the likelihood of investing in capital goods increases by 12% for small firms, 25% for medium-sized firms and 35% for large firms. The likelihood of spending more on R&D than micro firms rises from 4.4% for small firms to 9.3% for medium-sized firms, and to 13% for large firms. These are robust results, as the coefficients are quite similar when employment is the sole criterion used for size.[11]

[10] Of the 5,721 observations, 6.7% engaged with all three innovation channels, 1.6% used licenses and R&D, 28.6% spent on R&D and capital goods and 3.2% held a license and spent on capital goods. Only 10.5% spent on R&D, 1.3% only held a license and 24.1% only spent on capital goods. The results found that 24% did not engage with any of the innovation inputs.

[11] Based on employment data only, 21.2% of firms are micro (1–9 employees), 44.8% are small (10–49), 24.2% are medium sized (50–199) and 9.8% are large (> 200).

Table 4

Latin America (5 countries):[a] firms using innovation inputs (linear probability model)

	R&D		License		Capital goods	
	RE	FE	RE	FE	RE	FE
Foreign	-0.041*	-0.059	0.203***	0.027	0.003	0.059
	(0.02)	(0.08)	(0.02)	(0.06)	(0.02)	(0.07)
Exporting	0.089***	0.054	0.010	0.027	0.044***	0.032
	(0.02)	(0.04)	(0.01)	(0.04)	(0.01)	(0.03)
Internationally recognized quality certification (IRQC)	0.172***	0.138***	0.050***	-0.032	0.064***	0.005
	(0.02)	(0.04)	(0.01)	(0.03)	(0.01)	(0.03)
Virtual connectivity (VC)	0.136***	0.067**	0.024**	0.032	0.075***	0.030
	(0.01)	(0.03)	(0.01)	(0.02)	(0.01)	(0.02)
Multi-plant	0.009	0.011	0.046***	0.019	0.020	0.014
	(0.02)	(0.04)	(0.01)	(0.03)	(0.01)	(0.03)
Small	0.044**	0.017	0.010	-0.061	0.119***	0.138***
	(0.02)	(0.06)	(0.02)	(0.05)	(0.02)	(0.05)
Medium	0.093***	0.049	0.042***	-0.045	0.249***	0.265***
	(0.02)	(0.07)	(0.02)	(0.06)	(0.02)	(0.05)
Large	0.130***	0.089	0.078***	-0.086	0.349***	0.233***
	(0.02)	(0.08)	(0.02)	(0.07)	(0.02)	(0.06)
Year 2010	-0.038***	-0.017	0.015	-0.016	-0.0345***	-0.059***
	(0.02)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)
Year 2017	-0.269***	-0.210***	0.004	-0.008	-0.104***	-0.146***
	(0.02)	(0.023	(0.01)	(0.02)	(0.01)	(0.02)
Argentina	0.062***		0.041**		0.019	
	(0.02)		(0.02)		(0.02)	
Colombia	0.095***		0.003		-0.054***	
	(0.02)		(0.02)		(0.02)	
Ecuador	0.184***		0.064***		-0.003	
	(0.03)		(0.02)		(0.02)	
Peru	0.074***		0.004		0.025	
	(0.02)		(0.02)		(0.02)	
Constant	0.113***	0.325***	-0.004	0.139	0.307***	0.429***
	(0.07)	(0.05)	(0.02)	(0.06)	(0.02)	(0.04)
Observations	5 964	5 964	4 856	4 856	8 259	8 259
Wald stat chi^2	1141.77		437.69		1087.21	
Model F		10.19		0.75		7.32
R^2	0.182	0.167	0.087	0.0003	0.128	0.093
Hausman test	13.46		27.9**		34.86***	

Source: Prepared by the authors, on the basis of World Bank, "Enterprise Surveys" [online] https://databank.worldbank.org/source/enterprise-surveys.

Note: Standard errors in parentheses. ***p<0.01; ** p<0.05; * p<0.1.

[a] The omitted country is Uruguay.

In comparison with domestic firms, a larger share of foreign-owned firms export, hold an IRQC, are part of a multi-plant establishment and are large. The average VC index is higher as well. However, once we control for these characteristics in the estimates, foreign ownership does not have an additional positive impact on innovation engagement. The coefficient in the R&D model is actually slightly negative and statistically significant. In other words, what distinguishes domestic and foreign firms are not inherent differences, but a different incidence of key firm characteristics.

Specificities of time and place influence a firm's likelihood of spending on R&D. The coefficients for many of the country dummies are statistically significant, especially in the R&D model. The significance of the year dummies illustrates the impact of the broader economic context in which firm innovation unfolds; innovation engagement is lower in years of slower growth. In 2010, firms were less likely to use innovation inputs than in 2006 before the 'Great Recession'. In 2017, firms were even less likely to spend on R&D or new capital goods, as economic growth was low.

How does engagement with innovation inputs affect the production of innovation outputs? Table 5 shows the estimates of the second step model. The results indicate that firms that spend on R&D or new capital goods are significantly more likely to introduce a new process or product. These findings are particularly robust, as they are statistically significant in both the fixed- and the random-effects model. In the random-effects model, spending on R&D increases the likelihood that a firm will introduce a new process by 21% and a new product by 20%. The increased likelihood resulting from spending on capital goods is 17% for a new process and 10% for a new product. The use of foreign-owned licenses, on the other hand, has a much smaller impact on the introduction of a new process or product.

Table 5

Latin America (5 countries):[a] firms introducing a new product or process (linear probability model)

	New process		New product	
	Random effects	Fixed effects	Random effects	Fixed effects
R&D	0.210***	0.121***	0.204***	0.146***
	(0.02)	(0.03)	(0.01)	(0.03)
License	0.037*	0.039	0.066***	0.025
	(0.02)	(0.04)	(0.02)	(0.04)
Capital goods	0.165***	0.130***	0.098***	0.070**
	(0.02)	(0.03)	(0.01)	(0.03)
Foreign	-0.024	-0.212**	0.007	-0.106
	(0.03)	(0.10)	(0.03)	(0.08)
Exporting	-0.021	0.011	0.02	-0.021
	(0.02)	(0.04)	(0.02)	(0.04)
Internationally recognized quality certification (IRQC)	0.055***	0.022	0.005	0.032
	(0.02)	(0.05)	(0.02)	(0.04)
Virtual connectivity (VC)	0.055***	0.041	0.076***	0.062*
	(0.01)	(0.04)	(0.01)	(0.03)
Multi-plant	0.002	-0.040	0.036*	-0.022
	(0.02)	(0.04)	(0.02)	(0.04)
Small	0.001	-0.011	0.015	-0.062
	(0.02)	(0.07)	(0.02)	(0.06)
Medium	-0.010	-0.012	-0.01	-0.051
	(0.02)	(0.08)	(0.02)	(0.07)
Large	-0.036	-0.069	-0.038	0.019
	(0.03)	(0.10)	(0.03)	(0.00)
Year 2010	-0.181***	-0.191***	-0.135***	-0.092***
	(0.02)	(0.03)	(0.02)	(0.02)
Year 2017	-0.130***	-0.163***	-0.013	-0.006
	(0.02)	(0.03)	(0.02)	(0.03)
Argentina	-0.011		-0.036	
	(0.03)		(0.02)	
Colombia	0.038*		-0.043***	
	(0.02)		(0.02)	
Ecuador	-0.008		-0.004	
	(0.04)		(0.03)	
Peru	0.081***		-0.005	
	(0.02)		(0.02)	
Constant	0.40***	0.561***	0.486***	0.558***
	(0.02)	(0.09)	(0.03)	(0.08)
Observations	4 557	4 557	4 673	4 673
Wald stat chi^2	658.69		583.52	
Model F		8.23		5.03
R^2	0.130	0.088	0.118	0.092
Hausman test	19.45		31.15***	

Source: Prepared by the authors, on the basis of World Bank, "Enterprise Surveys" [online] https://databank.worldbank.org/source/enterprise-surveys.

Note: Standard errors in parentheses. ***p<0.01; ** p<0.05; * p<0.1.

[a] The omitted country is Uruguay.

The independent variables capturing firm characteristics are not significant in the estimate of the second step. This indicates that they do not have an impact on innovation outcomes beyond their impact on firm engagement with innovation inputs. A notable and robust exception is virtual connectivity, which is significant in three of the four estimates. One possible explanation for this is that firms using the Internet for business transactions also use it to learn about new technologies and products relevant to their particular production area. The use of an IRQC also has an additional positive impact but only for the introduction of a new process. Interestingly, once we control for other variables, foreign ownership has a slightly negative impact on the likelihood of introducing a new process in the fixed-effects model.

We also estimated equations 1 and 2 for each of the five countries individually.[12] Overall, the individual country models confirm the findings from the pooled model. Most importantly, in all five economies, engagement with R&D and capital goods significantly increases the likelihood of a firm introducing a new process or product.

2. National innovation system

Firms operate in a national environment of institutions and incentives that enable or hinder the development of their innovation capabilities. A set of interconnected micro, macro and meso factors shape firms' desire or willingness to innovate. They include, but are not limited to, the prevalence of Schumpeterian entrepreneurial spirit, policies affecting relative prices (such as exchange rate and technology support policies), the availability of necessary human capital and infrastructure and possibilities for collaboration with and spillovers from other firms and institutions.

According to the United Nations Industrial Development Organization (UNIDO, 2015, p. 6), "learning and innovation involve complex interactions between firms and their environment —not just the firms' network of customers and suppliers but also the technological infrastructure, institutional and organizational framework, and knowledge-creating and diffusing institutions." The different components of a national innovation system have to work in complementary fashion to enhance firm level innovation (Edler and Fagerberg, 2017; Lundvall, 1992).

Data from the Enterprise Surveys reveal the impact of two key elements of the national innovation context on firm innovation behaviour. The first variable captures whether the firm has engaged in cooperative innovation activities with external partners, and the second shows whether the firm received public support for innovation activities.[13] In order to test the impact of the two variables, we added them to equations (1) and (2) above. As the information is only available for the 2010 surveys, we cannot include it in the full panel estimates. Instead, we use OLS estimates for 2010 only. Given these restrictions, we consider the results tentative, with more research needed in the future.

Table 6 shows the variable means. The proportion of foreign firms that collaborate in innovation with external partners is considerably larger than the proportion of domestic firms, while the share of domestic firms receiving government support is slightly higher than the share of foreign firms.

[12] The results are available from the authors upon request.

[13] ECLAC (2011) offers an extensive discussion for Latin America of the importance of national innovation systems generally and research collaborations and public support specifically.

Table 6
Latin America (5 countries):[a] variable means, 2010
(Percentages)

	All	Nationality of ownership		Firm size			
		Domestic	Foreign[b]	Micro	Small	Medium	Large
Elements of innovation Ecosystem							
Innovation cooperation with external partners (%)	21.9	20.9	30.4	16.4	16.9	21.3	32.4
Government support for innovation (%)	11.6	11.8	10.8	6.1	9.9	12.7	17.1
Firm characteristics							
Foreign (%)	10.4	0.0	100.0	0.2	3.1	7.5	30.9
Exporting (%)	37.0	32.5	49.5	5.8	17.9	31.5	53.9
Virtual connectivity[c] (VC) (0-2)	1.6	1.6	1.9	1.2	1.6	1.75	1.9
Multi-plant (%)	12.3	9.9	33.1	4.0	8.7	12.9	26.9
Internationally recognized quality certification (IRQC) (%)	29.8	25.0	71.1	3.9	13.1	26.4	57.5
Micro (%)	14.3	16.2	0.2				
Small (%)	26.7	29.5	6.9				
Medium (%)	29.8	31.4	18.5				
Large (%)	29.2	22.9	74.4				
Innovation inputs							
R&D (%)	53.3	51.9	65.3	30.0	46.6	60.9	71.3
License (%)	13.8	11.1	37.2	4.8	8.3	13.9	26.8
Capital goods (%)	63.1	60.9	82.4	34.3	53.1	67.8	85.1
Innovation outputs							
New product (%)	68.1	63.1	73.2	51.3	62.8	67.5	72.0
New process (%)	55.3	55.1	56.5	46.1	53.4	59.9	63.7

Source: Prepared by the authors, on the basis of World Bank, "Enterprise Surveys" [online] https://databank.worldbank.org/source/enterprise-surveys.
[a] Argentina, Colombia, Ecuador, Peru and Uruguay.
[b] Foreign ownership of assets > 10%.
[c] This variable is not expressed in percentages, but in values from 0 to 2.

Table 7 shows the estimates for equations (1) and (2), with and without the inclusion of the two indicators of the national innovation system. Cooperation with other institutions has significant positive effects on engagement with R&D, spending on capital goods and the introduction of new products and processes, even after considering their impacts on R&D and capital goods. Public support is only significant for the R&D innovation channel. That is not surprising, given that public support often takes the form of subsidies or tax credits for R&D spending. Again, there is an independent impact on the introduction of a new process or product over and above the impact on R&D.

Table 7
Latin America (5 countries): ordinary least-squares (OLS) models with innovation cooperation and public support, 2010

	New product	New process	R&D	License	Capital goods	New product	New process	R&D	License	Capital goods
R&D	0.287***	0.207***				0.303***	0.229***			
	(0.02)	(0.02)				(0.02)	(0.02)			
License	0.061**	0.016				0.062**	0.017			
	(0.03)	(0.03)				(0.03)	(0.03)			
Capital goods	0.084***	0.168***				0.087***	0.173***			
	(0.02)	(0.02)				(0.02)	(0.02)			
Cooperation	0.050*	0.010***	0.209***	0.025	0.075***					
	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)					

Table 7 (concluded)

	New product	New process	R&D	License	Capital goods	New product	New process	R&D	License	Capital goods
Public support	0.086***	0.069**	0.108***	-0.001	0.008					
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)					
Foreign	0.056	-0.057	-0.083	0.236***	0.01	0.047	-0.06	-0.10**	0.236***	0.008
	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)	(0.040)
Exporting	-0.005	-0.028	0.093***	-0.004	-0.011	-0.0004	-0.024	0.104***	-0.004	-0.010
	(0.02)	(0.03)	(0.03)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.02)	(0.02)
Internationally recognized quality certification (IRQC)	0.013	0.081***	0.128***	0.049**	0.015	0.023	0.095***	0.162***	0.052**	0.025
	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)
Virtual connectivity (VC)	0.054**	0.061**	0.139***	0.025	0.076***	0.054**	0.062***	0.150***	0.026	0.080***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.0221)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Multi-plant	0.030	-0.015	0.010	0.058**	0.023	0.029	-0.020	-0.001	0.057**	0.0187
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Small	0.012	-0.031	0.099***	0.020	0.171***	0.010	-0.036	0.094***	0.019	0.169***
	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)	(0.03)	(0.03)
Medium	-0.010	-0.049	0.163***	0.046*	0.306***	-0.013	-0.05	0.161***	0.0454	0.304***
	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)
Large	-0.051	-0.088*	0.168***	0.097***	0.449***	-0.048	-0.086*	0.184***	0.098***	0.453***
	(0.04)	(0.05)	(0.04)	(0.03)	(0.04)	(0.04)	(0.05)	(0.04)	(0.03)	(0.04)
Argentina	0.019	-0.008	0.079**	0.054*	-0.008	0.021	-0.006	0.087**	0.055*	-0.005
	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.04)	(0.04)	(0.028)	(0.04)
Colombia	-0.062*	0.040	0.101***	0.017	-0.067**	-0.062*	0.039	0.104***	0.017	-0.066**
	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.035)	(0.03)	(0.03)
Ecuador	-0.107**	-0.049	0.080	-0.019	0.050	-0.108**	-0.050	0.081	-0.018	0.051
	(0.05)	(0.06)	(0.05)	(0.04)	(0.05)	(0.05)	(0.06)	(0.06)	(0.04)	(0.05)
Peru	-0.036	0.090***	0.111***	0.033	0.072**	-0.046	0.080**	0.098***	0.033	0.070**
	(0.03)	(0.03)	(0.03)	(0.025)	(0.03)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)
Constant	0.349***	0.212***	-0.019	-0.014	0.232***	0.361***	0.225***	0.009	-0.012	0.239***
	(0.04)	(0.04)	(0.04)	(0.03)	(0.042	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)
Observations	1 887	1 886	1 895	1 891	1 894	1 887	1 886	1 895	1 891	1 894
R^2	0.157	0.135	0.197	0.104	0.164	0.151	0.126	0.159	0.103	0.160

Source: Prepared by the authors, on the basis of World Bank, "Enterprise Surveys" [online] https://databank.worldbank.org/source/enterprise-surveys.
Note: Standard errors in parentheses. ***p<0.01; ** p<0.05; * p<0.1.

Another indicator of the importance of R&D support and innovation cooperation is the increase in R^2 when the two variables are included in the model. The increase is most pronounced for 'engagement with R&D' and 'introduction of a new process'. Taken together, the results offer empirical support for active government policies to advance innovation capabilities at the firm level.

3. Comparison with firms in China

Among upper middle-income economies, China stands out for its exceptional economic performance, which has made Chinese producers the fiercest competitors for Latin American firms in domestic and third markets alike over the past two decades (Jenkins, 2019; Paus, 2019; Gallagher and Porzecanski, 2010). A middle-income economy with GDP per capita roughly equal to that of aggregate Latin America, China has seen extraordinary growth in output and productivity over the last three decades (Zhu, 2012). Commenting on China's ranking in the Global Innovation Index 2016, Dutta, Lauvin and Wunsch-Vincent (2016, p. 18) point out that "China is now the only middle-income economy with innovation quality scores that display a balance similar to that of high-income economies".

Given China's performance in productivity and innovation, this model explores whether the connections between innovation inputs and outputs for firms in China are different from what has been observed in the five Latin American countries. We estimate equations (1) and (2) for 2012, the only year for which the World Bank has an Enterprise Survey for China.[14] A comparison of the regression results has to be treated with caution, since the China survey is a different survey for a different year, compared with the surveys for Latin American countries.

The descriptive statistics for the firms in China are summarized in table 8. The overwhelming majority of firms in the survey are privately owned; only about 5% are State-owned. Foreign firms account for 7.4% of all firms. With respect to firm size, 2% of the firms included in the survey are micro, 24.4% are small, 38.7% are medium-sized and 34.9% are large. Compared with Latin America, a smaller share of Chinese firms export (20.9% versus 37%). That may be a reflection of China's large internal market. On the other hand, many firms may be indirect exporters as first- or second-tier input suppliers to exporters that participate in global value chains (GVCs). Across firm sizes, a much higher percentage of domestic and foreign firms hold an internationally recognized quality certification, which is generally a requirement for GVC participation.

Table 8
China: variable means, 2012
(Percentages)

	All	Nationality of ownership		Firm size			
		Domestic	Foreign[a]	Micro	Small	Medium	Large
Firm characteristics							
Foreign	7.4	0.0	100.0	0.0	3.6	8.1	9.6
Exporting (%)	20.9	18.6	51.6	0.0	8.5	18.8	33.3
Virtual connectivity[b] (VC)	1.6	1.6	1.7	1.3	1.4	1.7	1.8
Multi-plant (%)	11.2	10.0	25.0	0.0	3.4	8.1	20.7
Internationally recognized quality certification (IRQC) (%)	71.9	70.8	85.4	31.4	49.5	73.7	88.0
Micro	2.0	1.9	0.0				
Small	24.4	25.4	12.1				
Medium	38.7	38.4	42.7				
Large	34.9	33.9	45.2				
Innovation inputs							
R&D (%)	41.3	40.2	53.2	11.4	22.7	45.6	51.2
License (%)	24.2	21.8	52.9	2.9	13.1	24.4	32.9
Capital goods (%)	56.5	55.5	69.4	17.1	45.5	58.2	64.8
Innovation outputs							
New product (%)	45.7	44.8	55.3	8.6	36.4	48.5	51.4
New process (%)	62.5	61.6	72.6	20.0	52.2	66.3	68.1

Source: Prepared by the authors, on the basis of World Bank, "Enterprise Surveys" [online] https://databank.worldbank.org/source/enterprise-surveys.
[a] Foreign ownership of assets > 10%.
[b] This variable is not expressed in percentages, but in values from 0 to 2.

A larger proportion of domestic and foreign-owned firms in Latin America is engaged in R&D and capital investment, but relatively more firms in China have a license. With respect to innovation outputs, a higher percentage of China's firms introduces a new process (62.5% versus 55.3% in Latin America), while a smaller share introduces a new product (45.7% versus 68.1%).

[14] Even though some of the questions were slightly different, a data set has been compiled with the same variables as for Latin America. The Enterprise Survey for China does not include questions about public support for innovation or collaboration with other entities.

Table 9 shows the OLS estimates of equations (1) and (2) for China's firms. The characteristics of firms engaging in R&D are the same in China as in Latin America. Exports, firm size, holding a recognized production standards certification and using virtual connections for interactions with clients and others are all positive and statistically significant. The findings for licenses and investment in capital equipment are slightly more varied. Engagement with R&D, licenses and new capital equipment increases the likelihood that a firm in China introduces a new process or product. Again, these results are in line with the findings for Latin America.

Table 9

China: OLS models, 2012

	New product	New process	R&D	License	Fixed assets
R&D	0.432***	0.263***			
	(0.02)	(0.02)			
License	0.223***	0.195***			
	(0.03)	(0.03)			
Capital goods	0.146***	0.181***			
	(0.02)	(0.02)			
Foreign	-0.001	-0.001	0.000	0.003***	0.001
	(0.00)	(0.00)	(0.001)	(0.00)	(0.001)
Exporting	-0.012	0.004	0.137***	0.107***	0.138***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Internationally recognized quality certification (IRQC)	0.017	0.047	0.049**	0.117***	0.019
	(0.03)	(0.03)	(0.03)	(0.02)	(0.03)
Virtual connectivity (VC)	0.020	0.079***	0.074***	0.068***	-0.031
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Multi-plant	0.108***	0.106***	0.120***	0.085***	0.016
	(0.03)	(0.04)	(0.04)	(0.03)	(0.04)
Small	0.157**	0.193**	0.072	0.047	0.269***
	(0.07)	(0.08)	(0.08)	(0.07)	(0.09)
Medium	0.131*	0.195**	0.255***	0.093	0.384***
	(0.07)	(0.08)	(0.08)	(0.07)	(0.09)
Large	0.087	0.143*	0.259***	0.120*	0.430***
	(0.07)	(0.08)	(0.08)	(0.07)	(0.09)
Cons	-0.026	0.020	0.006	-0.094	0.205**
	(0.07)	(0.08)	(0.08)	(0.07)	(0.09)
R^2	0.32	0.23	0.09	0.11	0.05
Observations	1 631	1 629	1 656	1 654	1 660

Source: Prepared by the authors, on the basis of World Bank, "Enterprise Surveys" [online] https://databank.worldbank.org/source/enterprise-surveys.

Note: Standard errors in parentheses. ***p<0.01; ** p<0.05; * p<0.1.

Overall, the estimates of the model suggest that the same attributes characterize firm engagement with innovation inputs in Latin America and China, and that engagement increases the likelihood of introducing a new product and process in all countries. However, comparing the estimates for China and Latin America suggests a possible link between innovation performance at the firm level and the aggregate level. Firms engaging with R&D seem to be more likely to introduce a new product or process in China than in Latin America. That difference in translation from firm innovation inputs into outputs may indicate differences in firm behaviour in the two areas.

Differences in average firm spending on R&D support that hypothesis. In both Latin America and China, the largest firms account for most of the R&D expenditures, generally more than 80%.[15] The reason is that average spending on R&D is so much higher for large firms than for firms in the other size

[15] The highest share was 97% for Colombia in 2006, and the lowest share was 72% for Peru in 2006. In China, the largest firms account for 85% of all R&D expenditures in 2012. The World Bank Enterprise Surveys for Ecuador do not have values for R&D.

categories. There is a large gap between the average R&D spending of micro, small and medium-sized firms on the one hand and large firms on the other (see table 10). Firm spending on R&D is higher in China than in Latin America across firm size categories, especially in large firms. The average large firm in China in 2012 spent much more than any Latin American country across all three years. State-owned enterprises do not drive this result, even though their average R&D expenditures are considerably higher than that of non-State-owned firms. Furthermore, the average R&D spending of large domestic firms in China is much higher than that of foreign-owned firms, in contrast to the Latin American countries where it tends to be lower (not shown).

Table 10

Latin America and China: average R&D spending, 2010 and 2012

(Percentages and current United States dollars)

	R&D spending/firm relative to large firms *(percentages, 2010)*				R&D/firm for large firms *(current US$)*		
	Micro	Small	Medium	Large	2006	2010	2017
Argentina	3.4	3.3	12.8	100	505 882	621 109	634 058
Colombia	1.4	1.7	4.8	100	622 581	658 390	284 956
Peru	1.5	5.2	21.8	100	146 611	304 911	312 482
Uruguay	0.7	9.6	24.6	100	226 778	141 257	84 852
China[a]	4.1	3.8	13.8	100		1 479 201	
State-owned		0.6	13.4	100		4 278 922	
Not State-owned (domestic)	3.8	9.7	20.8	100		1 189 651	

Source: Prepared by the authors, on the basis of World Bank, "Enterprise Surveys" [online] https://databank.worldbank.org/source/enterprise-surveys.

[a] 2012.

One possible reason for the higher degree of engagement with R&D in China may be a more supportive overall innovation ecosystem in China compared to Latin American countries. Dutta, Lauvin and Wunsch-Vincent (2016, p. xxv) argue that "Asian economies have benefited from a strong and strategic coordination role of governments in innovation".

V. Conclusions

Increased and broad-based innovation is the key for escaping the middle-income trap. Advancing innovation at the national level is a complex and multifaceted process, in which firms are central actors.

In this paper we analysed the innovation behaviour of firms in five Latin American countries between 2006 and 2017. Estimates of the two-step model demonstrate that, while R&D spending tends to be the most significant channel for innovation inputs, capital investment —and to a lesser extent use of a license— are important channels as well. The results show that exporting, having an internationally recognized quality certificate and using the Internet for business purposes are key characteristics of firms that engage with innovation inputs. In addition, engagement with innovation inputs significantly increases the likelihood of firms introducing a new process or product.

The results suggest that there is no missing link per se between innovation inputs and outputs to explain innovation underperformance at the aggregate level. However, the larger coefficient for China's estimates on R&D spending for the introduction of a new product, and the considerably higher R&D spending by the average large firm in China, suggest that there may be lower translation of innovation inputs into outputs in Latin America, and thus a difference in firm behaviour.

To account for possible differences in firm behaviour, quantitatively as well as qualitatively, it may be useful to look at the larger innovation ecosystem in which firms operate, as well as the structure of the economy. In all developed and developing economies, R&D expenditures tend to be concentrated in the manufacturing sector. That sector no longer plays such a significant role in Latin American economies. The share of manufacturing value added in output declined from 24.7% in 1980, to 14.2% in 2010 and 13.3% in 2017. In contrast, the manufacturing sector in China accounted for 31.6% of total value added in 2010, and 28.1% in 2017.

However, China and a few other Asian latecomers are the exception. Over the past three decades, middle-income economies have generally witnessed a decline in the relative position of the manufacturing sector. Some economists have referred to this phenomenon as premature de-industrialization (Rodrik, 2016; Palma, 2005). It is termed premature because the weight of manufacturing in today's middle-income economies, both in terms of employment and value added, started to decrease at much earlier GDP per capita levels than in today's industrialized economies. The decline accelerated after 2000 and was most pronounced in Latin America.

A number of authors have argued that the decline in the manufacturing sector and the concomitant rise of the informal sector with its many small low-productivity firms is linked to the move to a market-led strategy. Government support for technological learning in its different facets was limited and disjointed, which was not conducive to broad-based innovation (Paus, 2019; Cimoli and others, 2017; Ocampo, 2004). The market-based approach pursued by Latin American governments stands in stark contrast to the State-led approach followed by China, especially in terms of its increasingly deliberate focus on advancing innovation (Gallagher and Porzecanski, 2010).

The empirical findings support the case for active government policies to advance innovation in Latin America. First, the results demonstrate the interconnections between innovation policies and competitiveness policies, a link which other authors have highlighted (Mytelka, 1999). Firm characteristics that increase the likelihood of company engagement with innovation inputs are exports, virtual connections for client interactions and use of internationally recognized production standards. All of these factors indicate an awareness of the means, if not the ability, to compete nationally and internationally . Thus, on a broad level, provision of good broadband infrastructure for firms to have Internet access and support for acquiring certification in internationally recognized production standards play an important role in increasing firms' ability to compete and in increasing the likelihood that they will engage in innovation. Equally important are export support policies —especially avoiding overvalued exchange rates— and access to finance, given the importance of the capital investment channel for innovation outcomes.

With respect to innovation-specific policies, the results suggest that direct support for firm innovation and facilitation of innovation collaboration across organizations have a significant impact on advancing innovation engagement and outcomes. Furthermore, in Latin America's current low-growth context, pro-active policies may be necessary to crowd in private sector innovation engagement. In today's highly competitive international markets, such policies need to be part of a comprehensive and cohesive innovation-focused strategy that will enable an escape from the middle-income trap.

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Annex A1

Variables used in the analysis

Variable name, Survey question text, Variable name in survey, Dummy definition

Innovation inputs

Research and development

2006, 2010, 2017 (h8): During last fiscal year, establishment spent on R&D (excl. market research)?

Yes=1, No=0

Investment in fixed assets

2006, 2010, 2017 (k4): Purchase any new/used fixed assets?

Yes=1, No=0

License

2006, 2010, 2017 (E6): Do you use technology licensed from a foreign-owned company?

Yes=1, No=0

Innovation outputs

New product

2006, 2010, 2017 (h1): New products/services introduced over last 3 years?

Yes=1, No=0

New process

2006, 2010, 2017 (h5): During last 3 years establishment introduced new/significantly improved processes?

Yes=1, No=0

Other variables

Internet use

2006, 2010, 2017 (c22a): Do you currently communicate with clients and suppliers by email?

2006, 2010, 2017 (c22b): Establishment has its own website

Composite Index: Internet (based on c22a and c22b) (VC)

0=none

1=either email or website

2=both email and website

Internationally Recognized Quality Certification (IRQC)

2006, 2010, 2017 (b8): Does establishment have an internationally recognized quality certification?

Yes=1, No=0

Multi-plant member

2006, 2010, 2017 (a7): Establishment is part of a large firm?

For Ecuador (_2006_2010_2017_a7)

Yes=1, No=0

Employees

2006, 2010, 2017 (l1): Permanent, full-time employees at end of last fiscal year

Sales

2006, 2010, 2017 (n3): What were the establishment sales three years ago?

Foreign

2006, 2010, 2017 (b2b): % owned by private foreign individuals, companies or organizations

If b2b <= 10%, foreign=0

Exports

2006, 2010, 2017 (d3c): % of Sales - Direct exports

Exports=1, if d3c > 0, 0 otherwise

Innovation cooperation

2010 (_2010_LACe9): Last 3 years - cooperate on innovation w/other enterprises/science & technology institutions?

Yes=1, No=0

Public support

2010 (_2010_LACe10): Last 3 years - receive any public support for innovation-related activities?

Yes=1, No=0

Production and enterprise profitability in Ecuador's crop-growing sector

Xavier Arboleda, Natalia Bermúdez-Barrezueta and Segundo Camino-Mogro

Abstract

This article analyses the key determinants of enterprise profitability in Ecuador's crop-growing sector in 2007–2017. It presents data showing that productivity has a positive effect on the profitability of the firms in the sector, which suggests that higher productivity confers a competitive advantage that is reflected in higher profit levels. In contrast, capital stock, land valuation, foreign direct investment, exports and firm age are variables that are negatively related to profitability. Lastly, per capita GDP growth boosts enterprise profitability by increasing the aggregate demand for food products, which stimulates the sector's performance.

Keywords

Agriculture, agro-industry, agricultural productivity, labour productivity, income, profit, economic analysis, Ecuador

JEL classification

L2, L73, J43, Q12, Q17

Authors

Xavier Arboleda is Institutional Coordinator of the Superintendency of Companies, Securities and Insurance of Ecuador. Email: marboledaq@supercias.gob.ec.

Natalia Bermúdez-Barrezueta is a PhD candidate in Economics at the Institute of Economic and Social Research of the Louvain Institute for Data Analysis and Modelling in Economics and Statistics (IRES/LIDAM) of the Catholic University of Louvain, and the Department of Economics of Ghent University. Email: natalia.bermudez@ugent.be.

Segundo Camino-Mogro is a Visiting Professor at Universidad Espíritu Santo del Ecuador. Email: scaminom@uees.edu.ec.

I. Introduction

The production structure in Latin America and many developing countries, has been based on development of the crop-growing sector, which has meant that they mainly export commodities. Authors such as Aghion and Durlauf (2005) and Restuccia, Yang and Zhu (2008) argue that most of the workers in these countries are employed in agriculture, and that the low productivity of labour in the sector affects nearly all labour productivity in the country. Lagakos and Waugh (2013) believe that understanding why productivity differences in some countries are so much larger in agriculture than in other sectors is the key to understanding global income inequality.

Throughout Ecuador's path to development, the most rapid growth periods were driven by strong external demand and high international prices that stimulated exports, mainly of commodities (Domínguez and Caria, 2016). The country has also been characterized as a producer and supplier of raw materials. Owing to the economic and trade liberalization of recent years, Ecuadoran products —mainly bananas, cocoa and flowers— have been traded internationally and have gained market share over time (Camino-Mogro, Andrade-Díaz and Pesantez-Villacis, 2016). However, several sectors have become less efficient and have lost international market share, which can lead to a loss of productivity impacting sector profitability.

An underexplored topic is the relationship between total factor productivity (TFP) and the profitability of the crop-growing sector. Foster, Haltiwanger and Syverson (2008) note that enterprise selection is based on profitability, rather than productivity (although the two are likely to be correlated), as productivity is only one of several idiosyncratic factors that can determine profitability. Accordingly, producer profits are a monotonically increasing function of productivity; and selection based on profits is equivalent to selection on productivity.

The aim of this paper is to analyse the key determinants of profitability in Ecuadoran firms in the crop-growing sector in 2007–2017, and to contribute new empirical data to the existing information, through: (i) the use of underexplored administrative data, which contain financial information on all firms in the Ecuador, provided by the Superintendency of Companies, Securities and Insurance; (ii) the distinction between traditional physical capital and land, since without the latter there would be no production; (iii) the analysis of TFP as a potential determinant of profitability, using a dynamic model that reduces potential endogeneity and simultaneity problems; and (iv) the analysis of different crop-growing subsectors, with the aim of demonstrating possible intra-sector heterogeneity.

II. Literature review

There are many studies that examine the relationship between agricultural development and a country's overall growth and development, including Syrquin (1988) and Foster and Rosenzweig (2007). Some authors, such as Mellor (2000) and Johnson (2000), highlight the importance of agricultural productivity growth for achieving national economic development, particularly because a more productive agriculture sector can produce more efficiently and meet local food demand, while also exporting, which generates a foreign exchange inflow.

According to Bustos, Caprettini and Ponticelli (2016), this result occurs when: (i) labour productivity in agriculture is lower than in other economic sectors (Lagakos and Waugh, 2013; Gollin, Lagakos and Waugh, 2014; İmrohoroğlu, İmrohoroğlu and Üngör, 2013); and (ii) the other sectors are characterized as economies at scale that demand a large amount of human capital, as they compete through learning-by-doing (Ngai and Pissarides, 2007).

1. Productivity and growth

It is well known that aggregate productivity is a determinant of economic growth. The conceptual framework of economic growth developed by Kendrick (1961), Solow (1957) and other pioneers in the study of the determinants of economic growth, establishes that aggregate output is a function of capital, labour and a given level of productivity, which is an important source of growth in an economy. Other authors, such as Scarpetta and others (2000), Fukao and others (2004), Mundlak, Butzer and Larson (2008) and Ivanic and Martin (2018), have analysed growth at the sector level and broken the sector growth rate into contributions made by the intermediate products used in the production process, along with capital, labour and productivity growth (Jorgenson, 1991).

Although the growth models were developed under the assumption of exogenous inputs, various authors have questioned this idea and have introduced an endogeneity criterion (Romer, 1994; Crafts, 1995; Bernanke and Gürkaynak, 2001), which means that input decisions can be influenced by output growth. Moreover, input growth may be accompanied by specialization strategies —research and development (R&D) and innovation— which affect the productivity of the factors involved in the production process (Ruttan, 2001; Nelson and Winter, 2009). Sahal (1981) studied the determinants of technological innovation in the particular case of the farm tractor, and concluded that farm size (scale hypothesis) and experience acquired in the production process (learning hypothesis) are important space and time factors driving technical progress. Vieira Filho and Fishlow (2017) analysed the agricultural modernization process in Brazil, based on two phases: the dissemination phase, which takes into account macroeconomic factors, and the technology adoption phase, related to absorption capacity and decisions made by firms in the sector. They concluded that technological dissemination increases productivity and lowers product prices. The authors also note that the technological intensification process can also reduce the cost of inputs such as land and labour.

Along the same lines, McArthur and McCord (2017) consider that the increased use of fertilizers and practices linked to the Green Revolution[1] is a way of increasing productivity in the sector; it tends to generate structural change, and it triggers forms of economic growth in countries with low productivity rates and a large proportion of unskilled labour in the crop-growing sector. They also obtained positive results in terms of increased labour productivity in non-agricultural sectors, as did McMillan and Rodrik (2011). In other words, these practices relocate the labour force, which makes it possible to increase labour productivity in other sectors and, hence, in the aggregate.

