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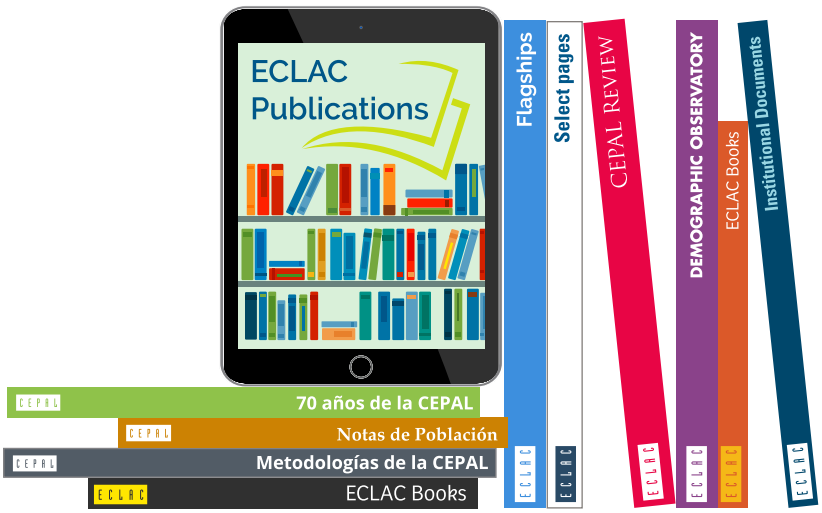

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Contents

Explanatory notes

The following symbols have been used in the tables in this publication:

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

— A dash indicates that the amount is nil or negligible.

A blank space indicates that the concept under consideration is not applicable or not comparable.

– A minus sign indicates a deficit or decrease, unless otherwise indicated.

. A full stop is used to indicate decimals.

/ A slash between years (e.g. 2022/2023) indicates a 12-month period falling between the two years.

- The use of an en dash between years (e.g. 2022–2023) indicates reference to the complete number of calendar years involved, including the beginning and end years.

Reference to "tons" indicates metric tons and the world "dollars" refers to United States dollars, unless otherwise specified.

Individual figures and percentages in graphs and tables may not always add up to the corresponding total because of rounding.

Economic development in Colombia since the early twentieth century

José Antonio Ocampo and Carmen Astrid Romero Baquero[1]

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Abstract

This article analyses Colombia's economic growth performance since the early twentieth century, the evolution of the public policies that have contributed to this and its main effects on social development and regional inequalities. Economic performance is divided into three periods: 1905–1929, 1930–1980 and 1981–2023. The first was characterized by the expansion of coffee production, an infrastructure investment boom and the beginning of oil extraction. The second saw the consolidation of industrial development and the diversification of agricultural production and exports. The last was characterized by increased State provision of social services, administrative decentralization and liberalization of foreign trade and the financial system, a combination whose economic results were deindustrialization, export reprimarization (with oil as the main product) and increased macroeconomic volatility.

Keywords

Economic development, economic history, economic growth, industrialization, economic crisis, external debt, economic liberalization, social development, regional disparities, Colombia

JEL classification

E60, I00, O10, N16

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[1] This article is based on a recent paper by the same authors (Ocampo and Romero Baquero, 2023), who are grateful to Francisco Rodríguez for his comments on an earlier version. It will also be published in F. Rodriguez (ed.), *The Elgar Companion to the Economies of Latin America and the Caribbean*, Cheltenham, Edward Elgar Publishing, forthcoming.

I. Introduction

This article analyses Colombia's economic growth performance since the early twentieth century, the evolution of the policies contributing to this and its effects on social development and regional inequalities. Since 1905, the country's per capita GDP has multiplied by a factor of 12.8. This gives a growth rate of 2.2% a year, which is slightly higher than the Latin American and world average, according to historical data from the Maddison Project Database,[2] leaving Colombia in the category of upper-middle-income countries in the World Bank classification.

Three quite different major phases can be distinguished in this growth record, involving profound structural changes. The country has had to cope with powerful economic cycles, associated with fluctuations in the terms of trade for its main export products and in external financing. There have also been substantial changes in economic policies and the institutions formulating them. There has been progress with human development, marred however by high levels of social inequality, labour market informality and underemployment and by limited achievements with social security. Lastly, economic development has tended to be concentrated in large cities and in the regions that are strong in the main export products.

The article is divided into seven sections, the first being this introduction. The second section discusses the major trends and changes in economic structures during the three main stages of development into which the analysis has been divided. The next three review economic trends during these three stages in more detail, with an emphasis on policy developments. The sixth section deals with the evolution of social indicators and regional inequalities, and the last section briefly concludes. Despite their importance in the country's history, only passing reference will be made to the consequences of rural violence and none to those of drug trafficking, whose economic effects have anyway been more limited than their effects on national politics and violence.

II. Trends, phases and structural change

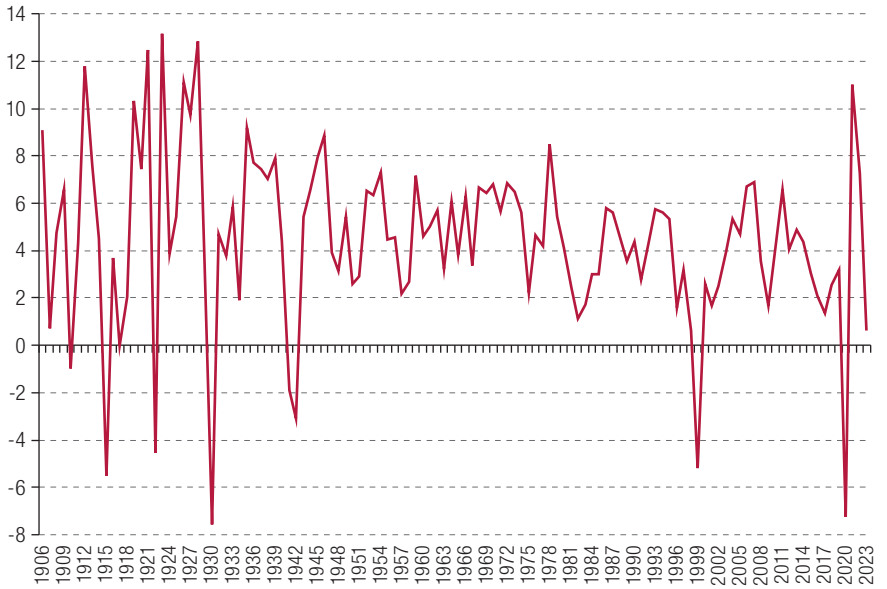
The development process has gone through three periods that differ substantially in terms of economic policies and structural change, while there have also been profound changes in the economies of Latin America and the world: 1905–1929, 1930–1980 and 1981–2023.[3] They are separated by important transitional phases, encompassing the Great Depression and the Second World War between the first and second periods and the Latin American debt crisis between the second and third.

Economic growth has been markedly cyclical. Figure 1 shows annual changes in GDP from 1906 to 2023. This variable was highly volatile until the Second World War, which was followed by a period of lower variability over the next half century, with volatility returning again from the late 1990s. The first half of the twentieth century saw sharp recessions triggered by the outbreak of the First World War, the subsequent sharp fall in commodity prices, the Great Depression and the Second World War. This phase of variability in growth rates was followed by one of steadier expansion that lasted until most of the way through the 1990s. A new period of instability began in the late twentieth century, with the worst years being 1999, as a result of the successive Asian and Russian crises, and 2020, owing to the effects of the coronavirus disease (COVID-19) pandemic.

[2] See Bolt and van Zanden (2020). The relevant comparisons with these data are for the period 1900–2018.

[3] See Bulmer-Thomas (2003), Bértola and Ocampo (2013) and Williamson (2014) on parallel processes in Latin America.

Figure 1
Colombia: GDP growth, 1906–2023
(Percentages)



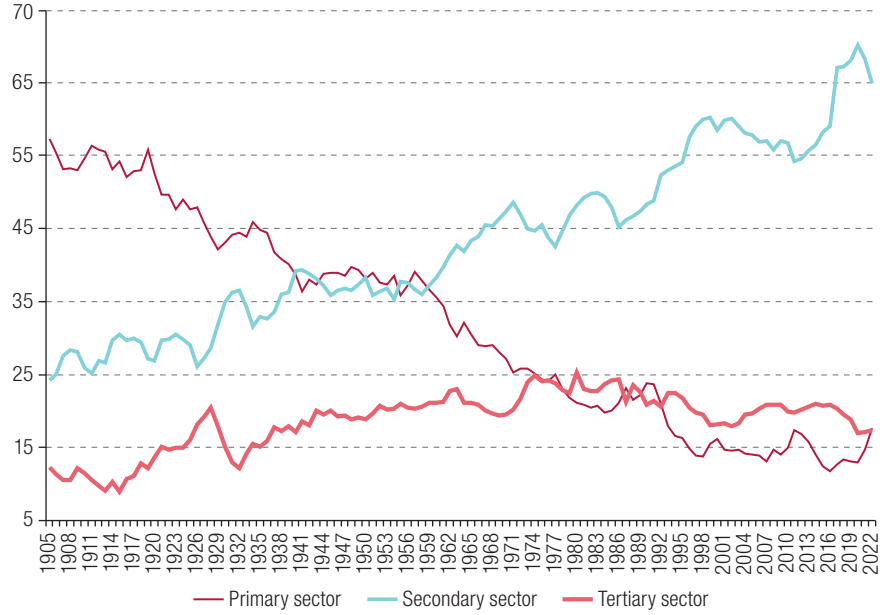
Source: C. A. Romero Baquero, "Estimación del PIB de Colombia, 1905-1960", paper presented to the Bank of the Republic, 2018, and data from the National Administrative Department of Statistics (DANE).

The country's cycles have been closely linked to international shocks, especially fluctuations in the terms of trade for its main export products (coffee for most of the twentieth century and oil in the twenty-first century) and in external financing cycles. The latter include the boom in private sector external borrowing in the 1920s, which was interrupted by the Great Depression, renewed access to international private sector financing in the 1970s, which was curtailed for the country during the Latin American debt crisis, and the new boom in the 1990s, cut short by the crises in Asia and the Russian Federation; the international financial market has continued to be cyclical since then, but less markedly.

The dependence on external commodity price cycles and external private sector financing shows the importance of balance-of-payments dominance (Ocampo, 2016). A positive aspect is the absence of crises caused by fundamentally domestic factors. However, the policies adopted to manage booms have significantly affected the severity of subsequent crises. In other words, procyclical management of booms has meant crises having to be managed with austerity policies.

Structural changes have been driven by both exports and production activities. In the first case, the main developments have been the growth and consolidation of the coffee economy in the first three decades of the twentieth century, relatively successful export diversification from the late 1960s to the early years of the twenty-first century, and the boom in oil exports since the end of the twentieth century. Other periods have been dominated by trends in domestic production activities, notably the emergence and development of manufacturing as an engine of growth between the 1930s and the mid-1970s and the rise of the service sector in recent decades. Thus, changes in the composition of output show a decline in the share of agriculture, which dominated production activity at the start of the twentieth century, first because of industrialization and then because of the rise of the service economy since the late twentieth century (see figure 2).

Figure 2
Colombia: sectoral GDP shares, 1905–2022
(Percentages)



Source: C. A. Romero Baquero, "Estimación del PIB de Colombia, 1905-1960", paper presented to the Bank of the Republic, 2018, and data from the National Administrative Department of Statistics (DANE).

Agriculture and agro-industry have created a business ecosystem that, while reasonably developed, has not been able to ensure competitiveness for a number of sectors and substantial opportunities for small-scale producers. In addition, there have been problems with distribution chains and road transport, especially on the municipal-level road infrastructure. The coffee sector has developed the best commercial and technological infrastructure and the best opportunities for small producers. After the coffee boom that characterized the early decades of the century, the agricultural sector diversified even as the country industrialized. Conversely, the trade liberalization of the 1990s had adverse effects not only on industrial activity, but also on a number of agricultural products, especially grains (maize, wheat, barley and soybeans). Thus, the behaviour of agriculture and industry has been complementary in periods of both good and poor performance (Ocampo, 2015; Kalmanovitz and López, 2006).

Cattle farming is a traditional line of business, but both milk and meat producers have managed to diversify, especially over the last 50 years. However, this sector has had a large environmental impact owing to deforestation and inappropriate land use, with even flat land being used for cattle farming, while hillside areas are used for agriculture. Other livestock activities have been dynamic, poultry farming first and pig farming later, but have been characterized in recent decades by an excessive dependence on imported inputs and thus weak national value chains (Lorente, 1986; DNP, 2015).

Modern manufacturing industry came into existence in the late nineteenth century but only began to take off in the 1930s, with its development consolidating in 1946–1974. It achieved only an intermediate level of diversification by Latin American standards, however: traditional branches still accounted for a quite large share by the end of the period of rapid industrialization, far more so than in Brazil and Mexico, although less than in the region's smaller economies (Bértola and Ocampo, 2013, table IV.7). Since its GDP share peaked in the second half of the 1970s, manufacturing industry has

experienced what has come to be known in the international literature as premature deindustrialization (Rodrik, 2016).[4] This is partly explained by the weakening of productive development policies, the very limited development of a science, technology and innovation system to link up with the productive sector, and a relative failure to cope with competition and find a place in the new forms of international trade organization.

Services are a growth alternative because of their resilience, their job-creating capacity and their cross-cutting contribution to productive modernization. This sector includes both traditional services such as commerce, transport, communications and tourism, and modern services linked to the use of information and communications technologies which have begun to transform traditional ones, such as e-commerce and financial and insurance services. A key challenge now is to consolidate modern services by way of increased coverage, the availability of technology and an education system that is aligned with this purpose.

Since the closing decades of the twentieth century, Colombia, like many Latin American and especially South American countries, has faced two major barriers to growth: premature deindustrialization and oil-led export reprimarization. Statistical estimates of the Kaldor-Verdoorn law (Kaldor, 1957 and 1968) show a clear relationship between productivity growth and industrial growth in the main Latin American economies, including Colombia (Ocampo and Romero Baquero, 2023, chapter 2). This relationship was strongest between 1925 and 1975, and then weakened in a context characterized by a slowdown in industrial growth and lower productivity gains. Very limited investment in research and development is undoubtedly an essential part of this story. According to data from the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2024), this expenditure does not exceed 0.3% of GDP, which places it at half the Latin American level and one tenth that of the high-income countries of the Organisation for Economic Co-operation and Development (OECD), of which Colombia is a member.

III. Economic take-off, 1905–1929

The Thousand Days' War (1899–1902), the worst of the nineteenth century civil wars, brought three-digit inflation (the first instance in Latin American history) as a result of money being issued to finance conflict-related expenses. This led to a ban on paper money issuance and adoption of the gold standard in 1903 and to a tradition of monetary conservatism that would manifest itself whenever inflation rose above a certain level. The government decreed (moderate) new issues in 1904, which were timely in the context of the country's severe economic crisis of those years. The ban on paper money issuance would finally be confirmed in 1910 by a constitutional amendment. Monetary stabilization led on to substantial growth in the country's banking sector.

The most salient development in the first decades of the century was the rapid expansion of coffee production in the west of the country, also known as the central coffee-growing region.[5] This followed the expansion which had taken place mainly in the east of the country in the nineteenth century and created more scope for small producers than that earlier development. Coffee exports began to increase at the end of the first decade of the century, rising by a factor of just over 4.5 between 1900–1904 and 1925–1929. The opening of the Panama Canal in 1914 and the completion in 1915 of the Pacific Railway, which drove the emergence of Buenaventura as a port, were also beneficial for coffee exports, partly thanks to the gradual integration of this railway with those of the central coffee-growing region.

[4] See also the studies by Fajnzylber (1983), Palma (2019) and Torres and Ahumada (2022) dealing with Latin America.

[5] The central coffee-growing region includes the departments of Caldas, Quindío and Risaralda, along with the north of Valle del Cauca and Tolima. For the history of Colombian regional development, see the study by Jiménez and Sideri (1985).

In 1906, once the foreign debt bequeathed by the war of independence had been paid off (Junguito, 1995), and after punctually making its debt service payments in the following years, Colombia regained access to the international capital market, albeit still only to a moderate degree. After this initial impetus, the country gained large-scale access to that market, which led to a considerable amount of international borrowing, especially between 1926 and 1928 (some US$ 200 million).

These resources largely went to infrastructure investment, especially in the railway network, which was, and remained, very underdeveloped. The financing mechanism was the issuance of bonds by the national government, some departments and municipalities and some banks on the New York Stock Exchange. The overall transfer of resources through the capital account was equivalent to 35% of exports in 1925–1929.

The coffee and external financing booms were accompanied by other developments that included banana exports,[6] the start of oil exports and the payment by the United States between 1923 and 1926 of a US$ 25 million indemnity for Panama's independence. No less importantly, in 1923 the country set up several modern economic institutions in the aftermath of the Kemmerer Mission: the Bank of the Republic (the central bank) and the Banking Superintendency, to manage the country's monetary, financial and exchange-rate policies, and the Office of the Comptroller General of the Republic, to oversee the civil service. The Bank of the Republic was created as a public-private institution, with the private sector having a majority on its board, to forestall the problems caused by National Bank money issuance at the end of the nineteenth century. This institution also had the task of replacing the heterogeneous monetary mass that the country still had with its own banknotes and coins, completing the efforts made in this direction since the beginning of the century.[7]

Economic growth was rapid (5.5% per annum for the whole period 1905–1929 and 3.0% per capita) but unstable, as noted in the previous section (see figure 1). Three phases can be distinguished. The first is the recovery from the end of the civil war to the outbreak of the First World War. The second encompasses the effects of that war, which reduced coffee prices and imports, and hence customs revenues, which were the main source of government financing, and rendered the main European currencies non-convertible. While the price of coffee rose significantly after the war, this was followed by the collapse of all international commodity prices in 1920–1921, one of the worst in world economic history.