The determinants of growth and profitability of the firms that comprise the crop-growing sector has been an underexplored topic at the enterprise level, mainly because of poor data availability, since in most countries it is a sector with a large informal component. Zouaghi, Sánchez-García and Hirsch (2017) analysed the case of Spain and found that variables such as location, market structure, innovation activities, size and age of the firm are determinants of the profitability of enterprises in the crop-growing sector. On the other hand, Galarza and Díaz (2015), who studied the sector in Peru, found a positive relation between agribusiness productivity and the age, gender and education of the owners, while the relationship is negative with respect to the size and market power of the firm. Vieira Filho, Campos and Ferreira (2005) studied the crop-growing sector in Brazil and found that technological innovation, a determinant of productivity in the sector, increases with the size of agribusiness complexes and degree of market concentration.

In general, the factors that can influence the profitability of firms in the crop-growing sector has been little analysed in the current literature, so there is a clear need to create microeconomic knowledge in this area, in order to generate policies aimed at strengthening the sector, to make efficient use of natural resources and contribute to the country's economic growth and development.

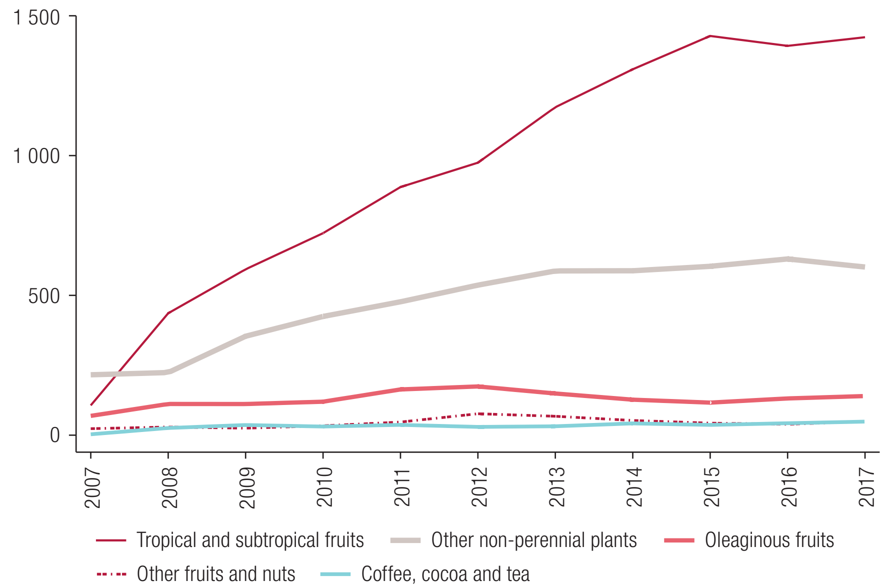
[1] This concept refers to productivity growth in the agriculture sector resulting from the use of more efficient techniques and practices.

III. Characteristics of the crop-growing sector in Ecuador

Agricultural policy has generated numerous lessons as a result of different approaches and public policy models aimed at reforming the agrarian structure implemented in the country. In the twenty-first century, the agriculture share of GDP declined relative to previous decades, reflecting less buoyancy than other sectors and a deterioration in the agricultural terms of trade relative to other industries in the economy. Nonetheless, the crop-growing sector is still of enormous economic and social importance, since it maintains production chains with major forward linkages, as in the case of the manufacturing sector through agribusiness, and backward linkages, as in the case of the transportation sector and other sectors that supply agricultural inputs.

Figure 1 illustrates the trend of sales revenue in the crop-growing subsectors that played the most important role in the Ecuadoran economy in 2007–2017. The tropical and subtropical fruit subsector (subsector A0122 of the International Standard Industrial Classification of All Economic Activities (ISIC)) accounts for 49% of the total annual revenues of the crop-growing sector in 2007–2017, according to data reported to the Superintendency of Companies, Securities and Insurance.[2] Eighty-one percent of the income generated by this subsector comes from the growing of bananas and plantains, 12% from mangoes and 6% from non-traditional fruits. Bananas and plantains account for an average of 42% of the income recorded in the crop-growing sector analysed in this study.

Figure 1
Ecuador: trend of sales revenue in the leading crop-growing subsectors, 2007–2017
(Millions of dollars)



Source: Prepared by the authors, on the basis of Superintendency of Companies, Securities and Insurance.

[2] In this study, the crop-growing sector refers to the following subsectors of the International Standard Industrial Classification of All Economic Activities (ISIC): Growing of non-perennial plants (A011), Growing of perennial plants (A012) and Plant propagation (A013).

The tropical and subtropical fruit-growing subsector has grown rapidly in revenue terms, expanding by an average of 20% per year in 2009–2014. However, its growth has slowed in recent years and, in 2017, it expanded by just 2%. The subsector with the highest growth rate is non-traditional fruits, at 42% per year. In 2016, revenues from the growing of non-traditional fruits —the product hit hardest within this subsector— fell by 36%.

The growing of non-perennial plants (A0119) is the second most dynamic subsector, accounting for an average of 27% of total agricultural revenue; the growing of flowers accounts for approximately 96% of this subsector (26% of the crop-growing sector as a whole). The flower growing subsector has posted annual growth averaging 12%, although in 2017 it actually shrank (-5%).

Crop exports have been one of Ecuador's main sources of income, despite it being a petroleum-producing economy. In 2004–2014, Ecuadoran exports mostly consisted of oil shipments to international markets. However, since 2014, the majority of export revenues have originated in the non-oil sector. This is explained partly by the fall in international crude oil prices, which has had a direct impact on the trade balance in oil.

Since 2014, non-oil products have represented an average of 61% of total annual exports. In 2018, 24% of non-oil exports were bananas, 7% natural flowers, 5% cocoa and 2% vegetable extracts and oils, according to figures reported by the Ministry of Production, Foreign Trade, Investments and Fisheries in 2019. Banana exports have seen sustained growth since 2016 (in which year they declined by 3% owing to the fall in commodity prices internationally), followed by positive growth rates of 11% and 5% in 2017 and 2018, respectively, evidencing the sector's slight recovery.

In the case of natural flowers, exports peaked in 2014 at US$918 million, but then fell back by 11% in 2015 and by a further 2% in 2016. In the following year, flower exports recovered with growth of 10%, before slipping again in 2018, by 3% relative to the previous year's level.

The commodity export matrix is thus driven by products such as bananas, cocoa, flowers and African palm, which play a key role in creating employment and generating non-oil income in the country. The boom in these products depends largely on the growth of demand in the international market and on efficient input use, which makes it possible to obtain quality products that are globally competitive.

IV. Methodology and data

1. Data

An unbalanced panel of data spanning 2007–2017 was used to estimate the production function of Ecuador's crop-growing sector and to determine the factors that affect the profitability of its constituent enterprises. The panel uses firm-level administrative data from financial statements reported to the Superintendency of Companies, Securities and Insurance, the entity tasked with supervising and controlling the formal business sector in Ecuador. On average, there were 1,015 active firms in the crop-growing sector each year, for which financial information is available for the entire period of analysis.

Table 1 describes each of the variables used to estimate the production function and then calculate total factor productivity (TFP).

Table 1
Definition of variables

Variable	Definition
Estimation of the production function	
Y	Total sales revenue: revenue obtained the firms' ordinary activities (excluding revenue from occasional activities, such as the sale of machinery and other fixed assets).
L	Number of workers
K	Capital stock: total net fixed assets. This is the sum of the real dollar value of buildings, machinery and vehicles, assuming depreciation rates of 5%, 10% and 20%, respectively, following Bravo-Ortega, Benavente and Gonzalez (2014).
M	Raw materials consumption: fuel expense + lubricant expense + transport expense + water and energy expense + raw material initial inventory expense + local purchase expense + raw material imports + maintenance and repair expense.
R	Land: book value of land assets in dollars as reported by the firm.
Estimation of the determinants of profitability	
Dependent variable	
ROA	Return on assets
Independent variables	
K	Capital stock
Terreno	Real dollar value of firms' land
HHI	Herfindahl-Hirschman Index
d.IED	Dummy variable that takes the value of 1 if the firm has foreign direct investment (FDI) and 0 otherwise, for each year of analysis.
PTF	Total factor productivity (TFP)
d.Exportación	Dummy variable that takes the value of 1 if the firm exports and 0 if the firm does not export any agricultural product for each year of analysis.
IPC Agri	Consumer price index (CPI) for goods in the crop-growing sector, obtained from the National Institute of Statistics and Censuses (INEC).
PIBpc	Per capita GDP growth rate
Antigüedad	Age of the firm

Source: Prepared by the authors, on the basis of C. Bravo-Ortega, J. Benavente and Á. González, "Innovation, exports, and productivity: learning and self-selection in Chile", *Emerging Markets Finance and Trade*, vol. 50, No. 1, Milton Park, Taylor & Francis, 2014.

Active firms engaging in activities related to the growing of non-perennial plants (A011), the growing of perennial plants (A012) and plant propagation (A013) of sector A of the International Standard Industrial Classification of All Economic Activities (ISIC) were selected.

Table 2 presents the descriptive statistics of the factors of production included in the function estimated to calculate TFP, such as sales revenue, net fixed assets (capital stock), consumption of raw materials,[3] the number of workers, and the number of observations analysed during the study period (2007–2017).

Table 2
Ecuador: descriptive statistics of the variables used to estimate the production function, 2007–2017
(Dollars and number of workers)

	N	Mean	Standard deviation	Min.	Max.	Percentile 25	Percentile 50	Percentile 75
Y	7 353	2 725 818.92	10 186 070.80	0.01	285 938 880.00	238 890.00	837 762.69	2 389 494.75
K	7 353	900 998.19	5 896 943.96	0.00	230 176 992.00	21 013.31	157 227.53	592 734.50
Terreno	7 353	684 700.57	3 675 217.29	0.00	94 305 513.90	0.00	84 169.93	445 482.97
L	7 125	108.00	407.00	1.00	13 679.00	5.00	23.00	96.00
M	7 353	941 763.96	4 737 022.31	4.46	185 246 112.00	26 665.63	151 013.52	618 447.69
N	7 353							

Source: Prepared by the authors.
Note: Y: sales revenue; K: capital stock; *Terreno*: value of the firms' land; L: number of workers; M: input expenses (including consumption of raw materials); N: number of observations between 2007 and 2017.

[3] This item includes fuel and electric energy expenses.

At the aggregate level, average income (Y) in 2007–2017 is US$ 2.7 million. The subsector with the highest (average) income during this period is the growing of tropical and subtropical fruits (A0122), in which 81% of income comes from the growing of bananas and plantains, 12% from mangoes and 6% from non-traditional fruits. Bananas and plantains account for an average of 42% of the income recorded in the crop-growing sector analysed in this study. The growing of non-perennial plants (A0119) ranks next and represents on average 27% of total income in the crop-growing sector, and the growing of flowers represents approximately 96% of this subsector (26% of the entire crop-growing sector).

In terms of employment, the number of workers (L) employed by firms in the crop-growing sector averaged 108 (a median of 23) during 2007–2017, although the number varies widely according to firm size.[4] Large firms report an average of 524 workers (a median of 321), compared to 103 (mean) and 89 (median) in medium-sized enterprises. In contrast, small and microenterprises in the sector report averages of 22 and seven workers, respectively.

The capital stock (K) reported by each firm in the crop-growing sector,[5] which has been approximated from the measurement of net fixed assets (having deducted cumulative depreciation and impairment by asset type), averages approximately US$ 900,000 (median US$ 157,000) in the 2007–2017 period. The average reported capital stock differs across subsectors. For example, the subsector with the highest level of capital is the growing of other tree and bushfruits and nuts (A0125), with each firm employing capital averaging US$ 11.5 million.[6] Another subsector with a high level of capital is the growing of oleaginous fruits (A0126), with average capital of US$ 3.4 million per firm in 2007–2017. Firms in the tropical and subtropical fruit growing (A022) and in the non-perennial plant growing sector (A019) report average capital of US$ 1.8 million and US$ 1.5 million per year, respectively.

Given the nature of the crop-growing sector and its intensive use of land as a factor of production, the analysis is performed by weighting this factor separately from the capital stock. In general, not all firms report this asset, since many of them choose to rent land from third parties, which is then considered as a production input. Expenses on inputs (M), which include raw materials consumption, average US$ 942,000 (median US$ 151,000) per firm in the crop-growing sector (A011, A012 and A013).

Table 3 details the factors used to analyse the determinants of corporate profitability in the sector, which include: ROA; capital stock (in natural logarithms); land value reported in dollars (in natural logarithms); TFP; the consumer price index (CPI) of products in the agriculture, livestock and fisheries sector, the age of the firm and the growth rate of per capita gross domestic product (GDP). In addition, descriptive statistics are included for the dummy variables included, such as FDI, exports and firm size.

Table 3
Ecuador: descriptive statistics of the variables used to estimate the determinants of profitability, 2007–2017

	N	Mean	Standard deviation	Min.	Max.	Percentile 25	Percentile 50	Percentile 75
ROA	7 347	0.156	3.585	0.000	234.790	0.000	0.018	0.067
K[a]	6 640	11.865	2.565	-13.393	19.254	10.679	12.249	13.453
Terreno[a]	4 928	12.254	1.967	3.595	18.362	11.307	12.534	13.468
d.IED	7 353	0.259	0.438	0.000	1.000	0.000	0.000	1.000
PTF	6 649	12.677	1.686	-5.175	17.985	11.786	12.870	13.768
d.Exportación	7 353	0.305	0.460	0.000	1.000	0.000	0.000	1.000
Antigüedad	7 353	12.639	11.241	0.000	78.000	4.000	10.000	18.000
IPC Agri	7 353	0.882	0.109	0.601	1.005	0.779	0.895	0.975
d.Microempresa	7 353	0.147	0.354	0.000	1.000	0.000	0.000	0.000

[4] Firm size is defined in the Organic Code of Production, Commerce and Investments of Ecuador.

[5] Does not include land, since this factor is analysed separately.

[6] This sector has a small number of enterprises and is highly concentrated. In 2017 there were approximately four firms.

Table 3 (concluded)

	N	Mean	Standard deviation	Min.	Max.	Percentile 25	Percentile 50	Percentile 75
d.Pequeña	7 353	0.395	0.489	0.000	1.000	0.000	0.000	1.000
d.Mediana	7 353	0.342	0.475	0.000	1.000	0.000	0.000	1.000
d.Grande	7 353	0.115	0.320	0.000	1.000	0.000	0.000	0.000
*Δ*PIBpc[b]	5 933	0.015	0.027	-0.027	0.061	-0.012	0.016	0.033
HHI	7 353	205.747	34.327	165.572	309.611	179.186	200.689	226.149
d.Exportación x d.IED	7 353	0.126	0.331	0.000	1.000	0.000	0.000	0.000
N	7 353							

Source: Prepared by the authors.

Note: ROA: return on assets; K: capital stock; *Terreno*: real value of firms' land in dollars; d.IED: dummy variable (1 if the firm has FDI and 0 otherwise); PTF: total factor productivity; d.Exportación: dummy variable (1 if the firm exports and 0 otherwise); Antigüedad: age of the firm; IPC Agri: consumer price index for goods in the crop-growing sector; d.Microempresa: indicator variable for firms belonging to the microenterprise group; d.Pequeña: indicator variable for firms belonging to the small enterprise group; d.Mediana: indicator variable for firms belonging to the medium-sized enterprise group; d.Grande; indicator variable for firms belonging to the large enterprise group; Δ PIBpc: per capital GDP growth rate; HHI: Herfindahl-Hirschman index; and N: number of observations between 2007 and 2017.

[a] Variables expressed in logarithms.

[b] PIBpc expressed as a logarithm.

The return on assets, which is used as an indicator of enterprise profitability in this analysis, reports a mean of 0.16 in the case of firms in the crop-growing sector and a median of 0.02. This reveals wide dispersion between sectors, as illustrated figure A1.2A of the annex, which shows the trend of ROA in the most profitable subsectors.[7] According to the information provided by the Superintendency of Companies, Securities and Insurance, the growing of other tree and bush fruits and nuts is the most profitable sector, with an average median return on assets of 0.09 in 2007–2017; and it also displays the highest productivity levels. Nonetheless, the subsector is highly concentrated, with an average of just two firms per year in 2007–2017. The second most profitable subsector is the growing of tropical and subtropical fruits, with a median ROA of 0.02 (mean 0.29), followed by the growing of oleaginous fruits, with a median ROA of 0.01 (mean 0.05).

(a) Empirical strategy

Seminal studies of the transition from macro to micro growth models, focusing especially on the agriculture sector, include Tintner (1944), Mundlak (1961), Heady and Dillon (1961) and Griliches and Mairesse (1995). These studies motivate the analysis of technological change as a component of the production function used to determine productivity.

To estimate the production function and then calculate TFP in the crop-growing sector, this study initially uses the traditional Cobb-Douglas production function model, on which the seminal studies of economic growth by Solow (1957), Denison (1967) and Romer (1986) are based. According to this traditional model, production is determined by intermediate goods, capital inputs, land and labour, controlling for the time factor and subsector (to reduce the possible macroeconomic and industrial shocks generated by the heterogeneity of firms), as expressed in the following equation:

$$Y_{it} = A_{it} F\left(X_{it}\right) \quad (1)$$

where Y_{it} is the sales revenue of each firm i in period t; X_{it} is a vector of factors containing K_{it} (which represents the real capital stock, approximated through net fixed assets excluding the value of land),

[7] ISIC sectors: Growing of other tree and bush fruits and nuts (A0125), Growing of other non-perennial plants (A0119), Growing of tropical and subtropical fruits (A0122), Growing of oleaginous fruits (A0126) and Growing of beverage crops (coffee, cocoa and tea) (A0127).

L_{it} is the number of workers reported by each firm in the crop-growing sector, and M_{it} is the amount of intermediate inputs (or raw materials) used in the production process. In addition, R_{it} is the value reported by the firm for land as a factor of production, given the nature of the crop-growing sector; and A_{it} is Hicks-neutral technical change, which is used as a measure of productivity. Among the controls, time dummy variables are included to capture and control for possible macroeconomic shocks in each of the years and controls for subsector, which are firm-specific characteristics that can vary over time.

Along these lines, the production function chosen to estimate TFP is of the Cobb-Douglas type, because it makes it easy to separate growth into contributions by the different factors of production, by taking advantage of the efficiency gains obtained by using these factors, as with the data provided in Gonçalves and Martins (2016), Syverson (2011), Van Beveren (2012) and Van Biesebroeck (2007). However, when controlling for time and the subsectors to which the agribusinesses belong, the returns to scale of the determinants were found to be decreasing, contrary to the results obtained when using the Cobb-Douglas type production function, in which returns to scale are constant. To some degree this responds to Gechert and others (2019), who warn of this problem when using this convenient simplification. However, the estimation advantages offered by this function for obtaining levels of return and input elasticities, mean it continues to be widely used in both theoretical and empirical growth studies.

In addition, land (R_{it}) is added as another fixed factor of production, as in Yutopoulos and Lau (1974) and Dias and Evenson (2010), to give:

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{\beta} R_{it}^{\tau} M_{it}^{\gamma} \quad (2)$$

Equation (2) is then expressed in logarithmic form, and the elasticities of the observable productive inputs with respect to sales revenue are obtained as follows.

$$\begin{aligned} y_{it} &= \beta_0 + \alpha k_{it} + \tau r_{it} + \beta l_{it} + \gamma m_{it} + \varepsilon_{it} \\ a_{it} &= \beta_0 + \varepsilon_{it} \\ \varepsilon_{it} &= \mu_{it} + \upsilon_{it} \end{aligned} \quad (3)$$

In the above, a_{it} represents TFP, which decomposes into β_0 representing the average efficiency level of firms over time, and ε_{it} , which corresponds to the time- and firm-specific deviation from its mean. The latter term (ε_{it}) has two independent and identically distributed idiosyncratic error components: μ_{it} and υ_{it}. Of these, μ_{it} represents unobservable heterogeneity; in other words, it captures productivity that is not observed by analysts, but is observed by firms in the crop-growing sector, since it affects their inputs; while the υ_{it} term is a random error that is uncorrelated with the inputs used to produce a good. Thus, equation (3) can be rewritten as follows:

$$y_{it} = \beta_0 + \mu_{it} + \alpha k_{it} + \tau r_{it} + \beta l_{it} + \gamma m_{it} + \upsilon_{it} \quad (4)$$

Equation (4) is used to estimate the production function of the Ecuadoran crop-growing sector, as well as those of the two subsectors with the highest levels of sales revenue and profits, namely tropical and subtropical fruits and non-perennial crops. Total factor productivity is then calculated using the elasticities estimated for each production input through the following equation:

$$\hat{a}_{it} = y_{it} - \hat{\alpha} k_{it} - \hat{\tau} r_{it} - \hat{\beta} l_{it} - \hat{\gamma} m_{it} \quad (5)$$

Equation (4), which contains the proposed crop-growing sector production function, is estimated through the generalized method of moments (GMM) proposed by Blundell and Bond (1998), in the style of Bournakis and Mallick (2018), since it deals with the problem of simultaneity bias and random measurement error bias in both the inputs and outputs of the function (Griliches and Mairesse, 1995; Van Biesebroeck, 2007; Bournakis and Mallick, 2018). This distinguishes it from the ordinary least squares (OLS) method, which causes biases in the estimators, overestimating the input coefficients of (endogeneity of inputs), underestimating the coefficient of capital (endogeneity of wear and tear) (Olley and Pakes, 1996) and causing biases related to the heterogeneity of technology inputs used by firms in production (De Loecker, 2007).

Using the OLS method with standard errors clustered by firm,[8] profitability, proxied by ROA, is modelled as a function of factors both internal and external to the firm, such as TFP, capital value, land value, firm age, crop-growing sector CPI, the Herfindahl-Hirschman index, whether or not it is an exporting firm, and whether it has any foreign direct investment in its capital structure. Whether the interaction between FDI and exports in any way influences the profitability of firms in the crop-growing sector is also analysed. Furthermore, it is estimated through fixed effects, without incorporating the fixed effect of time, since the aim is to evaluate variables such as per capita GDP, which fluctuate over time but are constant across firms.

The dependent variable with a one-period lag is also included among the independent variables, because profitability has a dynamic component; in other words, it is posited that previous years' profitability affects the firm's future performance. This is then estimated through the generalized method of moments, incorporating the lagged ROA, which captures the dynamic effect in the process of determining profitability, dealing with serial autocorrelation.

The final specification is as follows:

$$\begin{aligned} ROA_{it} = \beta_0 + \beta_1 ROA_{i,t-1} + \beta_2 Ln(K)_{it} + \beta_3 Ln(Terreno)_{it} + \beta_4 HHI_t + \beta_5 PTF_{it} \\ + \beta_6 Antigüedad_{it} + \beta_7 IPC_t + \beta_8 \Delta PIBpc_t + \beta_9 d.IED_{it} + \beta_{10} d.Exportación_{it} \\ + \beta_{11} d.IED * d.Exportación + Tamaño_{it} + Subsector_i + \mu_{it} \end{aligned} \quad (6)$$

with variables defined as follows: K is the capital stock, $Terreno$ is the value invested in land by firm I; HHI is the Herfindahl-Hirschman index, which captures the market concentration of the crop-growing sector each year; PTF is enterprise total factor productivity calculated previously through the production function, and $Antigüedad$ is the length of time the firm has been operating at the cut-off point in each year. In addition, the group of macroeconomic factors includes the variable $\Delta PIBpc_t$, which is the growth rate of per capita GDP, and IPC, which is the consumer price index of products in ISIC sector A. The dummy variables, $Exportación$ and IED, control for the existence of firms that export or whose capital structure includes some type of FDI, reepectively. In addition, controls were introduced for size and subsector.

V. Results

According to the characteristics of the productivity model specified above, table 4 reports the coefficients obtained for each of the inputs of the Cobb-Douglas type production function, as estimated through two methods: pooled OLS with a lagged dependent variable, and GMM.

The pooled OLS model overestimates the coefficient of the lagged dependent variable (that is, it maintains an upward bias (Angrist and Pischke, 2009)), while GMM is more consistent, because it corrects the simultaneity problem and minimizes the endogeneity effect among the inputs used by the firm (Arellano and Bond, 1991). Thus, the coefficient of the first lag of the dependent variable obtained through GMM is below that recorded in the OLS model, as can be seen in table 4.

[8] The results obtained using the OLS method with clustered standard errors can be provided upon request to persons wishing to consult them.

Table 4

Ecuador: estimation of the crop-growing sector production function, 2007–2017

y_{it}	Ordinary least squares (OLS))		Generalized method of moments (GMM)	
	(1)	(2)	(3)	(4)
y_{it-1}	0.7566***	0.7569***	0.6802***	0.6966***
	(0.0426)	(0.0448)	(0.0308)	(0.0397)
k_{it}	0.0337***	0.0347***	0.0259***	0.0271***
	(0.0119)	(0.0118)	(0.0089)	(0.0087)
r_{it}	0.0237**	0.0277**	0.0109	0.0151**
	(0.0112)	(0.0110)	(0.0068)	(0.0074)
l_{it}	0.0612***	0.0630***	0.0238**	0.0221**
	(0.0111)	(0.0111)	(0.0101)	(0.0096)
m_{it}	0.1168***	0.1095***	0.0557***	0.0416***
	(0.0130)	(0.0121)	(0.0079)	(0.0074)
Control for years	Yes	Yes	Yes	Yes
Control for sector	No	Yes	No	Yes
AR(1)[a]	-	-	0.0000	0.0000
AR(2)[a]	-	-	0.2756	0.2237
AR(3)[a]	-	-	0.4455	0.1552
CRS test[b] (F-stat)	898***	964***	2 373***	2 884***
R^2	0.9280	0.9314	-	-
Sargan test[a]	-	-	0.2150	0.1863
Instruments	-	-	139	139
Observations	3 096	2 964	3 096	2 964

Source: Prepared by the authors.

Note: Standard errors clustered by company in parentheses. * $p<0.1$; ** $p<0.05$; *** $p<0.01$. y_{it}: log sales revenue; k_{it}: log capital stock; r_{it}: log real dollar value of firms' land; l_{it}: log number of workers; m_{it}: log input expenditures (including raw material consumption); AR: autoregressive test.

[a] The *p*-value of the first-, second- and third-order autocorrelation tests, as well as the Sargan test, which are required in GMM, are reported. The instruments used in the generalized method of moments are the lagged differences of the variables *K*, *L*, *M* and *Terreno* (Land) at *t-1* and *t-2*.

[b] Test of constant returns to scale.

It should be noted that the consistency of the GMM model depends on the validity of the instruments created by the model, based on the lag of the explanatory variables (Fariñas, López and Martín-Marcos, 2014). To test the validity of the model, the Arellano-Bond estimator is reported, which measures three autoregressive (AR) processes,[9] in order to test for serial non-correlation with the inputs in at least the second autoregressive process AR(2).[10] In addition, the Sargan test is performed, which demonstrates the null hypothesis that all the overidentification restrictions are valid in the model, provided the error term is independent and identically distributed. That is, this test verifies the validity of the instruments generated in the analysis (Cameron and Trivedi, 2010).

Along these lines, when analysing the GMM, which is the model that best addresses the identification problems that are present, several results are obtained with respect to the elasticities of inputs in the sector. It is important to note that the production function of the crop-growing sector does not exhibit constant returns to scale. In other words, an increase in inputs does not imply an equi-proportional increase in output. Specifically, there is evidence of decreasing returns to scale, since the sum of the coefficients is significant and statistically less than 1, which indicates that a given variation in inputs produces a less than proportional variation in output.[11] This finding is closely related to the results obtained by Galarza and Díaz (2015) in the case of the Peruvian crop-growing sector.

[9] To simplify the content, table 4 only includes the results of the AR(1) and AR(2) autoregression tests. However, the null hypothesis of AR(3) is not rejected in any of the cases, as happens with AR(2).

[10] The null hypothesis is the absence of serial autocorrelation.

[11] Using lincom in Stata.

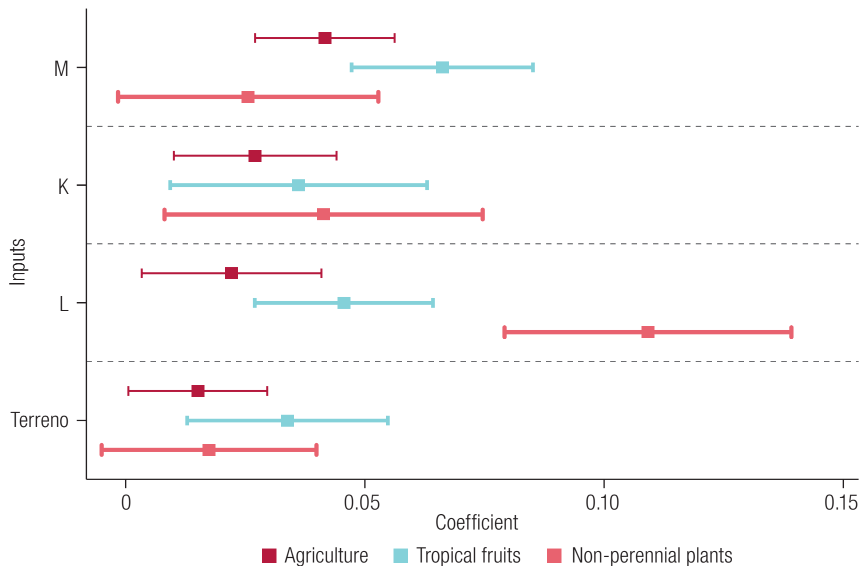
First, it is noted that the factor with the highest elasticity is M, which includes expenditures on inputs or raw materials. This is followed by K, with an elasticity of 0.03. Moreover, the results show that increase in the labour factor (number of employees) causes an increase in income. Lastly, $Terreno$ (Land) is the factor with the lowest elasticity (0.015), both in the overall sector average and in the two subsectors analysed.

The results differ when analysing the production function by subsector. Owing to their heterogeneity, the different agricultural subsectors have different patterns of input use that can depend on the degree of specialty of each subsector.

For example, the tropical and subtropical fruit growing subsector is intensive in raw materials use, which causes its results to be similar to those obtained for the crop-growing sector as a whole; however, the intensity of use of the other factors (K, L and $Terreno$) is above the average at the aggregate level.

In contrast, the perennial plant growing sector is, in general, more labour- and capital-intensive, but less intensive in the use of raw materials. In this subsector, land displays an elasticity similar to the average of the crop-growing sector as a whole. However, the coefficient in question is not significant, which indicates that this factor does not influence revenue generation in the sector. These results are shown in figure 2 and table 5.

Figure 2
Ecuador: estimated coefficients of the production function by subsectors of the crop-growing sector, 2007–2017



Source: Prepared by the authors.
Note: M: input costs (including consumption of raw materials); K: capital stock; L: number of workers; *Terreno*: real dollar value of land owned by the firms.

Table 5
Ecuador: estimation of the production function by subsectors of the crop-growing sector, 2007–2017

y_{it}	(1) Agriculture*	(2) Tropical fruits	(3) Non-perennial plants
y_{it-1}	0.697***	0.598***	0.780***
	(0.035)	(0.038)	(0.038)
k_{it}	0.027**	0.036***	0.041**
	(0.009)	(0.014)	(0.017)
r_{it}	0.015**	0.034***	0.017
	(0.007)	(0.011)	(0.011)
m_{it}	0.042***	0.066***	0.026*
	(0.007)	(0.010)	(0.014)
l_{it}	0.022**	0.046***	0.109***
	(0.010)	(0.010)	(0.015)
Controls[a]	Yes	Yes	Yes
Sargan test[b] [*p* value]	0.260	0.259	0.869
AR(1)[b] [*p* value]	0.000	0.000	0.003
AR(2)[b] [*p* value]	0.183	0.636	0.475
CRS test[c] (F-stat)	2 884***	1 488***	1 168***
Instruments	139	104	75
Observations	2 964	1 576	634

Source: Prepared by the authors.
Note: Standard errors clustered by company in parentheses. * p<0.1; ** p<0.05; *** p<0.01. y_{it}: log sales revenue; k_{it}: log capital stock; r_{it}: log real dollar value of firms' land; l_{it}: log number of workers; m_{it}: log input expenditures (including raw material consumption); AR: autoregressive test.
[a] Time and subsector controls from the six-digit International Standard Industrial Classification of All Economic Activities (ISIC) were included.
[b] Estimate for the entire crop-growing sector analysed, which includes ISIC subsectors A011, A012 and A013. The p-value of the first, second and third order autocorrelation tests, as well as the Sargan test, which are required in the generalized method of moments, are reported. The instruments used in the generalized method of moments are the lags of the differences of *K*, *L*, *M* and *Terreno* at *t-1* and *t-2*.
[c] Test of constant returns to scale.

Having obtained estimators for the inputs of the production function for the crop-growing sector described above, using GMM, total factor productivity was calculated using equation (5). This indicator is included as part of the determinants of profitability, the results of which are shown in table 6.

Table 6
Ecuador: analysis of the determinants of the return on assets among agribusinesses, 2007–2017

	Fixed effects			Generalized method of moments	
	(1)	(2)	(3)	(4)	(5)
L.ROA				0.2340***	0.2312***
				(0.0156)	(0.0165)
k	-0.0052**	-0.0051**	-0.0049**	-0.0024*	-0.0034*
	(0.0020)	(0.0020)	(0.0021)	(0.0015)	(0.0019)
r	-0.0075***	-0.0076***	-0.0069***	-0.0178***	-0.0188***
	(0.0022)	(0.0021)	(0.0021)	(0.0019)	(0.0021)
HHI	0.0003	0.0003	0.0002	-0.0001***	-0.0001**
	(0.0006)	(0.0006)	(0.0006)	(0.0000)	(0.0000)
d.IED	0.0016	0.0012	0.0003	-0.0146*	-0.0247***
	(0.0045)	(0.0046)	(0.0045)	(0.0083)	(0.0093)
PTF	0.0172***	0.0173***	0.0173***	0.0060*	0.0088**
	(0.0029)	(0.0035)	(0.0037)	(0.0036)	(0.0043)
d.Exportación	-0.0146***	-0.0151***	-0.0150***	-0.0218***	-0.0180***
	(0.0038)	(0.0038)	(0.0039)	(0.0044)	(0.0051)

Table 6 (concluded)

	Fixed effects			Generalized method of moments	
	(1)	(2)	(3)	(4)	(5)
Antigüedad	-0.0072	-0.0069	-0.0063	-0.0006***	-0.0007***
	(0.0100)	(0.0100)	(0.0103)	(0.0002)	(0.0002)
IPC Agri	0.4557	0.4299	0.3744	-0.0562	-0.0141
	(0.6338)	(0.6341)	(0.6545)	(0.0378)	(0.0399)
ΔPIBpc	0.1179	0.1103	0.1238	0.0908***	0.0916***
	(0.1099)	(0.1086)	(0.1117)	(0.0213)	(0.0216)
d.Exportación x d.IED	0.0052	0.0058	0.0047	0.0173***	0.0155**
	(0.0047)	(0.0048)	(0.0050)	(0.0057)	(0.0068)
Constant	-0.4057	-0.3760	-0.3285	0.1357***	0.4150***
	(0.5488)	(0.5524)	(0.5740)	(0.0368)	(0.1192)
Years	Yes	Yes	Yes	No	No
Size	No	Yes	Yes	Yes	Yes
Subsectors	No	No	Yes	No	Yes
Sargan [test *p*-value]	-	-	-	[0.0425]	[0.1564]
AR(1) [*p*-value]	-	-	-	[0.0000]	[0.0000]
AR(2) [*p*-value]	-	-	-	[0.9570]	[0.9551]
Instruments	-	-	-	193.0000	193.0000
Observations	3 921	3 921	3 754	3 595	3 443

Source: Prepared by the authors.

Note: Standard errors clustered by firm in parentheses. * $p<0.1$; ** $p<0.05$; *** $p<0.01$. L.ROA: return on assets in a previous period; k: capital stock in logarithms; r: real dollar value of firms' land in logarithms; HHI: Herfindahl-Hirschman index; $d.IED$: dummy variable (1 if the firm has foreign direct investment but 0 otherwise); PTF total factor productivity; $d.Exportación$: dummy variable (1 if the firm exports but 0 otherwise); $Antigüedad$: age of the firm; $IPC\ Agri$: consumer price index for agricultural goods; $\Delta PIBpc$: per capita GDP growth rate; AR: autoregression test.

Using ordinary least squares with clustered standard errors and fixed effects, results were obtained for equations (6) and (7), which analyse the different domestic, sectoral and macroeconomic factors that affect the profitability of enterprises in the crop-growing sector, as measured through ROA. In addition, to capture the dynamic component of profitability, the first order lag (t-1) is included in the specification, with estimation through GMM, and the results are compared. Table 6 shows the coefficients obtained for each of the variables analysed in the two different models, with standard errors that are robust to inter-firm heteroscedasticity.

First, incorporating the lag shows that this is a significant component in determining profitability. On average, improvement in the previous year's profitability has a positive influence on profitability in the current year, as shown in models (4) and (5).

Second, when analysing how the specific characteristics of agribusinesses affect their profitability, a negative and significant effect was obtained in the case of capital stock. This indicates that higher levels of capital, which include net fixed assets, are associated with negative returns, albeit weakly.

In other words, it can be inferred that investments in machinery as an asset are not generating positive returns in the agribusiness sector, so public policies that encourage farmers to use efficient technologies in the sector should be implemented. This result is consistent with the asset fixity theory, which claims that, in the crop-growing sector, periods of disinvestment or capital depreciation last longer than those of investment (Nelson, Braden and Roh, 1989), since it is difficult to dispose of capital that is specific to agricultural production and to transition to new technologies. In this connection, Rosenzweig and Binswanger (1993) note that agribusiness owners are generally risk-averse and only decide to invest in machinery when there are higher returns.

Land also has a negative and significant effect on the profitability of firms in the crop-growing sector, which is another indication that capital in the form of land is not being used most efficiently in the sector. It is worth noting that, although this effect is not very strong, it is greater than in the case of net fixed assets (K). Another hypothesis is that each unit of land is not profitable in terms of costs for the agricultural entrepreneur, since the acquisition of an additional unit of land does not generate positive returns, which may be related to the cost assumed by the producer.

The potential effect of foreign capital on profitability in the crop-growing sector is also analysed, and it is found that, in general, firms that have some form of FDI in their capital report lower levels of profitability in the short term, while there is no conclusive evidence of its effects in the long term. It could thus be inferred that firms in the crop-growing sector, on average, do not channel FDI (acquisition of capital goods, including land) appropriately; but that investment could be targeted towards movable working capital in the short term. This idea supports the hypothesis of the low technical level of agribusinesses in Ecuador, since investment in machinery that generates enterprise profitability is not taking place.

The impact on profitability of exporting was also analysed, and it was concluded that, on average, firms that export are 1.8% less profitable than those that do not. This result can be justified theoretically in terms of the sunk costs of entering international markets (for example, adjustments in quality requirements or logistical costs), whereby exporting firms initially incur unrecoverable fixed costs that may undermine the firm's profitability in the short run (Roberts and Tybout, 1997).

The simultaneous effect of being an exporting firm and the presence of FDI in the firm's capital structure reports a positive and significant effect on corporate profitability in the sector. In other words, firms that export and also have some type of foreign capital in their capital are 1.5% more profitable than those that do not satisfy these two conditions together. Abor and Adjasi (2008) analyse how FDI can influence the development of exports by a local firm, since it promotes technology transfer, which facilitates access to new international markets and improves the competitiveness of products with respect to the rest of the world. However, it could also be inferred that, by maintaining links with the international market, exporting firms are more attractive to investors, since they have a certain advantage in terms of generating income in the crop-growing sector, by operating in a larger market with more demanding quality standards.

Enterprise productivity also has a positive and significant effect on the profitability of firms in the crop-growing sector. On average, each 1% increase in productivity translates into a 0.01% increase in financial profitability. This result, as concluded in Stierwald (2009), seems to indicate that firms with higher productivity levels have a superior competitive advantage that is reflected in higher profits.

Lastly, firm age has a slight negative impact on corporate profitability in the sector: for each additional year that a firm has been operating, profitability decreases by 0.1%. This result is consistent with the empirical data found in previous work. Majumdar (1997), for example, concludes that the oldest firms in India have the lowest profitability rates, despite being the most productive, because they have not been able to adapt to the competitive business culture, in which the concept of satisfying consumer needs is becoming increasingly important. Other authors, such as Glancey (1998), Tan (2003), Fok, Chang and Lee (2004), Loderer and Waelchli (2010), and Coad, Segrar and Teruel (2013) also report results that are compatible with these conclusions.

In the case of market structure, it was found that greater concentration of the crop-growing sector has a negative impact on average corporate profitability, although the magnitude of this effect is small compared to the determinants analysed previously. It is therefore of little relevance to conclude that concentration really does negatively affect the profitability of firms in the sector, contrary to what has traditionally been proposed by Bain (1951) and Peltzman (1977), who defend the structure-conduct-performance hypothesis. From the result obtained, it would clearly be interesting to perform a more detailed analysis of the relationship between concentration and profitability at the subsector level, in the case of the firms in this segment, since the products involved are not very homogeneous. However, this is not the main aim of this paper.

As for external factors that could affect profitability in the crop-growing sector, the per capita GDP growth rate and the consumer price index for agricultural products were included. The results obtained show that increases in per capita GDP boost the profitability of agribusinesses by increasing the aggregate demand for food products, which stimulates the sector's performance. On the other hand, there is no significant evidence that the price index of agricultural products affects the profitability of agribusinesses.

VI. Conclusions and public-policy proposals

This paper analyses the key determinants of the profitability of Ecuadoran enterprises in the crop-growing sector between 2007 and 2017, using an administrative database covering all formally constituted firms in the sector provided by the country's business regulation and supervision agency. In addition, the two largest agricultural subsectors are studied, namely "Growing of tropical and subtropical fruits" (A0122) and "Growing of non-perennial plants" (A0119).

To obtain the main determinants of profitability, a traditional Cobb-Douglas type production function was estimated; and it was found that the crop-growing sector as a whole is intensive in the use of raw materials. It was also found to have, not constant but, decreasing returns to scale. On the other hand, the results by subsector are different in the use of inputs, since the tropical and subtropical fruit growing subsector uses raw materials intensively, as does the crop-growing sector as a whole, while the perennial plant growing sector is more labour- and capital-intensive, which demonstrates intra-sector heterogeneity in the use of traditional inputs in the production processes of agribusinesses.

It is also found that TFP has a positive effect on the profitability of firms in the sector, which seems to indicate that firms with higher levels of productivity have a greater competitive advantage that is reflected in higher profits. However, capital stock, land, FDI, exports and firm age are negatively related to profitability.

In terms of industrial and macroeconomic determinants, there is evidence that industry concentration reduces average enterprise profitability. On the other hand, per capita GDP growth boosts agribusiness profitability by increasing the aggregate demand for food products, which stimulates sector performance.

The results obtained suggest certain public policy recommendations, since capital stock and exports do not affect the profitability of agribusinesses positively in the short term. Policy-makers should promote the use of efficient technologies in the sector by providing incentives for farmers; or else provide financial credits that allow them to replenish capital more quickly, and, at the same time, serve as a more efficient technical upgrading of the sector to enhance financial returns.

On the export side, the process of internationalizing the products of agribusinesses should be monitored closely. It would need to be coordinated with the technical upgrading process, to ensure that the final product is of high quality and can be launched on the international market. It is worth noting that incentives should be applied equitably so as not to aggravate distortions in the market, but foster egalitarian development in the crop-growing sector.

Public policies to promote the technical upgrading of agribusinesses in Ecuador would make it possible to improve production yields, since having a crop-growing sector with diminishing returns to scale does not foster development or economic growth, especially in an agro-exporting country.

These proposals are consistent with the effect of simultaneously exporting and having of FDI in the firm's capital, since this increases profitability by promoting technology transfer, which facilitates access to new international markets and enhances the global competitiveness of its products.

Lastly, this study suggests future debates not only on enterprise profitability, but also on productivity and the heterogeneity of enterprises in this sector. The topic is therefore open to further research, whether from a methodological or from an economic development standpoint.

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Annex A1

Table A1.1
Ecuador: correlation matrix of the determinants of profitability in the crop-growing sector, 2007–2017

	ROA	k	r	HHI	d.IED	PTF	d.Exportación	Antigüedad	IPC Agri	$\Delta PIBpc$
ROA	1									
k	-0.121***	1								
r	-0.200***	0.326***	1							
HHI	0.0259**	-0.0217	-0.229***	1						
d.IED	-0.0146	0.149***	0.211***	0.0342***	1					
PTF	0.0164	0.512***	0.343***	-0.0217	0.182***	1				
d.Exportación	-0.0145	0.260***	0.119***	0.0340***	0.218***	0.346***	1			
Antigüedad	-0.0257**	0.0817***	0.0299*	-0.0124	0.146***	0.186***	0.111***	1		
IPC Agri	-0.0346***	0.0150	0.300***	-0.765***	-0.0447***	0.0223	-0.0561***	0.0216*	1	
$\Delta PIBpc$	-0.0150	0.00349	-0.0691***	0.454***	0.0139	-0.0120	0.0101	-0.0302**	-0.491***	1

Source: Prepared by the authors, on the basis of Superintendency of Companies, Securities and Insurance.

Note: Table of Pearson correlation coefficients. * $p<0.1$; ** $p<0.05$; *** $p<0.01$. ROA: return on assets; k: capital stock in logarithm; r: real dollar value of firms' land in logarithm; HHI: Herfindahl-Hirschman index; $d.IED$: dummy variable (1 if the firm has foreign direct investment and 0 otherwise); PTF: total factor productivity; $d.\ Exportación$: dummy variable (1 if the firm exports and 0 otherwise); $Antigüedad$: age of the firm; $IPC\ Agri$: consumer price index for goods in the crop-growing sector; $\Delta PIBpc$: GDP per capita growth rate.

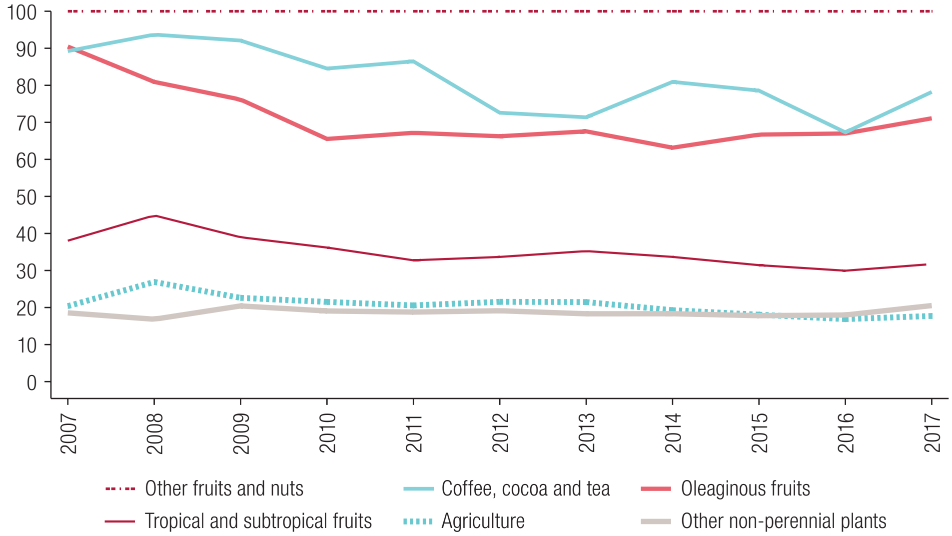
Table A1.2
Ecuador: descriptive statistics of variables used to estimate the production function by year, 2007–2017

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Y	13.53	13.43	13.59	13.57	13.62	13.51	13.62	13.67	13.62	13.54	13.63	13.58
	(1.523)	(1.678)	(1.667)	(1.812)	(1.743)	(1.873)	(1.829)	(1.789)	(1.843)	(1.940)	(1.883)	(1.811)
K	12.39	12.18	12.64	12.56	12.61	12.65	12.72	12.79	12.76	12.74	12.81	12.66
	(2.151)	(2.531)	(2.052)	(2.100)	(2.274)	(2.093)	(2.018)	(2.051)	(2.186)	(2.299)	(2.181)	(2.176)
L	3.371	2.988	3.219	3.416	3.505	3.229	3.202	3.191	3.183	3.148	3.313	3.248
	(1.711)	(1.870)	(1.911)	(1.833)	(1.826)	(1.807)	(1.805)	(1.793)	(1.782)	(1.776)	(1.635)	(1.796)
M	12.15	12.10	12.24	12.26	12.13	11.86	11.82	11.85	11.20	11.11	11.80	11.79
	(2.048)	(2.076)	(2.080)	(1.966)	(2.297)	(2.545)	(2.586)	(2.314)	(2.369)	(2.391)	(2.470)	(2.366)
N	250	413	582	634	709	735	759	760	834	872	805	7 353

Source: Prepared by the authors, on the basis of Superintendency of Companies, Securities and Insurance.

Note: Y: sales revenue; K: capital stock; L: number of employees; M: input costs (including raw material consumption).

Figure A1.1
Ecuador: market concentration in the crop-growing sector measured by the CR4 concentration ratio
(Percentages)



Source: Prepared by the authors, on the basis of Superintendency of Companies, Securities and Insurance.

Figure A1.2
Ecuador: main indicators of the agribusiness sector, 2007–2017

A. Return on assets

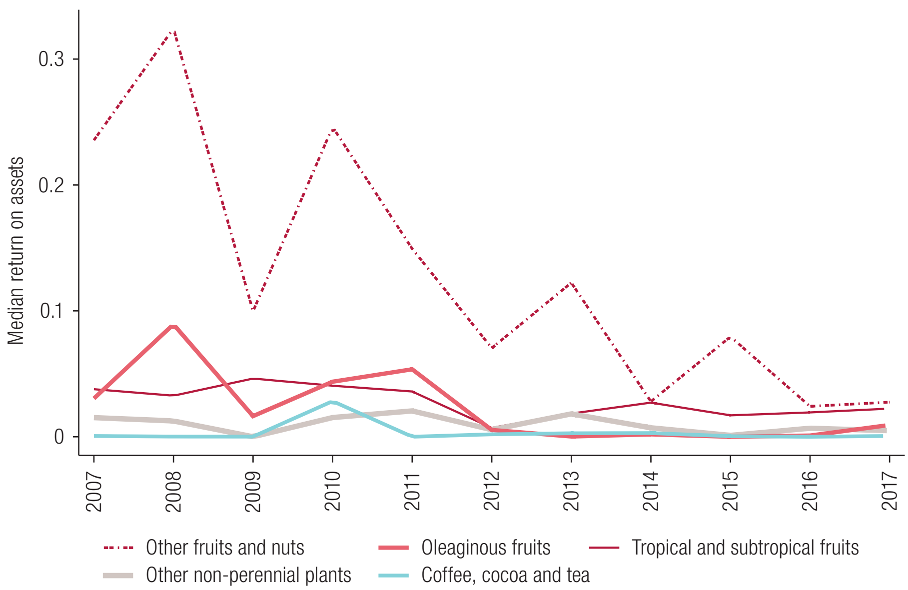
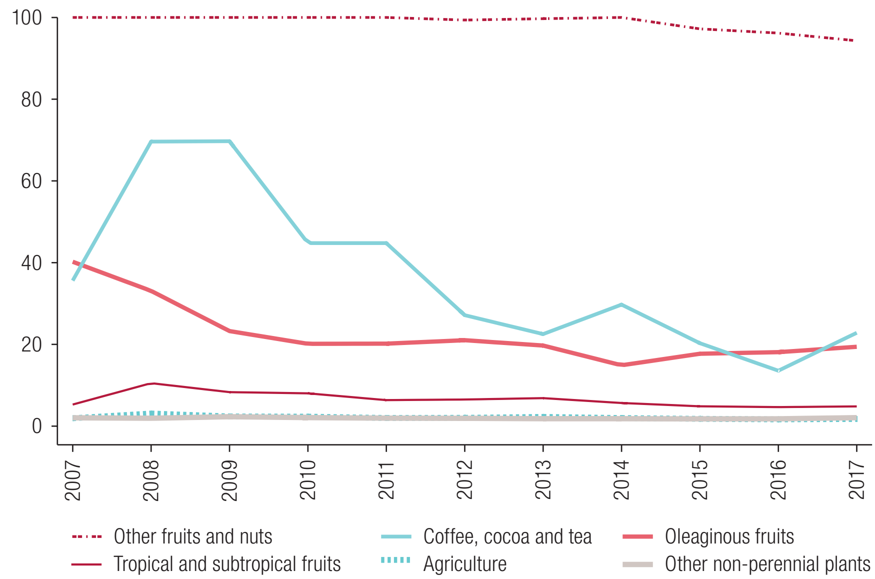


Figure A1.2 (continuation)

B. Herfindahl-Hirschman index
(percentages)



C. Growth of the crop-growing sector
(percentages)

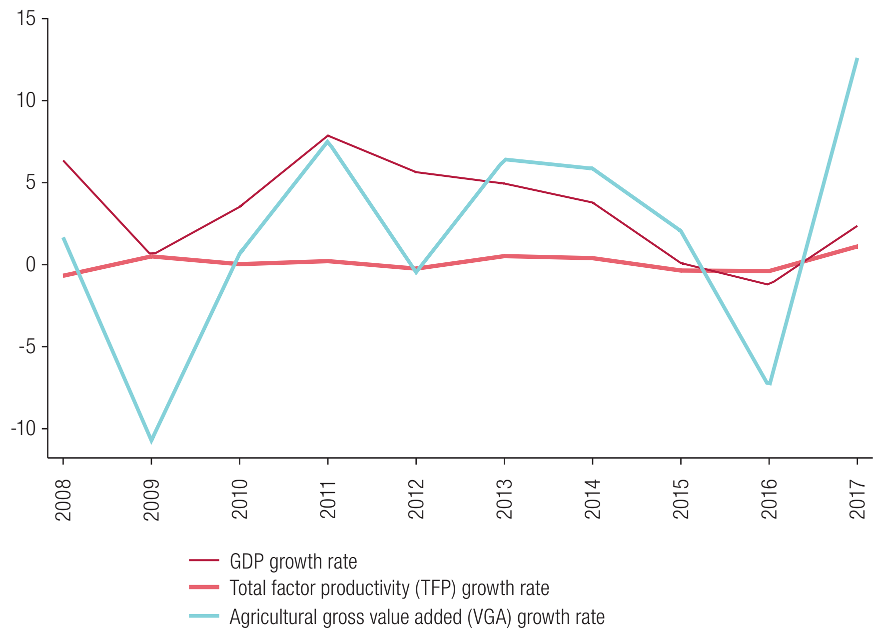
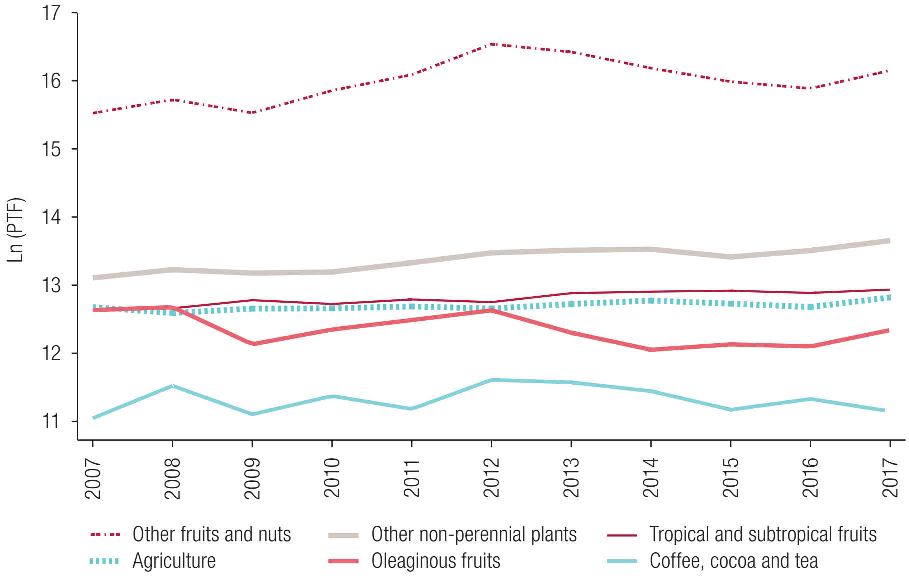


Figure A1.2 (concluded)

D. Total factor productivity (TFP) by subsector



Source: Prepared by the authors.

Inequalities and participation in the digital society: online experiences among children and adolescents in Brazil and Chile

Daniela Trucco, Patricio Cabello and Magdalena Claro

Abstract

This paper presents a comparative analysis of the Global Kids Online research network data from Brazil and Chile in 2016 relating to children's digital access, uses and skills. Results show that high-frequency users tend to be from higher socioeconomic groups. Girls and higher-income children perceive higher levels of risk on the Internet. The most common areas of use are related to learning and social life. The type of guidance that children receive matters: active mediation strategies at home and school are vital for increasing children's digital opportunities, while restrictive mediation tends to reduce them. Also, parental mediation appears to be unequally distributed, showing differences by age, gender and socioeconomic group. These results contribute to discussions on promoting digital opportunities and reducing risks.

Keywords

Information society, children, adolescents, Internet, social media, digital technology, digital divide, equal opportunity, households, schools, ICT indicators, Chile, Brazil

JEL classification

J13, L63, D63

Authors

Daniela Trucco is a Senior Social Affairs Officer with the Social Development Division of the Economic Commission for Latin America and the Caribbean (ECLAC). Email: daniela.trucco@un.org.

Patricio Cabello is an Assistant Professor at the Institute of Advanced Studies in Education of the University of Chile. Email: patricio.cabello@ciae.uchile.cl.

Magdalena Claro is an Associate Professor at the Faculty of Education of the Pontifical Catholic University of Chile. Email: mclarot@uc.cl.

I. Introduction

Digital technologies have spread over recent years in many societies, transforming different areas such as work, politics, education and even private life. Over the coming years, these transformations are expected to increase in most of the world's emerging economies. This is a response both to the new paradigms of scientific and technological innovation and to the new patterns of competitiveness that characterize the globalization process (Hirt and Willmott, 2014; Qu, Simes and O'Mahony, 2017).

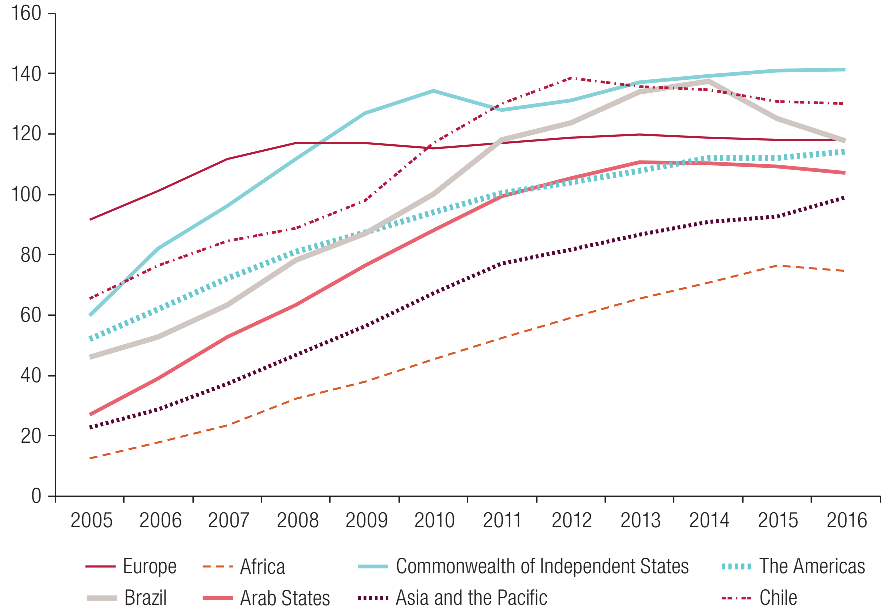
These changes require substantial transformations in the institutional labour market framework so that rights and negotiating power can be upheld in the new circumstances. They also require education and training systems to be permanently adjusted and updated so that they provide the skills and capabilities needed to work in the digital age (ECLAC, 2017; González and others, 2019). This new paradigm is likewise influencing activities in other areas of life: social relations, the production and acquisition of information and knowledge, the production and commercialization of goods and services and the exercise of citizenship, among others (Robinson and others, 2018; Scheerder, van Deursen and van Dijk, 2017).

Despite these trends, the so-called "fourth industrial revolution", predicated on innovation and the spread of information and communications technologies (ICTs), finds the Latin American economies in a situation of weakness in ICT infrastructure, while adoption of ICTs in the productive sector and society at large has been sluggish (Novick, 2017). Inequality is a historical and structural characteristic of Latin American and Caribbean societies that has reproduced itself even at times of growth and prosperity. There is a growing recognition that inequality is a multidimensional phenomenon. The accumulation or simultaneous reinforcement of disparities connected with social class, gender, racial or ethnic belonging or territory creates a complex structure of social relations, with numerous forms of discrimination that manifest themselves as inequalities in autonomy, well-being and empowerment and as pronounced differences in the exercise of rights (ECLAC, 2016a).

There is evidence that these inequalities may be reproducing themselves and increasing in the digital context, generating the so-called "digital divide" (Toyama, 2011; Scheerder, van Deursen and van Dijk, 2017). The concept of the digital divide was initially defined in dichotomous terms as the distance between those who have access to ICTs and those who do not. However, the evidence now is that as quantitative access increases and levels out, qualitative disparities are appearing in the way people use and engage with information technologies. These disparities are not only financial but also cognitive, social and cultural, leading researchers and public agencies to identify a "second digital divide" (DiMaggio and others, 2004; Montagnier and Wirthmann, 2011). This more refined approach shows that the benefits of using ICTs depend not only on physical access but also on individuals' situations and scope for engaging with and taking advantage of the opportunities provided (i.e., information, resources, applications and services) (Hargittai and Hinnant, 2008; Montagnier and Wirthmann, 2011; Selwyn, 2004; van Dijk, 2005).

Brazil and Chile are among the countries with the most widespread access to the Internet in the Latin American region. They are also well positioned in global rankings of social network users. The sources of access to the Internet have broadened significantly, particularly with the spread of smartphones and other mobile devices, which have democratized access to the web and broadened opportunities to connect any time and anywhere. As shown in figure 1, Brazil and Chile have very high rates of mobile phone penetration by global standards, with both being well above the average for the Americas region (which includes North American subscribers).

Figure 1
World regions, Brazil and Chile: mobile phone subscriptions
(Subscriptions per 100 inhabitants)



Source: International Telecommunication Union (ITU), World Telecommunication/ICT Indicators Database [online] https://www.itu.int/en/publications/ITU-D/pages/publications.aspx?parent=D-IND-WTID.OL-2021&media=electronic.

The ability to access the Internet from telephones, tablets and other devices has led to the emergence of a generation for whom being connected is part of daily life. Young Internet users have grown up in this connected era and are gaining access in increasingly diverse ways and at earlier ages. The Internet may have significant positive effects on different spheres of children's and adolescents' lives, creating present and future opportunities, while also bringing new risks (Haddon and Livingstone, 2014; Livingstone, Mascheroni and Staksrud, 2015; Cabello-Hutt, Cabello and Claro, 2017), whence the importance of helping them develop the skills they need to take advantage of the potential of technology while reducing the risks.

Social networks have become one of the most common ports of entry to Internet use, particularly among adolescents in Latin American countries. Research has shown how these platforms are changing social interactions among adolescents and youth, generating new codes of communication which are predominantly visual, with strong consumption and production of images (Murden and Cadenasso, 2018). There are also new risks to adolescents' health, such as excessive use of digital media and sleeping and nutrition disorders, among other problematic situations (Navarrete and others, 2017; Hooft, 2018). It is important to study how much and in what way adolescents are using social networks, and if there are any segmentations by sociodemographic variables.

There tends to be a general assumption that the younger generations are more technically savvy, but research has shown that they are not always effective at searching for and evaluating online content (Fraillon and others, 2014 and 2019) or at using the Internet in a manner that both meets their needs and avoids risks (Livingstone and Helsper, 2010; Vandoninck, D'Haenens and Roe, 2013). Research also shows that adults play an important role in helping children develop the skills to make positive use of online opportunities, instilling greater technical abilities in them and making them able to adapt more comfortably to changing digital environments and technologies (Dürager and Livingstone, 2012; Livingstone and others, 2015). Research in this area has found three general types of adult mediation: active mediation (parents talk to their children about appropriate behaviour when using the Internet), restrictive mediation (parents set rules to control their children's Internet use) and co-use (parents share the Internet experience with their children) (Livingston, Mascheroni and Staksrud, 2015). Within these general types, more specific practices have also been identified (see Dürager and Sonck, 2014), and more attention is being given to adolescents' experiences and perceptions regarding these different forms of mediation (Valkenburg and others, 2013).

This paper reviews children's and adolescents' Internet access and use and adult mediation strategies in Brazil and Chile, in the context of increasing digital access in the region. It aims to answer three research questions (RQs):

(i) RQ1: What online access do children have, what activities do they carry out and what are the perceived adult online mediation strategies in Brazil and Chile?

(ii) RQ2: What are the differences in access, online activities and perceived adult online mediation strategies by age, gender and socioeconomic group between children in Brazil and Chile?

(iii) RQ3: What is the association between school mediation and children's digital opportunities in Chile and Brazil?

By answering these questions, it will provide comparative data for policies aimed at guaranteeing that everyone has access to and can take advantage of the opportunities brought by the digital era in the Latin America and Caribbean region.

II. Methodology

1. The Kids Online Survey

The analysis presented in this document is based on data collected through a survey that has been conducted, in various formats, since 2010 by the European Union (EU) Kids Online research network, Global Kids Online and the Latin America Kids Online network, focusing on the cases of Brazil and Chile with data collected between August and November 2016.

(a) Chile

The Kids Online Chile survey was conducted between August and November 2016 with a representative national sample of 1,000 children and adolescents who were Internet users aged between 9 and 17 and 1,000 parents or guardians (one per child interviewed). Internet users were defined as people who had used the Internet at least once during the past three months (ITU, 2014). The study followed a four-stage cluster sampling method with a probability proportional to size (PPS): first, municipalities were selected and stratified; second, census areas were enumerated; third, homes were systematically selected; and fourth, children were randomly sampled. The probability weights took account of this selection method.

(b) Brazil

The Kids Online Brazil 2016 survey was conducted in 2016 by the Regional Centre for Studies on the Development of the Information Society (Cetic.br). The sample included 2,999 children and adolescents who were Internet users aged between 9 and 17 and 2,999 parents or guardians (one per child or adolescent interviewed), residing in permanent private households in Brazil. Internet users were defined as people who had used the Internet at least once during the past three months.

The survey involved stratified sampling of clusters in multiple stages. The number of stages in the sample plan depended on the role assigned to the selection of municipalities. Various municipalities were included in the sample with a probability equal to one (self-representative municipalities). In these cases, the municipalities served as strata for selecting the sample of census enumeration areas and, afterwards, of households and residents to interview, constituting a three-stage sample design. Other municipalities not necessarily included in the sample served as primary sampling units (PSUs) in the first sampling stage. In these cases, the probabilistic sample consisted of four stages: selection of municipalities, selection of census enumeration areas in the selected municipalities, selection of households, and then selection of residents. The probability weights took account of this selection method (CGI.br, 2017).

The analytical sample for this study consisted of 2,438 Brazilian children and teenagers aged 9 to 17.

2. Variables and measures

The following variables and measures were used in the analysis:

Access to the Internet. This was to ascertain where and how children accessed the Internet. In the case of Brazil, a yes or no answer was required for access locations and devices. In the case of Chile, the answers to the question about the frequency of Internet access shown below were recodified into a dichotomous variable, with "Never" and "Almost never" equated to "No access".

Frequency of Internet access. The question asked was "How often do you use the Internet?" The alternatives were "Never", "Almost never", "At least once a month", "At least once a week", "Every day or almost every day" and "Many times a day" (see table 1).

Digital uses index. This refers to what children do online and was measured using a set of 23 activities in Chile and 16 activities in Brazil with the question "Have you done these things in the past three months? Yes/no". The index was calculated by adding together the activities engaged in.

Socioeconomic group. In the case of Brazil, the classification was based on the Brazilian Criteria for Economic Classification (CCEB), as defined by the Brazilian Association of Research Companies (ABEP). This classification is based on ownership of durable goods for household consumption and the level of education of the household head. Ownership of durable goods is measured using a scoring system that divides households into the following economic classes: A1, A2, B1, B2, C, D, and E. The CCEB was updated in 2015, resulting in classifications that are not comparable with the previous edition, the 2008 CCEB (CGI.br, 2017). For Chile, the Ipsos protocol was used. This is a categorization with five values based on an index composed of a combination of the following indicators: goods, residential area classification, family income, quality of the home, main activity of the household head, education of the household head.

Index of active mediation at home. This index was constructed from the frequency with which respondents reported an adult at home engaging in active mediation strategies with them (the higher the frequency, the higher the value): 11 strategies with 4 levels of frequency in Chile and 10 dichotomous indicators in Brazil. This index, like all the others, was normalized for means comparison but not for the regression analysis.

Index of restrictive mediation at home. This index was constructed from the frequency with which respondents reported an adult at home engaging in restrictive mediation strategies with them (the higher the frequency, the higher the value): 13 strategies with 4 levels of frequency in Chile and 5 dichotomous indicators in Brazil.

Index of monitoring mediation at home. This index was constructed from the frequency with which respondents reported an adult at home engaging in three monitoring mediation strategies with them (the higher the frequency, the higher the value). This index was only constructed for Chile and not for Brazil, since no indicators were included in the latter's survey.

Index of active mediation at school. This index was constructed from the frequency with which respondents reported an adult at school engaging in active mediation strategies with them (the higher the frequency, the higher the value): 14 strategies with 4 levels of frequency in Chile and 7 dichotomous indicators in Brazil.

Index of restrictive mediation at school. This index was constructed from the frequency with which respondents reported an adult at school engaging in restrictive mediation strategies with them (the higher the frequency, the higher the value): three strategies with four levels of frequency in Chile and only one in Brazil, with no index being constructed for the latter.

Table 1
Brazil and Chile: demographic variables and frequency of Internet access among children and adolescents aged 9–17
(Percentages)

Variable	Alternatives	Brazil	Chile
Gender	Male	50.2	50.8
	Female	49.8	49.2
Socioeconomic group	A, B (Brazil) C1 and C2 (Chile)	23.3	17.7
	C/ (Brazil) C3 (Chile)	47.0	47.6
	D and E	29.6	34.6
Frequency of internet access	Less than once a month	1.7	4.3
	At least once a month	2.8	1.4
	At least once a week	8.9	5.9
	Every day or almost every day	15.1	38
	Many times a day	71.5	50.3

Source: Prepared by the authors.

The values of all these indices were standardized in a normal distribution for comparison (see table 2).

Table 2
Brazil and Chile: adult mediation indices for Internet use by children and adolescents aged 9–17
(Percentages)

Variable	Non-standardized								Standardized							
	Brazil				Chile				Brazil				Chile			
	Min.	Max.	Mean	Standard deviation	Min.	Max.	Mean	Standard deviation	Min.	Max.	Mean	Standard deviation	Min.	Max.	Mean	Standard deviation
Active mediation at home	0	10	6.55	2.76	0	44	23.56	10.83	-2.38	1.24	-0.01	1.00	-2.18	1.88	-0.01	1.00
Restrictive mediation at home	0	15	3.23	4.30	0	40	13.50	9.36	-0.77	2.64	-0.03	0.98	-1.47	2.75	-0.04	0.99
Monitoring mediation at home	N/A				0	12	3.82	4.03	N/A				-0.96	1.99	-0.02	0.99
Active mediation at school	0	7	3.60	2.50	1	54	27.39	12.55	-1.40	1.36	0.02	1.00	-2.10	2.12	0.00	1.00
Restrictive mediation at school[a]	N/A				0.00	8.00	5.52	2.36	N/A				-2.31	1.05	0.01	0.99

Source: Prepared by the authors.
[a] There was only one indicator for Brazil, so no index was constructed.

3. Analysis

A descriptive analysis was first carried out to understand children's and adolescents' online access and activities and the adult online mediation strategies perceived by them in Brazil and Chile. The different indicators for Internet access and use and perceived mediation strategies were analysed for each country by gender, age and socioeconomic group in order to identify social segmentation in digital participation. Summative indexes were constructed for each mediation type and were also analysed in accordance with these sociodemographic characteristics.

A regression model analysis was then performed to understand the association between school mediation and children's digital opportunities in Chile and Brazil, with age, gender and socioeconomic group included as control variables.

III. Results

This section describes online access and activities among children and adolescents and perceived adult mediation strategies in Brazil and Chile in relation to some of the main axes of social inequality in this region of the world: socioeconomic group, age and gender (ECLAC, 2016b).