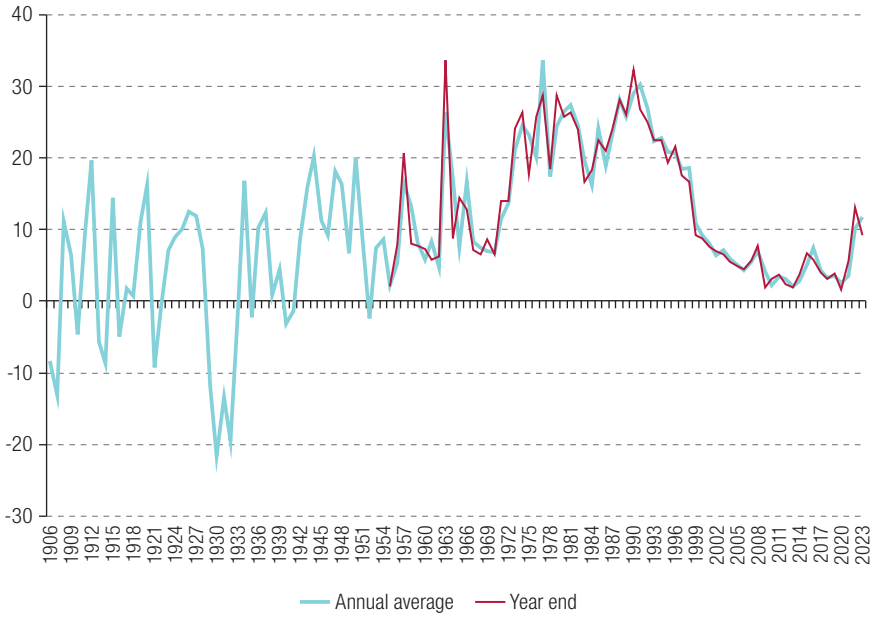
The third period began in 1923 and was among the most successful in Colombian economic history. Notwithstanding a dip in 1924, GDP grew very quickly between 1923 and 1928, by 8.5% annually, the highest in the country's economic history for a similar period, with particularly rapid growth between 1926 and 1928. The simultaneous expansion of the export sector and of public works financed by foreign debt were the driving forces behind this boom, which was reflected in a large build-up of international reserves and a huge monetary and credit expansion within the rules of the gold standard. Customs revenues and foreign borrowing facilitated the expansion of public spending, and annual inflation rose above 10% in 1925, 1926 and 1927 (see figure 3), but the only measures taken to curb it were the Emergency Act of 1927, which reduced tariffs to facilitate food imports, and the imposition of limits on rediscounting by the Bank of the Republic in January 1928 (Ocampo, 2021, chap. II).

The boom really ended in the second half of 1928 with the start of the decline in coffee prices and external financing, reflected in a large reduction in growth in 1929. However, the definitive slump came with the Wall Street Crash in October 1929.

[6] This expansion, which had begun in the late nineteenth century, was stopped by a major labour strike in 1928, one of whose effects was to displace production to other areas of the Caribbean in the following decades. For an appreciation of this process, see Bucheli (2005).

[7] See Ocampo (2021) and Uribe Escobar (2023) on these Bank of the Republic policies and those mentioned later.

Figure 3
Colombia: consumer price inflation, 1906–2023
(Percentages)



Source: Colombian Economic Growth Study Group (GRECO), *El desempeño macroeconómico colombiano: series estadísticas 1905-1997*, Bank of the Republic, 1999, and data from the National Administrative Department of Statistics (DANE).

IV. The industrialization era, 1930–1980

1. The Colombian economy between two international crises

The boom of the 1920s was followed by two major global economic crises: the Great Depression, which broke out worldwide in 1929 with the slump on the New York Stock Exchange, and the one linked to the Second World War.[8] The most striking impact of both was the worldwide intensification of State intervention in different spheres of the economy, which in Colombia was reflected in monetary, financial and exchange-rate policies and, owing to the collapse of international trade, in the reorientation of the development model towards the opportunities offered by the domestic market. The most important result of the latter process was the take-off of manufacturing industry, when the country caught up with other major Latin American economies in this area. The process also benefited from the integration of the domestic market, which was challenging given Colombia's geography. Major steps forward were the construction of railway infrastructure in the 1920s and the move towards the construction of a road network in the 1930s. The country thus embarked on "State-led industrialization", to use the terminology of Cárdenas, Ocampo and Thorp (2000) and Bértola and Ocampo (2013).

[8] See Ocampo (2015) for a discussion of the country's economy between the Great Depression and the Second World War. See also Ocampo and Montenegro (1984) and Sánchez Torres (1994) on the Great Depression.

Initial management of the Great Depression was within the rules of the gold standard, generating a strong contractionary effect that succeeded the expansionary management of the 1920s, i.e. procyclical behaviour in both situations. The effects were dramatic: international reserves dropped by almost four fifths and the money supply and prices by half (see figure 3). GDP contracted only moderately in 1930 and 1931 (see figure 1), not least because of the continued expansion of coffee production. It was shown that the country had the flexibility to manage the gold standard, as there was no loss of confidence in the Bank of the Republic, and the financial sector was able to handle the crisis, except for the mortgage banks, which went bankrupt, triggering the first of the country's financial crises.

The turning point was the decision by the United Kingdom to leave the gold standard on 4 September 1931, leading Colombia to establish exchange controls on 24 September. A sequence of decisions taken from 1932 onward resulted in the exchange rate undergoing a devaluation of 71% in real terms between 1931 and 1935, one of the largest in the country's economic history (see figure 4). Thereafter, a fixed but adjustable exchange rate was applied, including multiple rates at various times, a pattern the country would maintain until 1967. A moratorium on the foreign debt of the departments and municipalities was introduced in early 1932, followed by a total suspension of debt servicing in 1935. Protectionism was also part of the agenda, but had no significant effects because the 1931 tariff reform maintained a system of specific tariffs that lost their value with inflation. Much more important were exchange controls from 1931 and direct import controls from 1937.

Figure 4
Colombia: real exchange rate, 1905–2023
(Index: 2010=100)

Source: J. A. Ocampo and C. A. Romero Baquero, *Crecimiento económico colombiano y sus efectos sobre el desarrollo social y regional 1905-2019*, Bogotá, Bank of the Republic, 2023, and data from the Bank of the Republic.
Note: The exchange rate is estimated in pesos per dollar and adjusted for consumer prices in Colombia and its trading partners.

The most ingenious monetary measure taken in response to the crisis was to hand over the administration of the State salt mines to the Bank of the Republic so that it could advance the revenue expected from them to the government, allowing public spending to increase. The money supply

increased by more than 20% annually between 1931 and 1934, generating strong inflation in 1934 (see figure 3), which led to greater monetary and fiscal austerity from 1935 onward. A major tax reform adopted in this latter year introduced income and wealth taxes. Three public financial institutions were created in 1931 and 1932: the Caja de Crédito Agrario, an agricultural bank; the Banco Central Hipotecario (BCH), to deal with the collapse in mortgage lending; and the Corporación Colombiana de Crédito, to purchase bank portfolios.

With the outbreak of the Second World War, the growth seen since 1931 was halted, but there were also profound changes in economic policy. The most salient were policies aimed at sterilizing the monetary impact of the accumulation of international reserves owing to falling imports due to United States export restrictions during the war. These policies were considered by the great economist Robert Triffin (1944) to be the most complete and balanced anti-inflation system devised at the time in Latin America. The first development bank, the Instituto de Fomento Industrial (IFI), was also created in 1940. The United States pursued two strategies that had major effects on Colombia: the Inter-American Coffee Agreement and the renegotiation of Latin American foreign debts. To manage the former, the National Coffee Fund was created in Colombia.

Economic growth throughout this transitional phase was lower than in the previous period of economic take-off, but not slow, despite the contraction in GDP that resulted from the initial effects of the two crises (in 1930 and 1941–1942). For the period 1929–1945 as a whole, growth was 4.1% per annum, or 2.0% per capita. This was made possible by the rapid expansion of manufacturing production, the fastest in Latin America between 1929 and 1945 at about 8% per year (Bértola and Ocampo, 2013, table IV.2.B).

2. Industrialization on a firm footing

The last years of the War were the beginning of a long period, ending in the 1970s, whose central elements were intensifying industrialization, agricultural diversification, the development of numerous services and moderate growth of the State. In contrast, the coffee sector ceased to be key for growth as plantations aged. The growth of the State was associated with the expansion of social and infrastructure services, including in the latter case State provision of public services that had been provided in many areas by private companies, but on an inadequate scale.

There were also significant changes in monetary and credit policy. The most important were the monetary reform in 1951, the creation of the Monetary Board in 1963, which gave the government control over monetary policy, and the nationalization of the Bank of the Republic in 1973. The 1951 reform included the creation of new monetary management tools, among them the active use of bank reserve requirements and the ability to regulate interest rates, and endowed the Bank with development banking functions. For the performance of these latter, besides the functions already exercised by the Industrial Development Institute (IFI), new official banks were also created: Banco Popular in 1950, Banco Cafetero in 1953 and Banco Ganadero in 1956. Two new types of financial institution were likewise created: financial corporations in 1957 and saving and housing corporations in 1972.

A persistent feature of the situation, though, were recurrent balance-of-payments crises and the policies adopted to manage them, including devaluations, protection and, after a delay, diversification of the export base. These crises often reflected intermittent cycles, i.e. cycles of procyclical macroeconomic policy behaviour: expansionary measures when the external situation allowed, followed by retrenchments when balance-of-payments problems arose, with this second phase including the management of inflationary problems caused by devaluations.

The first crisis came in 1948 as a result of the sharp increase in import demand that followed the War and of the political crisis triggered that same year by the assassination of liberal leader Jorge Eliécer Gaitán. These events led in December 1948 to the first post-war devaluation, from 1.75 to 1.95 Colombian pesos to the dollar, preceded a few months earlier by the introduction of an unrestricted parallel foreign-exchange market that benefited non-traditional exports.[9] A further devaluation, from 1.95 to 2.50 Colombian pesos to the dollar, was implemented in 1951 to counter the effects of inflation on the real exchange rate; as part of this, however, the operation of the unrestricted parallel foreign-exchange market was suspended. The first post-war tariff reform, enacted in 1950, significantly raised the level of protection via a mixed system of specific and ad valorem tariffs. These measures were invariably supplemented by direct import controls, especially at times of foreign-exchange shortages.

After the coffee boom of the early 1950s came the coffee price collapse of the middle of that decade, which led to the reintroduction of the parallel market in 1955 and, especially, the largest devaluation in Colombian history in 1957: from 2.50 to 6.70 Colombian pesos to the dollar. As figure 4 shows, this devaluation and the ones that followed, unlike those of the first half of the 1930s, had a lasting effect on the real exchange rate. To this were added the Vallejo Plan, which allowed exporters to bring in the inputs they needed to make export products without paying import duties, the introduction of tax incentives for these activities and other production sectors in 1960, and the privilege for exporters of products other than coffee and oil of selling their foreign exchange on the open market.[10] The subsequent devaluations in 1962 (to 9 pesos) and 1965 (to 13.50 pesos) had no lasting real-term effects because of the inflation they generated. The tariff reforms of 1959 and 1964 heightened the protectionist trend, with the latter finally adopting a pure ad valorem tax system with a very high level of protection (an average tariff of 65.6%).

The most important measures came in 1967, when the system of mini-devaluations was adopted, together with a policy of exchange-rate unification. In addition, a clearly defined export promotion regime was introduced to expand the Vallejo Plan: the Export Promotion Fund (PROEXPO) was created at the Bank of the Republic to finance non-traditional exports, and the tax-free Tax Savings Certificate (CAT) was created to replace the tax advantages and preferential exchange rate that these exports had benefited from for several years. This shift in economic policy not only made it possible to cope better with the external crisis, but also opened the way, as will be seen, to the most rapid economic expansion of the post-war period.

Criticism of the State-led industrialization model became increasingly open in Colombia, as throughout Latin America, from the early 1970s. However, reforms to protectionist policies were gradual and did not extend to certain areas (exchange controls, for example). They included cuts in tariffs, especially very high ones, and reduced use of import controls. By the early 1980s, the average tariff had been cut to 26% (compared to 65.6% in 1964 and 48.5% in 1973), and 70.8% of tariff items were on the tariff-free import schedule (compared to 29.6% in 1974).

In the financial sphere, the basic objective was to adopt liberalization measures to do away with "financial repression". The first decisions in this area were taken in 1974 but were largely suspended by the strong stabilization policy implemented to manage the coffee boom of 1975–1978, which included fiscal austerity and firm measures to curb the build-up of international reserves and offset the monetary expansion this generated, including large-scale saving in the coffee sector and a virtual ban on new

[9] Colombia's exchange-rate history from those years onward is clearly recounted in Wiesner (1978) and Cárdenas (1997).

[10] The now classic treatment of the external sector of the Colombian economy during the period analysed in this section is in Díaz-Alejandro (1976).

external borrowing. This policy was followed by expansionary measures from late 1978, including an expansionary fiscal policy, further-reaching financial liberalization and a large increase in external financing, especially of the public sector (Junguito and Rincón, 2007).

One of the consequences of the new policy package was that between 1980 and 1982 Colombia, fortunately as a latecomer, joined the external financing boom that other Latin American nations had already embarked upon. The country's position when it began this borrowing phase was advantageous, thanks to its relatively small external debt and the considerable amount of international reserves that had been built up during the years of the coffee boom. Indeed, in contrast to the Latin American pattern, Colombia's external debt as a percentage of GDP was still smaller in 1982 and 1983 than in 1975. This would give the country a margin of protection that other Latin American countries did not have when the debt crisis struck in 1982.

In sum, economic growth between 1945 and 1980 was dynamic, averaging 5.1% a year. While somewhat lower than during the economic take-off, this was much more stable than the growth the country had experienced up to the Second World War (see figure 1). Per capita growth fell even more in comparison with the boom at the turn of the century, to 2.2% annually, because of accelerating population growth. The period of strongest growth was between 1967 and 1974, when the economy expanded at an annual rate of 6.3% a year, although this was also lower than during the boom of 1923–1928.

Industrialization progressed, peaking as a share of GDP in the mid-1970s (see figure 2); it was undoubtedly the engine of economic growth during this period.[11] The export sector's share of the economy declined, but it also diversified (see table 1). Coffee's share of exports fell from around three quarters up until the 1950s to half in the years before the coffee boom of 1975–1978. The share of oil and fuel oil dropped even more rapidly. The share of non-traditional exports, however, rose from less than a tenth in the 1950s to just over 40% in 1970–1974, with manufactured goods accounting for slightly more than commodities, which were mainly agricultural. At the same time, imports fell as a proportion of GDP and became concentrated in intermediate and capital goods. From the 1970s onward, the economy experienced moderate but steady inflation which lasted for almost three decades (see figure 3).

[11] See Garay and others (1998) on the evolution of manufacturing industry from 1967 and during this period.

Table 1
Colombia: GDP shares and composition of exports and imports
(Percentages)

	1945–1949	1950–1954[a]	1955–1959	1960–1964	1965–1969	1970–1974	1975–1979	1980–1984	1985–1989	1990–1994	1995–1999	2000–2004	2005–2009	2010–2014	2015–2019	2020–2022
A. GDP shares[b]																
Exports/GDP	21.6	19.0	17.8	16.5	15.8	14.9	15.1	14.2	17.3	20.7	22.0	26.8	28.3	27.9	26.1	22.7
Imports/GDP	16.7	21.4	18.4	16.3	15.5	16.8	16.0	19.1	15.6	21.2	28.9	26.5	34.7	42.6	44.4	46.6
B. Composition of exports[c]																
Coffee	72.1	78.7	76.2	68.9	61.0	50.5	57.9	48.7	37.4	18.7	16.3	6.5	5.7	4.0	6.4	7.4
Gold	5.6	2.7	2.5	2.8	1.7	1.8	2.7	6.4	7.4	4.1	0.9	2.0	2.3	5.1	5.2	7.4
Oil and fuel oil	14.6	13.6	14.3	16.1	13.5	6.9	3.9	6.6	17.5	19.9	25.2	28.2	28.1	50.1	37.6	31.2
Minor commodities[d]	7.7	5.0	7.0	9.1	15.0	19.8	16.6	19.0	19.0	26.9	23.2	23.8	28.0	20.6	25.4	28.0
Manufactures[e]				3.1	8.7	21.0	18.8	19.3	18.6	30.4	34.4	39.5	35.9	20.2	25.5	26.0
C. Composition of imports																
Consumer goods	14.6	9.4	7.3	7.9	9.9	13.2	11.9	10.2	13.9	19.1	19.6	19.8	21.9	23.6	22.4	
Intermediate goods	48.9	54.0	48.7	50.2	51.7	52.1	52.3	55.0	49.5	44.8	47.6	43.4	42.9	44.9	48.0	
Capital goods	36.5	36.6	44.0	41.9	38.4	34.7	35.8	34.7	36.6	36.0	32.8	36.8	35.3	31.5	29.6	
D. Current account deficit																
Current account deficit/GDP	-1.8	-0.5	0.7	-2.6	-2.4	-3.3	1.1	-4.6	-0.8	0.0	-3.6	-0.6	-2.1	-3.5	-4.6	-5.2

Source: For GDP shares: C. A. Romero Baquero, "Estimación del PIB de Colombia, 1905-1960", paper presented to the Bank of the Republic, 2018, and data from the National Administrative Department of Statistics (DANE); for export and import composition: Comptroller-General's Office (up to 1970) and Bank of the Republic (from 1970 onward); for the current account deficit: C. A. Romero Baquero, "El tipo de cambio en Colombia 1932-1974", doctoral thesis, Autonomous University of Barcelona, 2005, C. A. Romero Baquero, 2018, and data from the Bank of the Republic and DANE.

[a] Excludes 1951 for export composition.
[b] Goods and services at constant 1975 prices.
[c] Goods and gold.
[d] Bananas, flowers, other agricultural products, coal, ferronickel, emeralds and other mining products.
[e] Standard International Trade Classification (SITC) groups 5 to 8: chemicals and related products, n.e.s.; manufactured goods classified chiefly by material; machinery and transport equipment; and miscellaneous manufactured articles.

V. The Colombian economy during the Latin American debt crisis and economic liberalization, 1980–2023

1. The effects of the Latin American debt crisis

Colombia's moderate external borrowings meant that it was not exposed to the consequences of the Latin American debt crisis, but it was affected by the coffee price fall, large balance-of-payments current account deficits and more limited access to external financing. These effects were compounded by the need to stem the sharp deterioration in public finances caused by the expansionary fiscal policy adopted since late 1978, which moreover could no longer be financed on a large scale by external borrowing. The combination of a severe economic slowdown with large deficits in the balance of payments and public finances, compounded by a new domestic financial crisis,[12] was the keynote of the early 1980s.

Two completely different policy packages were adopted to deal with the macroeconomic crisis. The first, implemented in early 1983, essentially aimed at economic recovery. The government launched a social housing plan and created multiple Bank of the Republic credit lines for crisis-hit sectors, as well as a new fund, the business capitalization fund. On the external front, crisis management involved a radical reversal of the trade liberalization measures of the 1970s, with higher tariffs, strict direct control of imports, increased export subsidies, a moderate acceleration of the pace of devaluation and strong exchange controls. The financial crisis was handled by nationalizing a number of ailing institutions and providing liquidity to others.[13]

In mid-1984, the ongoing depletion of international reserves prompted a shift towards a more radical policy to correct the external imbalance. Although the import controls and subsidies for non-traditional exports that had been applied in the previous programme were maintained and exchange controls were tightened, the basic elements of the new policy were a lower fiscal deficit and, above all, a quickened pace of exchange-rate adjustment, which led to another of the largest real-term devaluations in the country's history (see figure 4). The worsening of the financial situation, owing to a crisis at Grancolombiano group, the country's largest, also led to the adoption of more radical measures to clean up the sector. This second phase was supervised (though not financed) by the International Monetary Fund (IMF) and supported by the President of the Federal Reserve Bank of New York, Paul Volcker, so that international banks would commit to granting new credits in proportion to their existing loans to Colombia.

The increase in coffee prices in late 1985, which was also managed with a view to encouraging saving in the coffee sector, allowed the economy to recover in 1986. Although the coffee boom was very short-lived, the economy managed to maintain an acceptable rate of growth in the following years thanks, in particular, to a rapid increase in mining and non-traditional exports, which substantially raised the export ratio after a long period of decline since the 1930s (see table 1). As a result of agreements with the World Bank in the middle of the decade, the economy was gradually opened up to imports (Ocampo and Romero Baquero, 2015).

There were two new developments at the end of the decade: the collapse of the International Coffee Agreement quota arrangement in 1989 and the decision to initiate a process of gradual import liberalization in February 1990. Because of the adverse effects of both events on the balance of payments, it was thought that a highly competitive exchange rate was key to the success of

[12] This crisis was moderate by international standards. See Ocampo (2021, figure IV.6).

[13] See Caballero and Urrutia (2006) and Ocampo (2021) on the financial crises and their management.

this trade liberalization. By the end of 1990, however, it was obvious that high rates of devaluation were translating into accelerating inflation (see figure 3). This prompted a strong monetary stabilization programme.

In sum, although Colombia was a relative success story during Latin America's lost decade, this was a period of sharp economic slowdown: at 3.5% per annum and 1.1% per capita, growth was the lowest of any period analysed and, in particular, lower than during the other transition phase, from 1930 to 1945.

2. The Colombian economy since 1990

The most recent period began with the combination of a new constitution and the implementation of a rapid liberalization process: "economic opening" in Colombian parlance. In 1991, the principles of social rights and decentralization were incorporated into the constitution, leading to growth in the size of the State to expand the provision of social services and delegate the provision of some of these services and other functions to the departments and municipalities. The growth of the State was accompanied by a sequence of tax reforms and decentralization, with the regions taking a large share of the nation's revenues.

From the economic point of view, the constitution granted autonomy to the Bank of the Republic and established that its responsibilities would be limited to central banking, stripping it of the development banking functions it had been carrying out since the financial reform of 1951. The constitution established that control of inflation would be the main objective of the Bank of the Republic, but that this function would be exercised in coordination with general economic policy. In an important judgement,[14] the Constitutional Court ruled in 1999 that this meant that monetary policy could not be set without regard to its effects on employment and growth. Thus, the model adopted occupied a middle ground between banks whose sole objective is inflation control, such as the Central Bank of Chile, and the United States Federal Reserve, which has three objectives: maximum employment, stable prices and moderate long-term interest rates.

Trade liberalization, meanwhile, resulted in a sharp reduction in tariffs to an average of 11.7%, the abolition of direct import controls and the removal of subsidies for non-traditional exports. This process was accompanied by the negotiation of the free trade agreement in the Andean Community, followed by agreements with other Latin American countries. The average tariff was subsequently reduced somewhat further, to 8.5% by 2010, and several free trade agreements were concluded, starting with the agreement with the United States, which entered into force in 2012, six years after it was signed, owing to the difficulty of securing the approval of the United States Congress.

Economic liberalization also involved rationalization of the State enterprise system, including the privatization of several enterprises in the electricity and telecommunications sectors and the adoption of different forms of partnership with the private sector on infrastructure projects. This was accompanied by a far-reaching liberalization of the financial sector favouring universal banks over the specialized banking system that had existed since 1923, a significant reduction in reserve requirements, the privatization of first-tier public banks, with the exception of the Caja de Crédito Agrario, and the disappearance of most of the development lending mechanisms and the conversion of those that remained into development banks. Of the directed lending arrangements of the past, only the allocation of a portion of the bank portfolio to the agricultural sector remained (Ocampo, 2021, chapter V).

[14] Judgement C-481 of 1999. See Constitutional Court (1999).

Economic policy, both monetary and fiscal, was expansionary from 1991 to 1997, generating strong growth in aggregate demand, especially between 1992 and 1994, which prompted a moderation in monetary policy. The increase in national government spending was largely financed by tax reforms and surpluses in the rest of the public sector. In fact, the fiscal deficit only started to rise in 1996, and remained at low levels.

Economic growth accelerated. The strong increase in imports (see table 1) that resulted from the combined impact of trade liberalization and sharp peso appreciation (see figure 4) helped to moderate inflation but led to a significant deterioration in the current account of the balance of payments: from a surplus in 1990–1992 to a deficit ranging between 3% and 6% of GDP for six consecutive years from 1993 onward (see table 1 for the evolution of the current account deficit). One of the components required to finance this deficit was a rapid increase in private sector external debt. By contrast, public external debt increased only moderately.

The end of the boom was triggered by the measures taken to deal with the sequential effects of the Asian crisis of 1997 and the Russian crisis of 1998. Monetary policy acted in a clearly procyclical way, generating a sharp rise in interest rates, which reinforced the recessionary pressures from abroad. This decision was taken to avoid a disorderly devaluation of the kind that had occurred in some East Asian economies. The exchange-rate band was altered twice (September 1998 and June 1999), but continued pressure on the ceiling of the band from the first half of 1998 led to a contraction of the monetary base and a rise in interest rates to one of the highest levels in the country's history (Bank of the Republic, 1999; Villar, Romero and Pabón, 2015).

Against this background, the financial boom of the 1990s ended with the third Colombian financial crisis, which broke out in 1998 and was dealt with by restructuring and capitalizing the public banking system and winding up some institutions, providing guarantee capital, buying up distressed assets and supplying liquidity.[15] The financial cycle fuelled the macroeconomic boom, especially during the first half of the 1990s, but also accentuated the crisis that erupted in mid-1998, leading in 1999 to Colombia's worst recession of the twentieth century (see figure 1). The effects of both the financial crisis and the recession would take several years to heal. Only in 2004 did the country's per capita GDP return to 1997 levels. Inflation declined sharply as a result of the demand crisis, cutting short the history of inertial inflation in the country that had lasted almost three decades (see figure 3).

Loss of confidence in the exchange-rate band that had been adopted in 1993 forced the Bank's Board of Directors to do away with this in September 1999 as part of an agreement with IMF, which demanded a free float before signing. A large devaluation and rapid correction of the balance-of-payments current account deficit allowed the Bank of the Republic to cut interest rates over the following years, thereby implementing a countercyclical monetary policy. Thus, following international trends, the Bank changed the way it conducted monetary policy from 1999 onward, using the base rate as its main tool while leaving the exchange rate to float, albeit with occasional interventions in the foreign-exchange market.

Economic activity recovered between 2004 and 2013, with a brief interruption caused by the 2008–2009 international crisis. High oil prices and plentiful external financing supported the economic boom. This growth process was cut short in 2014 when oil prices fell, and the Colombian economy quickly faced a sharp deterioration in the current account of the balance of payments and a large real devaluation that affected inflation. This led to an interest rate rise, i.e. an economic policy that was initially procyclical because the Bank of the Republic raised the base rate to combat price increases, while there was a moderate fiscal adjustment. As inflation fell, the Bank was able to reduce the interest rate from 2017. This policy change, coupled with a partial recovery in the terms of trade, set the stage for a moderate recovery.

[15] This crisis was also moderate by international standards (Ocampo, 2021, figure V.9).

The COVID-19 pandemic caused a severe recession, in response to which expansionary monetary and fiscal policies were adopted. The unwinding of these policies following the international inflationary effects triggered by the Russian Federation's invasion of Ukraine in February 2022 was more gradual than in other Latin American countries, which resulted in two years of strong economic growth but also a sharp slowdown in 2023.

In sum, the Bank of the Republic can be said to have pursued a generally procyclical policy during the last decade of the twentieth century, then a generally countercyclical one since the policy change in 1999, but with some phases of procyclical management and pronounced real exchange-rate volatility (see figure 4). Fiscal policy has been moderately expansionary on average, leading to a rise in public debt, particularly since the oil price drop in 2014 and, to a much greater extent, as a result of the pandemic.

Overall, economic growth in the twenty-first century has depended on external conditions: expansion between 2003 and 2014 followed by a slowdown between 2015 and 2019 and a strong cycle caused by the pandemic and subsequent recovery. In any case, economic growth over the whole of the economic liberalization phase has been slower than during the industrialization phase: 3.3% per year in 1990–2023 compared to 5.1% in 1945–1980. Owing to a sharp decline in the rate of population increase, per capita GDP growth has fallen by much less, from 2.2% to 2.0%.

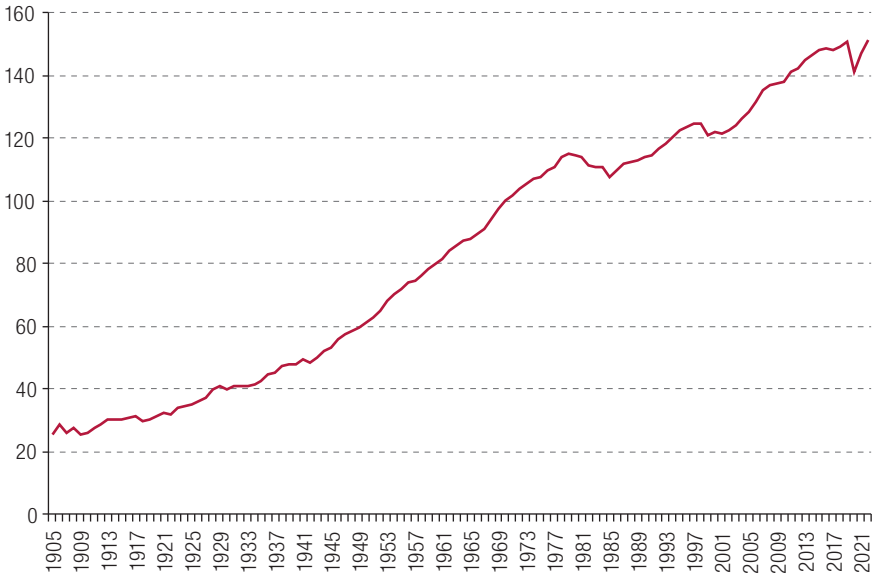
Thus, the expectation among advocates of economic opening that market reforms would accelerate economic growth did not materialize. Premature deindustrialization and limited productive sophistication leveraged on low investment in science, technology and innovation have significantly affected the growth process. Moreover, the dominance of the oil sector in the export basket has cut short the process of export diversification and thence more productive integration into the world economy (see table 1). Export diversification and the rise in exports as a share of economic activity that had begun in the mid-1980s, i.e. before economic liberalization, continued in the 1990s and peaked during the crisis at the end of the century, but were cut short by the oil boom of 2003–2014 and have not resumed (see table 1). Oil-driven reprimarization, coupled with real exchange-rate volatility, has not been conducive to the country achieving a better positioning in the global context that would also boost economic growth. The boom in strategic minerals is expected to lead to a new process of reprimarization in the region, and Colombia is no exception (ECLAC, 2023).

VI. Social development and regional inequalities

1. Social development

The great long-term structural transformations in the Colombian economy have also brought about major social improvements. The historical index of living standards, which summarizes the evolution of education, health and income indicators, rose sevenfold during the long century analysed (see figure 5). The life expectancy of a Colombian in 1905 was 30 years, the fertility rate was 7.35 children per woman, infant mortality was 187 children per 1,000 live births and the illiteracy rate in the population aged over 15 was 66%. By 2022, life expectancy had increased to 77, while the fertility rate had dropped to 1.72 children per woman, infant mortality to 12 children per 1,000 live births and the illiteracy rate to 4.2%. This had been accompanied by increased access to public services in the cities and, to a lesser extent, in the countryside. In other words, social progress has been considerable. As will be seen below, one exception to this trend has been the limited progress made with the social security system.

Figure 5
Colombia: historical index of living standards, 1905–2023
(Index: 1970=100)



Source: J. A. Ocampo and C. A. Romero Baquero, *Crecimiento económico colombiano y sus efectos sobre el desarrollo social y regional 1905-2019*, Bogotá, Bank of the Republic, 2023.
Note: Constructed as an average of per capita GDP, life expectancy at birth (with a minimum of 20 years and a maximum of 85 years) and the percentage of the population aged between 7 and 11 with primary education.

However, social development indicators conceal profound inequalities. Indeed, the evolution of the Gini coefficient shows a deteriorating trend throughout much of the twentieth century, with some partial improvements in certain periods.[16] New estimates of this coefficient in historical periods for which data were not previously available show a deterioration between 1940 and 1960, reflecting, among other factors, large-scale migration of unskilled rural workers to the cities (which kept these workers' incomes low in both urban and rural areas), inequitable land distribution and rural violence. This deterioration was followed by an improvement in the ratio between the mid-1970s and 1980, thanks to a reduction in income differentials by educational level and between urban and rural areas. The reforms of the early 1990s and the crisis of the late twentieth century led to a further deterioration. Lastly, the Gini coefficient declined slightly from 2009 to 2019 and has held fairly steady since then. Overall, the Gini trend since the mid-1970s has been one of fluctuation between the values of 0.5 and 0.6, which has not reversed the previous deterioration and is among the highest levels in Latin America and the world (see figure 6A).