1. Online access

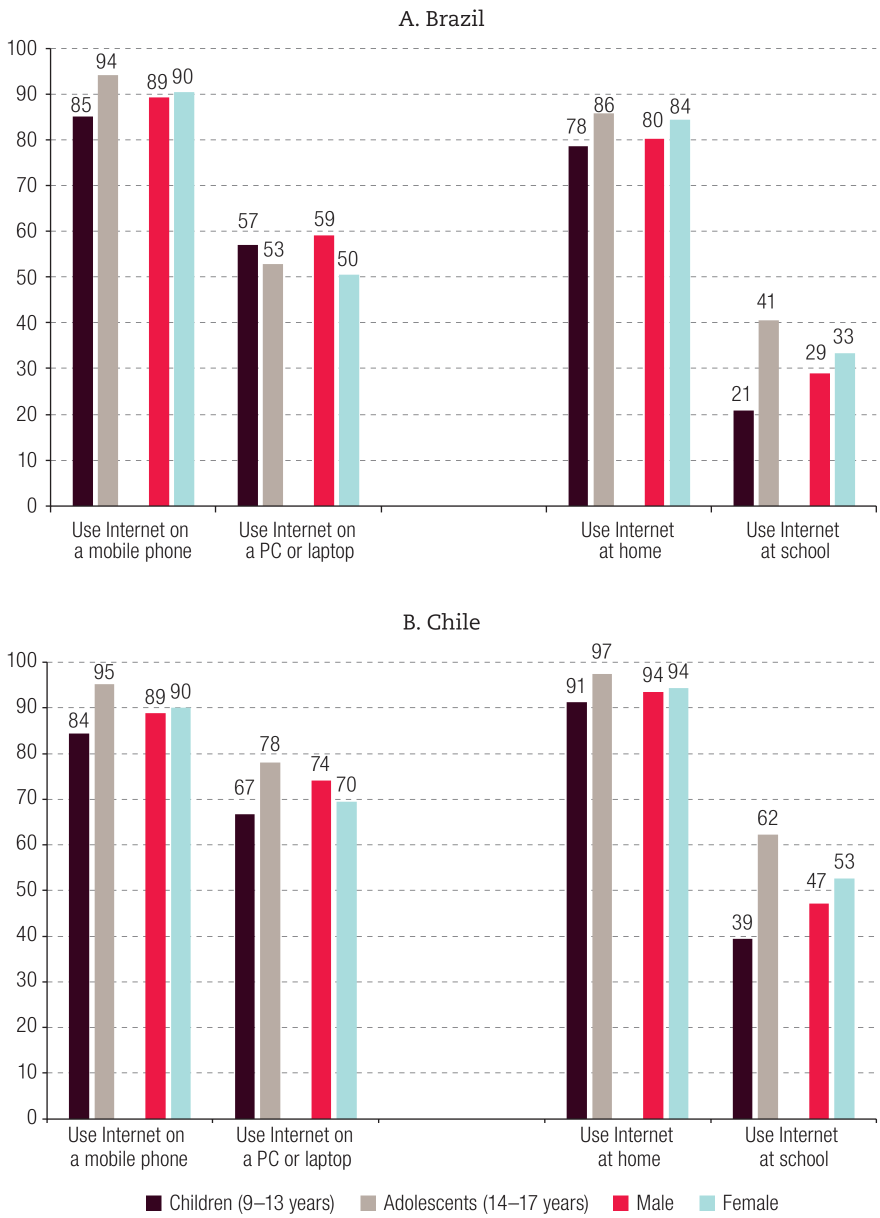
Children in Brazil and Chile who use the Internet access it mainly from home and from mobile phones. The two countries show similar trends in terms of the places and devices from which the Internet is accessed by children and adolescents, presenting higher access (more than double in the case of Brazil) at home than at school. Chile shows higher levels of use at home and, particularly, at school than Brazil.

Adolescents in both countries are more likely to access the Internet through their mobile phones than younger children (9–13 years) (see figure 2). Where use of a computer or laptop is concerned, there is a difference between Chile and Brazil, with adolescents in Chile also accessing the Internet through a computer more than children, whereas in Brazil it is the opposite. Also, children are less likely in general to access the Internet through a computer in Brazil than in Chile. In both countries, the greatest age gap is in school access, with adolescents making much greater use of the Internet at school than younger children, this being probably indicative of more active promotion of ICT use for school activities at the secondary level.

When the sexes are compared, little difference is found between girls and boys in the places and devices from which the Internet is accessed (see figure 2). The largest gaps in both countries are in computer access, with boys having more access than girls, and in-school access, with girls having slightly more access than boys.

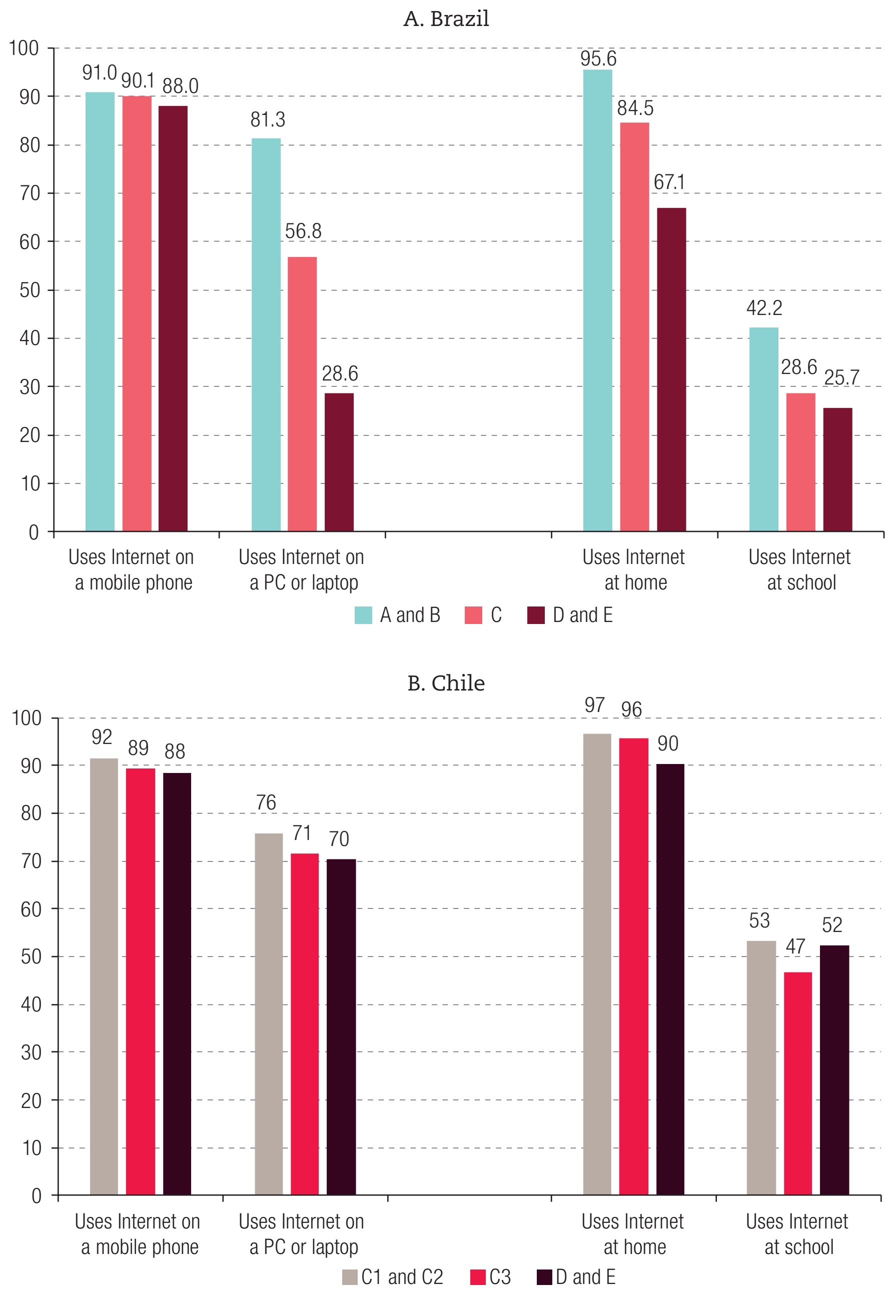
Figure 3 shows that mobile phone access to the Internet has been an equalizing point of entry in both countries. Close to 90% of children and adolescents of every socioeconomic group have access to the Internet through a mobile phone in both countries. There are still differences by socioeconomic group where computers are concerned, particularly in Brazil, where access to the Internet in schools is also unequal; when asked about the frequency of Internet use at school, only a little over half as many children from the lowest socioeconomic group as from the highest socioeconomic group reported using it. Home access to the Internet differed less by socioeconomic group in Chile than in Brazil, and there were hardly any differences in access at school. However, comparison of socioeconomic differences between Chile's and Brazil's results must be undertaken with caution, given that class segments are calculated differently (see the Methodology section).

Figure 2
Brazil and Chile: Internet access of children and adolescents (9–17 years), by age and gender, 2016
(Percentages)



Source: Prepared by the authors, on the basis of Global Kids Online data.

Figure 3
Brazil and Chile: Internet access of children and adolescents (9–17 years), by socioeconomic group, 2016
(Percentages)



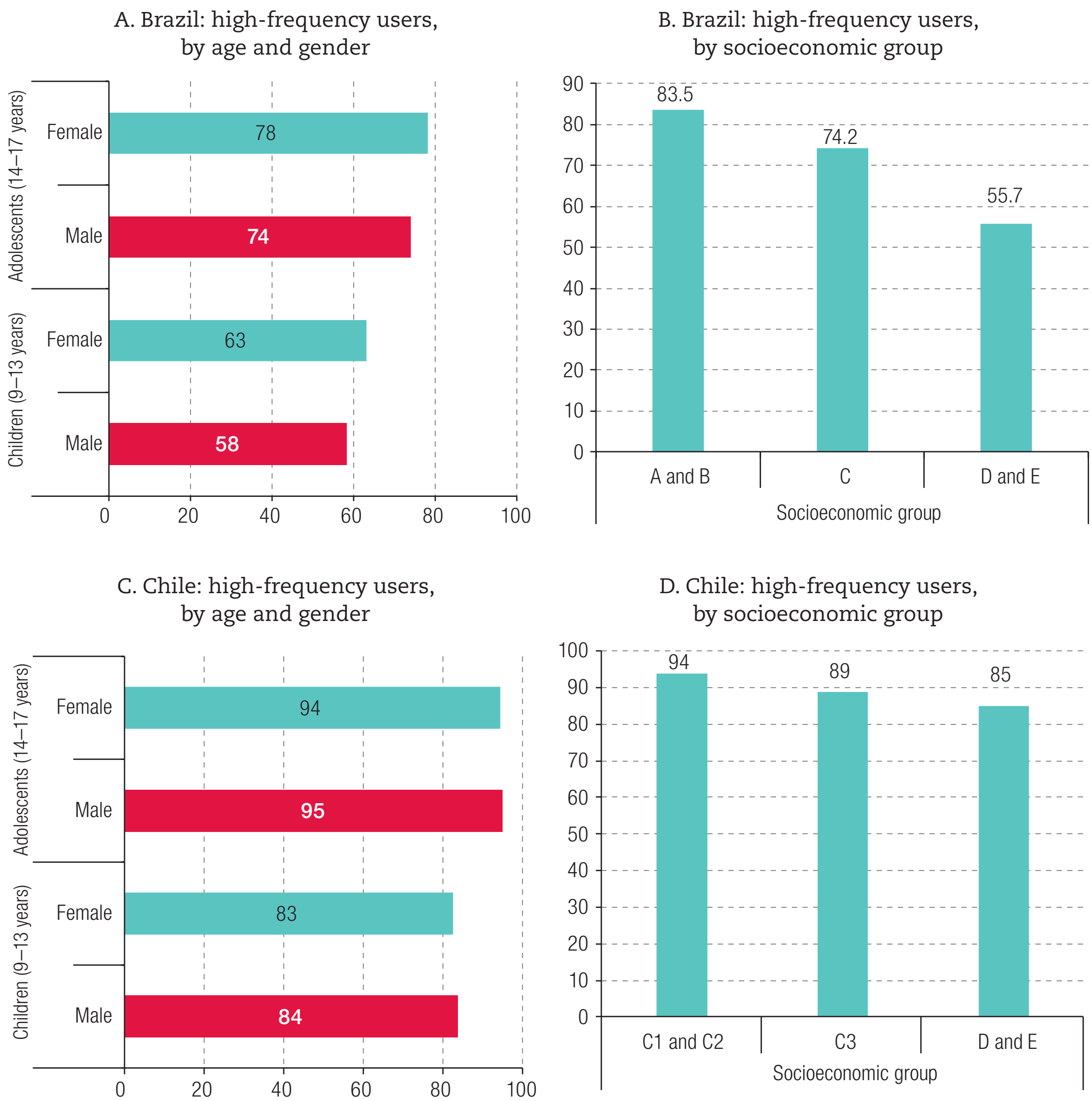
Source: Prepared by the authors, on the basis of Global Kids Online data.
Note: Socioeconomic groups are identified by different methodologies in Brazil and Chile.

With regard to frequency of use, a higher proportion of children were intensive users, i.e., connected to the Internet more than once a day, in Chile than in Brazil, which is probably related to Chile's higher levels of access at home. There seem to be no significant gender divides among intensive users, but adolescents were more connected than younger children in both countries (see figure 4A and 4C). There was socioeconomic segmentation among frequent users, this being more marked in Brazil than in Chile (see figures 4B and 4D).

Figure 4

Brazil and Chile: proportions of Internet-using children and adolescents (9–17 years) who are high-frequency users (more than once a day), by age and gender and by socioeconomic group, 2016

(Percentages)



Source: Prepared by the authors, on the basis of Global Kids Online data.
Note: Socioeconomic groups are identified by different methodologies in Brazil and Chile.

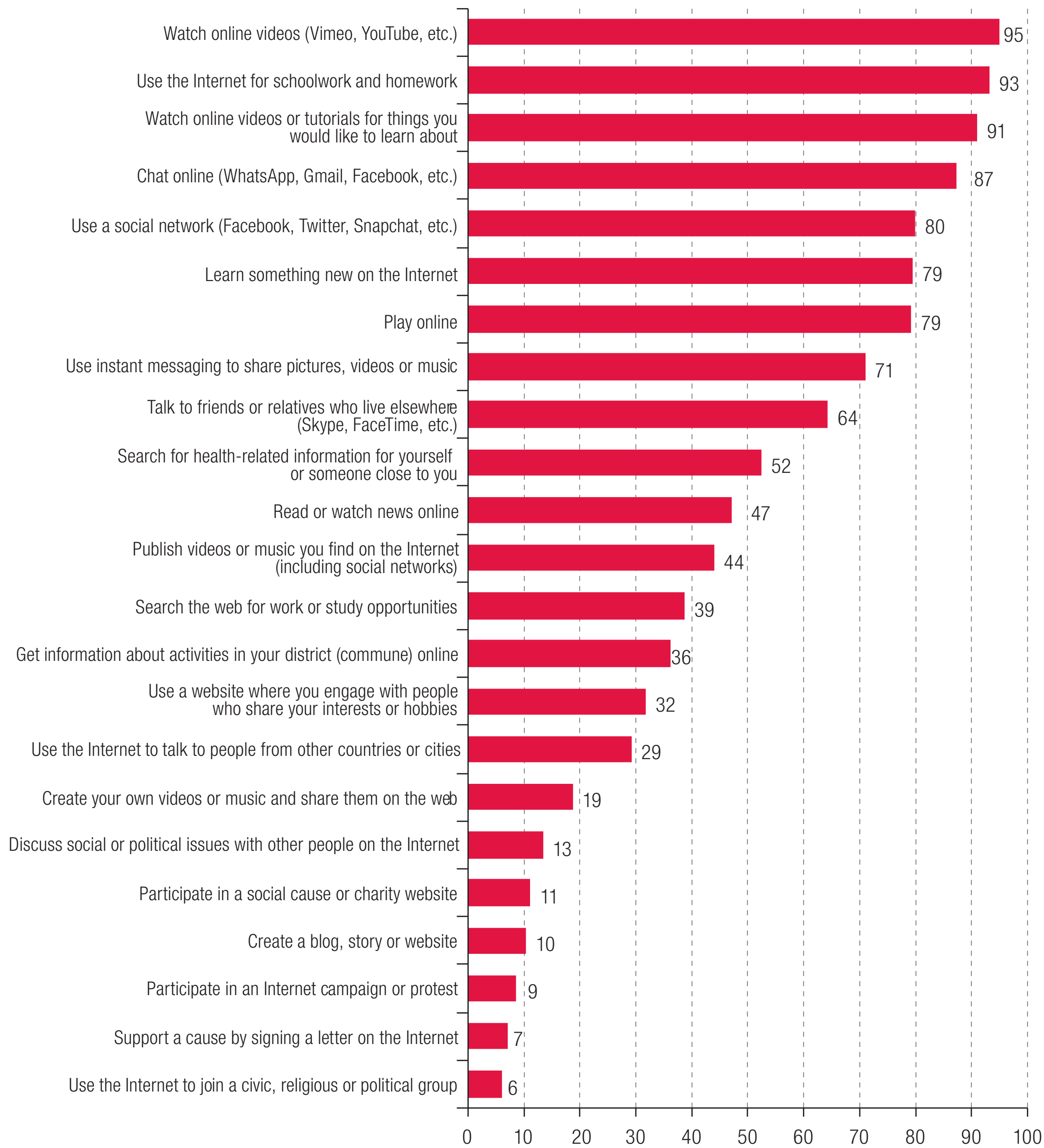
2. Online activities

Figures 5 and 6 show the online practices of children and adolescents in Chile and Brazil. In both countries, they evince high levels of formal learning activities (i.e., related to their schoolwork), informal learning activities (i.e., searches for information that interests them) and activities related to their social life, such as using social networks and chatting online.

Figure 5

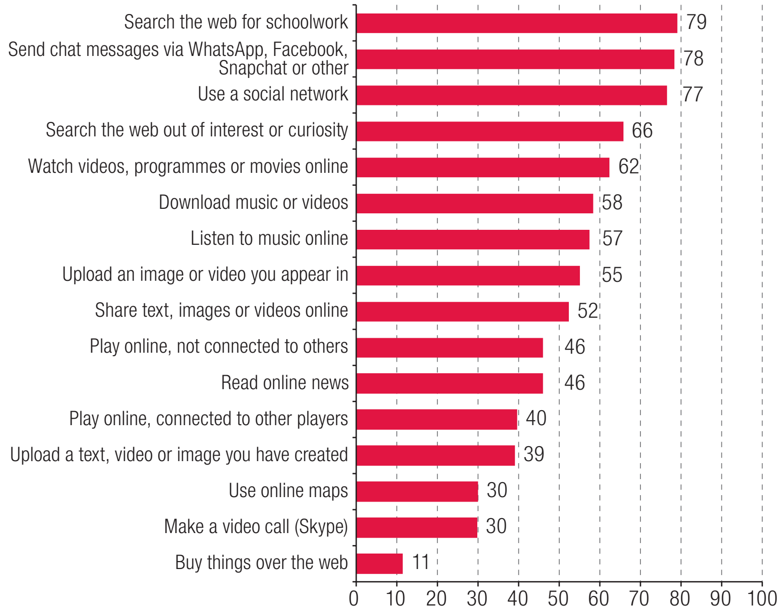
Chile: proportion of Internet-using children and adolescents (9–17 years) who have carried out each online activity within the last three months, 2016

(Percentages)



Source: Prepared by the authors, on the basis of Global Kids Online data.

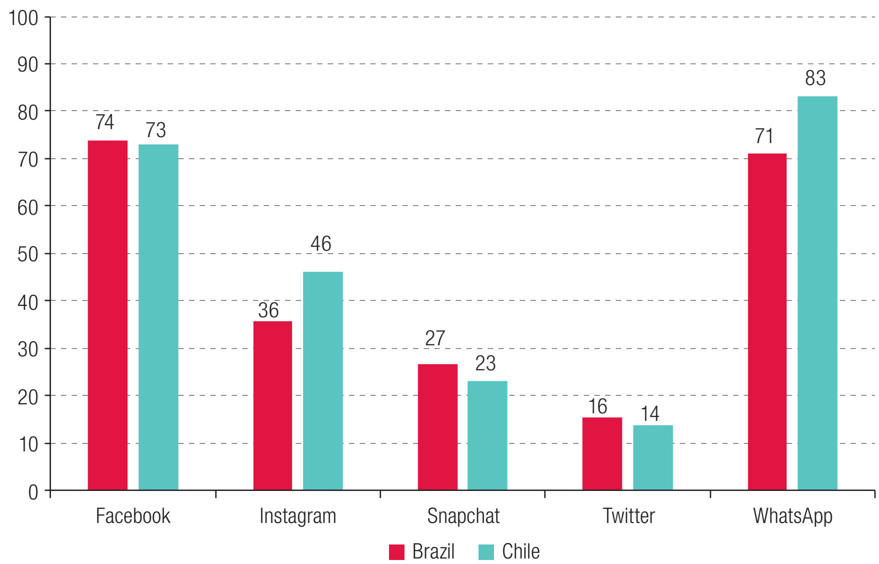
Figure 6
Brazil: proportion of Internet-using children and adolescents (9–17 years) who have carried out each online activity within the last three months, 2016
(Percentages)



Source: Prepared by the authors, on the basis of Global Kids Online data.

Regarding social network participation, close to 90% of adolescent Internet users in Brazil and Chile reported having a Facebook profile, although a significantly higher proportion of children had profiles in this network in Chile than in Brazil. The level of Instagram usage is also higher in Chile than in Brazil, while Snapchat and especially Twitter are much less popular in both countries (see figure 7 and table 3).

Figure 7
Brazil and Chile: children and adolescents (9–17 years) with a social network profile, 2016
(Percentages)



Source: Prepared by the authors, on the basis of Global Kids Online data.

Table 3
Brazil and Chile: children and adolescents with a social network profile, by age group, 2016
(Percentages)

		Facebook	Instagram	Snapchat	Twitter	WhatsApp
Brazil	Children (9–13 years)	60	23	18	10	59
	Adolescents (14–17 years)	92	49	36	22	86
Chile	Children (9–13 years)	60	30	17	11	77
	Adolescents (14–17 years)	89	65	31	18	91

Source: Prepared by the authors, on the basis of Global Kids Online data.

Table 3 shows the differences between children aged 9 to 13 and adolescents aged 14 to 17 regarding the percentages with a social network profile. In both countries, access to each social network is significantly higher for adolescents.

There are some differences in the way girls and boys use certain social networks, as those characterized by stronger visual features or applications, such as Instagram and Snapchat, are more attractive to girls, while for other networks there is no difference between girls and boys (see figure 8).

Figure 8
Brazil and Chile: children and adolescents (9–17 years) with a social network profile, by gender, 2016
(Percentages)

A. Brazil

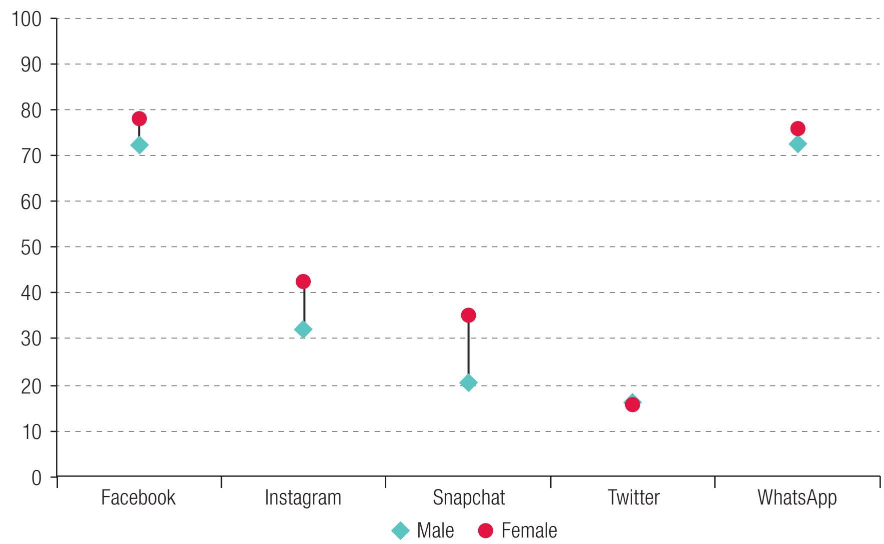
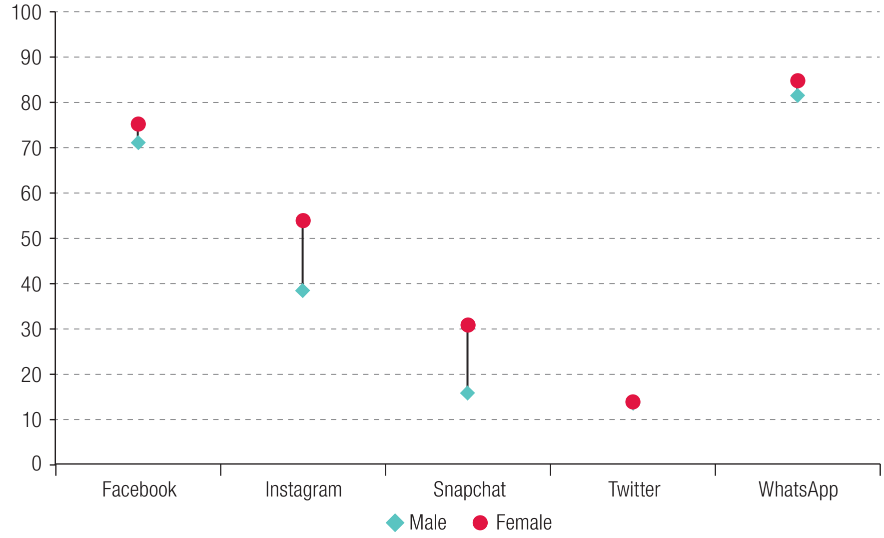


Figure 8 (concluded)

B. Chile



Source: Prepared by the authors, on the basis of Global Kids Online data.

In terms of socioeconomic background, Brazil shows significant gaps between children from the highest and lowest socioeconomic groups for all social networks except Facebook. Chile shows no significant socioeconomic differences (see figure 9). Facebook, like mobile phones, has penetrated most massively, reaching the largest sections of the population.

Figure 9
Brazil and Chile: children and adolescents (9–17 years) with a social network profile, by socioeconomic group, 2016
(Percentages)

A. Brazil

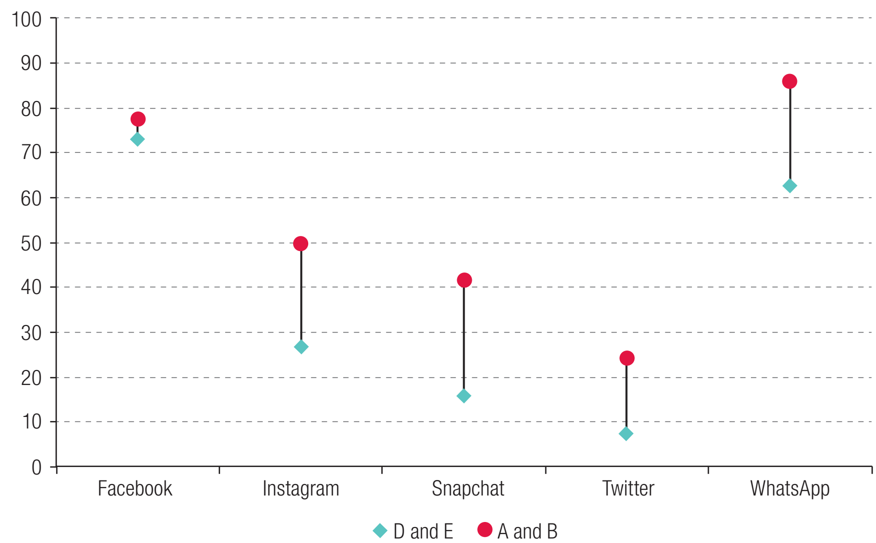
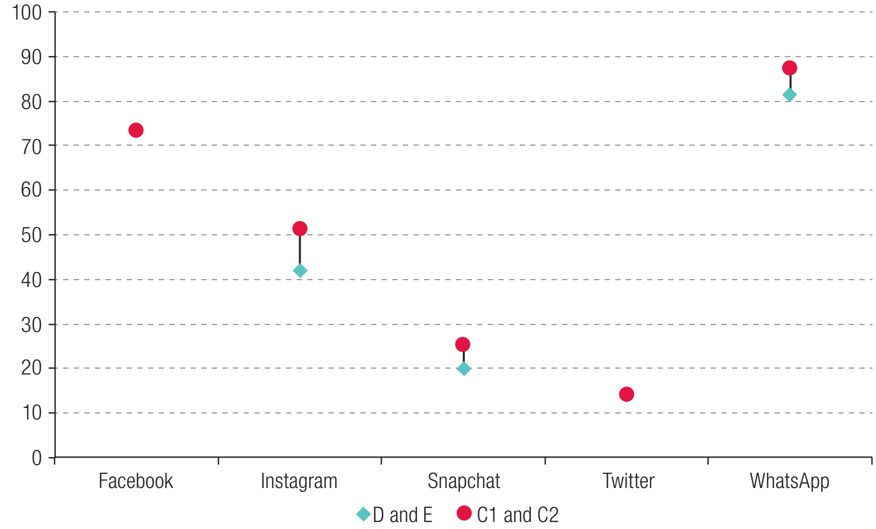


Figure 9 (concluded)

B. Chile



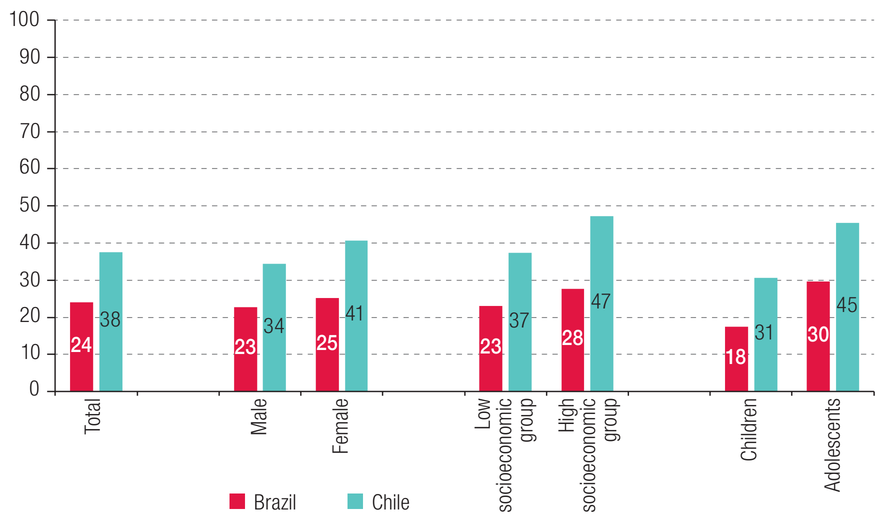
Source: Prepared by the authors, on the basis of Global Kids Online data.

Frequent use of the Internet and social networks by children and adolescents brings learning opportunities and new forms of social interaction, but also exposure to risks and potentially harmful experiences. The perceived level of harm, understood as the proportion of children who have felt bad or had an uncomfortable experience using the Internet within the past year, is higher in Chile (38%) than in Brazil (24%) (see figure 10). In both countries, levels of perceived harm are higher for older children and those from a higher socioeconomic background. In the case of Chile, there is a gender gap that affects girls negatively, since on average they perceive higher levels of harm than boys.

Figure 10

Brazil and Chile: proportions of Internet-using children (9–13 years) and adolescents (14–17 years) who have felt bad or uncomfortable because of something they have encountered on the Internet during the last year, 2016

(Percentages)



Source: Prepared by the authors, on the basis of Global Kids Online data.

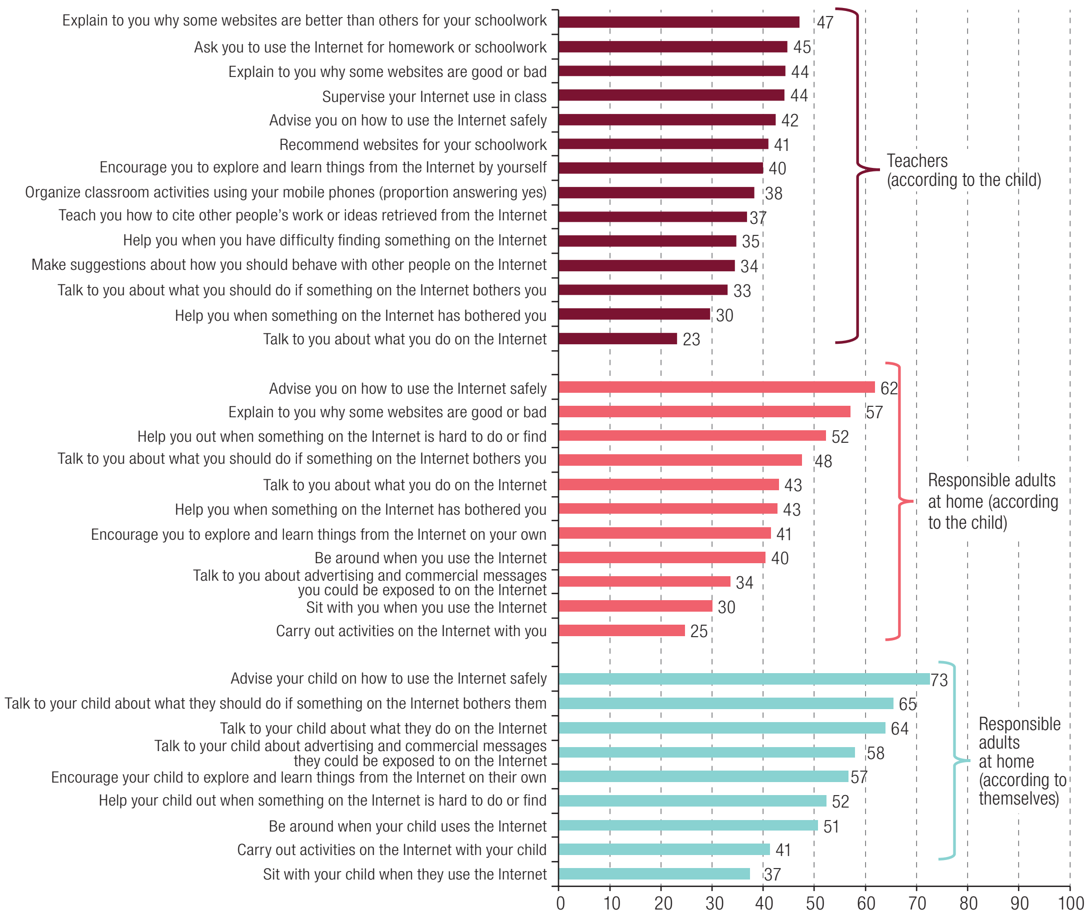
Note: In the case of Brazil, the age gap is statistically significant at a 95% confidence level and the socioeconomic gap is significant at a 90% confidence level. In Chile, all three gaps are statistically significant at a 95% confidence level, measured by the chi-square test.

3. Adult mediation strategies at home and school

(a) Active mediation strategies

As described in the Methodology section, active mediation strategies refer to the actions that adults take to guide children in their Internet use and explain the risks and opportunities involved. Children in Chile tend to perceive a similar level of adult involvement in their Internet use at home and at school (see figure 11). On average, around 40% of children who are Internet users feel that they are often supported in its use at home. The most common strategies are “Advise me on how to use the Internet safely” and “Explain to me why some websites are good or bad”. A lower percentage perceive the use of more active strategies, such as “Carry out activities on the Internet with me”. There is an apparent gap between how children perceive their parents’ mediation and what their parents perceive or report that they perceive. There is a group of adults that reports always carrying out every one of the strategies asked about. We assumed that the children’s responses were a stronger indicator when it came to generating a summative index. The data for Brazil show similar trends, with children perceiving high levels of parental involvement in activities such as explaining what to do on the Internet and suggesting how to behave towards others and use the Internet safely (Cabello-Hutt, Cabello and Claro, 2016).

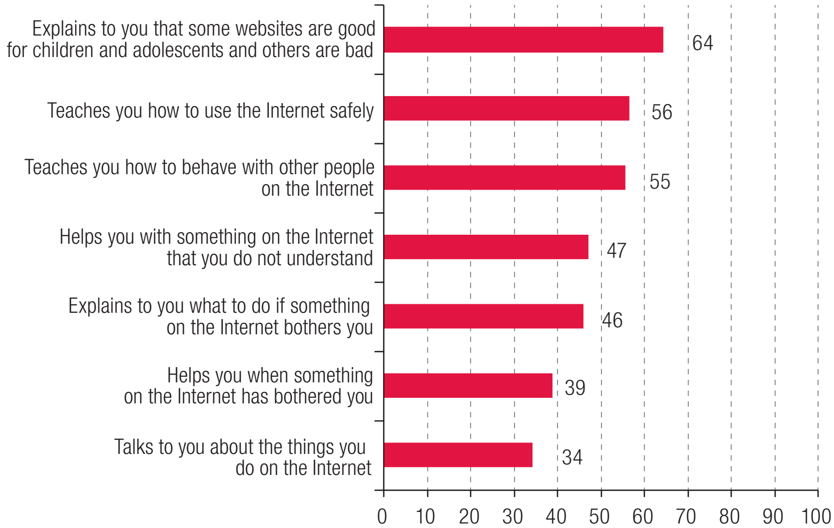
Figure 11
Chile: respondents answering “Always” or “Almost always” to questions beginning “How often do…”, 2016
(Percentages)



Source: Prepared by the authors, on the basis of Global Kids Online data.

As regards school mediation strategies, about half of Internet-using students in Brazil perceive they are receiving active support from a teacher at school. The highest-rated strategies are those related to safety and general norms of online behaviour (see figure 12).

Figure 12
Brazil: students stating that a teacher implements the following active mediation strategies, 2016
(Percentages)



Source: Prepared by the authors, on the basis of Global Kids Online data.

Home scored slightly higher than school on the average active mediation strategies index. The main finding regarding social gaps in adult mediation of children's and adolescents' Internet activities is consistent in both countries, namely that younger children and girls are more actively supported in their digital behaviour (see tables 4 and 5). Concerning mediation strategies at home, there are no differences between children of different socioeconomic groups in Chile, while there are differences in Brazil, where higher socioeconomic groups report higher levels of active mediation. In both countries, girls perceive higher levels of parental mediation than boys, and younger children than adolescents.

Table 4
Chile: normalized index of active mediation strategies at home (z-values), by gender, age and socioeconomic group, 2016

			Mean comparison	
Gender[a]	Mean	N	T (t-test)	Significance
Male	-0.15	499	-4.96	0.000
Female	0.16	469		
Age[a]			T (t-test)	Significance
Children (9–13 years)	0.18	519	6.01	0.000
Adolescents (14–17 years)	-0.20	449		
Socioeconomic group			F (analysis of variance)	Significance
C1 and C2	-0.05	168	1.76	0.173
C3	0.06	468		
D and E	-0.06	331		
Total	0.00	968		

Source: Prepared by the authors, on the basis of Global Kids Online data.
[a] Difference is statistically significant at a 95% confidence level.

Table 5
Brazil: normalized index of active mediation strategies at home (z-values), by gender, age and socioeconomic group, 2016

			Mean comparison	
Gender[a]	Mean	N	T (t-test)	Significance
Male	-0.07136504	1 206	-3.52	0.000
Female	0.07178206	1 199		
Age[a]			T (t-test)	Significance
Children (9–13 years)	0.23	1 135	11.01	0.000
Adolescents (14–17 years)	-0.21	1 270		
Socioeconomic group			F (analysis of variance)	Significance
A and B	0.08527488	538	5.81	0.003
C	0.0247242	1 102		
D and E	-0.09558627	765		
Total	0.00	2 405		

Source: Prepared by the authors, on the basis of Global Kids Online data.
[a] Difference is statistically significant at a 95% confidence level.

The trend is slightly different for perceived mediation strategies at school. In both Chile and Brazil (see tables 6 and 7), girls also perceive higher levels of mediation by teachers at school. But there is a smaller age gap, i.e., children and adolescents perceive similar levels of guidance from schoolteachers. There is also a socioeconomic gap between perceived active mediation strategies at school that is the opposite to the gap perceived at home, with higher-income children perceiving less guidance and mediation than lower-income children.

Table 6
Chile: normalized index of active mediation strategies at school (z-values), by gender, age and socioeconomic group, 2016

			Mean comparison	
Gender[a]	Mean	N	T (t-test)	Significance
Male	-0.10	442.70	-2.93	0.003
Female	0.10	428.51		
Age			T (t-test)	Significance
Children (9–13 years)	0.01	439.31	0.34	0.736
Adolescents (14–17 years)	-0.01	431.90		
Socioeconomic group[a]			F (analysis of variance)	Significance
C1 and C2	-0.24	154.97	6.99	0.001
C3	0.00	408.32		
D and E	0.12	307.92		
Total	0.00	871.21		

Source: Prepared by the authors, on the basis of Global Kids Online data.
[a] Difference is statistically significant at a 95% confidence level.

Table 7
Brazil: normalized index of active mediation strategies at school (z-values), by gender, age and socioeconomic group, 2016

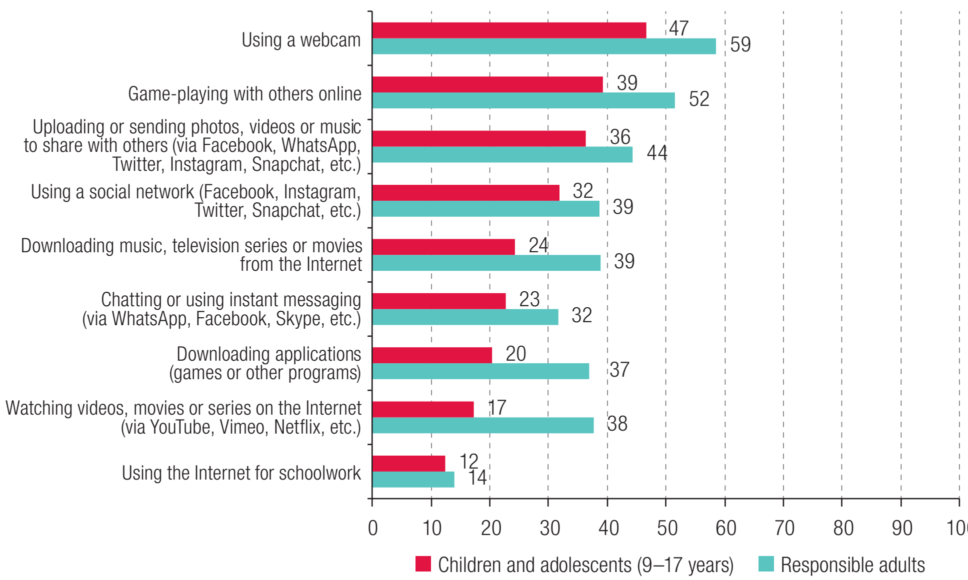
			Mean comparison	
Gender[a]	Mean	N	T (t-test)	Significance
Male	-0.13	1 160	-5.24	0.000
Female	0.09	1 159		
Age			T (t-test)	Significance
Children (9–13 years)	0.01	1 108	1.23	0.217
Adolescents (14–17 years)	-0.04	1 211		
Socioeconomic group[a]			F (analysis of variance)	Significance
A and B	-0.14	554	5.31	0.005
C	0.02	1 080		
D and E	0.02	685		
Total	-0.02	2 319		

Source: Prepared by the authors, on the basis of Global Kids Online data.
[a] Difference is statistically significant at a 95% confidence level.

(b) Restrictive mediation strategies

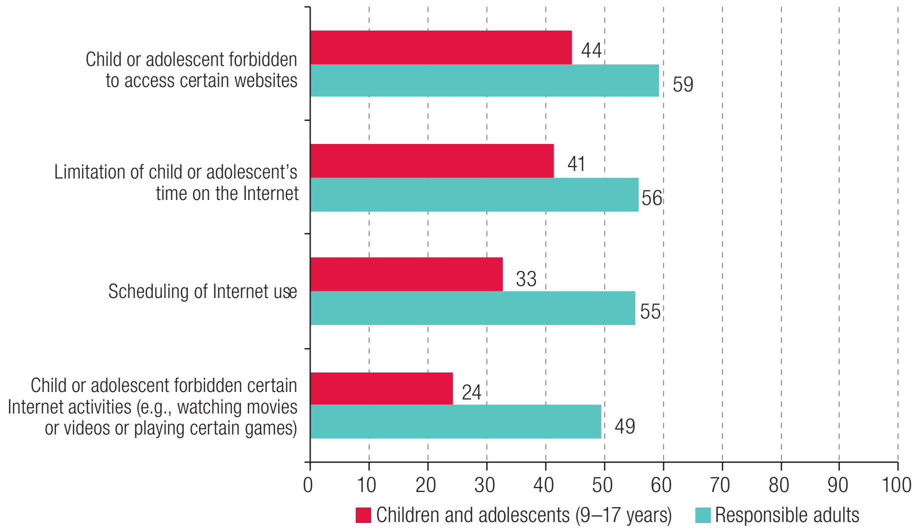
As presented in the Methodology section, the participants were also asked about their experience with restrictive mediation strategies. Figures 13 and 14 show the percentages of Internet-using children and adolescents in Chile who perceive different restrictive mediation strategies relating to their Internet use, compared to what responsible adults at home declare. The most common restrictions concern webcam use, game-playing with others online, access to certain websites and time spent online. As can be observed, these restrictions are intended to protect children from exposure to external risks. There are fewer perceived restrictions on using the Internet for schoolwork, watching movies or chatting with friends. However, there is a gap between adults' and children's perceptions that is consistent in every indicator, with adults always perceiving a higher level of mediation.

Figure 13
Chile: respondents stating that each online activity is forbidden to the child or adolescent or allowed only with permission or supervision, 2016
(Percentages)



Source: Prepared by the authors, on the basis of Global Kids Online data.

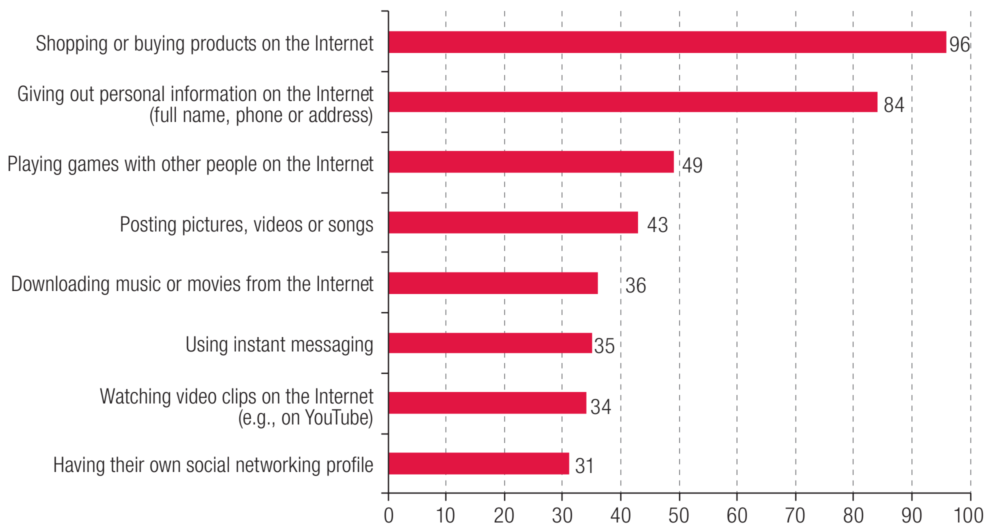
Figure 14
Chile: respondents stating that the responsible adult always or almost always enforces each measure, 2016
(Percentages)



Source: Prepared by the authors, on the basis of Global Kids Online data.

Although the indicators of restrictive mediation used in the Brazilian survey are slightly different from those in the Chilean survey, the results for comparable items show that between 40% and 50% of children in both countries are restricted in their online play with others and around 40% in the pictures or videos they are allowed to upload. In Brazil, the most common restrictions are, first, on shopping online and, second, on giving away personal information (see figure 15), items that were not included in the Chilean survey.

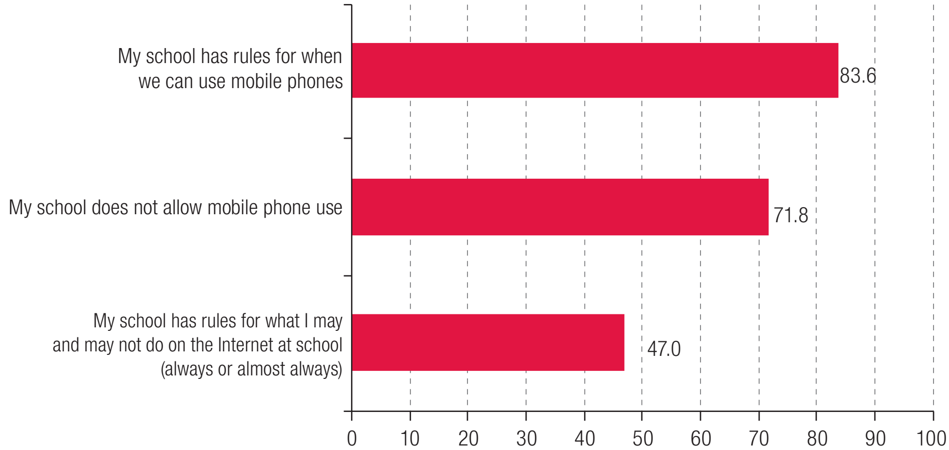
Figure 15
Brazil: children and adolescents (9–17 years) stating that each online activity is forbidden to them or allowed only with permission or supervision, 2014
(Percentages)



Source: Prepared by the authors, on the basis of T. Cabello-Hutt, P. Cabello and M. Claro, "Parental mediation in the use of ICT as perceived by Brazilian children: reflections on the 2014 ICT Kids Online Brazil Survey", *ICT Kids Online Brazil 2015: Survey on Internet Use by Children in Brazil*, São Paulo, Brazilian Internet Steering Committee (CGI.br), 2016.

Although the survey includes fewer indicators for schools' restrictive mediation strategies, children perceive high levels of restrictions on mobile phone use at school in Chile (see figure 16). The only indicator available from Brazil's 2016 survey is that 47% of young Internet users report that a teacher at their school sets rules for what they can or cannot do on the Internet at school, a similar proportion to that in Chile.

Figure 16
Chile: children and adolescents (9–17 years) reporting each restriction at school, 2016
(Percentages)



Source: Prepared by the authors, on the basis of Global Kids Online data.

Following the same methodology as for active mediation, an index of restrictive mediation strategies was generated and normalized for comparison purposes. The most obvious differences in perceptions of restrictive mediation strategies at home are by age group. Adolescents report higher levels of autonomy and fewer parental restrictions in both countries. Neither Brazil nor Chile shows any gender differences in perceptions of restrictive mediation at home (see tables 8 and 9). Regarding differences by socioeconomic group, results in Brazil show higher levels of restrictive strategies in families from the lower socioeconomic groups (see table 9), while in Chile it is families in the middle socioeconomic groups that present the highest levels of restrictions (see table 8).

Table 8
Chile: normalized index of restrictive mediation strategies at home (z-values), by gender, age and socioeconomic group, 2016

			Mean comparison	
Gender	Mean	N	T (t-test)	Significance
Male	-0.02	448.29	-0.95	0.344
Female	0.02	423.56		
Age[a]			T (t-test)	Significance
Children (9–13 years)	0.47	469.67	19.64	0.000
Adolescents (14–17 years)	-0.55	402.17		
Socioeconomic group[b]			F (analysis of variance)	Significance
C1 and C2	-0.15	148.86	3.36	0.035
C3	0.06	419.83		
D and E	-0.02	303.16		
Total	0.00	871.84		

Source: Prepared by the authors, on the basis of Global Kids Online data.
[a] Difference is statistically significant at a 95% confidence level.
[b] Difference is statistically significant at a 90% confidence level.

Table 9
Brazil: normalized index of restrictive mediation strategies at home (z-values), by gender, age and socioeconomic group, 2016

			Mean comparison	
Gender	Mean	N	T (t-test)	Significance
Male	0.0034	1 212	0.17	0.869
Female	-0.0033	1 218		
Age[a]			T (t-test)	Significance
Children (9–13 years)	0.50	1 145	26.28	0.000
Adolescents (14–17 years)	-0.44	1 285		
Socioeconomic group[b]			F (analysis of variance)	Significance
A and B	-0.21	545	22.76	0.000
C	-0.01	1 117		
D and E	0.17	768		
Total	0.00	2 430		

Source: Prepared by the authors, on the basis of Global Kids Online data.
[a] Difference is statistically significant at a 95% confidence level.
[b] Difference is statistically significant at a 90% confidence level.

Although the indicators are not strictly comparable (that for Brazil is based on a single item, while for Chile it was possible to generate a summative index of restrictive mediation at school), girls perceived higher levels of restrictive measures regarding Internet use at school in both Brazil and Chile (see tables 10 and 11). This was also the case for active mediation strategies (both at school and at home). In Chile, adolescents perceive more restrictions at school than at home, while in Brazil there is no significant difference. This difference in Chile probably has to do with the inclusion of regulations for mobile phones among the indicators used, as these affect adolescents more than children. Lastly, there are no differences in school mediation measures by socioeconomic group in either country.

Table 10
Chile: normalized index of restrictive mediation strategies at school (z-values), by gender, age and socioeconomic group, 2016

			Mean comparison	
Gender[a]	Mean	N	T (t-test)	Significance
Male	-0.08	501.75	-2.29	0.022
Female	0.08	485.33		
Age[a]			T (t-test)	Significance
Children (9–13 years)	-0.06	536.92	-1.75	0.080
Adolescents (14–17 years)	0.08	450.16		
Socioeconomic group			F (analysis of variance)	Significance
C1 and C2	-0.11	173.14	0.54	0.583
C3	0.01	473.62		
D and E	0.04	340.32		
Total	0.00	987.08		

Source: Prepared by the authors, on the basis of Global Kids Online data.
[a] Difference is statistically significant at a 95% confidence level.

Table 11
Brazil: children (9–13 years) and adolescents (14–17 years) reporting that a teacher sets rules on what may and may not be done on the Internet at school, by gender, age and socioeconomic group, 2016
(Percentages)

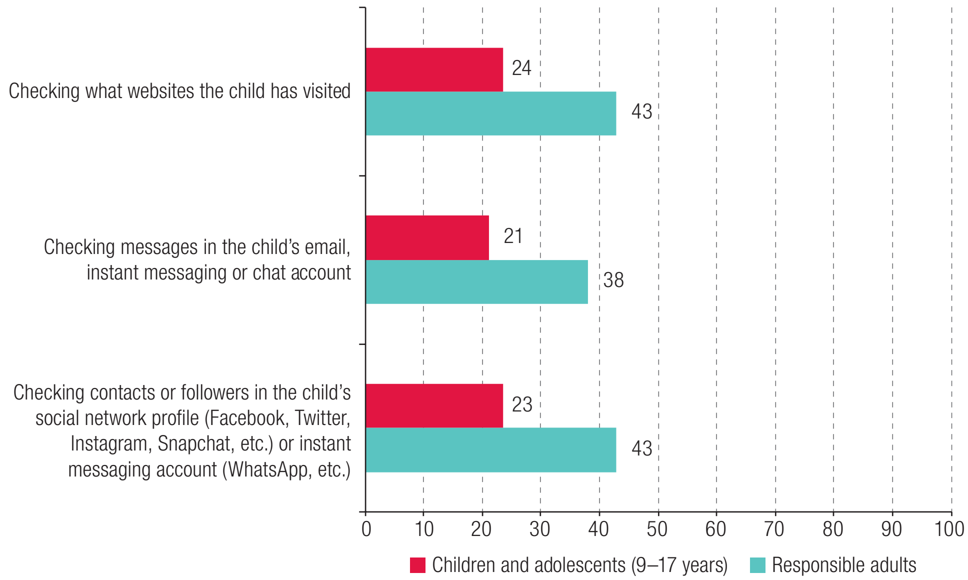
Gender[a]		Age		Socioeconomic group				
Male	Female	Children	Adolescents	A	B	C	D and E	Total
47	52	50	49	54	47	51	49	47

Source: Prepared by the authors, on the basis of Global Kids Online data.
[a] Difference is statistically significant at a 95% confidence level, as measured by the chi-square test.

The third type of mediation is technical monitoring (see figure 17). Again, there is a difference between children's and parents' perceptions. Only around 20% of Internet-using children in Chile report that their parents monitor their online activities, while almost double the proportion of responsible adults report implementing technical monitoring mediation strategies. In this case, the gap might also reflect children being unaware that their parents are checking up on their online activities.

Figure 17
Chile: respondents reporting that responsible adults always or almost always implement monitoring mediation strategies, 2016

(Percentages)



Source: Prepared by the authors, on the basis of Global Kids Online data.

In Chile, as with active mediation strategies, children and girls perceive higher levels of monitoring strategies at home than adolescents (see table 12), and there are no significant differences by socioeconomic group.

Table 12
Chile: normalized index of monitoring mediation strategies at home (z-values), by gender, age and socioeconomic group, 2016

				Mean comparison	
Gender[a]	Mean	N	Standard deviation	T (t-test)	Significance
Male	-0.10	470.37	0.95	-3.12	0.002
Female	0.10	454.40	1.04		
Age[a]				T (t-test)	Significance
Children (9–13 years)	0.26	501.32	1.05	9.75	0.000
Adolescents (14–17 years)	-0.30	423.45	0.84		
Socioeconomic group				F (analysis of variance)	Significance
C1 and C2	-0.03	155.70	1.00	0.48	0.620
C3	-0.01	449.63	0.97		
D and E	0.03	319.44	1.04		
Total	0.00	924.77	1.00		

Source: Prepared by the authors, on the basis of Global Kids Online data.
[a] Difference is statistically significant at a 95% confidence level.

4. Mediation strategies and digital opportunities

As described in the Methodology section, a summative index of digital opportunities was calculated in consideration of children and adolescents' online activities. Consistently with the results of the analysis done with data from Brazil by Cabello-Hutt, Cabello and Claro (2017), when the association of the different types of home mediation of children and adolescents' digital behaviour in Chile and Brazil with their digital opportunities was measured, active mediation strategies were found to be strongly related to greater opportunities for children and adolescents when the sociodemographic variables (gender, age and socioeconomic group) were controlled for (see tables 13 and 14). Restrictive mediation, conversely, was found to be strongly and negatively related to children's online opportunities, as would be expected, since these strategies reduce the times and spaces in which children can use the Internet. Lastly, monitoring strategies in Chile seemed to have a modest positive relationship with children and adolescents' digital opportunities.

Table 13

Chile: linear regression coefficients for children and adolescents' digital opportunities and mediation strategies in the home, 2016[a]

Model	Unstandardized coefficients		Standardized coefficients	t	Significance
	B	Standard error	Beta		
(Constant)	10.853	0.409		26.520	0.000
Index of adults' active mediation strategies in the home[b]	0.068	0.012	0.212	5.560	0.000
Index of adults' restrictive mediation strategies in the home[b]	-0.178	0.016	-0.467	-11.180	0.000
Index of adults' monitoring mediation strategies in the home[b]	0.090	0.033	0.104	2.690	0.007
High socioeconomic group (C1 and C2 as compared to D and E)	0.091	0.325	0.010	0.280	0.780
Middle socioeconomic group (C3 as compared to D and E)	-0.279	0.242	-0.039	-1.150	0.250
Adolescents (14–17 years) as compared to children (9–13 years)[b]	1.378	0.263	0.194	5.230	0.000
Male (as compared to female)	0.118	0.221	0.017	0.530	0.595

Source: Prepared by the authors, on the basis of Global Kids Online data.

[a] The index of digital opportunities is the dependent variable and R-squared is 0.28.

[b] Difference is statistically significant at a 95% confidence level.

Table 14

Brazil: linear regression coefficients for children and adolescents' digital opportunities and mediation strategies in the home, 2016[a]

Model	Unstandardized coefficients		Standardized coefficients	t	Significance
	B	Standard error	Beta		
(Constant)	6.938	0.193		35.860	0.000
Index of adults' active mediation strategies in the home[b]	0.085	0.013	0.103	6.380	0.000
Index of adults' restrictive mediation strategies in the home[b]	-0.449	0.016	-0.533	-28.630	0.000
High socioeconomic group (A and B as compared to D and E)[b]	1.094	0.101	0.200	10.780	0.000
Middle socioeconomic group (C as compared to D and E)b	0.627	0.083	0.137	7.510	0.000
Adolescents (14–17 years) as compared to children (9–13 years)[b]	0.619	0.088	0.131	7.010	0.000
Male (as compared to female)[b]	0.308	0.072	0.067	4.260	0.000

Source: Prepared by the authors, on the basis of Global Kids Online data.

[a] The index of digital opportunities is the dependent variable and R-squared is 0.43.

[b] Difference is statistically significant at a 95% confidence level.

Among the sociodemographic variables, age seems to be the only one that is relevant in Chile, in contrast to Brazil, where digital opportunities vary with gender and socioeconomic group. More specifically, in Brazil girls had fewer digital opportunities than boys, and the children of families in higher socioeconomic groups reported more digital opportunities (see table 14).

Tables 15 and 16 present the results of linear regression models that measure the association between school mediation and children's digital opportunities in Chile and Brazil, controlling for sociodemographic variables. Age is the most important of these variables in the school mediation models for both countries, showing a positive relationship with digital opportunities. As with parental mediation, Brazil's results show fewer digital opportunities for girls than for boys, while Chile does not present a gender gap. Socioeconomic group is again relevant in Brazil, where lower socioeconomic groups have fewer digital opportunities than higher socioeconomic groups. As for mediation strategies, active mediation at school, although significant, shows a modest effect only in Chile, and restrictive mediation strategies show no significant effect in either of the countries.

Table 15

Chile: linear regression coefficients for children and adolescents' digital opportunities and mediation strategies at school, 2016[a]

Model	Unstandardized coefficients		Standardized coefficients	t	Significance
	B	Standard error	Beta		
(Constant)	8.746	0.411		21.274	0.000
Index of adults' active mediation strategies at school	0.043	0.010	0.155	4.350	0.000
Index of adults' restrictive mediation strategies at school	-0.012	0.058	-0.007	-0.202	0.840
High socioeconomic group (C1 and C2 as compared to D and E)[b]	0.705	0.321	0.078	2.193	0.029
Middle socioeconomic group (C3 as compared to D and E)	0.036	0.245	0.005	0.147	0.883
Adolescents (14–17 years) as compared to children (9–13 years)	2.567	0.220	0.371	11.669	0.000
Male (as compared to female)	-0.096	0.221	-0.014	-0.433	0.665

Source: Prepared by the authors, on the basis of Global Kids Online data.

[a] The index of digital opportunities is the dependent variable and R-squared is 0.17.

[b] Difference is statistically significant at a 95% confidence level.

Table 16

Brazil: linear regression coefficients for children and adolescents' digital opportunities and mediation strategies at school, 2016[a]

Model	Unstandardized coefficients		Standardized coefficients	t	Significance
	B	Standard error	Beta		
(Constant)	5.16	0.20		25.70	0.00
Index of adults' active mediation strategies at school[b]	0.06	0.03	0.04	1.80	0.07
Index of adults' restrictive mediation strategies at school	0.02	0.16	0.00	0.10	0.92
High socioeconomic group (A and B as compared to D and E)[c]	2.84	0.19	0.32	14.60	0.00
Middle socioeconomic group (C as compared to D and E)[c]	1.61	0.17	0.21	9.69	0.00
Adolescents (14–17 years) as compared to children (9–13 years)[c]	2.92	0.14	0.39	20.71	0.00
Male (as compared to female)[c]	0.37	0.14	0.05	2.58	0.01

Source: Prepared by the authors, on the basis of Global Kids Online data.

[a] The index of digital opportunities is the dependent variable and R-squared is 0.22.

[b] Difference is statistically significant at a 90% confidence level.

[c] Difference is statistically significant at a 95% confidence level.

IV. Conclusions

The analysis presented in this paper has aimed at offering a comparative picture of the digital access and opportunities of children and adolescents in Brazil and Chile and the mediation strategies applied to them by adults, in the context of increasing digitalization of their societies. It has also looked to explore the main gaps associated with sociodemographic variables as significant axes of social inequality in the Latin America region.

Where access is concerned, the results showed similar trends in Brazil and Chile regarding places and devices from which the Internet is accessed, but young users in Chile are more likely to access the Internet through a computer and show higher levels of use at home and school than young Internet users in Brazil. Concerning sociodemographic differences, although access through mobile phones has increased in the past few years, there are still differences in equipment types and connectivity that need to be addressed in both countries.

Concerning Internet use at school, only half of young Internet users or fewer reported this in both countries. In the case of Brazil, these results are consistent with data indicating that while 96% of urban schools are connected to the Internet, only 39% of students report using the Internet at school (CGI.br, 2017). Although Brazil has made substantial long-term investments in digital education policies, such as the National Programme of Informatics in Education (ProInfo), in place since 1997, the majority of students do not mention school as somewhere they access the Internet. In many schools, computer laboratories are only available for teachers and administrative staff, and connectivity speed and quality are a problem (Costa and Senne, 2018). In the case of Chile, 81% of schools have Internet access (Ministry of Education, 2013) and there are 4.7 students per computer, which matches the Organisation for Economic Co-operation and Development (OECD) average (Ministry of Education, 2015). Despite these promising data, digital technologies are underused in Chilean schools (Hepp and others, 2017).

As for frequent users (i.e., those who report connecting to the Internet more than once a day), Chile shows a higher proportion, probably because of its higher levels of home access. With respect to sociodemographic differences, there are no gender gaps in the proportion of frequent users in either country. Nevertheless, high-frequency users tend to be from higher socioeconomic groups in both countries, with socioeconomic gaps being larger in Brazil than in Chile. It is important to mention the strong body of evidence indicating that more frequent Internet use is not in itself a beneficial activity; it depends on the adult guidance provided and the level of risk exposure (Cabello-Hutt, Cabello and Claro, 2017; Livingstone and others, 2017).

Where digital opportunities are concerned, the results show that the most common areas of digital activity are learning and social life. Both countries evince high levels of formal learning activities (i.e., activities related to schoolwork), indicating the importance of schools and teachers' guidance and mediation in promoting children and adolescents' digital opportunities in these countries. Informal learning activities (children looking for information on subjects they are interested in) are also important. Social networking and chatting online are likewise very frequent activities, especially among adolescents in both countries, probably because it extends the time and space of social interaction, something that is important at this stage of life (Boyd, 2007). These results are consistent with evidence showing that Brazil and Chile rank high for social network use in the world, in terms of users as a share of the population (Pavez, 2014).

The most widely used social networks in Brazil and Chile are Facebook and WhatsApp; Instagram and Snapchat show segmented use with clear age differences, while Twitter presents the lowest percentages of use. This finding is consistent with earlier analysis indicating that Twitter is a non-teenage-oriented network (Santoyo-Cortés and others, 2019), which may be explained by the fact that it is less about social relations and self-identity construction and more about public discourse

(O'Connor and others, 2010), political propaganda (Kalsnes, Krumsvik and Storsul, 2014) or marketing (Leung, Bai and Stahura, 2015). More in-depth studies of youths' social networking practices in the region are necessary given how they have been becoming part of behaviour in adolescence, when the construction of self-identity through social relationships is most intense (Navarrete and others, 2017; Murden and Cadenasso, 2018).

Concerning risks and the perception of harm, age and socioeconomic group are significant, with adolescents and higher socioeconomic groups showing higher levels of perceived harm. Both age and socioeconomic gaps may be linked to higher levels of Internet use, and thus higher exposure. However, as the Kids Online network research has shown, lower exposure to digital activities reduces not only risk but also digital opportunities and the potential for developing higher levels of digital skills to fully participate in the digital era (Dürager and Livingstone, 2012; Cabello-Hutt, Cabello and Claro, 2017). Consequently, the challenge is to promote these opportunities at the same time as taking specific protection measures.

An important finding is that there is also a gender gap: a higher percentage of girls than boys report perceived harm. This result calls for further and more qualitative research to understand the source of this gap and the types of activities or exposures that make girls and boys uncomfortable, depending on their gender. This would make it possible to understand the different resources and guidance strategies that boys and girls may need.

Regarding parental mediation, girls perceive higher levels of this than boys in both countries, which probably reproduces gender socialization practices whereby adults try to exert more control over girls' socialization (Cabello-Hutt, Cabello and Claro, 2016). The same trend can be observed in children as compared to adolescents, with children reporting higher levels of parental supervision and mediation. This shows how Internet use is part of the general social dynamic of parenthood and childhood, with children becoming more independent as they grow up and parents scaling back their guidance and supervision strategies.

Research has shown that the type of mediation is not the only factor related to risk or harm at a country level. Within a country, parental mediation should be considered in combination with other influences and characteristics of the child population, such as the role that schools and peers play, child development and resilience, and the sociodemographic characteristics of parents (Helsper and others, 2013). An integrated policy perspective should focus on the combination of elements required to comprehend and approach the problem. Policies must consider child development from a broad perspective, including the different dimensions associated with digital opportunities, such as access to material resources, households' socioeconomic background, parents' mediation role, education policies and children's skills, among others. The process of digital inclusion should be seen from a perspective that combines personal, family, cultural and structural factors (Cabello-Hutt, Cabello and Claro, 2017). Therefore, the challenge lies in building digital capacities and strategies for social and productive inclusion, online security and self-care.

Results from this research show schools to be an important mediation actor, particularly in Chile. The lesser Internet access at school of children in Brazil might be one of the factors explaining the more limited influence of school mediation strategies in students' digital opportunities in that country. "Education policy and the school system have been a positive point of entry to the digital world in the Latin American region. Especially in terms of providing more equitable access to technology but also in terms of offering pedagogical guidance that motivates students to use the technology independently for research and homework. However, there still is much to be done in terms of promoting an equitable formation of knowledge and cultural assets" (Trucco, 2013). An interesting finding is that, contrary to the situation in Brazilian homes, in Chile higher-income children perceive less guidance and mediation than lower-income children. This raises several questions, such as whether it means that higher-income children are given more autonomy at school. Alternatively, are schools providing remedial guidance and support for lower-income children? Both hypotheses should be tested in future research with a view to designing well-contextualized educational policies for schools with students from different socioeconomic backgrounds. It is also necessary to study the effect of these different strategies on the development of students' digital skills for learning and self-protection in a way that takes advantage of the benefits of technology so that they can develop and exercise their rights (ECLAC/UNICEF, 2014).

Concerning mediation strategies, they are a process that plays out mainly at home during childhood, so an important question is how parents can be involved. The results of this paper show how important parental mediation is for children's and adolescents' digital opportunities, with active mediation strategies having a positive association with opportunities, while restrictive strategies have a negative relationship. What might be the best approach to strengthening families' ability to develop these types of strategies and mediate children's use of technology? Parental mediation is not distributed equally, as this document has shown, whence the importance of adapting social policies to different contexts.

Social exclusion from the digital world, like other types of exclusion affecting adolescents and children, has long-term consequences for the skills they develop and their future opportunities to participate as full citizens in an increasingly digitalized world. The different levels of exclusion from the digital sphere tie in with other dimensions of social and economic exclusion in Latin America that are structural and mutually reinforcing (such as socioeconomic status, gender, ethnicity and race), as has been seen throughout this paper. Digital exclusion should therefore be addressed from a multidimensional perspective so that it can be approached with appropriate strategies for different populations.

The results presented in this paper in the context of the Kids Online network show that restrictions and controls are not everything, but that guidance and mediation also matter. Childhood development requires support from adults equipped to guide and promote the process of skill development and appropriation, instilling capabilities such as the ability to search, discriminate, synthesize, analyse and represent information in the digital environment and to use digital tools to share and collaborate with others. Educating children in these skills means going beyond technology as such and focusing on the capabilities needed to participate and be included in the digital world (Trucco, 2018).

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Supply, demand and economic growth in Mexico in the period 1980–2016

Marco Marquez

Abstract

Economic growth is produced by stimuli arising from supply and demand. On the supply side, growth depends on the accumulation of factors and their productivity. On the demand side, it is determined by government consumption, investment and spending and net exports. Input-output tables can be used to explain the contributions made by the growth of the components of each of the variables and to find the growth path followed by the economy. From this path it can be gauged whether the type of growth is more supply- or demand-led. This paper uses input-output tables to show that growth in Mexico has relied on more dynamic supply-side components, which is not conducive to the good performance of the economic system.

Keywords

Economic growth, economic policy, supply and demand, productivity, monetary policy, input-output analysis, Mexico

JEL classification

D24, D57, E52, O54

Author

Marco Marquez is a Mexican economist. Email: antoniomrqz@gmail.com.

I. Introduction

Different schools of economic thought have discussed the question of growth from a variety of perspectives. On the supply side, it has been explained by technological change and productivity (Jorgenson and Griliches, 1967; Solow, 1956; Romer, 1994). On the demand side, it has been explained by the circular flow model. Both Leontief (1941) and Keynes (1936) considered that this variable drove the level of output in the economy. Different growth hypotheses have been developed on the basis of the approaches of these two authors, such as those put forward from a Keynesian perspective by Harrod (1939) and Domar (1947), whose contributions were based on the assumption of an equilibrium situation. This was also the starting point of Leontief's model. In addition to determining the value of production from demand, this model asserts that the integration of production is the basis for growth. In fact, the work of identifying the key sectors in the economy rests on this pillar (Hirschman, 1958; Rasmussen, 1956; Sonis, Hewings and Guo, 2000).

This paper starts by using input-output (IO) tables to analyse the decomposition of sectoral growth. It considers the possibility of using the tenets of the neoclassical school to describe the table contents and establishing that output growth breaks down into two types of effects, the substitution effect and the income-expenditure or price-cost effect, which determine the contribution to growth of the supply side factors and the demand side components (Marquez, 2019). An IO table is composed of the matrix of transactions between branches and between these and factor suppliers, on the one hand, and purchasers of goods used in final consumption, on the other. The objectives of this article are to measure the composition of these contributions and to analyse the balance between the respective growth contributions of the factors and components concerned.

We assess the growth path and the equality of the contributions of the gross operating surplus coefficients and the inventory change coefficients together with gross capital formation, as these are accounting arrangements that can be related to saving and investment, respectively. The findings are used as a basis for explaining the bias in growth towards supply or demand in Mexico over the period 1980–2016. The article is organized into three sections. The first explains the models in the IO table and sets out the theoretical basis for assessing the contributions of the market factors and components that determine the growth path of an economy as given by its growth rate. The second section presents the context and characteristics of Mexican economic growth. This then provides the basis for expounding the hypothesis of this paper. As has been shown, the manufacturing export promotion model has resulted in internal disruption of the economic structure, in that inflows of imported intermediate inputs have increased at the expense of domestic ones (Aroche, 2006; Aroche and Marquez, 2012; Ruiz-Nápoles, 2004; Zárate and Molina, 2017). The growth of the Mexican economy has been supply-driven, and for that reason dynamic export growth has not been matched by output growth (De Souza and Gómez, 2018; Ros, 2008). Low growth continues because income account contributions on the supply side have been higher than expenditures on the demand side. In other words, it is perpetuated by the balances of the contributions of the income and expenditure coefficients of the accounts linked to the concepts of saving and investment. This is a reference to the financial balance, which in turn is equal to the combination of the trade surplus with production deficits in both the public and private sectors explained by internal structural disruption. This hypothesis is tested in the third section for the period 1980–2016. The contributions and growth paths of sectors, branches and the economy as a whole are identified in accordance with the 1980 and 2013 IO tables published by the National Institute of Statistics and Geography (INEGI), which are aggregated to 35 sectors at 2013 prices (Méndez, 2018). Lastly, some conclusions and economic policy considerations are presented.