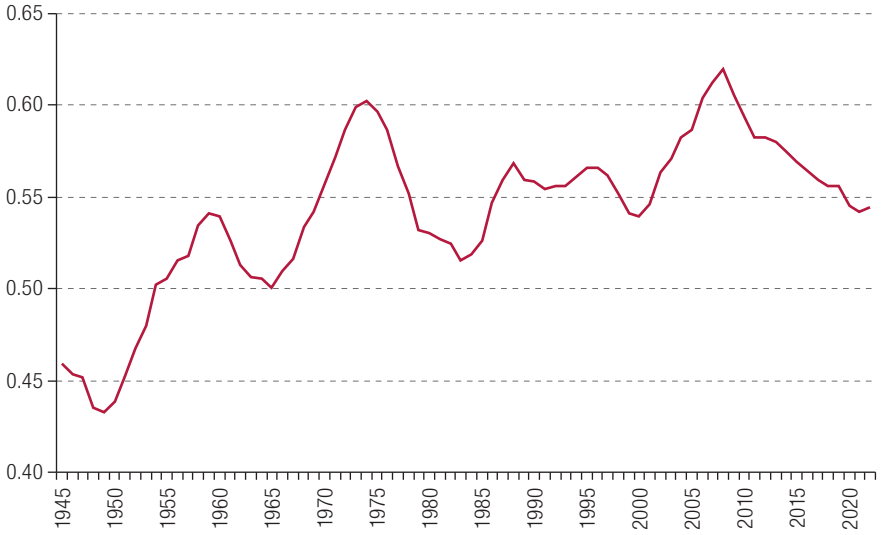
Rural-urban inequality manifests itself in dimensions other than income. Drinking water supply coverage in 1938 was 37.9% in urban areas and 1.3% in rural areas, and 85% and 37% in 2020, respectively. Access to sewerage services in the latter year was 81% in urban areas and only 16% in rural areas, whilst access to refuse collection services was 81% and 20%, respectively. It is also important to note that access to digital services constitutes a new form of inequality. In 2022, only 38% of households had a computer and 61% had access to the Internet, mostly in cities and among those affluent enough to afford them.

[16] See Urrutia and Berry (1975), Londoño de la Cuesta (1995) and Ocampo and Romero Baquero (2023, chap. 6) on the evolution of income distribution.

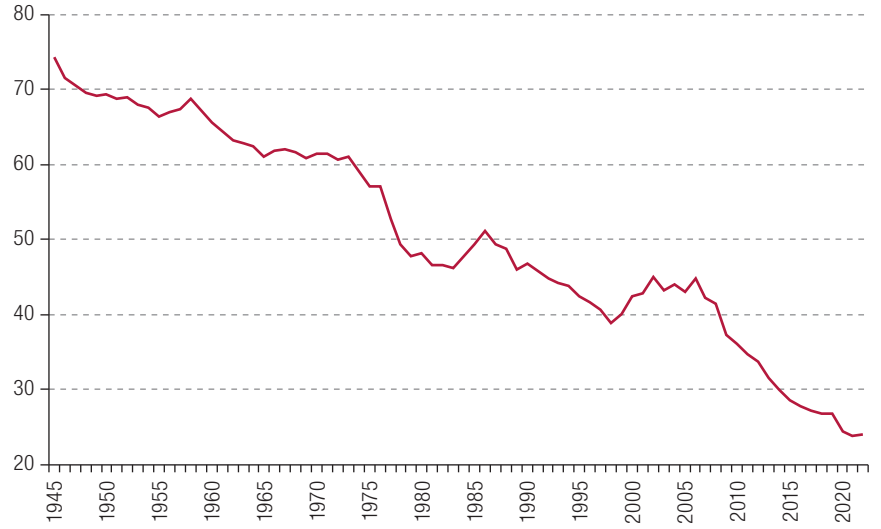
Monetary poverty has declined substantially over the long term, from about three quarters of the population in 1945 (and a higher proportion before that) to less than a quarter today. The determining factors have been economic growth and increased labour force participation, especially among women, but the downward trend has been affected by problems of income distribution and the effects of economic slowdowns or crises in the mid-1950s, the Latin American debt crisis, as well as those at the turn of the century, and the effect of COVID-19 (see figure 6B).

Figure 6
Colombia: inequality and poverty, 1945–2023

A. Gini coefficient
(Three-year moving average)



B. Proportion of the population below the poverty line
(Percentages)



Source: J. A. Ocampo and C. A. Romero Baquero, *Crecimiento económico colombiano y sus efectos sobre el desarrollo social y regional 1905-2019*, Bogotá, Bank of the Republic, 2023; and P. Astorga, "Functional inequality in Latin America: news from the twentieth century", *Discussion Papers in Economic and Social History*, No. 135, University of Oxford, 2015.
Note: The Gini coefficient is calculated using the methodology of Astorga (2015).

From a more detailed perspective, there has been substantial long-term progress with education services. The gross coverage rate for primary education was 35% in 1905, and full coverage was achieved in 2019; for secondary education, the rate rose from 4.6% to 97% between 1905 and 2021, and for tertiary education, although progress has been more limited, it rose from 0.1% to 53% in the same period (going by 2018 census projections). There has also been an increase in Colombians' average years of education over time, albeit a more modest one because of the number of older people who had no education as children or adolescents. The average Colombian had 2 years of education in 1900 and 8.5 years in 2019.[17]

However, increased educational coverage has been coming up against problems of quality, reflected in high repetition and drop-out rates and poor results in knowledge tests by international standards. There are also problems with teacher training and inadequate resourcing for education, particularly in rural areas.

Where health services are concerned, the epidemiological conditions of the population are known to have changed over time. The main causes of death during the first half of the twentieth century were intestinal infections, typhoid fever, malaria, leprosy, viral diseases such as smallpox and measles, and lung diseases. With the predominance of urban life from the 1970s, diseases of the circulatory system, diabetes and cancer became the main causes of death. In the last three decades, immune system diseases such as human immunodeficiency virus (HIV) and more recently COVID-19 have claimed human lives. Violent homicides are also a major cause of death in Colombia.[18]

2. Social development debates

There are multiple debates about the evaluation of social outcomes, of which four may be highlighted. The first relates to social security outcomes. In the area of health, benefits began with the creation of social insurance in 1946, but only reached formal workers. In the regions, official health services were provided in parallel for other people. The organization of this activity was thoroughly restructured by virtue of Act No. 100 of 1993. Thanks to the combination of the contributory regime with the subsidized regime introduced by this law, the health insurance system achieved universality, a very important historical result. However, the system faces serious difficulties owing to evasion and avoidance of contributions, delays in payments by the government to service providers for beneficiaries of the subsidized system, inefficient hospital care in a number of cases, and very widespread use of the expedited judicial rights protection procedure known as *tutela* to gain access to certain specialized services and medicines.

Pension coverage under the social security system was also concentrated on formal workers from its inception.[19] In contrast to the progress with health care, the passing of Act No. 100 of 1993 failed to solve this problem and introduced competition between the public system, now the Colombian Pension Administrator (Colpensiones), and the pension funds, most of which are private companies. This arrangement combines the pay-as-you-go system of Colpensiones with individual savings managed by the pension funds, resulting in very different benefits. Furthermore, about three quarters of older persons still do not have access to a pension and receive government support. There is a system that encourages pension saving for informal workers, but both mechanisms provide very limited benefits (Azuero Zúñiga, 2020).

A second debate is about the persistence of high levels of labour market informality and underemployment. A team of experts recently conducted an analysis of this issue, presented to the government in 2021 (Employment Mission, 2021), the thrust of which is that the Colombian labour

[17] See Helg (2022) on the evolution of the education sector.

[18] On these subjects, see Abel (1994).

[19] It should be noted that there were already company pension schemes in place in 1946, some of which still exist today.

market is dysfunctional. One in 10 members of the labour force is unemployed, and most of the rest are own-account workers or are employed in small enterprises with low productivity levels. Consequently, almost 6 out of every 10 employed persons work informally, meaning that they do not pay social security contributions, and 8 out of every 10 enterprises have between one and three workers. Some analysts consider that a fundamental reason for the low level of formal employment creation are the non-wage costs for companies, and accordingly efforts have been made to reduce these; others believe that the causes are multifaceted and originate in the sectoral structure of production, its location and the role of female employment and youth unemployment.

The third debate concerns the inequity of income distribution and the persistence of poverty. While poverty has been falling for more than a century, it is also true that wealth remains in the hands of a few. In the case of the most traditional asset, land, although the high concentration of ownership is an inheritance from the colonial period, studies show that the agrarian reforms applied so far have produced few results. Furthermore, armed violence in the countryside has manifested itself strongly in illegal land occupation. All this has hindered progress towards better distribution of rural income.

The fourth debate centres on the extent of regional public spending on education and health. The data indicate that regional health spending has historically been lower and more volatile than education spending. At the same time, there is a long-term relationship between the allocation of resources to these services and departmental per capita GDP, but for much of the twentieth century there was a degree of regional convergence, which stalled in the mid-1970s. Moreover, subnational public spending on education and health has been procyclical in relation to economic growth, tending to increase more during economic booms and increase less or even contract during crises (Ocampo and Romero Baquero, 2023, chap. 6).

3. Regional inequalities

Efforts have been made in many countries over recent years to reconstruct historical regional GDP, quite often involving revisions of the available series with new estimation methodologies such as that of Geary and Stark (2002 and 2019). These have been used for Colombia, with the estimation of regional GDP since 1918, just as they have for other countries around the world (Rosés and Wolf, 2019; Tirado-Fabregat, Badia-Miró and Willebald, 2020).

Departmental GDP has traditionally been concentrated in the wealthy cities making up the "golden triangle", namely the three largest cities (Bogotá, Medellín and Cali) with the central coffee-growing region in the middle, and a fourth city in the Caribbean (Barranquilla). More recent additions have been the cities close to the departments where oil production occurs (Bucaramanga, Villavicencio and Yopal). The medium-growth departments are located along the rest of the Caribbean coast and in the central zone, and the poor ones on the north and south Pacific coast and in the north-east.[20] These regional imbalances have been accompanied by low convergence between departments. By subperiod, there was weak convergence between 1925 and 1965, regional inequalities stabilized between 1965 and 1990, and there has been relative divergence since 1990 (Ocampo and Romero Baquero, 2023, chap. 4).[21]

This very uneven regional development is associated with different causes. Because of its mountainous geography, Colombia is more culturally and spatially diverse than many Latin American countries and has a variety of climates. This situation forced people to concentrate in the highlands (more than 1,000 metres above sea level) to protect themselves from the prevalence of disease in

[20] The departments with average GDP are the former Bolívar (which includes Bolívar, Córdoba and Sucre), Boyacá, Tolima, Cauca, the former Magdalena (which includes Magdalena, César and Guajira) and Huila, and the poor departments are Chocó, Nariño and Norte de Santander.

[21] Other studies have also found regional divergence in recent years. See Acosta and Bonet-Morón (2022) and Galvis-Aponte, Galvis-Larios and Hahn (2017).

the lowlands. Moreover, the cold highlands were better for agricultural production, and the bulk of manufacturing industry was located there. Two thirds of Colombia's population still live in the highlands today, even though they make up much less than half the country's land area. The service sector has become more regionally diversified, but connectivity constraints have discouraged the creation of modern service enterprises on the Pacific coast or in the Colombian Amazon.

Another element of regional imbalance, especially since 1950, has been violence, which has been concentrated in rural areas, leading to heavy migration into the areas that make up the golden triangle. Lastly, the limited progress made with technological transformation and innovation is also concentrated in certain regions. For example, the departmental innovation index with information from 2019 and 2020 for the country's 32 departments has found a strong concentration of science, technology and innovation activities in the major cities of the golden triangle, the central coffee region and the Caribbean region, while the science and technology ecosystem is weak in the south-west, the Orinoco region and the Amazon region (DNP/OCyT, 2022).

VII. Conclusions

Since the early twentieth century, Colombian development has gone through three periods characterized by significant differences in respect of economic policies and structural change: 1905–1929, 1930–1980 and 1981–2023. The most important features of the first period were the rapid expansion of coffee production in the west of the country, the beginning of oil exports, and high public investment in transport and communications, underpinned by good external borrowing conditions during the 1920s. This was accompanied by the development of improved State institutions for monetary, credit and exchange-rate management in 1923, which boosted the financial sector, and the search for new sources of central government revenue, given the vulnerability of customs receipts to international trade restrictions.

The second period was characterized by the consolidation of the industrial sector, especially between 1946 and 1975, and the diversification of agriculture and, with a lag, of the export structure. These processes were supported by protectionist policies, gradually supplemented by measures to strengthen non-traditional exports. It was also a period in which modern services were developed, often by the State, and social service provision was expanded. Meanwhile, the Bank of the Republic created a large array of monetary instruments and underwent a transition to State control with the creation of the Monetary Board and subsequent nationalization. The new instruments, together with exchange-rate shifts, were essential for managing recurrent balance-of-payments crises until the 1960s. The Bank also began to perform the functions of a development bank in 1951, and between the 1930s and 1950s a number of State-owned financial institutions were created.

The last period began with the effects of the Latin American debt crisis. The early 1990s saw the combined effects of the new constitution, which laid the groundwork for further growth of the State to expand social services provision and pursue decentralization, and liberalization of the economy in respect of foreign trade and the financial system. Contrary to the assumptions of those who promoted the latter measures, rapid economic growth did not occur. On the contrary, the Colombian economy has faced two major obstacles to development: the abandonment of industry as a driver of the productive sector, and the reprimarization of the export structure, now dominated by oil. The former led to premature deindustrialization, with negative effects on the diversification of the economic structure and productivity. The latter had the effect of halting export diversification and generating instability associated with oil price fluctuations.

Overall, a positive feature of Colombian development was a relative aversion to inflation and a stronger tradition of macroeconomic stability than in other countries of the region, the most important effect of which was to allow the country to avoid the Latin American debt crisis of the 1980s; the most

salient exception to this tendency was vulnerability to the successive Asian and Russian crises of the late twentieth century. Growth was slightly above the regional average and structural transformation was positive, albeit with weaker diversification of the manufacturing sector than in the larger countries of the region. Deindustrialization followed from the 1980s onward and was characterized by very limited investment in science and technology, both being typical of Latin America. Export diversification was only successful from the 1960s until the beginning of the twenty-first century. As a result, heavy dependence on coffee and later oil exports has been an important feature of the country, as has the frequency of balance-of-payments crises during periods of decline in the prices of these commodities, accompanied in some cases by disruptions to external financing.

Lastly, this economic growth process has benefited the country's various social strata and regions in very different ways. In social terms, there has been progress with living standards and poverty reduction, albeit in a context of great social inequalities, high levels of labour market informality and a poorly developed pension system. Inequalities are also reflected in access to State services in the most disadvantaged regions, especially in rural areas, which in a number of cases have also been affected by violence. At the regional level, inequality has been characterized by the concentration of production, population and employment in the cities that make up the golden triangle and Barranquilla and, since the beginning of the twenty-first century, in the oil-producing departments.

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The Amazon region at the heart of the Brazilian economy's commodity-export model: the case of the State of Pará

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Abstract

The Brazilian economy has undergone far-reaching changes, related especially to the loss of industrial capacity as deindustrialization has spread and commodity-export production has expanded. The Brazilian Amazon region forms part of the expansionary logic of the agro-industry and mining sectors. This article analyses the economic reproduction model of one of the main federative units located in that region, the State of Pará. It uses the specialization coefficients and location quotients of Brazil's 27 subnational federative units, to make a case study of that State. The findings reveal a declining industrial structure, particularly in manufacturing industry, accompanied by growth in the mining and metallurgical sector. Economic activity has become increasingly concentrated in the production of raw materials and semi-finished industrial inputs, of low technological content.

Keywords

Economic development, regional development, industrialization, manufacturing and mining industries and products, agroindustry, productivity, production specialization, structural adjustment, Brazil

JEL classification

O14, O18, R11

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I. Introduction[1]

Capitalist development is founded on specific requirements regarding the use of geographical space at each point in time; and these have repercussions on the economic, social and environmental relations of the territory in question. This implies understanding the significance of production in the different regional spaces, not only in relation to the dynamic of national capital but also, as a capitalist world economy, in the context of the global capitalist accumulation process. In the case of the Amazon region, one of the defining features of its economic and social formation has been the extraction of natural resources and their export in commodity-form, and that remans the case today (Santos, 1980; Leal, 2010; Trindade and Oliveira, 2011 and 2017).

In the last three decades, the deindustrialization of the Brazilian economy in the different subnational areas has wrought major changes in production structures, especially in the less industrialized ones. Changes become established in the regional model, as the peripheral-regional economies assume a new reproductive condition of commodity-export specialization that impacts the economic dynamics of the national model, further weakening the more diversified industrial linkages (Trindade, Cooney and Oliveira, 2016; Bruno, 2021; Almeida, Pires and Cunha, 2022; Morais, 2019; Persona and Oliveira, 2016).

This article considers the adequacy of the regional economic structure of the State of Pará (one of the largest territorial units and the chief economic centre of the Brazilian Amazon), the current commodity-export dynamic of the national economy, and the resulting implications for the process of regional capitalist development. To this end, it presents and analyses empirical data, compiled and processed methodologically, and puts forward theoretical arguments to interpret the current model of capital reproduction in the Brazilian economy, which is classified as commodity-exporting with productive specialization.

The purpose of studying the Amazon region, using widely recognized indicators of regional analysis —the specialization coefficient and the location quotient— is to broaden economic knowledge of this important region of Brazil and, at the same time, to make a more in-depth analysis of the current difficulties and limits of the regional development model.

The text is divided into five sections including this introduction. Section II deals with the historical aspects of the economic formation of the Brazilian Amazon region, specifically the State of Pará. Section III uses statistical indicators to study the profile of Brazil's subnational (State) economies, and defines the analytical parameters to be used. Section IV, which is the core of the study, presents and analyses the configuration of the commodity-export logic of Pará's economy; and section V presents final thoughts.

II. Modalities of reproductive organization of capital in the Brazilian Amazon

The economic trajectory of the Brazilian Amazon region in the last four decades (1980–2020) has adhered to the aim of satisfying international market demand, through economic relations in which it acts as a supplier of commodities and semi-processed products (fruits, minerals, timber, meat and soybeans). In the case of the State of Pará, its participation in the international division of labour has involved supplying commodities, mainly minerals but also beef and, more recently, cereals. This indicates the existence of forms of productive organization with their own dynamics and relationships, but mediated by structural factors that steer their path through time (Costa, 2012; Mesquita and Junior, 2019; Trindade and Oliveira, 2011; Trindade and Ferraz, 2023).