II. The input-output table, growth and equilibrium

The construction of the IO table is based on the study of circular flow, which treats the economy as a complex system of productive agents who acquire the goods produced for the purpose of using them as inputs in their own goods production processes, while at the same time selling these goods to demanders, who in turn use them as inputs. In an open model, outputs can be used for consumption or investment, among other purposes, while producers also purchase factors, among other non-produced goods (Aroche, 2017; Aroche and Marquez, 2019). The columns of the IO matrix (1, 2, ..., n) show the value of the goods purchases by each of the producers (1, 2, ..., n) from each of the sellers (1, 2, ..., n). That is, each producer produces a homogeneous good (Leontief, 1936). Leontief's (1936) IO model takes the form of a system of equations in which the production function of the branches and the preferences of agents are givens, while the unknowns are relative prices and quantities (Miller and Blair, 2009). The IO table is based on the circular flow study, which treats the economy as a complex system of productive agents interrelated from production to consumption, or vice versa (Aroche, 2017).

In his open model, Leontief (1941) starts from the accounting equilibrium recorded for the value of production in the IO table by means of equation (1), where the column vector of the value of production (x) is equal to the inverse matrix $((I - A)^{-1})$ multiplied by the final demand vector (f). The matrix (A) of technical coefficients is produced by a transformation of the inter-industry transactions matrix (Z), which represents the proportions of inputs per unit of output. In the model, the value of production is determined by final demand, which is the component exogenous to the production structure, the latter being understood as the set of relationships between branches.

$$x = \left(I - A\right)^{-1} f \tag{1}$$

$$x' = v'\left(I - E\right)^{-1} \tag{2}$$

Equation (2) is the Ghosh (1958) model, which expresses the inverse solution in determining the value of production. According to this model, output is defined by supply, i.e. by the change in the components of value added (v'), which is expanded by the multiplier matrix $((I - E)^{-1})$ of the coefficients of delivery (E). This approach gave rise to the plausibility debate (Rose and Chen, 1991; De Mesnard, 2009; Guerra and Sancho, 2011; Oosterhaven, 2012) and even to its theoretical reinterpretation as the pricing model (Dietzenbacher, 1997; Miller and Blair, 2009). However, the nature of such models means that both are only plausible if the economy exhibits balanced growth (Aroche and Marquez, 2019).

Considering that the sum of the input and factor coefficients equals 1 in each branch of the IO table, equation (3) describes the unit of output on the side of purchases of domestic inputs $(i'Z^i)$ and imported inputs $(i'Z^m)$, and the payment of factors such as capital (k') and labour (l'), plus the net costs of State intervention, i.e. taxes minus subsidies (γ'). As Leontief (1936) pointed out, this is a homogeneous model of degree one in prices; hence it is a relative quantity model. Physical unit (quantity) and monetary unit (price) models are similar when prices relative to relative quantities are equal to 1 (Weisz and Duchin, 2006).

$$\begin{aligned} x_j = i'Z^i + i'Z^m + k_j + l_j + \gamma_j = iZ + v_j \rightarrow x_j\left(\widehat{x_j}\right)^{-1} = i'Z\left(\widehat{x_j}\right)^{-1} + v_j\left(\widehat{x_j}\right)^{-1} = i' \\ = i'A + v_jP \rightarrow i' - i'A = v_j \rightarrow i' = v_j\left(I - A\right)^{-1} \end{aligned} \tag{3}$$

On the sales side, the value of production (x) is measured in the IO table by adding up sales of intermediate inputs domestically $(Z^i i)$ and abroad $(Z^m i)$, plus the final demand components (f), such as consumption (c), investment (r), government expenditure (g) and net exports (o), i.e. exports minus imports of final goods. From this perspective, the quantity model (Miller and Blair, 2009) can be calculated from demand as:

$$x = Z^i i + Z^m i + c + r + g + o = Zi + f \rightarrow \widehat{x_i^{-1}} x_i = \widehat{x_i^{-1}} Z + \widehat{x_i^{-1}} if \rightarrow \ i = Ei + \phi \rightarrow i - Ei = \phi \rightarrow i = \left(I - E\right)^{-1}\left(\phi\right) \tag{4}$$

In this case, both $(I - A)^{-1}$ and $(I - E)^{-1}$ in equations (3) and (4), respectively, are the multiplier matrices. These are useful for studying the economic structure from the IO tables, which set out from the situation of accounting equilibrium.

The model and the IO table refer to the short run (i.e. technology does not change). Empirically, when national and international statistical offices publish new matrices, they always recalculate not only the gross value of production (x, x'), but also the technical and delivery coefficients (A, E). At the same time, it seems that no model has been developed that satisfactorily explains the transition from one year's matrix to the next (Schumann, 1994). Moreover, attempts to construct a dynamic model have not been brought to a satisfactory conclusion (Leontief, 1953 and 1970). Thus, the model has continued to employ comparative statics techniques to analyse the evolution of economies, with emphasis on the differential in the amounts produced by technological change and by final demand (Miller and Blair, 2009).

Setting out from equations (3) and (4), Marquez (2019) studies changes in the inputs and factors used in production by comparing the IO tables for two time periods (0, 1). He uses the Slutsky method to decompose the change in the coefficients contained in the differential $\Delta x = x^1 - x^0$ by two types of effects. The first, the substitution effect, is zero.[1] It refers to the exchange of factor and input coefficients per unit of output. What is involved on the demand side, meanwhile, is the trade-off between the coefficients of intermediate and final demand. The second effect is the price-cost or income-expenditure effect, which suggests a shift in the factors or components driven by the growth rate in the economy. This effect identifies the contributions of the coefficients in the IO table. If the economy today has changed compared to the past, this means that one unit plus the real change is produced. For example, if the economy has grown by 30%, it means that 1.3 units are produced today compared to the past. Assuming that the production functions are subject to constant returns, the 30% change implies a zero increase in the coefficients but a uniform 30% increase in the use of each input (prices are assumed to be invariable), expressed by constant returns $(\Delta x(A^t, v'^t) = x(\Delta A^t, \Delta v'^t))$. Thus, the output increment is equal to $1 + \Delta = x^t(A^t, v'^t) + \Delta(A^t, v'^t) = x^{tt}(A^{tt}, v'^{tt})$. The change, then, can be defined as the difference between the current growth with constant returns and the past ratios, i.e.:

$$\Delta' = \Delta x^{tt}\left(A^{tt}, v'^{tt}\right) - x^{t-1}\left(A^{t-1}, v'^{t-1}\right) = i'\left(\Delta A^{tt} - A^{t-1}\right) + \left(\Delta v'^{tt} - v'^{t-1}\right) \rightarrow \Delta' = i'A^* + v'^* \tag{5}$$

Equation (5) shows the growth path of the economy according to the growth contributions of the factor and input coefficients $(\Delta_j(A^*, v'^*))$. Setting out from this, a simile of the price model is expressed from the Leontief matrix, i.e. the price-cost effect, which, rather than explaining prices by factor coefficients, models growth by factor contributions (see equation (6)):

$$\Delta_j = i'A^* + v_j^* \rightarrow \Delta_j - i'A^* = v_j^* \rightarrow \Delta_j\left(I - \widehat{\Delta_j^{-1}} A^*\right) = v_j^* \rightarrow \Delta_j = v_j^*\left(I - A^{\Delta}\right)^{-1} \tag{6}$$

[1] As demonstrated in the work of Jorgenson and Griliches (1967) and revisited in the subject of productivity from the perspective of the IO model (see Miller and Blair, 2009).

The result of (6) establishes the growth rate of the sector as the product of factor inputs (v'^*) and a matrix of multipliers $\left((I-A^{\Delta})^{-1}\right)$ containing the matrix of technical input coefficients $\left(A^{\Delta}=\widehat{\Delta^{-1}}A^*\right)$. The value of (6) is not the unit row vector as in the case of (3), but the row vector of growth in the branches.

We can develop equations (5) and (6) in a way that parallels equation (4) and obtain the contributions to growth of the intermediate and final demand coefficients $\left(\Delta\left(E^*,\varphi^*\right)\right)$. Equation (7) establishes the income-expenditure effect with a structure similar to that of Ghosh's (1958) model:

$$\Delta=\left(I-E^{\Delta}\right)^{-1}\varphi^* \tag{7}$$

Both the Leontief and Ghosh models are equilibrium models that are deduced from the table, so they combine elements of demand-induced supply or components of supply-induced demand. This decomposition does not do the same because it decomposes the growth rate separately between supply and demand. However, it does enable us to analyse the balance of the contributions of the purchase or sale coefficients. Then, according to equation (5) and its extension for demand, equilibrium implies that the balance is zero. However, as the level of disaggregation of the accounts increases, the balances evince an inverse relationship, as shown in equation (8):

$$\Delta'=\Delta\rightarrow\Delta'-\Delta'=\left(i'A^*-\left(E^*i\right)'\right)+\left(v^{*'}-\varphi^{*'}\right)=\rho \tag{8}$$

In equation (8), ρ is a row vector that measures the sum of the differences between the contribution coefficients of intermediate purchases and sales $((i'A^*-(E^*i)'))$ and of the balance of the contributions of value added with final demand $((v^{*'}-\varphi^{*'}))$. The result is a null row vector.

The IO table disaggregates the input coefficients into domestic (A_i) and foreign (A_m), and the value added coefficients into employment compensation (w), operating surpluses (k) and production taxes net of subsidies $(tr-\zeta)$. On the demand side, it disaggregates the intermediate demand coefficients into their domestic (E_i) and foreign (E_x) components and the final demand coefficients into private consumption (ϱ), government consumption (γ) and net exports (χ), i.e. exports minus imports. The coefficients of inventory changes and gross fixed capital formation are also disaggregated. However, these items are company expenditures that can be aggregated into one account labelled for the time being as investment (π).

In an equilibrium condition, the changes in supply and demand are the same, so that $\Delta'=\Delta$ is satisfied and thus companies' income is assumed to go to saving and their expenditure to investment. Then, by disaggregating the contributions of the coefficients, we rewrite (8) as (9) in terms of the contribution to growth of the disaggregated coefficients and conclude that the balance of $-\left(k_j^{\Delta}-\pi_i^{\Delta'}\right)$ is equal to the sum of the remainder of the differences in the supply and demand coefficients:

$$\begin{gathered} i'A_i^{\Delta}+i'A_m^{\Delta}+w^{\Delta'}+k^{\Delta'}+\left(tr-\zeta\right)^{\Delta'}=E_i^{\Delta}i+E_x^{\Delta}i+\varrho^{\Delta}+\pi^{\Delta}+\gamma^{\Delta}+\chi^{\Delta}\rightarrow \\ -\left(k^{\Delta'}-\pi^{\Delta'}\right)=\left(i'A_i^{\Delta}-\left(E_i^{\Delta}i\right)'\right)+\left(i'A_m^{\Delta}-\left(E_x^{\Delta}i\right)'\right)+\left(w^{\Delta'}-\varrho^{\Delta'}\right)+\left(\left(tr-\zeta\right)^{\Delta'}-\gamma^{\Delta'}\right)-\chi^{\Delta'} \\ -Fn^{\Delta}=\left(Pr_i^{\Delta}\right)+\left(Pr_{xm}^{\Delta}\right)+\left(Pv^{\Delta}\right)+\left(Pb^{\Delta}\right)-\chi_i^{\Delta'} \end{gathered} \tag{9}$$

Equation (9) shows that the discrepancies between the growth contributions of $k^{\Delta'}$ and π^{Δ} are equal to the sum of the domestic $\left(Pr_i^{\Delta}\right)$ and external $\left(Pr_{xm}^{\Delta}\right)$ production, private (Pv^{Δ}), public (Pb^{Δ}) and trade (χ^{Δ}) balances measured by the equality of supply and demand growth when output changes and expressed by the balance of the contributions of the supply factors and the demand components.

Just as income and production are the same in the short run in national accounting, here we assume that growth is the same across these variables. This identity allows us to formulate equation (9).[2]

It has been shown from demand models (Harrod, 1939) that in the dynamic equilibrium between supply and demand, when the economy grows, the growth condition is that the natural rate and the warranted rate be the same between saving and investment. In the case of equation (9), if the financial balance $\left(-Fn^{\Delta}=-\left(k_j^{\Delta}-\pi_i^{\Delta'}\right)=0\right)$ and all other differences are also zero, change allows aggregate output to grow with price stability.

If the growth path is intensive, i.e. growth is mainly explained by some supply or demand component but satisfies the condition $k^{\Delta}=\pi^{\Delta} \therefore Fn^{\Delta}=0$, then the intensity of that factor causes a deficit or surplus in its balance and its opposite in the other differences in equation (9). However, the paths along which the system operates are different and can even be combined.

At the level of aggregate supply and demand, if $Fn^{\Delta}=0$ but there is a growth path with an intensive factor, supply and demand shifts are prone to imbalances between k^{Δ} and π^{Δ}, and the economy may exhibit price-distorting growth. When $Fn^{\Delta}>0$, the increase in demand is greater than the increase in supply, and investment contributes more than saving. There are consequently surpluses in the other items in equation (9), and the system tends to have higher price increases because of the supply effect than because of the demand effect. In the case of $Fn^{\Delta}<0$, i.e. when saving contributes more than investment, the impact on the aggregate equilibrium point of the market is a decrease in prices with an increase in quantities. This is because demand increases by less than supply. Falling prices imply a devaluation of the economic system and suggest that the economy is running deficits in other balances. According to this circularity reasoning, the only way to guarantee growth without higher prices is for the proportions of supply- and demand-driven growth to be the same, since an increase in one factor entails an increase in one component.

III. The Mexican economy

After the 1980 crisis, the Mexican economy transformed its economic structure and brought in a development strategy based on trade liberalization and market deregulation, among other measures (De Souza and Gómez, 2018; Guillén, 2010; Ruiz-Nápoles, 2004). Monetary policy until 1994 focused on discussion of how to increase investment incentives. Thereafter, monetary policy focused on the inflation targeting regime (Capraro and Perrotini, 2011).

This process transformed the conditions of the production structure, since opening up the economy had the potential to lead to increased investment. Thus, the signing of the North American Free Trade Agreement (NAFTA) solved the problem of growth by attracting foreign direct investment (FDI) from the United States (Pastor, 2012) and even resulted in more diversified exports. From consisting mainly of oil, they became mainly industrial (Ruiz-Nápoles, 2004), but at the same time interdependent with the United States business cycle (Antón 2011; Aroche and Marquez, 2016).

However, Mexico's low rates of economic growth have been explained by the influence of the exchange rate as an investment determinant (Moreno-Brid, 1998; Puyana and Romero, 2010; Blecker, 2009; Ibarra, 2008). These low rates have also been explained by imbalances between the natural and warranted rate in Harrod's (1939) model, resulting from a low level of productivity relative to the investment coefficient. This implies capital accumulation and lower employment (Avendaño and Perrotini, 2015; Ros, 2008).

[2] From the aggregate point of view, in an economy with a State and an external sector, the income and output identity dictates that the difference between private sector saving and investment is equal to the public deficit plus the trade surplus (Dornbusch, Fischer and Startz, 2004).

The Mexican economy has moved from internal to external industrialization, which is more vulnerable to shocks from the international economy. Studies on the economic structure have confirmed that the low level of growth and employment is due to the weakness of the internal linkages underpinning the economic structure (Aroche, 2006; Ruiz-Nápoles, 2007; Marquez, 2018). Zárate and Molina (2017) argue that the integration of this structure into global processes is reflected in the substitution of domestic inputs by imported inputs and that the domestic structure does not have the capacity to benefit from international trade. Other types of studies have pointed out that the low level of growth is due to a lack of dynamism in the industrial sector, low productivity and balance-of-payments constraints (Avendaño and Perrotini, 2015; Calderón and Sánchez, 2012; Moreno-Brid, 1998; Morones, 2016; Ros, 2013; Sánchez and Moreno-Brid, 2016).

Owing to the change in the disaggregation criteria of INEGI, it is impossible to analyse economic activity in conjunction with structural change in Mexico, which would come out in the methodology for measuring output, since from a statistical point of view a change in the way economic activity is disaggregated signals a change in structure (Aroche, 2006). The analysis of the period 1980–2013 has been carried out using the databases prepared in accordance with the two methodologies described, one for the period 1980–1993 and the other for the period 1993–2016, and published by INEGI. However, these two periods represent two distinct major stages in the transition of the economic model and structural change in the Mexican economy.

The first database, covering the period 1980–1993, covers the process of economic policy transformation. A number of events altered the course of the economy. The change in the export model during this period involved the start and continuing pursuit of market deregulation and disengagement from economic activities previously considered strategic, as well as export-led growth.

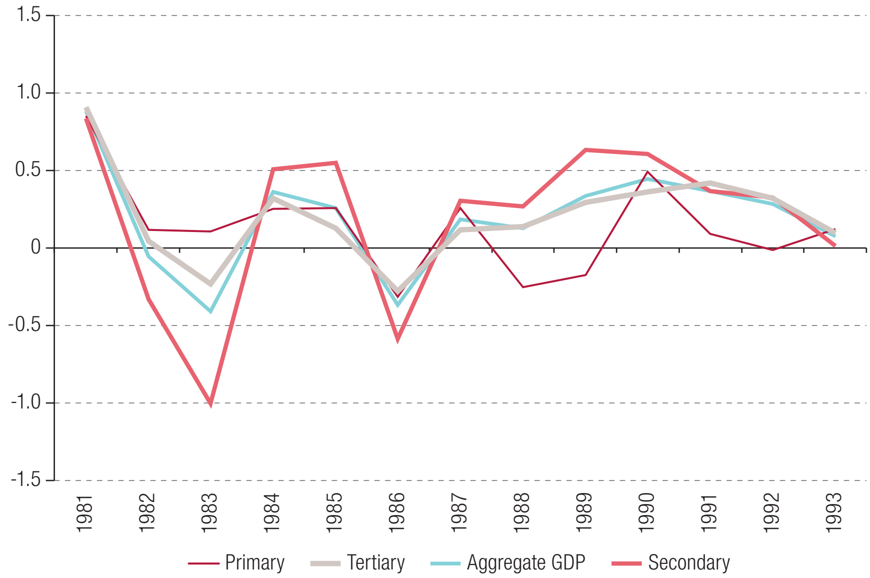
Figure 1 shows the growth rates of gross domestic product (GDP) in the whole economy and in the primary, secondary and tertiary sectors for the period 1980–1993 at 1993 prices, according to INEGI data. It shows the drop in 1983 due to the debt crisis a year earlier, and that of 1986 due to the fall in oil prices in 1985, which combined with inflation and devaluation of the currency against the dollar. Average growth during the period was 0.19%.[3] Correlation was higher, slightly more so in the service sector than in the industrial sector.

In 1994, the process of adopting the new growth model ended and a period characterized by a policy of preferential export promotion (essentially with the United States) began, continuing to the present day (Ruiz-Nápoles, 2007). The political cycle began to become desynchronized from the economic cycle: as the data reveal, the Fox, Calderón and Peña administrations did not experience crises in their election years, as was previously the case (Guillén, 2010). Figure 2 shows the GDP performance of the economy and the different sectors at 1993 prices during the period 1994–2016, when the average growth rate of 2.5% had a 98% correlation with industrial growth and 96% with that of services. This period of preferential export promotion policy can be divided into two subperiods, the first from 1994 to 2001 and the second from 2002 to 2016. The 1994–2001 subperiod was characterized by average growth of 3%. The signing of NAFTA allowed FDI to increase and act as a lever of growth (Ros, 2004). In addition, this period was characterized by diplomatic ties that fostered integration with the United States (Pastor, 2012).

The economy managed an export boom during this period, as it shifted from a primary economy to one diversified into labour-intensive medium-technology manufacturing (Ros, 2004). The Mexican economy had to cope with external factors that caused a change in the dynamism of trade and output at that time. Externally, the pace of trade slowed owing to non-tariff barriers after the attacks on the United States in 2001 (Pastor, 2012). Domestically, trade was changed as a result of reforms to free zones by the 2002 border area and border strip regime in Mexico.

[3] This growth rate is close to the 0.16% calculated by Márquez (2010) for the period 1981–1988, when he analysed structural change from the perspective of the behaviour and composition of output from 1921 to 2007.

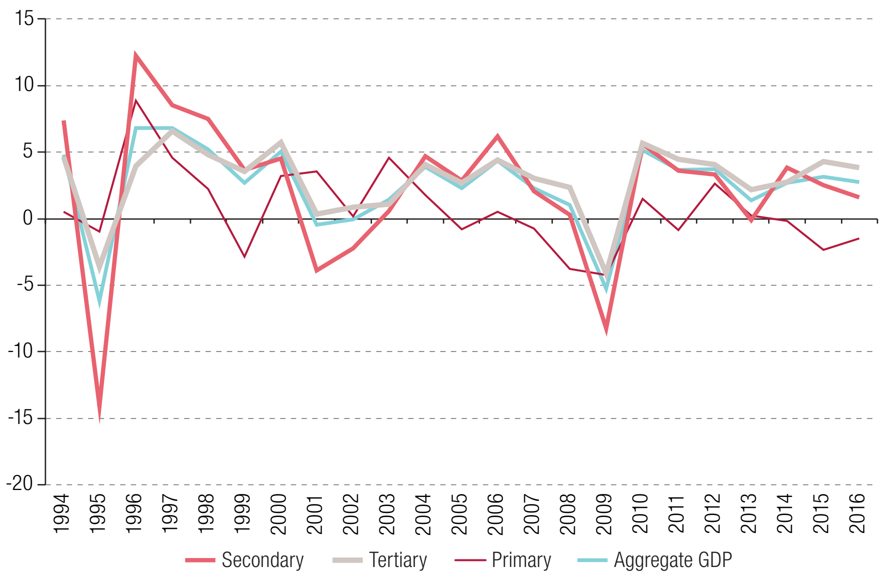
Figure 1
GDP growth in the aggregate and by sector, at 1993 prices, 1981–1993
(Percentages)



Source: Prepared by the author, on the basis of data from the National Institute of Statistics and Geography (INEGI).

The subperiod 2002–2016 was characterized by the dominance of preferential manufacturing export trade to the United States market and a diversified import trade. This increase in imports from other countries, such as China, created a trade deficit in the auto parts market (Álvarez and Cuadros, 2012). As figure 2 shows, the average growth rate was 2.3% during the period 2002–2016. The data show that the decline in 2009 was made up for by growth in 2010. This subinterval was characterized by macroeconomic stability and strategic reforms, such as the 2013 energy and education reform and the 2014 financial reform.

Figure 2
GDP growth in the aggregate and by sector, at 1993 prices, 1994–2016
(Percentages)



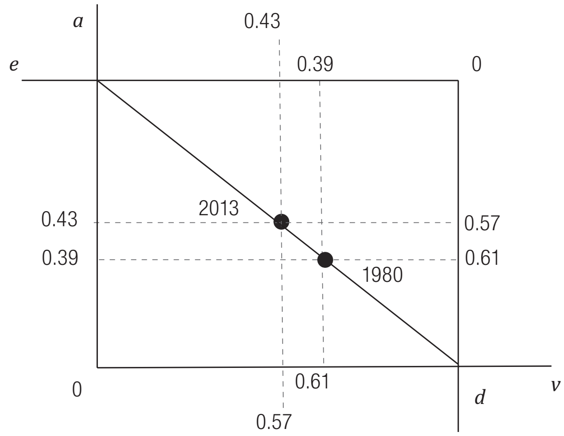
Source: Prepared by the author, on the basis of data from the National Institute of Statistics and Geography (INEGI).

The export-led economic growth model resulted in both FDI and manufacturing exports increasing (Ros, 2008). However, not only was growth low, but so was per capita income, and this went together with income concentration problems and low rates of expansion of formal employment, owing to a rise in informal employment (Fujii, 2003; Cruz, 2013; Ros, 2004). It seems that trade and investment effects have not acted as growth determinants. This context suggests a hypothesis: that the increase in investment in the economy is not correlated with savings, since export growth has produced a surplus and imported intermediate inputs have grown by more than domestically produced ones. Therefore, the financial surplus is composed of an external production surplus and net exports, with a domestic production deficit, private and public, resulting from the disruption of the industrial system and the profile of the economic growth model.

IV. Results

Figure 3 shows the general equilibrium of the economy, i.e. the aggregate output of its branches in the 1980 and 2013 IO tables, expressed by the input (a) and value added (v) coefficients for supply and by the delivery (e) and final demand (d) coefficients for demand. These coefficients express proportions per unit of output; for example, one unit of output explained by supply is composed at the 1980 point by 0.61 of the v coefficient and 0.39 of the a coefficient, and by the same proportions for the e and d coefficients, respectively. The isoquant of supply and demand is one of equilibrium with a vector of unit prices, as shown by the diagonal of the box in figure 3.

Figure 3
Mexico: general equilibrium, 1980 and 2013
(Coefficients per unit of output)



Source: Prepared by the author, on the basis of data from the National Institute of Statistics and Geography (INEGI), input-output tables.

The chart shows that between 1980 and 2013 the economy's v coefficient decreased and a increased (from 0.39 to 0.43 per unit of output). Internally in a, the imported input coefficient increased from 0.04 to 0.14. At the same time, the composition of the v coefficient underwent a decline (from 0.61 to 0.57), composed of an increase in the gross operating surplus (from 0.37 to 0.40) and a fall in the employee compensation coefficient (from 0.17 to 0.16) and in indirect taxes net of subsidies (from 0.06 to 0.003). These results can be explained by low labour productivity and the low rate of accumulation (Avendaño and Perrotini, 2015; Ros, 2008).

On the demand side, figure 3 shows an increase in the coefficient of intermediate demand (e) as a counterpart to the increase in the aggregate coefficient of intermediate consumption. Analysis of the composition of the d coefficient shows that the total coefficient of private consumption decreased (from 0.42 to 0.37); that of government expenditure increased (from 0.03 to 0.07); that of investment (i.e. gross capital formation together with the change in inventories) held steady at 0.13%; and, lastly, that of net exports fell (from 0.02 to -0.01).

Table 1 shows the composition of output by sector of the economy (x') over the total for the economy (X), i.e. $\frac{x'}{X}$ and the supply and demand coefficients for each of them, calculated on the basis of the IO tables. It can be seen that the share of output increased in the service sector, to the detriment of the primary and secondary sectors. On the supply side, the use of domestic intermediate input coefficients $(i'A^i)$ decreased between 1980 and 2013, while that of imported ones $(i'A^m)$ increased. The operating surplus (k) coefficients of the primary and service sectors increased, while in industry they remained almost the same as in 1980. Wage (w) coefficients decreased in all sectors. Broadly speaking, intermediate input coefficients increased and value added coefficients decreased.

On the demand side, table 1 shows that the intermediate sales coefficients $((E^i i)')$ decreased. The external sales coefficients $((E^m i)')$ increased in the industrial sector, decreased in the primary sector and remained unchanged in services. Consumption coefficients (ϱ) decreased in all sectors, and government expenditures (γ) increased only in services, decreasing in the primary and secondary sectors. Investment coefficients (π) increased in all sectors except services. Net export coefficients (χ) increased in the primary and industrial sectors, while they declined in the tertiary sector. Overall, intermediate sales increased in the secondary and tertiary sectors, but declined in the primary sector. Final demand was higher in the primary sector than in the industrial and tertiary sectors.

Table 1

Composition of the gross value of production by sector and supply and demand coefficients in the input-output matrices, 1980 and 2013

(Units of output)

Sector	1980											
	$\frac{x'}{X}$ (percentages)	$i'A^i$	$i'A^m$	w'	k'	$(tr-\xi)'$	$(E^i i)'$	$(E^m i)'$	ϱ'	γ'	π'	χ'
Primary	12	0.24	0.01	0.18	0.56	0.00	0.60	0.07	0.26	0.00	0.06	0.02
Secondary	46	0.51	0.08	0.15	0.24	0.03	0.36	0.07	0.38	0.01	0.22	-0.03
Tertiary	42	0.20	0.01	0.20	0.47	0.12	0.27	0.01	0.51	0.06	0.07	0.09
Sector	2013											
	$\frac{x'}{X}$	$i'A^i$	$i'A^m$	w'	k'	$(tr-\xi)'$	$(E^i i)'$	$(E^m i)'$	ϱ'	γ'	π'	χ'
Primary	8	0.21	0.07	0.07	0.66	0.00	0.53	0.06	0.07	0.00	0.10	0.24
Secondary	42	0.42	0.26	0.09	0.23	0.00	0.24	0.31	0.29	0.00	0.26	-0.11
Tertiary	49	0.20	0.05	0.24	0.50	0.01	0.30	0.01	0.49	0.14	0.03	0.03

Source: Prepared by the author on the basis of the 1980 matrix (at 2013 prices) and of National Institute of Statistics and Geography (INEGI), 2013 input-output tables.

Note: The expressions denote the following concepts:

$\frac{x'}{X}$: Composition of output.
$i'A^i$: Domestic intermediate inputs coefficients
$i'A^m$: Imported intermediate input coefficients.
w' : Wage coefficients.
k' : Operating surplus coefficients.
$(tr-\xi)'$: Coefficients of taxes net of production subsidies.
$(E^i i)'$: Domestic intermediate demand coefficients.
$(E^m i)'$: Imported intermediate demand coefficients.
ϱ' : Final consumption coefficients.
γ' : Government spending coefficients.
π' : Investment coefficients.
χ' : Net export coefficients.

At the sector level, the economic data show that intermediate consumption and final demand decreased in the primary sector, which means that value added and intermediate demand increased. In the case of industry and services, intermediate consumption and intermediate demand increased and value added and final demand decreased.

In order to decompose the changes in output in the economy during the period 1980–2016, we used the average growth rates for output, the sectors and the branches with the two INEGI databases available, which were used to analyse the behaviour of GDP in the previous section. Table 2 shows the composition of the growth path according to the average change in output (Δ) in the two databases. The growth path followed by the economy resulted in an expansion of 1.34%, and from a supply side perspective was intensive in intermediate input coefficients and operating surpluses. On the demand side, the path was biased towards intermediate demand coefficients. In private consumption, the growth path of the economy moved from one Cartesian coordinate of inputs and factors (0.4337 and 0.5663) to another (0.4396 and 0.5738) whose combination produces 1.0134 units, i.e. a change of 1.34%.

Table 2

Growth contributions by supply factor and demand component, 1980–2016

(Percentages)

Sector	Supply						Demand					
	Δ	$iA_i^{\Delta'}$	$iA_m^{\Delta'}$	w'^{Δ}	k'^{Δ}	$(tr-\zeta)'^{\Delta}$	$E_i^{\Delta}i'$	$E_m^{\Delta}i'$	ϱ'^{Δ}	γ'^{Δ}	π'^{Δ}	χ'^{Δ}
Total	1.34	-5.11	10.07	-0.84	3.16	-5.94	0.39	0.19	0.50	0.10	0.18	-0.01
Primary	0.43	-3.34	5.78	-11.41	9.47	-0.08	0.23	0.02	0.03	0.00	0.04	0.10
Secondary	1.18	-8.12	18.34	-5.55	-0.79	-2.71	0.29	0.37	0.35	0.00	0.31	-0.13
Tertiary	1.59	-0.32	4.20	4.42	4.45	-11.15	0.47	0.01	0.78	0.23	0.04	0.06
Branch	Δ_i	$iA_i^{\Delta'}$	$iA_m^{\Delta'}$	$w_j^{\Delta'}$	$k_j^{\Delta'}$	$(tr-\zeta)_j^{\Delta'}$	$E_i^{\Delta}i'$	$E_m^{\Delta}i'$	ϱ_i^{Δ}	π_i^{Δ}	γ_i^{Δ}	χ_i^{Δ}
Agriculture, animal husbandry, forestry, fisheries and hunting	0.98	5.89	7.76	-8.41	-4.86	0.60	0.62	0.12	0.21	0.00	0.06	-0.03
Mining	0.23	-5.90	3.29	-10.98	16.00	-2.17	0.11	0.00	0.00	0.00	0.03	0.09
Electricity generation, transmission and distribution, supply of piped water and gas to final consumers	2.54	-12.93	13.22	-13.46	16.63	-0.91	1.88	0.01	0.64	0.00	0.00	0.02
Construction	1.08	-35.93	4.74	1.71	30.49	0.07	0.10	0.00	0.00	0.00	0.98	0.00
Food industry	1.24	-17.76	0.91	-0.18	16.44	1.83	0.22	0.06	1.03	0.00	0.01	-0.08
Drinks and tobacco industry	1.61	4.80	9.26	-8.76	15.81	-19.51	0.08	0.01	1.35	0.00	0.02	0.13
Manufacture of textile inputs and textile finishing	-0.45	11.42	19.88	-6.69	-21.68	-3.38	-0.29	-0.38	-0.08	0.00	0.00	0.30
Manufacture of textile products other than apparel	-0.72	8.73	27.64	1.58	-41.50	2.83	-0.17	-0.19	-0.36	0.00	-0.03	0.03
Manufacture of apparel	0.02	-11.44	22.01	4.10	-8.92	-5.73	0.00	0.00	0.01	0.00	0.00	0.00
Tanning and finishing of hides and leather and manufacture of products of hide and leather and substitutes thereof	-0.73	-4.21	16.75	-8.11	-4.43	-0.74	-0.12	-0.17	-0.63	0.00	-0.02	0.21
Wood industry	-0.01	6.68	10.56	-1.37	-13.57	-2.31	-0.01	0.00	-0.01	0.00	0.00	0.00
Paper industry	1.71	9.90	17.20	-7.94	-13.82	-3.64	1.02	0.84	0.53	0.00	0.05	-0.73
Printing and allied industries	0.54	6.72	5.48	-3.57	-4.31	-3.79	0.35	0.11	0.15	0.02	0.00	-0.10
Manufacture of oil and coal derivatives	0.19	-58.52	9.41	21.24	21.37	6.70	0.12	0.07	0.06	0.00	0.00	-0.06
Chemical industry	0.66	-0.91	11.66	-7.99	-1.03	-1.06	0.32	0.38	0.27	0.00	0.02	-0.33
Plastic and rubber industry	1.14	6.13	21.44	-8.23	-12.34	-5.85	0.56	0.74	0.34	0.00	0.03	-0.53
Manufacture of products from non-metallic minerals	0.81	28.03	9.21	-9.54	-24.01	-2.88	0.62	0.12	0.06	0.00	0.00	0.00
Basic metal industries	1.00	-6.03	5.04	-6.86	9.62	-0.75	0.57	0.39	0.00	0.00	0.10	-0.05
Metal products manufacturing	1.17	12.33	11.28	-9.56	-4.99	-7.89	0.54	0.82	0.19	0.00	0.11	-0.48
Machinery and equipment manufacturing	1.89	-3.09	29.35	-9.02	-11.83	-3.52	0.09	1.57	0.04	0.00	1.74	-1.55
Manufacture of computer, communication, measuring and other equipment and electronic components and accessories	1.93	-14.27	64.46	-17.14	-27.00	-4.12	0.02	1.54	0.25	0.00	0.37	-0.25

Table 2 (concluded)

Branch	Supply						Demand					
	Δ_i	$iA_i^{\Delta'}$	$iA_m^{\Delta'}$	$w_j^{\Delta'}$	$k_j^{\Delta'}$	$(tr-\zeta)_j^{\Delta'}$	$E_i^{\Delta}i'$	$E_m^{\Delta}i'$	ϱ_i^{Δ}	π_i^{Δ}	γ_i^{Δ}	χ_i^{Δ}
Manufacture of electricity generation accessories, electrical appliances and equipment	1.31	-0.83	42.42	-14.19	-22.35	-3.74	0.11	0.89	0.23	0.00	0.20	-0.13
Manufacture of transport equipment	3.50	-2.93	24.74	-12.38	-2.02	-3.91	0.39	0.81	0.81	0.00	0.62	0.86
Other manufacturing industries	1.58	3.74	36.99	0.00	-34.96	-4.18	0.26	0.82	0.62	0.00	0.14	-0.26
Commerce	1.88	6.07	2.57	-3.89	17.60	-20.46	0.63	0.00	0.85	0.00	0.14	0.26
Transport, post and storage	1.59	-7.00	5.25	-1.07	2.44	1.97	0.36	0.00	1.04	0.00	0.10	0.08
Information in mass media	4.66	18.75	7.60	-23.12	17.06	-15.64	1.98	0.02	2.61	0.01	0.06	-0.02
Financial and insurance services	4.81	19.90	3.65	-39.49	12.64	8.11	1.22	0.41	3.37	0.02	0.00	-0.21
Real estate and movable and intangible goods leasing services	1.66	1.18	1.29	-0.65	4.89	-5.05	0.30	0.00	1.35	0.00	0.01	0.00
Professional, scientific and technical services	1.33	-17.99	3.60	24.46	-7.29	-1.45	1.21	0.04	0.09	0.02	0.00	-0.04
Education services	0.86	-15.35	1.81	6.57	7.17	0.67	0.01	0.00	0.19	0.67	0.00	0.00
Health and social assistance services	1.12	-20.18	3.72	21.47	-5.95	2.06	0.01	0.00	0.31	0.80	0.00	0.00
Cultural and sporting leisure services and other recreational services	0.38	-15.20	3.19	2.32	8.70	1.36	0.02	0.00	0.32	0.03	0.00	0.00
Temporary accommodation and food and drink preparation services	0.58	-7.02	5.22	1.24	3.82	-2.68	0.09	0.00	0.49	0.00	0.00	0.00
Other services except government activities	66.50	-60.79	3.25	43.76	11.76	2.69	0.06	0.00	0.17	0.44	0.00	0.00

Source: Prepared by the author, on the basis of data from the National Institute of Statistics and Geography (INEGI), input-output tables of 1980 and 2013.