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The Amazonian economy has been based on commodity exports since colonial times, renewed and modernized from the mid-twentieth century onward with the consolidation of the process of occupation and physical, social and economic integration of its territory into the national economic space (Santos, 1980; Loureiro, 2009; Schmink and Wood, 2012; Leal, 2010; Trindade and Oliveira, 2011; Bunker, 2003).

The Amazon region integrated directly into the international accumulation circuit during the rubber cycle of the late nineteenth century; and it participated in the international division of labour as a supplier to industries of the United States and Europe that sought rubber for various production circuits (Leal, 2010; Santos, 1980).

The Brazilian economy's transition to an industrial model —which occurred in the second quarter of the twentieth century and displaced the national economy's dynamic centre of accumulation— ignored the Amazonian economy. This was despite the economic parallel that existed between the latter's rubber economy and the coffee economy of São Paulo, both of which were founded on an outward-looking growth structure based on commodity production for export (Furtado, 1998).

The problem of regional development did not start to receive serious attention from the political authorities until the Brazilian national State became consolidated, and a federative order was established as from the 1930s. Until the early 1950s, the regional problem in Brazil was addressed only marginally in the federal government's political agenda. It was more confined to political discourse and assistance actions —especially those related to drought in the Northeast region— rather than being raised as a national development policy issue in its own right (Cano, 2007; Oliveira, Trindade and Fernandes, 2014).

As Guimarães (1997, p. 42) notes, the establishment and consolidation of regional inequalities was a very complex process in which the articulation and integration of the regions arose from a single hegemonic one. However, heavy pressure exerted by regional social and political demands, gradually altered this trend —initially through an institutional framework to support regional development established by the federal government as an instrument of planned action. Emblematic examples include the creation of the Superintendency of the Plan for Economic Valorization of the Amazon in 1953, which became the Superintendency for the Development of the Amazon in 1966; and, in the Northeast, the Superintendency for the Development of the Northeast, founded in 1958 (Ianni, 1986; Silva, 2002; Oliveira, Trindade and Fernandes, 2014).

In their analysis of the impact of changes in the interregional division of labour in Brazil resulting from the rapid industrialization of the Southeast between the early 1940s and late 1960s, Oliveira and Reichstul (1973) argued that the North (Amazon) region was not affected greatly by this process and remained partially isolated from the domestic market. Difficulties in transportation, communications and linkages with the foreign market might explain this isolation, which initially prevented an integration dependent on the Southeast region, as happened with the economy of the Northeast.

Starting in the mid-1960s, implementation of the State-led development strategy, which combined fiscal and financial incentives with public investments in infrastructure and productive activity (especially mining), would definitively alter the regional production structure and hasten the growth of industrial economic activity in the 1970s and 1980s (Ianni, 1986; Buarque, Lopes and Rosa, 1995; Guimarães, 1997).

In this new phase, mercantile and commercial capital, linked to the traditional extractive economy that predominated in the region, is displaced by industrial and financial capital, driven by the national State. In this new context, commercial interaction gives way to a process of national productive integration, which reinforces the heavy presence of large State-owned enterprises, transnational groups and much of national private capital, with investments that are protected by regional policies providing tax and financial incentives (Marques and Trindade, 2014; Costa, 2012; Guimarães, 1990).

Buarque, Lopes and Rosa (1995) estimate that the economic, social and environmental transformation process in the region occurred in a spatially very uneven manner. The actions in question differed greatly in intensity, form and determinants, in addition to concentrating a significant part of the region's dynamism. They also established a general model of economic exploitation that differed greatly from what had pertained historically in the region, as exemplified by establishment of the Manaus Free Trade Zone in the State of Amazonas and the Grande Carajás Programme in the State of Pará.

The international economic crisis of the late 1970s, compounded by the effects of the oil shock, had a huge impact on industrial production costs in the central countries, leading them to reorganize their production apparatus and transfer their energy-intensive industries to peripheral economies such as Brazil. In a context of recession and slowdown in the Brazilian economy, the federal government defined its objectives for the Amazon region through the second National Development Plan. This integrated the region's economy definitively into national capital accumulation and, first and foremost, established a natural resource frontier, particularly as a supplier of mineral products (Loureiro, 2009; Leal, 2010; Trindade, 2001; Marques and Trindade, 2014).

The industrial valorization of Amazonian mineral resources, that is their extraction and conversion into merchandise, began in the 1950s with the manganese mining project in Amapá (then federal territory), from which the first ore exports were shipped in 1957. However, it was not until the second half of the 1970s, amid the international energy and economic-financial crisis mentioned above, that the mining industry received a major boost to its production and exports, with the aim of generating foreign exchange to shore up the country's balance of payments (Warren, 1973; Monteiro, 2005; Leal, 2010; Coelho, Monteiro and Cota, 2007; Marques, 2012).

This State intervention was decisive for organizing the institutional framework, creating infrastructure and raising the financial resources needed to develop mining in the Amazon region. Through centralized policies, and engaging both national and foreign capital, the State created favourable conditions for capital expansion in the region, with the aim of modernizing it. Industrial mining was one of the main vectors of this process. In the 1980s, as an important part of the strategy to boost development of the Brazilian Amazon, with the establishment of the agricultural and agro-mining poles, the federal government created the Grande Carajás Programme, with the aim of accelerating the installation and start-up of mining and metallurgical projects[2] (Coelho, Monteiro and Cota, 2007; Marques, 2012).

As noted, the 1990s saw more intensive application of liberal economic policies, which redefined the conditions of the Brazilian economy's international integration and the role of the State itself in the economy, which had repercussions on the financial and production domains. In this context, integrated regional development policies gave way to increasing reliance on integration and interaction with the international market, and the dynamic of transnational corporations (Furtado, 1992; Cano, 2008; Cruz, 2007; Carneiro, 2002).

In the last few decades, the course of the Amazonian economy has been based much more on the commodity-export logic than steered by a regional national development policy. Even given the changes in the Brazilian political landscape that occurred in the early 2000s and enabled a partial recovery of the State's capacity for intervention and the rescue of the National Policy for Regional Development, the structural moorings of the neoliberal period of Fernando Henrique Cardoso remained intact (Barbosa, 2012; Gonçalves, 2013; Trindade and Oliveira, 2017).

The final balance of these economic shifts reveals a model of productive specialization oriented towards the foreign market that differs from the previous export model (of the late nineteenth and early twentieth centuries). Not only is it based on new segments of accumulation, whether agricultural,

[2] The Grande Carajás Programme included execution of the Ferro Carajás Project, the construction of Alumínio Brasileiro S.A. and Alumina do Norte do Brasil S.A., Consórcio de Alumínio do Maranhão S.A. and the Tucuruí Hydroelectric Power Plant, in addition to several other prospective projects. For a full discussion of the Programme, see Pandolfo (1994), Lobo (1996) and Trindade (2001).

mineral or assembly industries (maquila), but the new exported products make greater use of machinery and tools, in addition to bringing large swathes of land under exploitation (Osorio, 2012a and 2012b; Trindade and Oliveira, 2017).

Thus, the concentration and persistence of primary activities in peripheral subnational regions, as in the case of the State of Pará, tend to reflect specific production models, which can only be understood in the light of historical and structural conditions that go beyond the objective determinants of production. This problem must be analysed through the connections and relationships established with the global and national economies and their shifts in time and space, as discussed in the following section.

III. Production model of Brazil's subnational economies: an empirical approach

1. Spatial and sectoral indicators and databases

To address the relevant aspects of the structural change empirically and analyse the reproductive model in the context of the economy of the State of Pará, two approaches were used: one spatial and the other sectoral. Regional indicators were chosen to analyse the problem posed by the structural changes that have occurred in the State (Haddad, 1989; Delgado and Godinho, 2011; Krugman, 1991; Monastério, 2011; Isard, 1960). It should be noted that these indicators are treated as providing empirical and analytical support, and serve as descriptive statistics for the treatment of the economic regionalization that is established.

The regional reproductive model is evaluated using the specialization coefficient, which measures an economy's degree of specialization or diversification, with values ranging from 0 (minimum) to 1 (maximum). A value equal to or close to zero indicates that the territorial unit (State) has the same sectoral composition as the benchmark space (Brazil), so there is no specialization in that territorial unit; in other words it is diversified. At the opposite extreme, a coefficient equal to or close to one indicates that the territorial unit has a specialized structural profile (associated with a specific sector) compared to the structure of the benchmark space.

The specialization coefficient (CE_i) is a relative and synthetic measure of a territorial unit's specialization or diversification. It compares the sectoral distribution of the variable in territorial unit i (in this case, the States) with the sectoral distribution of the variable in the benchmark space (in this case, Brazil). The specialization coefficient is calculated using the following equation:

$$CEi = \frac{1}{2}\sum_{k=1}^{k}\left[\frac{X_{ik}}{X_i} - \frac{X_k}{X}\right] \quad (1)$$

As a complement to analysis of the specialization coefficient, the production structure can also be evaluated in terms of the sectoral composition and concentration of industrial activities through the location quotient. This indicator measure the relative concentration of a given industry (or sector) in a territorial unit (in this case, the States) compared to the proportion of that same industry in the benchmark space (in this case Brazil). Thus, a high location quotient for an activity in a given territorial unit indicates the extent to which the regional or local production structure is concentrated in that industry.

The value of the location quotient does not have a reference interval and can be greater than or equal to zero. However, according to Delgado and Godinho (2011), a location quotient greater than one in a given sector indicates that the territorial unit in question is relatively specialized in that sector; and, on the contrary, if the location quotient is less than one it is not considered specialized. If the location quotient results are very high, the mean value can be used as a benchmark.

The location quotient (QL_{ik}) evaluates the degree to which territorial unit X is specialized in one of the K categories of activities analysed relative to the benchmark space (Brazil). It compares the importance of category (or class) K in territorial unit i (a State) relative to the benchmark. The location quotient is given by the following formula:

$$QL_{ik} = \frac{\frac{X_{ik}}{X_i}}{\frac{X_k}{X}} \quad (2)$$

The main database used to calculate the regional analysis indicators and most of the other measures of structural change and regressive specialization was the Annual Survey of Industry – Enterprise (*PIA-Empresa*) of the Brazilian Institute of Geography and Statistics (IBGE). This survey collects economic and financial data on industrial firms and their local units. It is implemented by adopting two strata as criteria: a mandatory inclusion stratum and a random stratum. The mandatory stratum consists of a census of firms with 30 or more employees. The random stratum is formed by firms with five or more employees selected at random without repetition. Since the results for most federal units are published at the division, or two-digit, level of the National Classification of Economic Activities, it was decided to use the statistics of industrial firms with five or more employees at the division level.

The starting year for the survey was chosen as 1996 because this was when IBGE reorganized the Annual Survey of Industry (PIA) to adapt it to the parameters of the new model of economic statistics production. In addition, as from 1996, *PIA-Empresa* replaced the industrial census, which until then had been used as the main data source for analysing national industry, thus launching a new statistical series (IBGE, 2004).

From a sectoral perspective, the aim was to measure the effects of structural changes in the industrial structure of the State federative units, driven by their economies' new requirements in terms of external engagement. To this end, indicators and variables were used to explain the degree of structural change (Carneiro, 2008; UNIDO, 1997), as well as the structural characteristics (Midelfart-Knarvik and others, 2000) that form the basis for the industrial sectors' economic performance (Midelfart-Knarvik and others, 2000). This aimed to relate the regressive shift in the State's production structure to the organization of a new reproductive model centred on the mining and metallurgy sector.

2. The heterogeneity of Brazil's subnational economies

In an attempt to identify the pattern of industrial specialization and concentration, the spatial dimension was addressed firstly by constructing a typology of the industrial structure present in Brazil's different States and regions, based on the results of the regional analysis indicators. The variable used for this purpose was the industrial transformation value (VTI),[3] which is considered an indirect indicator of the industry's value added. It is reported in *PIA-Empresa*, classified in 17 sectors of economic activity within general industry (extractive and manufacturing) spanning 1996–2016.

To gauge the degree of heterogeneity in regional production structures and their distribution across national territory, the values of the specialization coefficient were grouped in quartiles. This made it possible to derive a typology for the different production models in the industrial structures, classified as: high diversification (first quartile), medium-low diversification (second quartile), medium-high specialization (third quartile) and high specialization (fourth quartile). The aim of this technique is merely to provide an approximate reading of the production model of the different subnational regions, prior to

[3] VTI is the difference between the gross value of industrial production (VBPI) and the costs of industrial operations. The gross value of industrial production comprises the sum of sales of industrial products and services (net industrial income), the variation in stocks of finished goods and work-in-process, and own production for fixed assets.

analysing the specific case of the State of Pará. Table 1 shows the results of the specialization coefficient for Brazil's 27 subnational entities and indicates the productive structure and the sectoral importance of industrial employment in 1996–2016.

Table 1
Brazil: specialization coefficient and production model of subnational units, 1996 and 2016

Federative unit	1996				2016			
	Coefficient of specialization	Production structure model	Sectoral density and share in State employment *(Percentages)*		Coefficient of specialization	Production structure model	Sectoral density and share in State employment *(Percentages)*	
São Paulo	0.136	High diversification	2 119 567 formal jobs	42.00	0.160	High diversification	2 406 696 formal jobs	32.98
Rio Grande do Sul	0.174	High diversification	485 420 formal jobs	9.62	0.195	High diversification	640 136 formal jobs	8.77
Paraná	0.251	High diversification	312 415 formal jobs	6.19	0.232	High diversification	622 588 formal jobs	8.53
Pernambuco	0.287	High diversification	124 730 formal jobs	2.47	0.228	High diversification	206 261 formal jobs	2.83
Minas Gerais	0.293	High diversification	503 491 formal jobs	9.98	0.237	High diversification	791 331 formal jobs	10.85
Santa Catarina	0.340	High diversification	340 065 formal jobs	6.74	0.292	High diversification	638 575 formal jobs	8.75
Rio de Janeiro	0.341	High diversification	398 546 formal jobs	7.90	0.384	Medium-low diversification	416 621 formal jobs	5.71
Bahia	0.355	Medium-low diversification	100 758 formal jobs	2.00	0.328	Medium-low diversification	213 760 formal jobs	2.93
Goiás	0.387	Medium-low diversification	79 631 formal jobs	1.58	0.314	High diversification	225 025 formal jobs	3.08
Paraíba	0.447	Medium-low diversification	39 331 formal jobs	0.78	0.500	Medium-high specialization	71 364 formal jobs	0.98
Amazonas	0.450	Medium-low diversification	59 283 formal jobs	1.17	0.389	Medium-low diversification	92 419 formal jobs	1.27
Ceará	0.476	Medium-low diversification	109 687 formal jobs	2.17	0.389	Medium-low diversification	223 367 formal jobs	3.06
Federal District	0.502	Medium-low diversification	14 998 formal jobs	0.30	0.475	Medium-high specialization	29 283 formal jobs	0.40
Maranhão	0.518	Medium-low diversification	21 240 formal jobs	0.42	0.480	Medium-high specialization	40 002 formal jobs	0.55
Espírito Santo	0.523	Medium-high specialization	68 756 formal jobs	1.36	0.529	High specialization	122 967 formal jobs	1.69
Mato Grosso	0.538	Medium-high specialization	35 911 formal jobs	0.71	0.473	Medium-high specialization	94 307 formal jobs	1.29
Piauí	0.542	Medium-high specialization	14 086 formal jobs	0.28	0.430	Medium-high specialization	28 105 formal jobs	0.39
Mato Grosso do Sul	0.553	Medium-high specialization	25 840 formal jobs	0.51	0.379	Medium-low diversification	99 842 formal jobs	1.37
Sergipe	0.556	Medium-high specialization	18 516 formal jobs	0.37	0.399	Medium-low diversification	43 010 formal jobs	0.59
Alagoas	0.572	Medium-high specialization	61 840 formal jobs	1.23	0.448	Medium-high specialization	72 963 formal jobs	1.00
Rio Grande do Norte	0.581	High specialization	39 289 formal jobs	0.78	0.323	Medium-low diversification	63 028 formal jobs	0.86
Pará	0.602	High specialization	52 758 formal jobs	1.05	0.677	High specialization	96 089 formal jobs	1.32
Tocantins	0.638	High specialization	2 731 formal jobs	0.05	0.525	High specialization	16 021 formal jobs	0.22
Rondônia	0.663	High specialization	13 478 formal jobs	0.27	0.592	High specialization	32 799 formal jobs	0.45
Acre	0.664	High specialization	1 519 formal jobs	0.03	0.626	High specialization	5 000 formal jobs	0.07
Roraima	0.665	High specialization	692 formal jobs	0.01	0.653	High specialization	2 246 formal jobs	0.03
Amapá	0.741	High specialization	2 198 formal jobs	0.04	0.662	High specialization	2 878 formal jobs	0.04

Source: Prepared by the authors, on the basis of Brazilian Institute of Geography and Statistics (IBGE), Pesquisa Industrial Anual – Empresa (PIA-Empresa) 1996 and 2016.