Note: The expressions denote the following:

Δ : Growth rate.

$iA_i^{\Delta'}$: Growth contribution of domestic input coefficients.

$iA_m^{\Delta'}$: Growth contribution of imported input coefficients.

w'^{Δ} : Growth contribution of wage coefficients.

k'^{Δ} : Growth contribution of operating surplus coefficients.

$(tr-\zeta)_j^{\Delta'}$: Growth contribution of coefficients of production taxes net of subsidies.

$E_i^{\Delta}i'$: Growth contribution of domestic intermediate demand coefficients.

$E_m^{\Delta}i'$: Growth contribution of imported intermediate demand coefficients.

ϱ'^{Δ} : Growth contribution of final consumption coefficients.

γ'^{Δ} : Growth contribution of government expenditure coefficients.

π'^{Δ} : Growth contribution of investment coefficients.

χ'^{Δ} : Growth contribution of net export coefficients.

At the sectoral level, services grew most. Structural change was driven by changes in the composition and growth of output (Márquez, 2010); data from the 1980 and 2013 IO tables confirm this. The contributions of the service factors were driven by the coefficients of imported inputs, wages and capital payments. In the secondary sector, their growth was due to imported intermediate inputs, while in the primary sector it was due to capital payments along with inputs. Thus, on the supply side, imported intermediate inputs contributed most to the growth of the sectors and the economy.

On the demand side, growth in the primary sector was driven by domestic intermediate sales and net exports. In the secondary sector, it was explained by external intermediate demand, consumption and government spending. In the tertiary sector, the external intermediate sales, consumption and investment components contributed most to the sector's growth.

At the branch level, the results can be aggregated into five groups: (i) the group of branches that grew the most, falling within a range of $\Delta > 2\%$ (5 branches); (ii) the second set, of activities growing in the range $1.5\% < \Delta_i < 2\%$ (8 branches); (iii) the third, in the range of $1\% < \Delta < 1.5\%$ (8 branches); (iv) the fourth, in the range of $0\% < \Delta < 1\%$ (10 branches); and (v) the group in which the branches presented declines, i.e. $\Delta < 0\%$ (4 branches). Thus, considering the dynamism displayed in each group, the service sector proves to be the most dynamic in the first. This sector contains the two most dynamic branches in the production structure, financial services and media information services, which are intensive in the domestic input and operating surplus coefficients.

In each of the groups, the best-performing branches were intensive in imported intermediate inputs. In particular, “other services except government activities” performed best in the first group, “manufacture of computer, communication, measuring and other equipment and electronic components and accessories” in the second, “professional, scientific and technical services” in the third, “agriculture, animal husbandry, forestry, fisheries and hunting” in the fourth and “tanning and finishing of hides and leather and manufacture of products of hide and leather and substitutes thereof” in the fifth, with growth that was intensive in imported intermediate inputs.

On the final demand side, the leading branches in the first, third and fourth groups are financial services, professional services and agriculture, which are intensive in domestic intermediate sales and in consumption. In the second group, the electronics branch is intensive in external intermediate sales and government spending. Lastly, in the fifth group, the tanning industry is intensive in net exports. This last intensity feature is maintained in those branches that are neither the most dynamic nor the most sophisticated in terms of production. In most branches of the production structure, however, net exports do not contribute to growth.

Table 3 shows the balances of factor contributions and supply and demand components, respectively. As discussed in the first section, the table has been constructed on the assumption that saving is carried out by businesses through the gross operating surplus account. Therefore, from the demand point of view, the flow of such income is earmarked for investment. However, even if equation (8) is satisfied, table 3 is read as branch revenue minus branch expenditure.

Table 3
Balances of the growth contributions of factors and components
(Percentages)

Sector	Balance					
	Fn^{Δ}	Pr_i^{Δ}	Pr_x^{Δ}	Pv^{Δ}	Pb^{Δ}	χ^{Δ}
Total	3.1	-5.5	9.9	-1.3	-6.1	0.012
Primary	9.3	-3.6	5.8	-11.4	-0.1	0.100
Secondary	-0.5	-8.4	18.0	-5.9	-3.0	-0.130
Tertiary	4.1	-0.8	4.2	3.6	-11.2	0.060
Branch	Fn^{Δ}	Pr_i^{Δ}	Pr_x^{Δ}	Pv^{Δ}	Pb^{Δ}	χ^{Δ}
Agriculture, animal husbandry, forestry, fisheries and hunting	-5	5.3	7.6	-8.6	0.5	0.030
Mining	16	-6.0	3.3	-11.0	-2.2	0.089
Electricity generation, transmission and distribution, supply of piped water and gas to final consumers	17	-14.8	13.2	-14.1	-0.9	0.020
Construction	30	-36.0	4.7	1.7	-0.9	0.000
Food industry	16	-18.0	0.8	-1.2	1.8	-0.078
Drinks and tobacco industry	16	4.7	9.2	-10.1	-19.5	0.135
Manufacture of textile inputs and textile finishing	-22	11.7	20.3	-6.6	-3.4	0.304
Manufacture of textile products other than apparel	-41	8.9	27.8	1.9	2.9	0.026
Manufacture of apparel	-9	-11.4	22.0	4.1	-5.7	0.001
Tanning and finishing of hides and leather and manufacture of products of hide and leather and substitutes thereof	-4	-4.1	16.9	-7.5	-0.7	0.208
Wood industry	-14	6.7	10.6	-1.4	-2.3	0.001
Paper industry	-14	8.9	16.4	-8.5	-3.7	-0.727
Printing and allied industries	-4	6.4	5.4	-3.7	-3.8	-0.098
Manufacture of oil and coal derivatives	21	-58.6	9.3	21.2	6.7	-0.057
Chemical industry	-1	-1.2	11.3	-8.3	-1.1	-0.334
Plastic and rubber industry	-12	5.6	20.7	-8.6	-5.9	-0.534
Manufacture of products from non-metallic minerals	-24	27.4	9.1	-9.6	-2.9	0.005

Table 3 (concluded)

Branch	Balance					
	Fn^{Δ}	Pr_i^{Δ}	Pr_x^{Δ}	Pv^{Δ}	Pb^{Δ}	χ^{Δ}
Basic metal industries	10	-6.6	4.6	-6.9	-0.9	-0.054
Metal products manufacturing	-5	11.8	10.5	-9.7	-8.0	-0.484
Machinery and equipment manufacturing	-14	-3.2	27.8	-9.1	-5.3	-1.547
Manufacture of computer, communication, measuring and other equipment and electronic components and accessories	-27	-14.3	62.9	-17.4	-4.5	-0.246
Manufacture of electricity generation accessories, electrical appliances and equipment	-23	-0.9	41.5	-14.4	-3.9	-0.127
Manufacture of transport equipment	-3	-3.3	23.9	-13.2	-4.5	0.862
Other manufacturing industries	-35	3.5	36.2	-0.6	-4.3	-0.261
Commerce	17	5.4	2.6	-4.7	-20.6	0.260
Transport, post and storage	2	-7.4	5.2	-2.1	1.9	0.083
Information in mass media	17	16.8	7.6	-25.7	-15.7	-0.021
Financial and insurance services	13	18.7	3.2	-42.9	8.1	-0.213
Real estate and movable and intangible goods leasing services	5	0.9	1.3	-2.0	-5.1	-0.004
Professional, scientific and technical services	-7	-19.2	3.6	24.4	-1.5	-0.038
Education services	7	-15.4	1.8	6.4	0.7	0.000
Health and social assistance services	-6	-20.2	3.7	21.2	2.1	0.000
Cultural and sporting leisure services and other recreational services	9	-15.2	3.2	2.0	1.4	0.000
Temporary accommodation and food and drink preparation services	4	-7.1	5.2	0.8	-2.7	0.000
Other services except government activities	12	-60.8	3.2	43.6	2.7	-0.001

Source: Prepared by the author, on the basis of data from the National Institute of Statistics and Geography (INEGI), input-output tables.

Note: The expressions denote the following:
Fn^{Δ} : Financial balance.
Pr_i^{Δ} : Domestic production balance.
Pr_x^{Δ} : External production balance.
Pv^{Δ} : Private sector balance.
Pb^{Δ} : Public sector balance.
χ^{Δ} : Contribution of net exports.

The table 3 results suggest that in the Mexican economy the financial balance, i.e. the difference between the contributions of savings and investment (Fn^{Δ}), is in surplus and is underpinned by the domestic (Pr_i^{Δ}), private (Pv^{Δ}) and public (Pb^{Δ}) production deficits. The external production $\left(Pr_x^{\Delta}\right)$ and trade (χ^{Δ}) surpluses reflect the logic that revenues are greater than expenditures, suggesting that they do not contribute to the (Fn^{Δ}) surplus, but rather diminish it.

At the aggregate level, the Mexican economy does not meet the zero balances condition, which means that its growth path is not the most favourable. At the sector level, both the primary and tertiary sectors maintain the characteristics of the Fn^{Δ} surplus and their respective deficits. The industrial sector presents a Fn^{Δ} deficit which is underpinned by the external production surplus Pr_x^{Δ}.

According to Marquez (2019), economies are unlikely to experience zero financial balances at the aggregate level. As more branches approach this balance from the left or right, the economy can be said to be developed. Using the author's criterion for a set of developed economies, i.e. a range between a Fn^{Δ} surplus of 0.1% and a deficit of -0.1%, no branch in the Mexican economy is found to approach these levels. The branch closest to this range is chemicals, with a deficit of -1%, which is sustained by the Pr_x^{Δ} surplus. At the other extreme, the branch that is furthest from $Fn^{\Delta} = 0$ is the "manufacture of textile products other than apparel" branch, with a balance of -41%, owing to surpluses in the remaining balances.

The results in table 3 show that the financial surplus of the primary sector is due to the surplus of the mining industry. In the service sector, meanwhile, it is the commerce and information in mass media branches that account for the surpluses, with the latter being one of the most dynamic.

If the criterion of grouping branches by the growth rate in each sector is maintained (see tables 2 and 3), it can be seen that the branches that are most prominent in the first and third groups show opposite situations in their main balances. While the Fn^{Δ} of the "other services" branch is in surplus, that of the "professional services" branch is in deficit. What contributes to these results is Pr_x^{Δ}, which is in deficit in one case and in surplus in the other. In the second and fifth groups, the branches with the highest growth according to their range have Fn^{Δ} deficits and rely on the Pr_x^{Δ} surpluses. In the case of the fourth group, agriculture has a Fn^{Δ} deficit to which all balances except that of Pr_x^{Δ}, which is in deficit, contribute. If FDI has grown in the economy, the positive balances seem to suggest that earnings have been greater, and these are due to the Pr_i^{Δ}, Pv^{Δ} and Pb^{Δ} deficits.

V. Conclusions

As discussed earlier, the hypothesis regarding the development of an economy is based on productive integration: the more sophisticated this is, the more development there will be. It also seems to be true that the greater the number of branches meeting the condition of zero financial balances for factor and component contributions, the more developed the economy will be.

Structural change depends not only on the productive sector, developing in the interrelationships between purchases and sales of intermediate inputs, but also on the agents that make up the system. Accordingly, the balances of contributions to production, i.e. the branches' purchases and sales of intermediate inputs and agents' income or expenditure, measured via the components of value added and final demand, show how the change is constituted.

This paper has not followed the traditional approach to using the IO model to study the economic system (i.e. focusing on the analysis of intersectoral relations). However, it opens the way to a new aspect of the model in its dynamic character that makes it possible to analyse changes in intersectoral relations, as this perspective is supported by the components of the IO table and their translation into economic theory.

From this analysis, the results for the Mexican economy show that it has been intensive in intermediate inputs from abroad. They also indicate that this path, together with the trade balance of growth contributions, has been the basis for the financial surplus, which is constituted by a domestic production deficit in both the private and public sectors. The positive net export balance of the economy is explained by the basic branches of industry and the primary sector, since in most of industry these balances are negative.

Thus, in addition to using industrial policy to help create a coherent domestic industrial structure, there is a need to transfer part of the public deficit to the private sector. Even if this does not put the economy on an optimal development path, it will provide a basis for better development of the population.

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The Argentine automotive chain since the convertibility crisis: an analysis of its evolution and principal problems (2002–2019)

Bruno Perez Almansi

Abstract

The aim of this article is to analyse the main characteristics of the Argentine automotive sector and its performance during the first part of the twenty-first century. The article begins by describing the essential aspects of the links in the chain. It then provides a brief historical overview of the Argentine automobile industry from its beginnings until the convertibility crisis of late 2001. Lastly, it analyses the evolution of the sector in the subsequent stages, those of post-convertibility (2002–2015) and the Cambiemos government (2015–2019). This review is based on the specialist literature and different statistical sources. The article ends with a reflection on the structural difficulties faced by the Argentine automobile industry and the way these manifested themselves during the stages analysed.

Keywords

Automobile industry, industrial development, history, industrial production, value, industrial policy, employment, international trade, trade policy, Argentina

JEL classification

L62, O14, N16

Autor

Bruno Perez Almansi is a PhD candidate in Economic Development at the National University of Quilmes. Email: bperezalmansi@unsam.edu.ar.

I. Introduction

Argentina is among the world's 50 vehicle producing countries and one of the three largest manufacturers in Latin America. The automotive sector is one of the most important within the country's economic and social structure because of its contributions to industrial employment, gross production value and total exports, among others. After the crisis of the convertibility regime, the automotive branch led the country's industrial growth with strong increases in employment, production, exports and productivity (Barletta, Katashi and Yoguel, 2013). Despite this encouraging performance, however, difficulties were encountered in the integration of production linkages, something that was manifested in large trade deficits, owing to growing imports of auto parts (Cantarella, Katz and Monzón, 2017).[1] Following the change of government in 2016, Argentina experienced a shift towards trade opening and economic liberalization, which led to the contraction of its domestic market. In the automotive sector, these policies, coupled with the crisis in Brazil, had a negative impact on the industry, pushing up trade deficits and leading to a large drop in production between 2018 and 2019.

However, the vicissitudes and problems faced by the Argentine automotive complex in recent decades have not been due to local or short-term difficulties alone. The sector suffers from the dilemmas characteristic of manufacturing in a semi-peripheral country organized under the auspices of global value chains. Certain limitations shared by these countries can be highlighted, including: (i) total foreign control of the final vehicle manufacturing branch (dominated globally by a handful of multinational companies); (ii) specialization in the lower value added activities of the chain; (iii) dependence on foreign technology; and (iv) difficulty for local auto parts companies in competing internationally. This situation is also compounded by the rapid technological and production transition that the sector is undergoing globally because of the digitalization, electrification and automation of vehicles.

However, one special feature of the Argentine automotive complex is particularly salient: the relative size of its trade deficit. This is manifested, first, in the size of the sectoral deficit between 2002 and 2019, which amounted to some 60% of the trade surplus for the entire national economy in the period. Second, this difficulty is particularly serious because it aggravates a characteristic problem of Latin American economic structures, and that of Argentina in particular: the external constraint due to lack of foreign currency. This constraint, which has been studied in numerous papers, is the pressure on the demand for foreign exchange in an economy with an unbalanced production structure at times of economic and industrial growth due to the increase in imports of capital goods and intermediate inputs required to sustain the growth process.[2] This problem has been central throughout Argentina's economic history and represents one of the main obstacles to economic development.

In consideration of this, the present paper sets out to analyse the evolution of the Argentine automotive value chain over the last few decades. It begins by describing the main characteristics of the country's automotive sector. It then draws on the specialist literature to summarize the history of the Argentine automobile industry from its beginnings until the early twenty-first century (1920–2002). Next, it

[1] This comes on top of the trade deficit in the passenger vehicle segment.

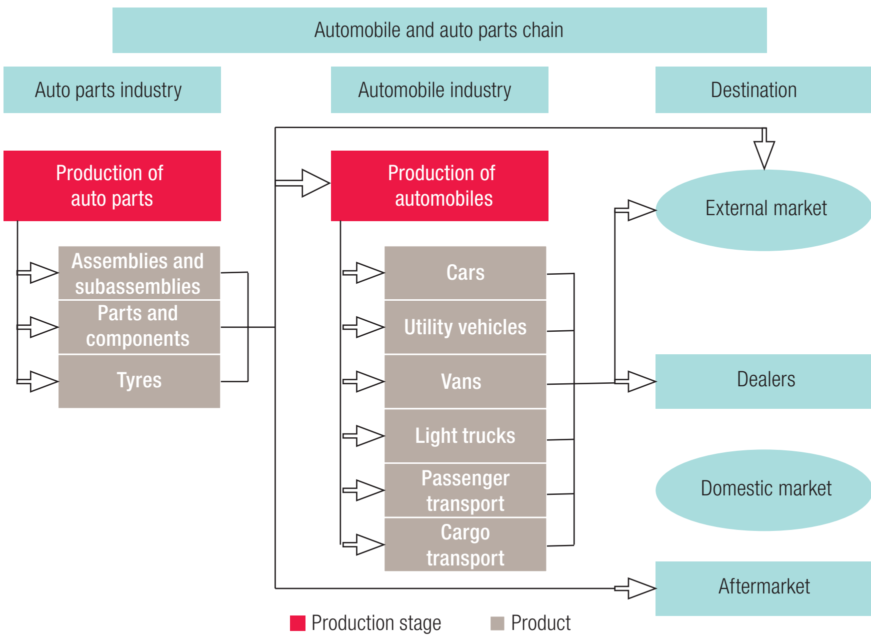
[2] This has historically been a constraint on development in Argentina, since activity levels and economic growth rates have been restricted by the availability of foreign currency (Wainer and Schorr, 2014). In other words, during stages of industrial growth, "bottlenecks" in the availability of foreign currency arise, making it difficult to transform the sector and develop more complex production processes. The first time the country's external sector experienced such bottlenecks was in the 1930s, when they manifested themselves at different points in the import substitution model. The extensive and, above all, the intensive growth of industry depended on imports of capital goods and intermediate inputs. However, the foreign exchange needed to finance these imports came primarily from the exports of the agricultural and livestock sector, whose supply, especially in the case of agriculture, was virtually stagnant. On a theoretical level, the problems of external constraint were addressed in Latin America by the structuralist and dependency schools towards the middle of the last century. Among the first studies to relate this issue to the erratic behaviour of the Argentine economy were the foundational works of Braun and Joy (1968) and Diamand (1973). Years later, Thirlwall (1979) formalized the problem by arguing that the growth rate required for full employment was higher than that compatible with external equilibrium.

analyses the main policies implemented and the economic performance of the automobile industry during the post-convertibility period (2002–2015) and the period of the Cambiemos government (2015–2019). These reviews are based on different statistical sources, such as the UN Comtrade Database, the National Institute of Statistics and Census (INDEC), the Centre for Production Studies (CEP XXI), the Association of Automotive Dealers of the Argentine Republic (ACARA), the Motor Vehicle Manufacturers Association (ADEFA), the Association of Argentine Component Manufacturers (AFAC) and the General Directorate of Customs, among others. This article ends with some reflections on the structural difficulties of the Argentine automotive sector and the way these manifested themselves during the stages studied.

II. The production structure of the Argentine automotive sector

In the automobile industry, as in any production process, different stages of work take place before a motor vehicle is manufactured and marketed. In most cases, the production stages consist of casting, pressing (production of metal sheets), production of the structure or bodywork (joining the sheet metal components to the bodywork structure), painting, assembly and fitting, quality control and marketing (see diagram 1). Thus, in general terms, the automobile and auto parts chain is structured into four main links: (i) suppliers of generic inputs, (ii) suppliers of auto parts, (iii) automobile manufacturers and (iv) dealers.

Diagram 1
Argentina: structure of the automobile and auto parts chain



Source: Prepared by the author, on the basis of Ministry of Treasury and Public Finance, "Automotriz y autopartista", *Informes de Cadenas de Valor*, No. 4, 2016, July.

1. The first link in the automotive value chain: suppliers of generic inputs

The first link consists of a group of firms supplying generic inputs: steel, aluminium, plastics and petrochemicals, glass and rubber, among others (Ministry of Treasury and Public Finance, 2016). These are generally basic heavy industries that typically need to maintain very large scales of production to operate efficiently and are therefore highly concentrated. This is the case with steel (Tenaris, Ternium and Acindar), aluminium (Aluar) and the plastics and petrochemicals sector (Perez Almansi, 2020).

2. The second link in the automotive value chain: the auto parts industry

The second link is made up of auto parts firms whose function is to process the generic inputs and produce parts, components and systems. They make a wide range of products, which can be classified into: (i) generic components (e.g. nuts and bolts); (ii) non-mechanical parts (glass, trim, silencers, seats, fuel tanks and radiators); (iii) miscellaneous components (seat belts, mirrors, upholstery, wheels, tyres and inner tubes, among others); (iv) electromechanical systems and components (e.g. shock absorber systems, ignition systems, steering and suspension systems, braking systems, electrical system, carburettors, clutches, injection pumps, etc.); and (v) core technologies (engines and engine parts, transmission systems and gearboxes) (Ministry of Treasury and Public Finance, 2016).

According to data from the Ministry of Labour, Employment and Social Security, more than 1,200 companies belonged to the auto parts sector in 2016.[3] Moreover, this is the link in the automotive sector that employs the most workers, with 54,625 registered jobs in 2013. The composition of this branch is very heterogeneous. If it is classified on the basis of size (by employee numbers), there are companies with between 25 and 1,500 employees. Another aspect that distinguishes them from one another is the market they work for, e.g. for vehicle producers, suppliers to these or the aftermarket. Any of the three types can also generate some export business, with multiple combinations. Another way to differentiate within this link is by whether companies are domestically or foreign-owned.[4] There are also substantial differences in materials, which means that there are different production processes involving different auto parts companies (e.g. glass and plastics).[5] All these factors make the composition of the sector quite complex and heterogeneous (see diagram 2).

At the same time, auto parts companies have organized internationally into production rings distinguished primarily by their degree of linkage with vehicle manufacturers and the level of technological sophistication of their products. The first ring is made up of the suppliers from which carmakers source directly, which are the producers of complete systems, also known as module suppliers or megasuppliers.[6] These firms have world-class engineering and manufacturing processes, with modular production and design capabilities. They also have a high level of technological sophistication that meets the requirements and demands of the major automotive multinationals. They are responsible for the development of engine parts and steering and suspension systems (Barletta, Katashi and Yoguel, 2013).

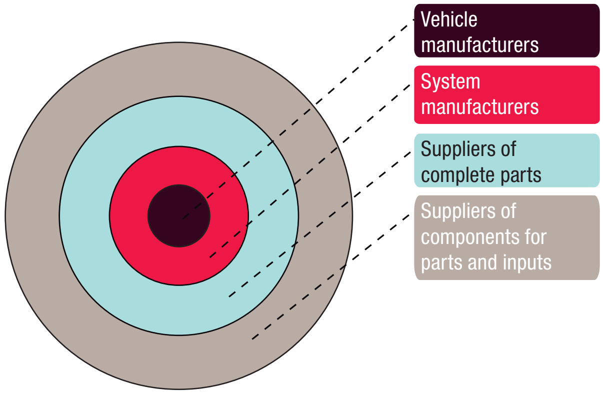
3 According to the Association of Argentine Component Manufacturers (AFAC), however, there were actually about 400 in 2016. AFAC argues that the Ministry of Labour's databases include many repair shops and that its own figures are the correct ones.

4 There are a few cases of mixed ownership (J. Cantarella, General Manager of AFAC, personal interview, 10 October 2017).

5 Lastly, different trade unions are also present in these firms. The largest is the Metalworkers Union (UOM), followed by the Union of Automotive Transport Mechanics and Allied Workers (SMATA) and then the Union of Plastic Workers and Employees (UOYEP). There are also glass, chemicals, rubber and even textiles unions (J. Cantarella, General Manager of AFAC, personal interview, 10 October 2017).

6 These have the closest relationship with the vehicle manufacturers, so that they are sometimes said to form "ring 0.5" (Arza and Lopez, 2008).

Diagram 2
Rings of auto parts companies



Source: Prepared by the authors, on the basis of T. J. Sturgeon and J. V. Biesebroeck, "Global value chains in the automotive industry: an enhanced role for developing countries?", *International Journal of Technological Learning, Innovation and Development*, vol. 4, No. 1–3, August, 2011 [online] https://doi.org/10.1504/IJTLID.2011.041904.

These auto parts companies in the first ring are the ones that deal with the second ring, which includes the suppliers of complete parts, i.e. specialized components for the assembly of the most advanced modules and systems. The products they make include forged or stamped parts, aluminium injection-moulded parts, cast parts and plastic parts (Ministry of Treasury and Public Finance, 2016). In the third ring are firms that produce more standardized and less technologically complex parts and components. These include spark plugs, forks, connecting rods, bearings, gaskets, washers, disc or drum brakes and air filters. These companies sell their products mainly to those in the second ring, but they can also sell to vehicle manufacturers to continue with the manufacturing process (Castaño, 2012).[7] In 2013, the main auto parts companies with operations in Argentina were Mirgor, SKF, Metalsa, Pabsa, Faurecia, MAHLE, Denso, Visteon, Frict-Rot, Gestamp, Industrias Lear, Famar Fueguina, Cibie and ZF Sachs. Of these, only Mirgor and Famar Fueguina are of Argentine origin and the rest are foreign-owned (see annex table A1.1).

3. The third link in the automotive value chain: vehicle manufacturers

The third link comprises the vehicle manufacturers, which assemble and finish motor vehicles. These firms produce cars, vans and utility vehicles, trucks and buses. It is a concentrated market, made up of 11 multinational companies located mostly in the provinces of Buenos Aires and Córdoba. They are Ford, General Motors, Mercedes-Benz, Volkswagen, Fiat, Peugeot, Renault, Toyota, Iveco, Scania, Honda and Nissan (see annex table A1.2).[8] They employed about 27,000 workers between them in 2013, representing 32% of total employment in the industry (Barletta, Katashi and Yoguel, 2013).

7 There is also the aftermarket, which in 2013 was made up of 453 auto parts manufacturers employing 21,100 people. This is a highly fragmented market, essentially made up of small firms (251 firms employ between 10 and 49 workers) (Barletta, Katashi and Yoguel, 2013).

8 Honda started vehicle production in 2011 but discontinued it in 2020 except for motorbikes. Nissan joined the other car manufacturers in Argentina in 2018. Scania, although a vehicle manufacturer, operates in Argentina as a producer of transmission components (see annex table A1.2).

4. The fourth link in the automotive value chain: dealers

Lastly, marketing and repair services are provided by the 233 official dealerships, which had 17,500 employees as of 2013 (20% of all employees in the sector). They have been taking on a new technical role in sales and repair services, which have become increasingly important because of the type of models produced since the 1990s. Another stage in the marketing process is carried out by unofficial dealerships which, according to statistics from the Employment and Business Dynamics Observatory (OEDE), numbered 62 and employed 3,100 workers as of 2009 (Barletta, Katashi and Yoguel, 2013).

III. A brief history of the Argentine automobile industry (1920–2002)

In 1922, Ford inaugurated the first vehicle assembly plant in Argentina (Belini, 2006, p. 110) to supply a small domestic market that was beginning to develop around commodity export activities (Schvarzer, 1996). That year marks the beginning of the automobile industry in Argentina. Production grew strongly during the period of import substitution industrialization. However, some basic features of the complex, such as its relative technological backwardness and its negative foreign-exchange balance, remained unchanged. According to classic studies of the sector, this problem was due essentially to foreign ownership and the small scale of local production (Sourrouille, 1980; Nofal, 1989; Katz and Kosacoff, 1989).[9]

As for the local auto parts industry, its development during this period was marked by other processes, such as its segmented growth[10] (Bil, 2017) and its heavy dependence on and subordination to the vehicle manufacturers. What this meant, especially for Argentine firms, was the imposition of specific production processes and strict price and quality controls (Sourrouille, 1980). Most of the specialized literature endorses this idea, and it was studied in depth during the stages that followed the import substitution industrialization phase. It has been concluded that this relationship became increasingly rigid and hierarchical, with a predominance of commercial or rent-seeking logics in the regional market (Novick and others, 2002), and with fewer and fewer positive effects on the local economy and employment (Santarcángelo and Pinazo, 2009).

The 1970s saw the beginning of a profound international restructuring of the sector that greatly accelerated the global integration of production. Part of this was a shift from mass production of undifferentiated goods to a slower-growing, differentiated form of production. So began the era of competition on quality, bespoke products and batch production. This gave rise to the need for flexible manufacturing lines able to produce different products using the same basic equipment configuration, without major reorganization and with short set-up times (Coriat, 2000). These changes were accompanied by technological innovations following the appearance of the microchip in 1971 and then of computers and information and communications technologies (ICTs). The changes described were further reinforced by these scientific and technical advances, allowing high levels of immediate control of production and higher degrees of industrial automation. This series of changes marked the transition from “Fordism” to “Toyotism”, also known as flexible production. As far as the global automobile industry is concerned, the new situation consolidated Japan as one of the major automotive producers (Boyer and Freyssenet, 2002; Coriat, 2000).

[9] However, a number of studies argue that these limitations were a consequence of the late development of Argentine capitalism by international standards, with this feature determining the future trajectory of the automotive sector and making it impossible for it to develop through the public policies of a capitalist State (Harari, 2014; Bil, 2016 and 2017).

[10] Larger firms supplied vehicle manufacturers and smaller ones the aftermarket (Bil, 2016).

As part of the changes resulting from the restructuring of global capitalism in the late twentieth century, there were other alterations in the organization of production whose primary purpose was to boost competitiveness by reducing costs and increasing variety (Gereffi and others, 2001; Gereffi, Humphrey and Sturgeon, 2005). At the heart of these changes were the decisions taken by certain multinational companies to transfer some parts of the production process, usually the least profitable and sophisticated ones, to other firms (outsourcing) and to other countries (offshoring), most of them on the periphery. Thus, companies outsourced generic or low-value production processes that centred on volume and the price-competitiveness ratio, but retained for themselves the segments that added the most value (essential or core activities) (Porta, Santarcángelo and Schteingart, 2017). This led to greater interdependence in international trade networks, since a large part of the value of exports came to contain value imported from more than one origin. This meant that such exports may pass through more than one destination before reaching final consumers, thereby forming so-called global value chains (Gereffi and others, 2001).

From 1990 onward, on the basis of this new organization, vehicle manufacturers started to transfer various activities to their suppliers. However, this process did not entail complete outsourcing, as close links were forged between the vehicle manufacturers and system suppliers, with the latter taking on an increasingly important role in the entire production process (Arza and López, 2008; Castaño, 2012).

At the same time, despite the global reorganization of production, the automobile industry did not fully constitute itself as a global value chain, but relied on regional hubs. This is explained by a number of factors: (i) the fact that vehicle manufacturers interact with other agents in the regions where they produce and sell, both “upstream” (e.g. suppliers). and “downstream” (e.g. key distributors and financing, maintenance and repair services), leading to regionalization of operations because of issues of both physical proximity (important essentially in the case of suppliers) and market capture (well-established distribution, financing and after-sales networks are vital); (ii) cultural barriers; (iii) the fact that economies of scale in production are usually achieved at the regional level; (iv) environmental, safety and other regulations; (v) the use of specific fuels; and (vi) the fact that the level of tariff protection is often determined at the regional level (Rugman and Collinson, 2004).

In South America, this form of regional integration in the sector was expressed in the Common Automotive Policy (PAC) between Argentina and Brazil. The origins of the PAC date back to 1988, when the two countries established the twenty-first Protocol on the regulation of trade flows in the automotive complex within the framework of the Economic Integration and Cooperation Programme (PICE) approved in December 1986 (Vispo, 1999). However, it was not until 1991 that the Protocol entered into force, after being amended several times and included in Economic Complementarity Agreement (ACE) No. 14, which was concluded under the auspices of the Latin American Integration Association (LAIA). The stipulations of most importance for the automotive chain were national treatment for vehicles and auto parts from each country in the other’s market, the removal of para-tariff barriers in bilateral trade, and tariff-free bilateral trade for a certain quota of vehicles and for auto parts, with the quota not to exceed 15% of FOB exports of vehicles from each country, and on condition that the local content requirements of each country were met, among others (Dulcich, Otero and Canzian, 2020). This agreement still did not provide for joint regulation of out-of-area trade, and the national regimes in place in each country retained a major role (Gárriz and Panigo, 2016).

The local industry was severely affected during the convertibility period (1990–2001), and the deindustrialization trend that had started in the mid-1970s was consolidated (Azpiazu, Basualdo and Schorr, 2001; Schvarzer, 1996). However, vehicle manufacturers in the automotive sector were not harmed by the structural reforms of that decade, as they benefited from a new “automotive regime”, comprising a series of decrees issued between 1990 and 1992. The structure of this regime was negotiated under the auspices of the Coordinating Commission for the Restructuring of the Automobile Industry, created by the Menem government in 1990 (Etchemendy, 2001). The main features of the regime were:

(i) a wage agreement between employers and trade unions aimed at moderating wages and keeping down vehicle prices; (ii) a commitment by companies to investing to bridge the technological gap with international markets; (iii) a tariff barrier of 30% (when the average tariff for the whole economy after the trade reform was around 10%) combined with the option for vehicle manufacturers to import units at a tariff of only 2%; and (iv) import quotas with a rate of 10% of annual local production for commercial vehicles (Villalón, 1999; Etchemendy, 2001). In turn, foreign vehicle manufacturers were favoured by the 1993 Foreign Investment Act (No. 21.382), which did not set conditions on profit remittances, specific taxation or capital repatriation (Kosacoff and Porta, 1997).

As a consequence of these measures, and of economic policy as a whole, there was substantial concentration and internationalization of the auto parts industry in the automotive sector (Kosacoff, 1999). This marked a process of disintegration in the automobile industry that profoundly affected certain forms of production (auto parts and some metallurgical activities, among others) and certain firms (especially small and medium-sized ones), in both productive and employment terms (Azpiazu, Basualdo and Schorr, 2001; Perez Almansi, 2021).

After the 1998 South-East Asian crisis and the 1999 devaluation of Brazil's currency, Argentina began to find it difficult to obtain external financing. With the potential for privatizations exhausted, the rigid convertibility regime ran up against its limitations, leading to an acute economic crisis in late 2001. This crisis resulted in GDP falling by some 25% in three years and unemployment and poverty levels rising to around 25% and 50%, respectively, culminating in the fall of the government of the Alliance for Work, Justice and Education. This was a turning point in Argentina's economic history, as it ushered in a new post-convertibility phase[11] spanning the governments of Eduardo Duhalde, Néstor Kirchner and both of Cristina Fernández de Kirchner's terms in office.

The following section therefore analyses the performance of the Argentine automobile industry during the post-convertibility period (2002–2015), taking into account the historical and structural problems that afflicted it and changes at the global, regional and local levels. In addition, special attention is paid to relative developments in the different sectors of the industry.

IV. The performance of the automobile industry during the post-convertibility period (2002–2015)

1. Emergence from the crisis and a period of expansion

In the automotive sector, despite the expansionary effect of the regional agreements of the 1990s, there were large declines in vehicle production, exports and domestic sales in the last years of the period in the context of the economic recession. As a result of this situation, at the Florianópolis Summit of December 2000, the member countries of the Southern Common Market (MERCOSUR) approved the Agreement on the Common Automotive Policy of MERCOSUR (PAM), whose objective was to lay the foundations for free trade in automotive goods within the bloc. This treaty set the tariff on vehicles

[11] There is something of a consensus that the 2001-2002 crisis marked a real change of direction (Schorr, 2013). At the same time, various analyses distinguish two distinct phases in the post-convertibility stage (Perez Almansi, 2019). However, studies differ on the causes and timing of the shift. For example, Fanelli (2015) and Damill and Frenkel (2013) argue that the change occurred in 2007, following the implementation of "short-termist" economic policies. The Research Centre for Argentine Development (CENDA, 2010) places the break in 2008, attributing it to the rise in international commodity prices. According to Basualdo (2011), the change of phase occurred in 2008, following the government's confrontation with agricultural organizations. For Schorr and Castells (2015), it took place between 2007 and 2008 when the interests of the workers and the industrial bourgeoisie ceased to be complementary. Despite these disagreements, though, analysts concur in dividing this stage into two phases. Broadly speaking, the first was one of higher economic and industrial growth with a relatively weak and competitive exchange rate, and the second was characterized by lower growth rates and a tendency for the exchange rate to appreciate.

produced outside MERCOSUR at 35% and established a proportional limit on tariff-free sectoral trade between Argentina and Brazil, known as the flex.[12] The provisions of the agreement were very important for the industry and shaped the dynamics of foreign trade in the automotive sector with Brazil in the following years (Gárriz and Panigo, 2016).

After the 2001–2002 crisis and the departure of the Alliance government, there was a succession of presidents until Eduardo Duhalde, of the Justicialist Party, consolidated his position at the head of the national executive branch. He adopted a number of policies driven by criticisms of the convertibility model and a quest for economic revival based on a "competitive and stable real exchange rate" and a stable macroeconomic framework (Ortiz and Schorr, 2007).

In 2002, the Duhalde government and the Brazilian government concluded the thirty-first Additional Protocol to the ACE between Argentina and Brazil. This instrument set a new value for the flex. The margin of permitted imports was raised aggressively from 1.1 to a value of 2.6 in 2005, with free trade scheduled for 2006. Furthermore, local content standards for vehicles were relaxed. Even though this regime required 35% Argentine local content, Cantarella, Katz and Monzón (2017) argue that it was difficult to implement and never enforced, and that it was strongly opposed by vehicle manufacturers. This situation implied a "death foretold" for vehicle local content requirements. Also in 2002, the MERCOSUR automotive trade agreement with Chile (ACE 35) was amended and a new one was signed with Mexico (ACE 55).

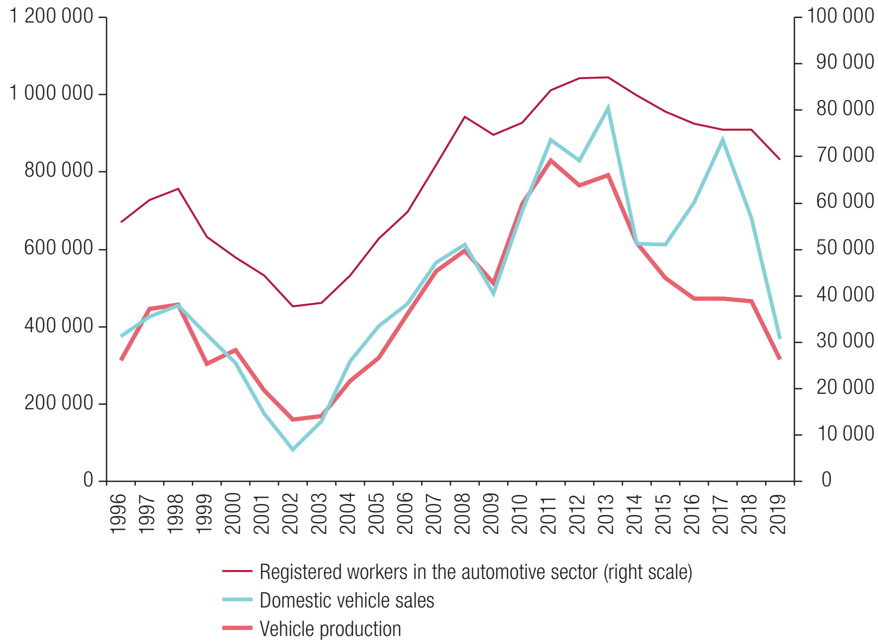
Another crucial reform was also carried out in the sphere of foreign trade policy during this administration: the amendment of the Temporary Admission Regime established in 1998, which allowed the temporary import of goods for industrial processing. They were exempted from customs duties on condition that the final product was exported. The change consisted in the establishment of the In-Factory Customs Regime (RAF) (Decree No. 688/2002), which involved a simplification and expansion of the Temporary Admission Regime for the automotive sector. Imported inputs were allowed to enter the country duty-free, with this cost only to be paid when units were sold to a local dealer. In this way, parts and components used in finished vehicles for export became cheaper to import.

In 2003, Néstor Kirchner, also of the Justicialist Party, became President and continued with certain elements of the previous economic system, such as the maintenance of the "strong dollar" regime. He also began a policy of restoring the incomes of the middle and lower social sectors and revived the ailing domestic market (CENDA, 2010). Thus, in 2003, the economy and industry began to come out of recession and the economic cycle was reactivated. In the automotive sector, production and domestic and foreign sales began to recover rapidly (see figure 1).

The trade agreements continued in 2005, when MERCOSUR complementation pacts were concluded with Peru (Partial Scope-Economic Complementation Agreement No. 58) and the Andean Community (CAN), comprising the Bolivarian Republic of Venezuela, Colombia and Ecuador (Partial Scope-Economic Complementation Agreement No. 59). In 2005, the Incentive Regime for the Competitiveness of Local Auto Parts (Decree No. 774/2005) was enacted to encourage the substitution of imported auto parts with domestically produced ones. Vehicle manufacturers were granted an 8% rebate on imported components that they replaced with domestic ones. In 2006, furthermore, a new bilateral agreement between Argentina and Brazil reduced the maximum protocol value of the flex from 2.6 to 1.95, a level that remained in place until 2014.

[12] This stipulated that for every dollar of automotive goods that Argentina exported to Brazil in 2001, it could import a maximum of US$ 1.105 duty-free from the country. This limit was designed to keep sectoral trade between Argentina and Brazil in balance.

Figure 1
Argentina: domestic vehicle production and sales and registered employment in the automotive sector, 1996–2019
(Vehicle units and average annual employment)



Source: Prepared by the author, on the basis of information from the Motor Vehicle Association (ADEFA), the Association of Automotive Dealers of the Argentine Republic (ACARA) and the Employment and Business Dynamics Observatory (OEDE).

The automobile industry thus experienced a period of great prosperity in the country during those years. In 2007, Néstor Kirchner stated in his inaugural speech at the International Auto Show that "the automobile industry is the backbone of economic growth" (*Perfil*, 2007). Local car production reached an all-time high in 2011 (828,771 units), as did domestic sales in 2013 (963,917 units) (see figure 1). Similarly, the trade balance in finished cars reversed its deficit trend of the 1990s (see figure 2). The better performance of vehicle exports than imports is essentially explained by high growth in the country's main trading partner, Brazil, which took some 75% of vehicle exports during the period.[13]

Different actors in this production chain were part of the group of winning companies in that period (Santarcángelo and Perrone, 2012; Gaggero, Schorr and Wainer, 2014).[14] In the early years after the 2002 devaluation, the turnover of the automotive sector was equivalent to 7% of the total for Argentina's top 500 companies. Its share increased markedly in subsequent years, until it accounted for 17.3% of turnover in 2010 (Santarcángelo and Perrone, 2012, p. 13). This dynamic reflects a large increase in the size of the automotive firms[15] and the importance of their position at the top of Argentine industry. Among their number were different vehicle manufacturers (Toyota, Volkswagen, Ford, Fiat, General Motors, Renault, Mercedes-Benz, Peugeot-Citroën and Honda) and, in some years, a handful of auto parts companies (Scania, which although a vehicle manufacturer did not produce motor vehicles

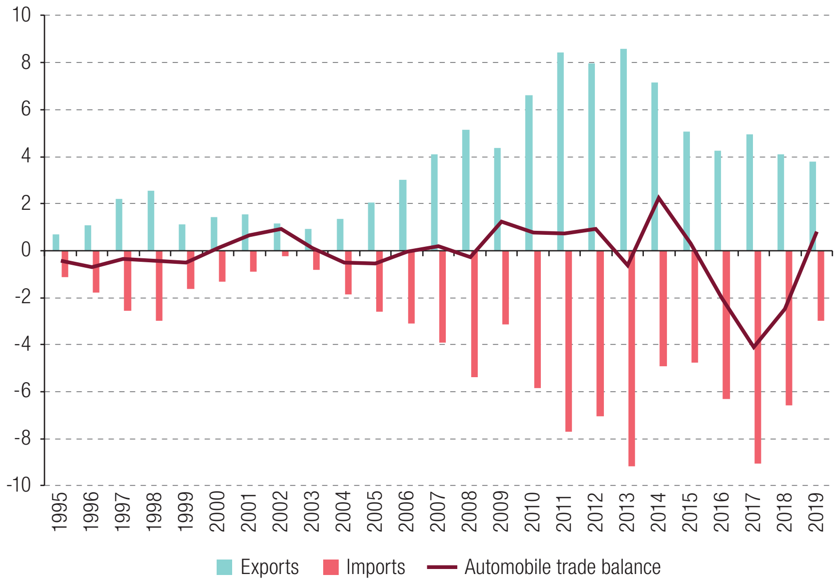
[13] Brazil's GDP measured in constant 2010 dollars increased by 85% between 2002 and 2014, according to World Bank data.

[14] Considered in terms of participation in the economic elite, which, depending on the database used, might be the 200 companies with the highest turnover in the local market, other than financial companies (*Revista Mercado*), or the top 500 companies in the National Survey of Large Corporations (ENGE) of the INDEC, again excepting financial companies.

[15] According to Santarcángelo and Perrone (2012), much of the growth in the profitability of the vehicle manufacturers at the top of the industry was underpinned by the weakness of wages in the years following the devaluation, in the context of a sharp increase in labour productivity in the vehicle manufacturing sector. These two elements together explain the strong growth in the sector's profitability and thence the great dynamism of vehicle production during the post-convertibility period.

in the country but only gearboxes, and Mirgor, Dana and Famar), although at lower levels than the other group (Santarcángelo and Perrone, 2012).[16] Thus, the sales share of these auto parts companies was much smaller than that of the car manufacturers, with the former only accounting between them for 6% to 7% of the total turnover of the automotive firms in the industrial elite, while the remaining 93% and more were vehicle manufacturers (Santarcángelo and Perrone, 2012, p. 18).

Figure 2
Argentina: vehicle trade with the world, 1995–2019
(Billions of dollars)



Source: Prepared by the author, on the basis of information from UN Comtrade Database.

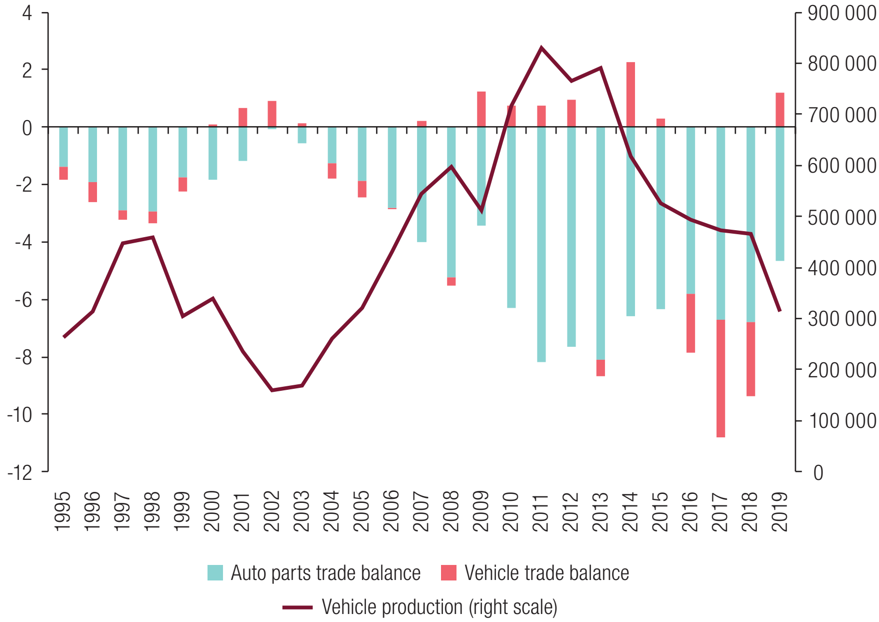
2. External constraints and more protectionist policies

The international crisis of 2008–2009, growing capital flight and an incipient deterioration in the current account of the balance of payments led to various disruptions in Argentina's economic and political situation, which worsened in the following years (Basualdo, 2011; Gaggero, Gaggero and Rúa, 2015; Kulfas, 2016). In the automotive sector, this meant falls in production and in domestic and foreign sales. By the end of 2009, however, the effects of the crisis had begun to fade. A second cyclical upswing in the industry, driven by policies to stimulate domestic demand and by economic growth and currency appreciation in Brazil, began thereafter and lasted for a few years (see figures 1 and 2).

However, this second phase of growth was characterized by an increase in imports of auto parts, whose expansion kept pace with that of vehicle production (see figure 3). Against this backdrop of external difficulties, a new law (No. 26.393) was passed in 2008 to incentivize the domestic auto parts sector, using tax incentives to encourage vehicle manufacturers to employ parts and components produced in the country. However, this legislation did little to reduce the sectoral deficit (Pérez Artica, 2019). In addition, the tariff positions in the sector covered by the import permits known as non-automatic licences (LNA) increased between 2008 and 2011, and more restrictive permits known as advance import affidavits (DJAI) were applied from 2012 onward (Perez Almansi, 2020).

[16] At the same time, another group of companies involved in the production of basic inputs for the automobile industry were also clearly among the winners of the period. They included the basic metal industries (Ternium, Tenaris Siderca, Acindar and Aluar) (Gaggero, Schorr and Wainer, 2014; Gaggero and Schorr, 2016).

Figure 3
Argentina: vehicle production and vehicle and auto parts trade balance, 1995–2019
(Billions of dollars and vehicle units)



Source: Prepared by the author, on the basis of information from the Motor Vehicle Association (ADEFA), the Association of Argentine Component Manufacturers (AFAC) and the UN Comtrade Database.

Thus, the large deficit in the auto parts segment was one of the main problems of this stage. Whereas in the 1990s the average annual auto parts deficit for each car produced was US$ 4,951, between 2003 and 2015 this average value rose to US$ 8,040 (Cantarella, Katz and Monzón, 2017, p. 267). A more thorough analysis of the composition of imports shows that, of the US$ 4.816 billion in component imports recorded over the course of 2006, some US$ 2.96 billion or 63% represented direct purchases by vehicle manufacturers (Cantarella, Katz and Monzón, 2017, p. 268). In 2005, vehicle manufacturers' share of auto parts purchases had been 58%, which means that there was a year-on-year increase of 5 percentage points between these two years (Cantarella, Katz and Monzón, 2017, p. 268). In 2015, this share held steady at around 65%, highlighting the particular importance of the final link of the chain in the foreign trade dynamics of the downstream links (Cantarella, Katz and Monzón, 2017, p. 268).

While this is partly due to global transformation processes, including the international fragmentation of production, the trend towards vertical disintegration of large industrial firms, the international division of labour established by these large firms and the introduction of new areas into world trade, such as China (Sturgeon and others, 2009; Frigant and Zumpe, 2017), not all countries went through this process of disintegration in the automotive production chain or the trade balance difficulties experienced by Argentina. Table 1 shows the countries with the largest auto parts trade surpluses and deficits in 2015. Argentina is at number 120 in this ranking, being one of the 8 countries with the largest deficits in the auto parts trade.

The problem is of particular importance for Argentina, furthermore, because of the difficulties arising from the external constraint. This situation has historically limited Argentina's development, as activity levels and economic growth rates have been restricted by the availability of foreign currency (Wainer and Schorr, 2014).

Table 1
Countries with the largest auto parts trade deficits and surpluses, 2015
(Billions of dollars)

Rank	Country	Auto parts trade balance
1	Japan	35.20
2	Germany	33.50
3	China	31.00
4	Republic of Korea	27.30
5	Poland	8.51
6	Czechia	7.74
7	Italy	7.58
8	Mexico	6.47
9	Thailand	5.67
10	Romania	5.61
119	Belgium	-4.09
120	Argentina	-4.24
121	Brazil	-4.41
122	Saudi Arabia	-5.59
123	Australia	-5.74
124	Spain	-9.87
125	Russia	-10.20
126	United Kingdom	-17.10
127	Canada	-21.70
128	United States	-61.60

Source: D. Panigo and others, "El autopartismo latinoamericano en un contexto de proteccionismo global, reshoring y debilitamiento de acuerdos regionales de comercio", *La encrucijada del autopartismo en América Latina*, Buenos Aires, Association of Latin American Economic Thought (APEL)/Universidad Nacional de Avellaneda (UNDAV) Ediciones, 2017.

At the same time, Brazil's economic stagnation since 2013 has had a considerable impact on the sector.[17] Thus, in 2014, the Argentine government renewed its bilateral agreement with Brazil, and the protocol value of the flex (which had stood at 1.95 since 2006) was reduced to 1.5. This reduced the quantity of vehicles and auto parts that could be imported from Brazil. In addition, the ProCreAuto plan was established. This was a scheme to provide loans in 60 instalments at subsidized rates for the purchase of low- or mid-range models manufactured in the country.

In short, the Argentine automobile industry expanded greatly during this period, driven by demand from Brazil and a domestic market that was on the rise after the crisis. This was manifested in increased production, sales, exports and employment in the sector, surpassing the levels seen in the 1990s and setting new records in the country. However, the complex ran a persistent trade deficit that was worse than in the 1990s. This was largely explained by the increase in imports of auto parts, which grew along with the number of vehicles produced in the country. This situation continued to worsen after the 2008–2009 crisis and contributed to the growing problem of foreign currency shortages in the Argentine economy. Government responses focused on providing incentives to vehicle manufacturers to purchase local parts and increasing protectionist measures. However, these initiatives were not enough to reverse the process.

[17] At the same time, Brazil was implementing the Innovar-Auto incentive programme, designed to deal with the inroads of Asian, Mexican and European vehicles and to encourage investment in the domestic market, with the result that Argentina lost investment attracted by Brazil.

V. The Cambiemos government (2015–2019)

The inauguration of Mauricio Macri as President of Argentina marked a turning point in the orientation of macroeconomic and productive policy. From December 2015 onward, the new government implemented a policy whose salient features were trade liberalization and financial and exchange-rate deregulation, which represented a notable departure relative to the previous stage (Burgos, 2017; Wainer and Belloni, 2017). At the macroeconomic level, during 2016 the devaluation caused by the unification of the exchange market, together with the adjustment of tariffs, led to an increase in inflation which was not accompanied by higher wages, affecting real wages and domestic consumption (Neffa, 2017). In addition, high real interest rates proved ineffective in slowing inflation and negatively affected the volume of investment. In turn, the new policies had a marked impact on the decline of the overall industrial sector (Grasso and Perez Almansi, 2017).

With regard to the automobile industry, a number of public policies affecting the sector were implemented. Among them, mention should be made of those related to trade liberalization, such as the replacement of the restrictive type of import permit, the DJAI, which had resulted in a ruling against Argentina at the World Trade Organization (WTO). This was replaced by the Integrated Import Monitoring System (SIMI), which was applied to some 10% of the tariff positions formerly affected by the DJAI.

Additionally, the Regime for the Development and Strengthening of Argentine Auto Parts Act (No. 27.263) was enacted in 2016. Under this law, an electronic tax credit voucher was granted to automotive companies purchasing domestic parts and components.[18] In 2017, the only year of economic growth during Macri's administration, the "One Million Cars" plan was presented, the aim of which was to increase car output to one million vehicles on the basis of an agreement between the State, companies and trade unions. This plan promised greater investment, new technologies, new labour agreements and measures to make car-buying easier.

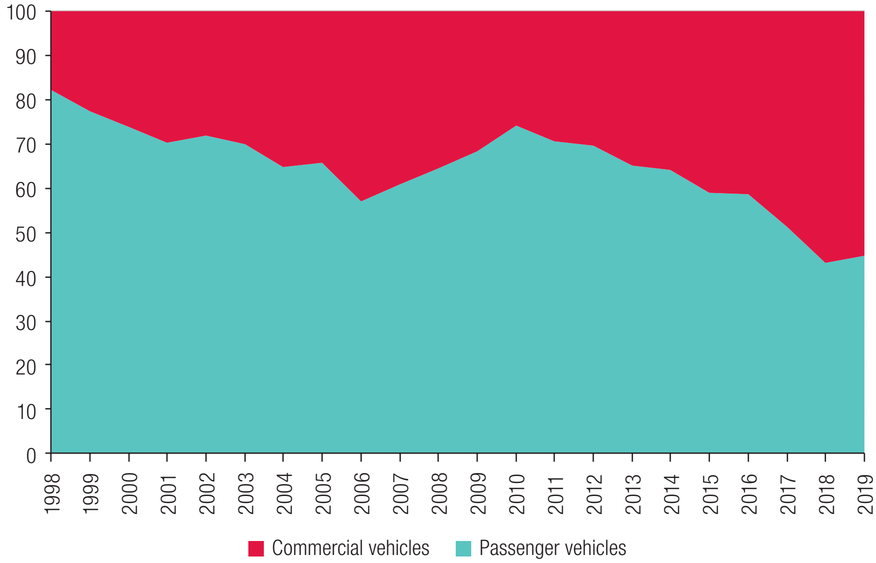
In 2018, after the rise in international interest rates and the worsening of internal inconsistencies, Argentina began to run out of sources of external financing. It turned to the International Monetary Fund (IMF), which granted one of the largest loans in IMF history. The financial crisis led to a devaluation of the country's exchange rate and an increase in the tax levied by the State.[19] Thus, taxes of 3 Argentine pesos per United States dollar were levied on exports of industrial products, which affected both vehicle manufacturers and auto parts exporters. As a result of this general situation, the economic crisis worsened and the recession deepened in 2019 as consumption, production and employment, among other indicators, all fell.

As a result, automotive production plummeted to less than 300,000 vehicles, the lowest level of the decade (see figure 1). Concomitantly, the Argentine automobile industry changed its productive specialization. The decline in production was confined mainly to cars, leaving commercial vehicles (including trucks and vans, a segment largely dominated by pick-ups) almost unaffected, with a consequent increase in their share in the total output of the automobile industry (see figure 4). In the domestic market, the specialization in pick-ups was spurred by the fresh boost to production in the agricultural and energy sectors because of the sector-specific regulatory changes implemented by the Argentine government in 2016–2019 (Dulcich, Otero and Canzian, 2020). It also reflected a strategy implemented by vehicle manufacturers based in the region, as they were increasingly specializing in the production of small vehicles in Brazil and medium-sized and large vehicles in Argentina. In the second case, the process was led by three companies and models in particular: Toyota (with its Hilux model), Volkswagen (with its Amarok) and Ford (with its Ranger).

[18] The value of the voucher ranged from 4% to 15% of the value of the locally purchased parts and components.

[19] This rose from 20 Argentine pesos per dollar in 2017 to 60 Argentine pesos per dollar in 2019, and was accompanied by restrictive exchange controls.

Figure 4
Argentina: composition of automotive production by vehicle type, 1998–2019
(Percentages)

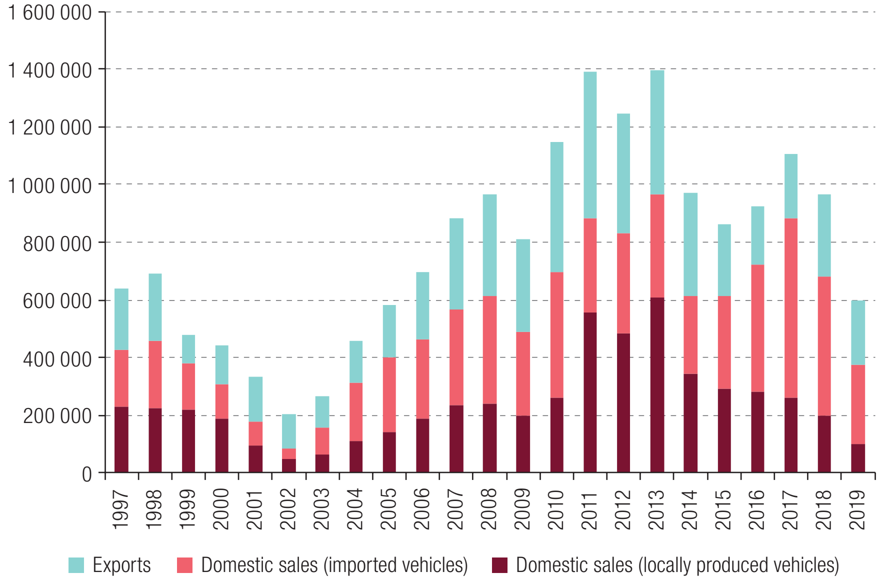


Source: Prepared by the author, on the basis of information from the Motor Vehicle Association (ADEFA).

Thus, when the performance of the automotive sector is compared between Cristina Fernández de Kirchner's last term in office and the Cambiemos government, several significant changes can be observed. Firstly, between 2016 and 2019 there was a large trade deficit in the sector due mainly to the importation of auto parts. However, a comparison of the two phases shows that, while vehicle production fell by 36% between 2012–2015 and 2016–2019 (971,868 fewer units), the auto parts trade balance only fell by 16% (US$ 4.618 billion less), a relatively small decline that did not keep pace with the fall in vehicle production (see figure 5).

However, the most significant changes were in exports and domestic sales, as can be seen in the evolution described in figure 5. Thus, while 29% of sales in the domestic market were of foreign vehicles in the 2012–2015 period, this percentage increased to 51% of the total during the Cambiemos administration. Their share displaced that of exports and local sales of domestically produced vehicles. This change in trend shows the consequences of the government's trade opening policies (Pérez Ibáñez, 2021).

Figure 5
Argentina: domestic sales of imported and locally produced vehicles and vehicle exports, 1997–2019
(Vehicle units)



Source: Prepared by the author, on the basis of information from the Motor Vehicle Association (ADEFA) and the Association of Automotive Dealers of the Argentine Republic (ACARA).

The contraction of local production was associated with the massive influx of imported vehicles, mainly from Brazil, a country that went through years of economic contraction.[20] Brazil sold its surplus vehicles in Argentina, thus increasing the trade asymmetry between the two countries. In view of this situation, and within the framework of the Agreement on the Common Automotive Policy between the two countries, at the end of 2019 the outgoing Cambiemos administration established a new automotive agreement with the incoming government of Jair Bolsonaro in Brazil. The new treaty amended the protocol value of the flex coefficient for sectoral trade between the countries, which stood at 1.5[21] (i.e. US$ 1.5 could be imported duty-free from Brazil for every US$ 1 exported from Argentina in automotive goods). Under the new agreement, the flex was raised to 1.7, with the consequent increase in the quantities that could be imported from Brazil to Argentina. What was new about this treaty, however, compared to the previous ones, was that this protocol value was established retroactively, with effect from 2015 (see tables 2 and 3).

Table 2
Argentina: total flex (vehicles, auto parts and agricultural machinery), third quarter of 2015 to second quarter of 2020
(Imports and exports in billions of dollars)

Imports	Exports	Flex
37.95	22.93	1.65

Source: Prepared by the author, on the basis of information from the General Customs Bureau.

[20] This contraction began in late 2013 and worsened in the following years.

[21] The flex was set at 1.95 from 2006 until 2014, when it was reduced to 1.50.

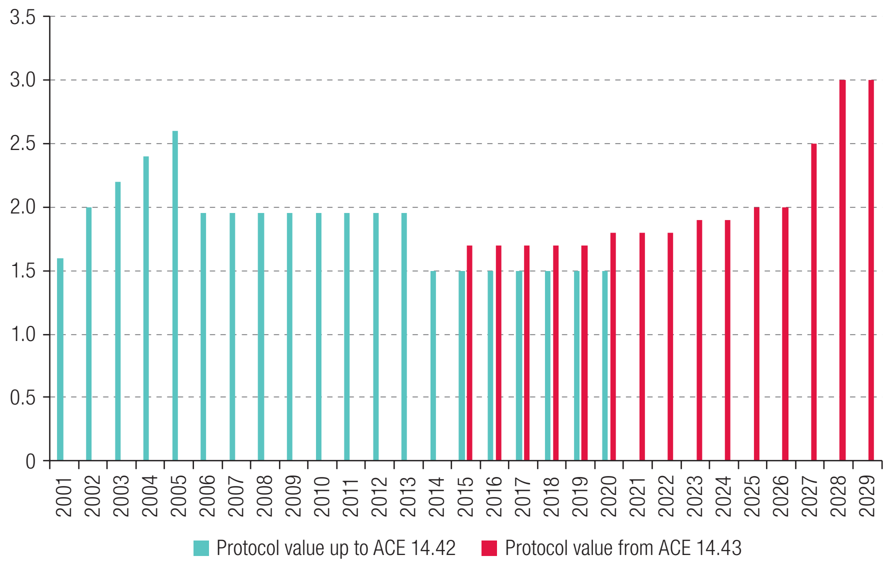
Table 3
Argentina: flex and excess or deficit by product, third quarter of 2015 to second quarter of 2020
(Balances in billions of dollars)

Product type	Flex	Favourable or adverse balance
Vehicles	1.34	2.77
Auto parts	2.35	-4.81
Agricultural machinery	103.11	-1.51

Source: Prepared by the author, on the basis of information from the General Customs Bureau.

This was because throughout the period in which the flex of 1.5 that had been set in ACE 14.42 ought to have been in force, the flex actually applied was 1.65. For that reason, it was then increased to 1.7 and the fines for companies whose imports had overshot were waived. The actual amount of excess imports during the period totalled US$ 4,811,979,669 in the auto parts sector and US$ 1,508,714,913 in the agricultural machinery sector. The losses of tariff preference when the flex is overshot are prescribed in article 13 of ACE 14.38.[22] From this, a fine of approximately US$ 400 million can be calculated for companies carrying out such imports, with the Argentine State foregoing the corresponding tariffs because of the retroactive increase of the flex in ACE 14.43 (see figure 6).

Figure 6
Protocol value of the flex coefficient before and after Economic Complementarity Agreement (ACE) 14.43, 2001–2029



Source: Prepared by the author, on the basis of information from the Latin American Integration Association (LAIA).

Lastly, this agreement set trade conditions for the following 10 years (see figure 6), whereas previously they were reviewed every three years or so. This agreement implies steady increases in the protocol value of the flex until 2029, widening the asymmetry in Argentina's trade with Brazil, as greater quantities of automotive products can be traded tariff-free.

[22] This article provides that "where imports of Automotive Products between the Parties exceed the limits provided for in the Flexes referred to in Article 11, and after application of Article 12 if appropriate, the margin of preference referred to in Article 9 shall be reduced to 25% (residual tariff equal to 75% of the tariffs set out in Article 3 of this Agreement) for auto parts (subparagraph (j) of Article 1) and to 30% (residual tariff equal to 70% of the tariff established in Article 3 of this Agreement) for other Automotive Products (subparagraphs (a) to (e) of Article 1) of the tariffs that affect the value of the excess imports in each Party, according to the provisions of this Agreement" (LAIA, 2008, p. 7).

In summary, the sectoral trade deficit in the auto parts sector persisted during this period, remaining high despite the contraction in vehicle production. At the same time, there was a sharp increase in imports of finished vehicles from Brazil as a result of the trade opening policies of the Cambiemos government and the crisis in that country. The effects of this development are reflected in a greater loss of dollars through trade, which has been coupled with the remission of fines and the increase in the protocol value of the flex. They are also reflected in the loss of productive capacity in the sector as a result of the decrease in domestic production and employment.

VI. Final reflections

Some final reflections can be made concerning the trajectory of the Argentine automotive chain since the end of convertibility. First of all, it should be noted that although the sector went through a period of prosperity during the post-convertibility period, reflected by increases in production, employment and the trade balance in finished vehicles, it was highly dependent on imported inputs throughout. This problem worsened after the trade liberalization of the 1990s, and the situation continued to deteriorate during the first decades of the new century. The dynamics of regional trade and production since the creation of MERCOSUR also intensified during the post-convertibility period, as manifested in Argentina's growing dependence on Brazil in respect of trade and production.

There was also a marked difference in the relative performance of the different actors in the sector. Multinational vehicle manufacturers did best during this stage. This points to poor integration of the automotive production chain, as reflected in the increase in the imported component of vehicles. This became evident at the times of greatest expansion in automotive production, highlighting the strong correlation between the two variables.

Secondly, the analysis revealed that the problems described in the previous period worsened during the Cambiemos government, while certain virtuous characteristics were lost. Comparisons between the last years of Kirchnerism and the period of Macri's government revealed how persistent the sectoral trade deficit in the auto parts sector was, since it remained high and declined much more slowly than the production of final vehicles.

At the same time, there was a large increase in imports of finished vehicles from Brazil as a result of the trade liberalization policies of the Cambiemos government and the crisis in that country. These measures marked a clear contrast with the trade protectionism deployed by Cristina Fernández de Kirchner's last administration. The consequences of this situation were the worsening of the external constraint, due to a greater loss of dollars through trade, and the reduction of the sector's productive capacity as a result of the reduction in local production and employment. This was compounded by the Cambiemos government's decision to remit fines for excess imports of automotive goods and to steadily increase the protocol value of the flex until 2029, which means that future administrations will be tied to greater trade asymmetry with Brazil.

Thus, the analysis carried out in this article opens up new questions about the causes of these developments and how the main problems with them can be overcome. First of all, it must be asked whether the public policies of a semi-peripheral country such as Argentina have any real prospect of guiding its automobile industry in a more prosperous and sustainable direction. It seems pertinent to make comparisons with other countries that have similar characteristics, with the aim of finding successful cases and replicating their methods. At the same time, the reasons for the disparity between the different branches of the sector should also be explored. There is a need for more in-depth studies on the relationships within the Argentine automotive chain. This requires further research into the behaviour of multinational vehicle manufacturers and their strategies in peripheral countries, since these companies form the core of the network. The current phase of global capitalism imposes major restrictions on peripheral countries and their economic development projects, increasingly restricting the pathways towards a different role for these nations on the international stage. As far as the automobile industry is concerned, all indications are that control of the chain will remain in the hands of a small group of companies from developed countries. Therefore, finding the best way to engage with them seems to be an unavoidable task.

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Annex A1

Table A1.1

Argentina: leading auto parts companies producing in the country, by turnover, 2013

Company	Country of ownership	2013 turnover *(millions of dollars)*	Products
Mirgor	Argentina	225	Air-conditioning systems, steering boxes
SKF	Sweden	201	Bearings and accessories, among other things
Metalsa	Mexico	199	Chassis and structural assemblies
Pabsa	Canada	157	Seats and seat components
Faurecia	France	157	Seats, instrument panels and door panels
Mahle	Germany	135	Valves
Denso	Japan	133	Air-conditioning systems, radiators and air filters, among other things
Visteon	United States	126	Air-conditioning systems, condensers and radiators, among other things
Frict-Rot	United States	125	Shock absorbers and exhaust systems
Gestamp	Spain	115	Assembled and welded elements, dies and stamped assemblies
Industrias Lear	United States	114	Seats and wiring harnesses
Famar Fueguina	Argentina	100	Stereos and alarms, among other things
Cibie	France	86	Headlights and interior lights
ZF Sachs	Germany	79	Clutches and shock absorbers

Source: E. Inchauspe and N. García, "El complejo automotriz-autopartista en América Latina. Estrategias globales, regionales y desempeño reciente", *La encrucijada del autopartismo en América Latina*, Buenos Aires, Association of Latin American Economic Thought (APEL)/Universidad Nacional de Avellaneda (UNDAV) Ediciones, 2017.

Table A1.2

Argentina: vehicle manufacturers producing in the country, 2013

Company	Turnover *(dollars)*	Production *(units)*	Exports *(units)*	Staff employed	Models produced
Volkswagen	31 213 019	106 711	62 399	7 830	Suran and Amarok; gearboxes
Ford	21 181 521	102 280	66 727	3 061	Focus and Ranger; engines
Toyota	20 119 969	94 468	64 342	4 746	Hilux and Hilux SW4
Peugeot-Citroën	15 560 878	115 302	29 189	4 945	Berlingo, 207 Compact, 308, 408, C4 (Sedan, Lounge and Hatch) and Partner
Renault	15 116 419	117 635	51 049	3 185	Clio Mio, Kangoo, Symbol and Fluence
General Motors	14 294 016	111 355	65 070	3 529	Classic and Agile
Fiat	13 414 179	104 891	72 830	3 051	Palio and Siena; gearboxes
Mercedes-Benz	9 575 383	20 502	12 222	2 068	Sprinter, OF 1722, LO 915, OH 1518, OH 1618, OH 1718, OF 1418, Atron 1720/1624/1634
Iveco	3 755 300	6 344	195	907	Trucks: Eurocargo Attack, Eurocargo, Tector, Cavallino, Cursor, Stralis, Trakker; bus chassis: 170E22
Honda	2 201 645	11 519	9 272	856	City
Scania	2 161 681	0	0	534	Transmission components

Source: Motor Vehicle Association (ADEFA), "Anuario 2013" [online] http://www.adefa.org.ar/es/estadisticas-anuarios-interno?id=48.

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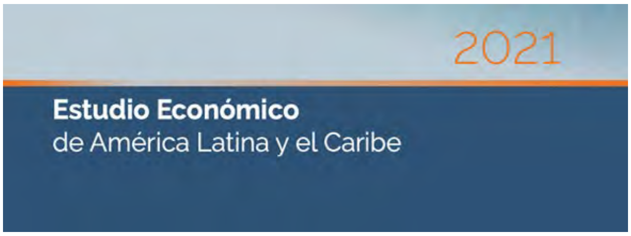

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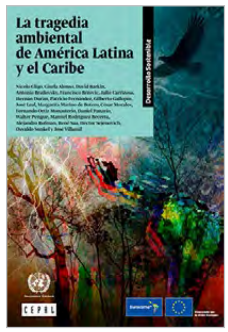

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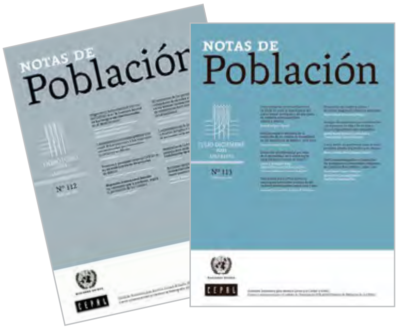

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