A review of variations in the values of the specialization coefficients in all States between 1996 and 2016 shows that production structures in the first quartile were less affected by the structural change process in the Brazilian economy, despite the reduction in the share of industrial employment, as can be seen by comparing the data in the respective formal jobs columns. The exception in this group was the State of Rio de Janeiro, which, by adopting a less diversified production model, dropped back to the second quartile. This is explained largely by the loss of the relatively more diversified and integrated production structure of this State's economy (Bruno, 2021; Gonçalves, 2013; Libânio, 2012).

The condition of increasing specialization, extended to a larger territorial area in the country (75% reflect low diversification and high specialization), shows that the logic of the productive specialization reproduction model is gradually becoming generalized, producing two combined effects. The first of these is the steadily declining share of industrial employment, along with a reduction in formal employment; and the second is the strengthening of hyper-specialization in some parts of the country, such as the eastern Amazonian States (Pará and Amapá).

Tables 2 and 3 show the States with the highest concentration of VTI by economic activity, relating the national average value and the value of the location quotient in each sector, in 1996 and 2016, respectively. The results show that States with specialized production structures tend to concentrate in sectors requiring a large volume of natural resources and traditional low-tech industries. In contrast, subnational units with diversified productive structures report activities that are more widely distributed across the sectors of the economy, or even specialize in high-tech activities, as seems to be the case in Rio Grande do Sul, Paraná and Santa Catarina.

Table 2
Brazil: location quotient of subnational unit with the most concentrated industrial transformation value and national average, by sector of economic activity, 1996

National average location quotient		Federative unit with the highest location quotient	Location quotient	Production model
1 Oil and natural gas	1.016	Rio G. do Norte	10.209	High specialization
2 Extraction of metallic minerals	3.167	Amapá	35.806	High specialization
3 Extraction of non-metallic minerals	2.129	Rio G. do Norte	11.522	High specialization
4 Food and beverages	1.760	Mato G. do Sul	3.670	Medium-high specialization
5 Textiles, leather and footwear	1.225	Ceará	5.403	Medium-low diversification
6 Wood products	4.122	Rondônia	47.593	High specialization
7 Pulp and paper	0.839	Amapá	6.722	High specialization
8 Chemicals	0.642	Bahia	2.822	Medium-low diversification
9 Rubber and plastics	0.596	Acre	2.995	High specialization
10 Manufacture of non-metallic mineral products	1.894	Tocantins	6.297	High specialization
11 Metallurgy	1.021	Maranhão	9.298	Medium-low diversification
12 Metal products	0.588	Tocantins	1.780	High specialization
13 Machines and tools	0.397	Santa Catarina	2.219	High diversification
14 Electronics and electronic products	0.462	Amazonas	5.984	Medium-low diversification
15 Motor vehicles	0.222	Minas Gerais	1.629	High diversification
16 Other transport equipment	0.609	Amazonas	9.265	Medium-low diversification
17 Furniture and miscellaneous products	0.914	Federal District	3.600	Medium-low diversification

Source: Prepared by the authors, on the basis of Brazilian Institute of Geography and Statistics (IBGE), Pesquisa Industrial Anual – Empresa (PIA-Empresa) 2016.

Table 3
Brazil: national average and value of location quotient of subnational unit with the highest concentration of industrial transformation value, by sector of economic activity, 2016

National average location quotient		Federative unit with the highest location quotient	Location quotient	Production model
1 Oil and natural gas	0.945	Sergipe	6.946	Medium-high specialization
2 Extraction of metallic minerals	0.855	Pará	12.746	High specialization
3 Extraction of non-metallic minerals	1.774	Rio G. do Norte	9.626	Medium-low diversification
4 Food and beverages	1.553	Acre	3.465	High specialization
5 Textiles, leather and footwear	1.235	Paraíba	7.157	Medium-high specialization
6 Wood products	4.632	Amapá	61.457	High specialization
7 Pulp and paper	0.956	Maranhão	7.709	Medium-high specialization
8 Chemicals	0.654	Bahia	2.258	Medium-low diversification
9 Rubber and plastics	0.604	Bahia	1.660	Medium-low diversification
10 Manufacture of non-metallic mineral products	1.944	Federal District	6.620	Medium-high specialization
11 Metallurgy	0.790	Maranhão	4.636	Medium-high specialization
12 Metal products	0.783	Rio G. do Sul	1.862	High diversification
13 Machine tools	0.508	Rio G. do Sul	1.818	High diversification
14 Electronics and electronic products	0.598	Amazônas	6.385	Medium-low diversification
15 Motor vehicles	0.387	Paraná	1.984	High diversification
16 Other transport equipment	0.564	Amazônas	5.384	Medium-low diversification
17 Furniture and miscellaneous products	0.909	Mato G. do Sul	4.741	Medium-low diversification

Source: Prepared by the authors, on the basis of Brazilian Institute of Geography and Statistics (IBGE), Pesquisa Industrial Anual – Empresa (PIA-Empresa) 2016.

In States that have more specialized productive structures, primary activities predominate, serving the specific needs of the national and international division of labour. In all Brazilian States, the indicators reveal not only a historical process of unequal economic expansion, but, above all, the formation of specific reproductive models that reveal the economic profile of each State.

As the capitalist economic space has been based historically on uneven development, the interregional peripheral model shapes the spatial characteristics of the Brazilian economy. Thus, there is a mosaic of regional inequalities in addition to "fragmentation"; but there has also been an evolution in the last two decades (1996–2016) in which productive specialization has increased and industrial diversity has declined. In the current economic context, this explains industrial structure regression and its counterpart in the increasing specialization of the peripheral-regional economies. The next section of this article analyses this in detail, through a case study of the economy of the State of Pará.

IV. Structural change and commodity-export specialization in the economy of the State of Pará

1. The regressive specialization of the economy of the State of Pará

The premise adopted in this study is that, in developing countries and peripheral subnational economies, the phenomenon of deindustrialization —as a structural change process— tends specifically to involve regressive specialization. The production structure regresses, with consequent labour precarity and an increase in the production of commodities destined mainly for the foreign market. To support this argument and classify the nature of change in the industrial structure of the State of Pará, variables and indicators identified in the literature are deployed to measure and classify the structural change and the regressive specialization process (Carneiro, 2008; Monastério, 2011; Botelho, Souza and Avellar, 2016).

To measure the trend towards regressive specialization, Carneiro (2008) proposes to test the following processes empirically: (i) the reduction in the share of industry in the State's GDP; (ii) the reduction in the densification of production chains, measured as the ratio between VTI and the gross value of industrial production (VBPI); and (iii) the increase in the share of lower-tech sectors in the industrial structure. To contribute to these indicators, the following variables are added as measures of deindustrialization: (i) the share of manufacturing in total formal employment, based on data obtained from the annual social information report; and (ii) labour productivity, measured through the ratio between VTI and the number of persons employed, using data from the IBGE Annual Industrial Survey, following Botelho, Souza and Avellar (2016).

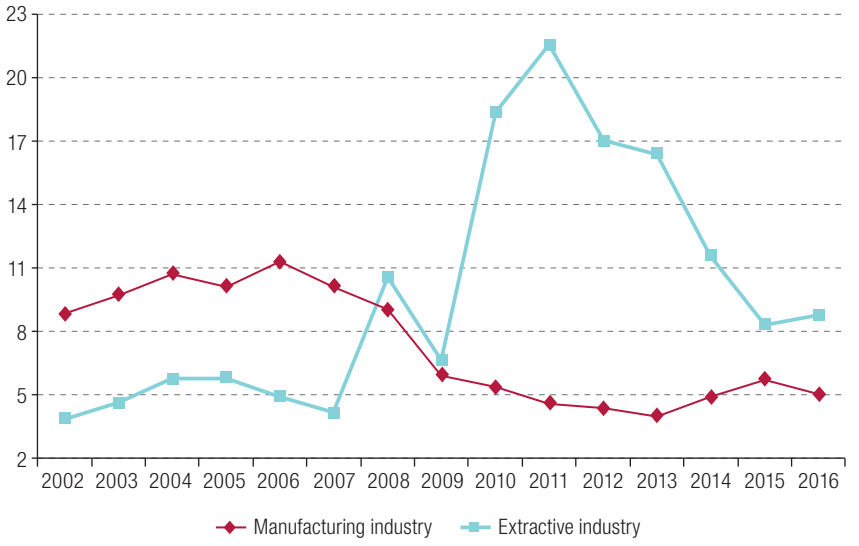
(a) Reduction in the share of industry in GDP and trend in industrial employment

In the State of Pará, the reduction in the GDP share of manufacturing industry, particularly since 2006, has gone hand in hand with an increase in share of mining, which amounted to 21.53% in 2011, as shown in figure 1.

Moreover, owing to the impact of the 2008 crisis, manufacturing industry was overtaken by the extractive industry and has been unable to regain its position. The increase in the share of agriculture in total value added, from 8.82% in 2008 to 12.43% in 2016, also contributed to the decline of manufacturing industry.

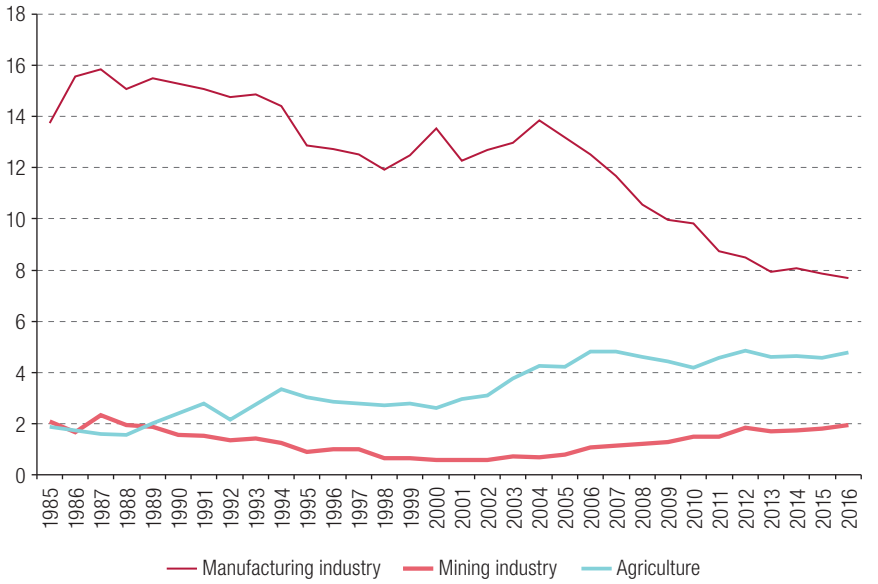
Figure 2 shows the trend of formal employment in the main sectors of Pará's economy (extractive industry, manufacturing industry and agriculture) between 1985 and 2016. It shows clearly that the manufacturing share of total employment in the economy fell steeply from 15.83% in 1987 to 7.68% in 2016. This was accompanied almost simultaneously by an increase in employment in agriculture since 1988, and by a slight increase in the extractive industry share of employment since 2002.

Figure 1
State of Pará, Brazil: share in value added of extractive and manufacturing industries, 2002–2016
(Percentages of GDP)



Source: Brazilian Institute of Geography and Statistics (IBGE), Contas Regionais do Brasil, 2002–2016.

Figure 2
State of Pará, Brazil: share of formal employment in total employment in manufacturing industry and selected economic sectors, 1985–2016
(Percentages)



Source: Prepared by the authors, on the basis of Ministry of Labour and Employment of Brazil, Relação Anual de Informações Sociais (RAIS), 1985–2016.

The growth of manufacturing employment in the first few years of the 2000 decade can be explained mainly by the national economic policy of boosting the domestic market, which also allowed for income growth (Carvalho, 2018). In the economy of Pará, this was reflected particularly in the wage good sectors (the food and beverage industry).

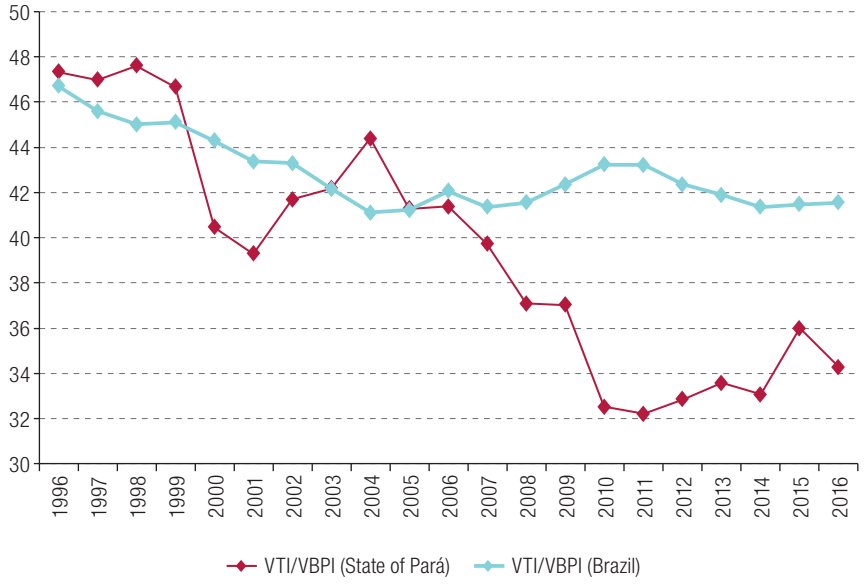
However, the downtrend in industrial employment precedes a more serious structural problem, namely the declining share of manufacturing industry in GDP, which is one of the symptoms of regressive specialization noted by Carneiro (2008). Moreover, its performance is similar to that of national manufacturing industry, which in 1986 accounted for 27.1% of formal jobs in the Brazilian economy but then fell continuously to reach 15.5% in 2016.

(b) Reduction in industrial density

The second measure used to verify the regressive specialization process is the industrial density index (or coefficient of industrialization). This is measured as the ratio between VTI and VBPI and is used to gauge the densification of production chains. The higher this coefficient, the greater the industrial density and, consequently, the greater the value added by the production chain or sector in question.[4]

Figure 3 shows that the density of Pará's manufacturing industry fell sharply by 23.96% between 1996 and 2016, whereas for Brazil as a whole the index decreased by 11.20% in the same period. In 1996, the Pará State and national VTI/VBPI ratio started from similar levels; but from 2004 onward, following a brief period of recovery, the densification of Pará's industry declined rapidly until 2011, when the indicator recorded its lowest value (32.20%).

Figure 3
Brazil and State of Pará: manufacturing industry density index, 1996–2016
(Percentages)



Source: Prepared by the authors, on the basis of Brazilian Institute of Geography and Statistics (IBGE), Pesquisa Industrial Anual – Empresa (PIA-Empresa) 1996–2016.
Note: The industrial density index is measured as the ratio between industrial transformation value (VTI) and gross value of industrial production (VBPI).

[4] According to Almeida, Feijó and Carvalho (2007, p.1), a fall in this ratio means that greater use is being made of imported inputs, which for the industry as a whole represents a transfer abroad of output and its respective value added, as happens in the mining and metallurgical sector in the State of Pará.

Since then, the performance of manufacturing industry in Pará has fluctuated without signs of progressive recovery, as can also be seen in figures 1 and 2, which show a reduction in industrial density, and a consequent loss in capacity to create jobs and improve incomes among the population. In the case of extractive industry, growth has been associated with a larger share of VTI in industrial production, which rose from 59.62% in 1996 to 72.47% in 2016.

This fall in the VTI/VBPI ratio signifies a weakening of the productive links of industry in both Pará and Brazil as a whole, subjecting the economy's production structure to a pattern of regressive specialization (Carneiro, 2002; Filgueiras, 2013; Almeida and Santos, 2015; Trindade and Oliveira, 2017). However, in the case of Pará, the sharp fall in the coefficient indicates that the reduction in the share of industry was also accompanied by a significant increase in production by natural resource-intensive sectors.

This development has occurred more intensively in regions viewed as frontiers of capital accumulation, with a robust expansion of commodity production (Rivero and Cooney, 2011; Loureiro, 2009; Marques, 2012; Trindade and Ferraz, 2023). However, this relationship conceals the most troubling feature of Pará's economy, namely the rapid growth of the extractive industry combined with the relative decline of manufacturing. This is revealed by the rise in VTI, which involves an increase in labour productivity associated with the mining of metallic minerals, mainly iron ore, copper, aluminium and manganese (Monteiro and Cruz, 2012; Trindade and Oliveira, 2017).

(c) Larger share of low-tech sectors in the industrial structure

The third measure proposed by Carneiro (2008) is the technological coefficient, for which the economics literature establishes various sector taxonomies. These seek to categorize branches of industry according to their technological coefficient, in terms of both products and production processes. However, owing to the specific characteristics of the production structure in each economy, none manages to represent the technological profile of industry satisfactorily (Urraca-Ruiz, Britto and Souza, 2013).[5]

Considering the profile of the economic structure of Pará, this study uses a classification that encompasses both manufacturing and extractive industries. The sector taxonomy proposed by Ferraz, Kupfer and Haguenauer (1996) is particularly interesting, because it combines different industrial classification criteria, resulting in four groups: (i) resource-intensive industries; (ii) traditional industries; (iii) durable goods industries and their suppliers; and (iv) industries that disseminate technical progress.

For the purposes of this study, a number of adjustments were made to take account of the sector structure of industry in Pará. Moreover, given the negligible presence of industries that disseminate technical progress, the corresponding activities were added to the durable goods industries and suppliers group, leaving three industry groupings, classified as follows: (i) natural resource-based industries; (ii) traditional or low-tech industries; and (iii) medium and high tech durable goods industries.

Figure 4 shows the performance of these three industry groupings in 1996–2016, using the share in VTI as a benchmark variable. The natural resource-based group of industries diverges increasingly as from 2006, coinciding with the fall in industrial value in the other two groups. This result correlates positively with these sectors' share in GDP and negatively with their capacity to create jobs and densify the State economy.

[5] Firstly, the pre-established classifications in sectors of greater and lesser technological efficiency may underestimate the innovative performance of sectors that traditionally do not innovate, but which can incorporate technical progress through intersectoral relationships. Secondly, the specifics of the technological level assumed by the economy stems from the historical circumstances that led to the formation of its productive capacity. Lastly, such classifications do not adequately take into account the capacity of the different sectors to foster the productive development of the economy through chain effects (Urraca-Ruiz, Britto and Souza, 2013).

Figure 4
State of Pará, Brazil: share in industrial transformation value of industrial sectors by technological coefficient, 1996–2016
(Percentages)

Source: Prepared by the authors, on the basis of Brazilian Institute of Geography and Statistics (IBGE), Pesquisa Industrial Anual – Empresa (PIA-Empresa) 1996–2016.

Among industries that make intensive use of natural resources, the growth in metallic mineral mining is positive, while the performance of the wood products industry is negative. The performance of low-tech (traditional) industries was sustained exclusively by the food and beverage sector. The medium- and high-tech industry group, which in Pará consists mainly of supply industries, was driven by the growth of the metallurgical sector.

2. Nature and direction of the structural change in industry in the State of Pará

As noted above, owing to the changes that have occurred in the last four decades, Pará's production structure has come to be centred mainly around the mining economy, to the detriment of other industrial activities, thereby creating a new reproductive dynamic in the regional economy. The expansion of the mining and metallurgical industry has therefore served as the vector of the State's GDP growth path in recent decades. However, this industry has been unable to forge closer linkages with the State's economic structure, as noted by Hirschman (1961), since it relies essentially on a commodity-export model in which growth is driven mainly by the foreign market (Furtado, 1998 and 2000; Mello, 1990; Mollo and Amado, 2010).

The effects of this production logic on the economy of the State and region worsened in the second half of the 1990s, owing to the liberalizing policy measures adopted by the federal government. In particular, export tax exemptions had a direct effect on the State's tax revenues and discouraged investment policies since it was impossible to increase public spending (Trindade, Portugal and Brandão, 2017).

Thus, the changes that have occurred in Pará's industrial structure in recent decades are explained largely by the vigorous expansion of the mining and metallurgy industry. Table 4 reports selected indicators of the trend of industry in the State in the last two decades (1996–2016). The extractive and manufacturing industries reflect opposing trends in employment, industrial transformation value, and labour productivity.

Table 4
State of Pará, Brazil: industry performance in terms of employment, industrial value and productivity, by sector of activity, 1996 and 2016
(Percentages and thousands of reais)

Industrial sectors	1996			2016		
	Employment *(Percentages)*	Industrial transformation value *(Percentages)*	Productivity *(Thousands of reais)*[a]	Employment *(Percentages)*	Industrial transformation value *(Percentages)*	Productivity *(Thousands of reais)*[a]
General industry	100.00	100.00	14 714	100.00	100.00	29 403
Extractive industry	7.67	31.41	60 222	20.87	68.20	96 089
Manufacturing industry	92.33	68.59	10 931	79.13	31.80	11 818
Oil and natural gas	0.00	0.00	490	0.00	0.00	0
Extraction of metallic minerals	6.91	30.10	64 148	19.91	67.83	100 169
Extraction of non-metallic minerals	0.77	1.31	25 057	0.96	0.37	11 340
Food and beverages	22.17	15.67	10 396	35.08	11.95	10 014
Textiles, apparel, leather and footwear	4.47	1.26	4 156	3.02	0.46	4 444
Wood products	41.82	15.05	5 295	10.36	1.85	5 248
Pulp and paper products	3.70	10.03	39 917	2.11	0.87	12 076
Chemicals and pharmaceuticals	2.94	2.80	14 026	3.69	1.81	14 454
Rubber and plastics	1.01	0.39	5 714	2.03	0.28	4 024
Non-metallic minerals	3.18	2.68	12 383	7.58	2.62	10 147
Metallurgy	4.79	15.92	48 932	4.59	8.97	57 496
Metal products, excluding machinery and tools	1.15	0.64	8 224	2.73	0.65	6 979
Machines and tools	1.09	0.77	10 362	3.55	1.51	12 524
Computers, electronics and electricity	0.29	0.04	2 115	0.29	0.04	3 779
Automobiles, trailers and bodyworks	0.87	0.17	2 870	0.42	0.03	2 070
Other transport equipment	0.34	0.46	20 042	0.76	0.37	14 444
Furniture and miscellaneous products	4.52	2.71	8 813	2.93	0.41	4 118

Source: Prepared by the authors, on the basis of Brazilian Institute of Geography and Statistics (IBGE), Pesquisa Industrial Anual – Empresa (PIA-Empresa) 1996 and 2016.

[a] Figures updated to 2016 by the General Price Index – Domestic Availability (IGP-DI).

In the case of extractive industry, growth is due mainly to the evolution of metallic mineral production, in which productivity increased by more than 50% during the period. In contrast manufacturing industry saw reductions in employment (-14.2%) and in VTI (-53.6%), while productivity grew by just 8.1%, owing partly to productivity gains in the metallurgical industry (17.5%).

In 1996–2016, the mining and metallurgy sector increased its share of VTI by 1.6 times, driven especially by metallic mineral production, which more than doubled its share from 30.10% in 1996 to 67.83% in 2016, accompanied by a large productivity gain, as shown in table 4.

This result only partially reflects the robust growth of commodity production in Brazil in the decade of 2000, driven by the sharp rise in international prices associated with the "China effect" (Filgueiras, 2013; Serrano, 2013). In the case of mineral commodities, the international flow intensified greatly in response to burgeoning Chinese demand as from the early years of that decade; and it maintained high growth rates despite the 2008–2009 crisis.

A large portion of Brazil's supply of metallic mineral products is produced and exported by the State of Pará, which generates 6% of the country's total exports. In 2018, the State recorded the third largest trade balance of Brazil's subnational units, with an export value of some US$ 14.4 billion, of which iron ore accounted for more than 60%.

In recent decades, the State of Pará has traded intensively in basic industrial inputs and semi-finished products of mineral origin (metallic minerals), destined almost exclusively for the foreign market. Throughout the decade of 2000, the metallic mining sector generated between 75% and 85% of Pará's total exports and amounted to some US$ 8.9 billion in 2016, as shown in table 5.

Table 5
State of Pará, Brazil: total and metallic mining sector exports and growth rate, 1997–2016
(Thousands of dollars and percentages)

Year	Value of exports *(Thousands of dollars)*				Relative variation *(Percentages)*		
	Extractive industry (A)	Metallurgy (B)	Metallic mining industry (C)	Total exports (D)	A/D	B/D	C/D
1997	951 746	781 132	1 732 878	2 263 399	42.0	34.5	76.6
2000	975 084	863 119	1 838 203	2 439 752	40.0	35.4	75.3
2005	2 289 694	1 500 779	3 790 474	4 756 257	48.1	31.6	79.7
2010	8 378 392	2 636 518	11 014 910	12 833 142	65.3	20.5	85.8
2016	6 918 804	2 080 568	8 999 373	10 511 067	65.8	19.8	85.6
Average annual growth rate *(Percentages)*							
1997–2016	96	35	71	64			

Source: Prepared by the authors, on the basis of Ministry of Development, Industry, Trade and Services of Brazil, Comex Stat [online database] http://comexstat.mdic.gov.br/es/home.

Between 1997 and 2016, the sector's exports grew an average of 71% per year, more than quintupling their dollar value (measured free on board (FOB)). This outstripped the performance of total exports, which grew by an annual average of 64%. Extractive activity also outpaced the manufacture of metal products. The way in which this economic dynamic is progressing —gradually reducing and destroying the few manufacturing activities installed in the State, while intensifying the mining-metallurgical matrix— tends to reinforce the economic model of commodity-export specialization, and thus assumes new functional characteristics of peripheral dependency (Osorio, 2012a; Martins, 2011; Trindade and Oliveira, 2017; Bruno, 2021).

V. Final thoughts

The structural changes that have taken place in the Brazilian economy, owing both to the subordinate and passive external integration of the 1990s and to the macroeconomic adjustments of the last three decades, have affected the various subnational economies in different ways. Nonetheless, their main effect has been to accentuate the dependent and commodity-exporting nature of the State economies. The analysis presented in this article focuses on the specific case of the State of Pará.

The starting point is a theoretical approach that treats the course of capitalist development as a historically unequal process, subjected to structural shifts, not necessarily progressive, which, from a regional standpoint, show how capital relates and acts in different territorial economic spaces. This dynamic unfolds among countries with different levels of development, but also between national subspaces that reflect very pronounced structural and social asymmetries, as exemplified by Brazil.

Brazil reflects varying levels of territorial economic development: some subnational regions have highly diversified production structures while others, located in the peripheral zones of the country, are highly specialized. The structural change involving economic reprimarization is a trend that has been observed generally in the Brazilian economy in recent decades; but, in the subnational units, it tends to reflect specific features owing to the characteristics of each production structure and its mode of external engagement, as demonstrated throughout the article.

The Pará economy has become increasingly specialized, accompanied by a loss of industrial diversity, specifically in manufacturing industry, combined with growth of the mining sector, as revealed by the indicators analysed. The production structure has become concentrated increasingly in the production of raw materials and semi-finished industrial inputs —that is, in low-tech items.

The observed trend entails a shift of production towards the mining and metallurgy sector, especially in the extractive industry, which has its counterpart in the decline of manufacturing industry. The fact that this dynamic has intensified in the last twenty years would suggest that the explanation goes beyond the rise in commodity prices in the foreign market. This needs to be analysed further in future studies, especially in terms of the effects of the Brazilian taxation model.

Salient features of the mining and metallurgical sector include highly concentrated technological progress, the way in which it operates internationally, and the fragile linkages it establishes with the rest of the regional production structure.

Based on the theoretical and empirical analysis, the current commodity-export model of the economy of the State of Pará can be represented in general by the following three key characteristics. However, this attempted synthesis does not pretend to be the last word on the subject.

(i) Intensive use of imported machinery and technology. This is undoubtedly the most salient characteristic of the new commodity-export model. It makes it possible to establish production with a high capital-labour ratio, which in turn determines and fosters high labour productivity. In addition, the use of modern technologies makes it possible to reduce production costs —either through the introduction of machinery and new production processes or by increasing the scale of production through a more efficient and flexible use of the transport system— in the face of profitability gains and the cyclical expansion of the international market.

(ii) Production and marketing that are highly integrated in global markets and under the financial control of large transnational corporations. This is an aspect that usually differentiates commodity production, whether mineral or agricultural: the high degree of capitalization and integration with demand-side sectors in the global production chain. Global integration, meanwhile, raises the issue of the transfer of rents abroad, which is part and parcel of the peripheral economies' dependency logic.

(iii) Continued environmental degradation, resulting from increasing pressure on forests and the plundering of nature, which translates into intensive but unequal economic and social use of natural resources, as happens mainly with mining.

These are some of the determinants of the new phase of capital reproduction in the Amazon region, whose main pillars of accumulation (cattle ranching, agriculture and mining) maintain domestic and external relations and interactions that give rise to the current commodity-export productive specialization model.

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On tragedy and hope: *homo economicus*, the invisible hand and reality

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Abstract

This article classifies goods according to their technical characteristics of rivalry and excludability, with the inclusion of new categories ranging from zero rivalry to infinite rivalry and from excludability to imposed access. The conceptual framework reveals concrete challenges in meeting the conditions of the first theorem of welfare economics, demonstrating that only private goods are the epitome of market theory, with an immense range of goods for which provision by means of free prices does not exist or is Pareto inefficient. A theoretical origin of externalities is proposed, as well as the technical or practical impossibility of completing markets and, through the price system, achieving their internalization. Lastly, the article demonstrates that many of the problems expected from market failures are fictitious because, rather than *homo economicus,* we are *homo sapiens*, the most cooperative beings in nature.

Keywords

Economic development, social welfare, welfare economics, markets, consumer goods, consumption, competition, social aspects

JEL classification

A13, P0, Z1

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I. Introduction

The first theorem of neoclassical welfare economics states that if consumers and producers are perfectly competitive, taking prices as given, if a complete set of markets exists and if there is perfect information, the market equilibrium —if it exists— is Pareto efficient. Together, these three conditions are known as a perfect market and their unfulfillment as market failure. The theorem indicates that, without market failures, free exchange guided by free prices will lead to Pareto efficiency, a term named after its creator, the Italian economist Vilfredo Pareto, an Italian fascist sympathizer who was appointed senator for life by Mussolini. A Pareto improvement is the reallocation of goods to benefit at least one person without harming anyone and a Pareto optimum is achieved when all Pareto improvements have been exhausted. This fundamental theorem is the formalization of Adam Smith's famous "invisible hand", which is often taken out of context and is mentioned only once in *The Theory of Moral Sentiments* of 1759 and once in *An Inquiry into the Nature and Causes of the Wealth of Nations* of 1776. In the former, Smith used the renowned expression to explain why landowners would divide their property into virtually equal shares. The author states: "It is in vain that the proud and insensitive landowner sees his extensive fields and, without thinking about the needs of his brothers, in his imagination consumes all the harvest that grows in them.…They are led by an invisible hand to make nearly the same distribution of the necessaries of life, which would have been made, had the earth been divided into equal portions among all its inhabitants" (Smith, 1759/2018, p. 128).

In his most important work, *An Inquiry into the Nature and Causes of the Wealth of Nations*, Smith uses the well-known expression to argue the importance of investing at national level:

> By preferring the support of domestic to that of foreign industry, he intends only his own security; and by directing that industry in such a manner as its produce may be of the greatest value, he intends only his own gain, and he is in this, as in many other cases, led by an invisible hand to promote an end which was no part of his intention (Smith, 1776/2012, p. 445).

However, Adam Smith's familiar phrase is used as a synonym for market efficiency, supposedly proven by the first theorem, which is a typical example of the deductive method, where the conclusion is determined by its premises. Like any mathematical theorem, it is a proposition that is always valid because the hypotheses define the result. If market equilibrium exists, using the conceptual framework of the first theorem, it is impossible not to arrive at the "invisible hand" since the very conditions that are imposed unequivocally establish the corollary. Within this perfect market, inaction is the best response, the famous *laissez faire*, *laissez passer*, since free prices would incorporate the information necessary to exhaust all possible Pareto improvements. The only problem is that the perfect market exists solely in an imaginary world; however, we economists tend to forget this and are left with the presumed, and perhaps desired, end result. The reality is that the basic model of market efficiency, which is supposedly universal, is based exclusively on one type of good, "private goods". Beyond this type of good and, in general, when one of the extreme conditions of the first theorem of welfare economics is not met, it is practically impossible for the free market to reach a Pareto optimum.

II. The exception as a rule

Classifying goods on the basis of two technical characteristics —rivalry and excludability in consumption— is very useful. Rivalry reflects the degree to which my consumption affects others' consumption of the same good at the same time. If I eat part of an apple, that part will no longer be simultaneously available to others, but when I watch a movie on Netflix, this in no way prevents tens of thousands of

other people from watching the same movie at the same time. That is, my consumption or use of that good does not affect in any way the simultaneous consumption or use of the same good by others, so its consumption is non-rival.

When classifying goods by their degree of rivalry, they are divided into the following categories: (i) individual goods, where my consumption prevents the simultaneous consumption of that unit of the good by others, as in the case of the apple, and (ii) collective goods, where several consumers —in this case, the term "users" would be more accurate— can simultaneously use the same unit of the good (see table 1). The consumption of collective goods may be congestible or non-congestible. With respect to non-congestible collective goods, which we will call "club goods", rivalry is non-existent since my consumption does not affect others' consumption in any way, as in the case of Netflix. Regarding congestible collective goods, my consumption does not impede that of others, but it does affect it, with varying degrees of rivalry. An example of this is a congested road or when the "tragedy of the commons" occurs, where any attempted consumption impedes consumption by all. This is an extreme case that represents a generalization of the problem presented by Garrett Hardin (1968) in his paper of the same name. An example would be the congested road that becomes gridlocked with my usage. In the case of club goods, non-rivalry may have a threshold beyond which such goods become congestible; in such cases we will call them "saturable club goods". Examples of these are roads, which can handle up to a certain number of vehicles without congestion, and Netflix, should its technology platform reach maximum capacity.

Table 1
Goods according to degree of rivalry

Rivalry	Rivalry	My consumption prevents consumption by others	A	Individual consumer goods
		My consumption affects consumption by others	B	Congestible goods
		No one can consume	C	Tragedy of the commons
	Non-rivalry	My consumption does not affect consumption by others	D	Club goods

Source: Prepared by the author.

Excludability is the technical possibility of exclusion from consumption of a good. In practice, excludability and non-excludability also depend on the institutional framework and, essentially, on property rights. An apple is a good with a high degree of technical excludability, but property rights can be established whereby apples are freely accessible and free of charge. By contrast, software —and knowledge in general— is a good that is generally easy to access. However, patents are imposed to restrict its consumption, thereby achieving a high level of excludability at the institutional level. While I could find a way to technically access the software, if I got caught, I would face severe penalties. Exclusive property rights of a good make it possible to establish prices and exchange it on the market; in other words, to turn that good into a commodity. These are collective decisions that should reflect civilizational and technical advances, as well as the circumstances of a given society in the pursuit of the common good. Ultimately, they are also profoundly political acts, reflecting power relations within society and globally. A clear example of this at the international level are the barriers imposed to access knowledge generated in developed countries, which is not the case for the consumption of global environmental goods produced in developing countries.

The cost of enforcing exclusive property rights is inversely proportional to the ease of exclusion. Thus, easily accessible goods often enter the market differently, without charging prices directly to consumers. One example is free-to-air television, where anyone with a television set can watch, for free, a movie broadcast by a given television channel. In this case, the business model revolves around requiring sponsors to pay for advertising, rather than the impossible task of charging a fee to viewers. However, technological progress can affect the degree of excludability. Cable television and services such as Netflix offer series and movies of the consumer's choice and without advertising, but only for those who pay a monthly fee. Thanks to new technologies, exclusion from these services is quite simple.

Excludability in easily accessible goods can also be achieved through imaginative solutions. Generally, garbage collection services are provided by the public sector, which charges citizens a flat fee or tax, regardless of the amount of service consumed. Garbage collection was generally considered a service with low excludability, since it was very costly to discriminate between those who paid collection fees and those who did not. In other words, garbage was collected from everyone, until one municipality started requiring citizens to purchase municipal garbage bags, rather than charging them fees. This simple change achieves not only excludability in collection (only garbage that has been placed in the municipality's bags is collected); in addition, those who generate more waste pay more, as is desirable. If the special garbage bags were private, the service could be provided spontaneously by the market. However, it would not allow competition since an existing company in the sector would always be able to serve one more customer at a lower cost than that of a newcomer. This is what is known as "economies of scale", which reduce average costs and generate "natural monopolies", where it is always better for the same company to provide more services than for new companies to enter the market. The problem is that garbage collection is a basic service, so demand is quite insensitive or inelastic to price. As a result, private service would lead to a monopoly with significant market power. This is one of the reasons why, in general, garbage collection remains a public service. Now let us look at the example of street lighting service. Even if you never go out at night, you have to pay the same rate as the neighbour who always goes out at that time. There is still no technical or institutional way to achieve excludability in this service, so it will have to continue to be financed with taxes and the private sector will not be able to provide it spontaneously.

Unless otherwise specified, this analysis refers only to the different levels of technical excludability.

When considering their degree of excludability, goods are classified into (i) goods from which my consumption can easily be excluded, called "excludable goods", as in the case of an apple; (ii) goods where it is very costly or impossible to exclude my consumption, called "free-access goods", as in the case of a road with many entrances; and (iii) goods where even I cannot exclude myself from consumption, called "imposed-access goods", such as national defence (see table 2).

Table 2
Goods according to degree of excludability

Excludability		
Excludability	Non-excludability	
I can be excluded from consumption	I can exclude myself from consumption	I cannot exclude myself from consumption
A	B	C
Excludable goods	Free-access goods	Imposed-access goods

Source: Prepared by the author.

Rivalry and excludability will now be combined. In the economic literature there are several conceptual frameworks, many ambiguities and a great deal of confusion when defining public and private goods. This classification often depends on whether the goods are provided by the State or the market, and whether they are publicly or privately accessible. In this article, goods will be classified solely on the basis of their respective technical characteristics of rivalry and excludability, regardless of who provides them or the associated property rights.

Private goods are characterized by individual consumption and excludable access (for example, an apple) and correspond to cell AA in table 3. The greater the ease or lower the cost of achieving excludability and the smaller the possibility of collective consumption, the purer the private goods will be and the greater the probability that the market will produce them spontaneously and efficiently in the Pareto sense. All other goods will generally be considered market failures, since free market provision,

if possible, will only be efficient in exceptional cases. At the other extreme of private goods are pure public goods, such as national defence; that is, club goods with compulsory access, which correspond to cell DC in table 3.

Table 3
Goods according to degree of rivalry and excludability

				Excludability		
				Excludability	Non-excludability	
				I can be excluded from consumption	I can exclude myself from consumption	I cannot exclude myself from consumption
				A	B	C
Rivalry	Rivalry	My consumption prevents consumption by others	A	Private goods (e.g. apple)	Winner-take-all (e.g. Mocha Dick)	
		My consumption affects consumption by others	B	Congestible excludable goods (e.g. road with access control)	Congestible free-access goods (e.g. road with no access control)	Congestible imposed-access goods (e.g. habitat)
		No one can consume	C	Tragedy of the commons (e.g. gridlocked road with access controls)	Tragedy of the commons (e.g. gridlocked road with no access controls)	Tragedy of the commons (e.g. collapsed habitat)
	Non-rivalry	My consumption does not affect consumption by others	D	Excludable club goods (e.g. Netflix)	Open-access club goods (e.g. open-access software)	Pure public goods (e.g. national defence)

Source: Prepared by the author.

The closer goods come to the characteristics of non-rivalry and non-excludability, they are referred to simply as public goods, and it is increasingly difficult for the free market to provide them and, if it does, to provide them efficiently. To understand this intuitively, let us examine the extreme cases. Once a club good like Netflix is created, excludability is undesirable owing to its Pareto inefficiency, given that the more people enjoy the good up to its saturation level, the better off someone is without anyone being worse off. For an imposed-access good like national defence, establishing exclusive property rights is completely ineffective, thus there are no market prices and the commercial production of the good using the price system is unfeasible.

This conceptual framework may also be used to understand the origin of "externalities". An externality is an effect of compulsory access on third parties, caused by the actions of an agent whose objectives differ from that effect. Defining whether something is an externality depends on subtle differences. Let us take as an example my neighbour's beautiful garden. If the intention was to decorate the house and that also provided a pleasant landscape for the whole neighbourhood, it is a positive externality. If the flower garden was created specifically to brighten up the neighbourhood, it is no longer an externality, but rather an intentional contribution to benefit others. If someone intentionally sought to live near that house to benefit from the garden landscape, it is not an externality either, because the benefit was not gained from compulsory access and the new neighbour is intentionally making use of a good for which exclusion is unnecessary or very costly. The two essential ideas in the definition of an externality employed here are: (i) the agent producing it is acting in his or her own interests and is not deliberately seeking to benefit or harm others and (ii) these benefits or harms entail compulsory access for third parties.

According to the present approach, positive externalities will arise from the production of an imposed-access good, while negative externalities will result from the use of a congestible good or from mutual blocking of access to a good. The neighbour's garden is a public good that generates a positive externality —a beautiful landscape— while ugly billboards that partially cover the garden would be visual pollution analogous to environmental pollution; that is, a negative externality resulting from the consumption of the congestible good called "habitat". The landscape of the neighbour's garden corresponds to a "local public good" because it is a club good with compulsory access that is restricted

to a specific place, unlike global or national public goods, such as the fight against climate change or national defence, respectively. For residents of other neighbourhoods, my neighbour's garden will be a free-access good, and if they try to view the garden from my house simultaneously, they will reach a point where they will block each other. This will generate negative externalities once again, this time for accessing the good.

A special case is that of individual but easily accessible goods, which can result only in the "tragedy of the commons" by mutual blockage or a "winner-take-all" situation (cell AB in table 3), because the winner effectively takes all without leaving anything to others. One example is the hunt for Mocha Dick, the giant white sperm whale that inhabited the seas off Mocha Island in Chile in the nineteenth century and inspired *Moby Dick*, the novel written by Herman Melville in 1851. Many whalers spent decades hunting the giant whale and may have blocked each other in the process, such that the sperm whale survived close to a hundred hunting attempts and some 20 harpoons in its body, until a single "winner" caught it in 1838.

III. The world is one big market failure

It is worth recalling that the first theorem of neoclassical welfare economics states that perfect competition, complete markets and perfect information are sufficient conditions for free prices to lead us to a market equilibrium that, if it exists, results in the famous invisible hand. In other words, it reaches a Pareto optimum.

The technical or practical impossibility of establishing effective property rights owing to a good's low excludability renders ineffective the existence of a price for such a good. As a result, it will generally not be provided by the market. In the —unfortunate— case of Mocha Dick, an individual "consumer" good, the market solution states that, if the exclusive right to hunt the sperm whale had been auctioned, the one who most wanted it would have acquired it and the result would be Pareto efficient. But how much would it have cost to enforce this exclusive right? If in practice it was impossible to enforce it, no informed and rational person would have purchased the right. In the case of free-access goods, such as free-to-air television, the market can provide them without using the price system directly, thus Pareto efficiency is not guaranteed. Only highly excludable goods would remain as direct candidates that meet all the conditions of the first theorem.

Turning now to analyse the technical characteristic of rivalry, the consumption of collective goods with a high degree of rivalry is a source of negative externalities. In turn, externalities are a form of incomplete markets. If the first motorists on the congestible road or the first residents from other localities who came to see my neighbour's garden could negotiate with each of the new users to determine their respective access, an efficient situation could plausibly be reached, but such a market does not exist. Consequently, congestible goods would break the second condition of the first theorem of welfare economics.

Conceptually, the neoclassical means of correcting an externality so that it reaches Pareto efficiency is its internalization; that is, ensuring that the agent producing the externality assumes the corresponding marginal cost or benefit that it creates in the system. Another example of a negative externality is if my officemate smokes and I am harmed by their cigarette smoke. If an air market is created, my colleague would have to pay me for consuming the clean air to which I am entitled, thus internalizing the externality being created, and we would supposedly reach Pareto efficiency through free exchange. The problem is that in the real world there are many participants who are unknown and even changing, as in the case of the congestible road or the commotion over the neighbour's garden, and if negotiation were possible, the transaction costs would be enormous.

Privatizing the road or access to the garden view (that is, giving property rights to a private agent) would be a type of centralized solution because the negotiation concerning access would not take place directly between the beneficiaries and the injured parties and, as such, efficiency would not be reached through mutual exchange and the respective exhaustion of the Pareto improvements. Moreover, Pareto efficiency would not even be guaranteed, since by having a marginal cost of zero to serve a new user and not directly receiving the cost of new users, the private administrator of the good will benefit from maximizing income, even if this leads to the tragedy of the commons. In countries such as Singapore, the public administrator of a congestible road charges new users a price close to the full marginal cost that such use entails, thereby internalizing the externality and approaching Pareto efficiency, but this requires a public rationale rather than a private one.

While collective goods involving a high degree of rivalry generate negative externalities among users, low-rivalry collective goods prevent competitive markets, since in principle it will always be cheaper to serve more people with an existing collective good than to produce new similar goods, thus breaking the first condition of the theorem once again. Returning to the issue of economies of scale and natural monopolies, such as garbage collection services, it will always be cheaper to serve one more user than to establish a new company to provide the service. An extreme case of this are club goods, where the marginal cost of serving a new user is zero and where exclusion produces Pareto inefficiency.

In short, all collective goods would break either the first or second condition of the first theorem of welfare economics, such that free market provision, if feasible, would not necessarily be Pareto efficient. As seen in the case of Singapore's roads, this does not mean that the provision of collective goods cannot be Pareto efficient. In their seminal articles, Samuelson (1954) establishes the optimal conditions for providing public goods and Buchanan (1965) does the same for congestible goods, which he calls "club goods". However, instead of a free market, these solutions correspond to centralized and cooperative arrangements, respectively.

For the much-desired efficiency of the free market, Adam Smith's famous invisible hand, we would then be left with only highly excludable and individually consumed goods: private goods. These goods are the exception, rather than the rule, yet they constitute the epitome of market theory and mainstream modern economics, which, as a corollary, justifies State intervention only to correct market imperfections. The problem with *laissez faire, laissez passer* is that, using proponents' own terminology, the world is one big market failure.

IV. Cooperation or competition?

A Beautiful Mind, the four-time Oscar-winning 2001 film based on journalist Sylvia Nasar's 1998 book of the same title, chronicles the life of mathematician John Nash of the United States, winner of the 1994 Nobel Prize in Economic Sciences for his contributions to non-cooperative game theory. Viewers will recall poor John desperately looking for an original idea for his thesis when he was a 20-year-old PhD student in mathematics at Princeton University. One night, while at a bar on campus with his friends, a beautiful blonde woman walks in surrounded by other attractive friends. Jokingly, one of Nash's companions proposes duelling until there is only one suitor left for the blonde woman. His friend and rival Martin Hansen then starts to quote Adam Smith and everyone says in unison that, in competition, individual ambition serves the common good, while one person concludes with "every man for himself". Nash —portrayed by Australian actor Russell Crowe— lights up and says that Adam Smith needs to be revised because if everyone goes for the blonde woman, they will block each other. He concludes that Adam Smith was wrong: competition is not necessarily good and could lead to the worst of all worlds. At that moment, Nash decides that this will be the subject of his thesis. When he presents his initial progress to his supervisor, Professor Albert Tucker, the latter comments in amazement, but with

absolute certainty of the genius of the idea, that he is changing 150 years of economic history. Today, the Nash equilibrium is a central concept in game theory and teaches us that, given the interdependence of our actions and other agents' response capacity, it is cooperation —and not competition— that leads us to collectively optimal situations.

The classic game to represent the Nash equilibrium is the "prisoner's dilemma". It consists of the following scenario: two guilty parties are imprisoned and held incommunicado, each with the option of confessing or not confessing. If neither confesses, both will receive light sentences; if one confesses and the other does not, the one who confesses will go free and the one who does not will receive the harsher sentence; lastly, if both confess, both will receive an intermediate sentence. In a framework of self-interest and mutual distrust, the "dominant strategy" of both parties will be to confess, since that will be the best response, regardless of what the other party does. From my selfish point of view, if I confess and you do not, I will go free. This is a better outcome than if neither you nor I confess, where I would receive a light sentence. If both you and I confess, I will receive an intermediate sentence, which is better than if I do not confess and you confess, in which case I would receive the heavier sentence. Considering these "rational" premises, both parties will end up confessing and receiving intermediate sentences. However, this result is Pareto-inefficient because, without confessing, both could have received light sentences. It is cooperation —and not competition— that would have led to the optimal solution. If the dilemma is repeated each year indefinitely, the prisoners may come to cooperate —that is, not confess— in pursuit of their own self-interest, but to do so they must be persuaded that the other will act in an equally selfish manner. If at any point the prisoners believe that the other has adopted a code of honour that, regardless of the circumstances, prevents him or her from confessing, once again their respective "rational" responses will be to confess. In other words, in repeated prisoner's dilemma, "cooperation" results in selfishness and mutual distrust. If both parties truly held as a code of honour never to confess, the dilemma would be solved, even if playing it just once. It is not *homo economicus*, but rather *homo sapiens*, with values, capacity for learning, mutual trust and spirit of cooperation, that leads us to the best of all worlds.

Supporters of exclusive property rights and Pareto efficiency would have recommended to Nash and his friends that, instead of duelling or going all at once for the blonde woman, they should draw lots among themselves for the right to approach her. The lucky winner would then start to auction off his "right to approach" until the person willing to pay the highest price would get the right to approach the blonde woman on his own. Even if this situation were plausible, everyone would have to respect the right of the auction winner, which would require either absolute mutual trust (again, cooperation and not competition) or the involvement of university police (a centrally provided local public good) to ensure the "right".

Although it may seem ridiculous to try to determine who gets to approach the blonde woman on the basis of property rights, the example conveys the equally —or even more— absurd intention to commodify all dimensions of life. The most extreme example of this is anarcho-capitalism, in which even the administration of justice, public safety and national defence must be provided by private courts, police and armies, respectively. These companies would have to compete to provide better service to citizen-customers, according to the principle that only exclusive property rights can guarantee individual sovereignty or freedom, in addition to the assumption that competitive markets can always exist and that they alone lead to socially optimal resource allocation. Its founder and main proponent was the economist Murray Rothbard of the United States, who defended the legality of child labour and parenthood as property rights over children, and denounced Milton Friedman himself as an enemy of the free market (Rothbard, 2002). Authors associated with anarcho-capitalism, such as Anderson and Hill (2004), have presented as evidence of the success of their proposals the respect for property rights and the resolution of conflicts without need of the State that, according to them, occurred in the United States Far West in the eighteenth and nineteenth centuries.

There is a long-standing discussion as to whether a certain aspect of the administration of justice is a public or private good, as Correa, Peña and Vargas (2000) highlight. It would also be possible for security firms to serve as substitutes for the police since a certain degree of excludability is possible. However, the private national defence proposed by anarcho-capitalists would undoubtedly constitute a public good whose commercial provision would be impossible or completely inefficient. Ethical considerations aside, the anarcho-capitalist system, framed in the "libertarian" political movement, ignores the problems of supply and efficiency that the free market would face with anything other than private goods, even more so if economic actors focus on anarcho-capitalist individualistic premises.

Returning to the tormented Nash, and with apologies to all blonde women, he and his friends faced another dimension of the non-excludability problem, which the biologist Garrett Hardin raised in his 1968 article "The tragedy of the commons". Hardin was distressed about the risk he saw in human overpopulation, predicting that it would result in the inevitable collapse of common goods, which are open-access congestible goods. This would be particularly serious in the case of renewable resources, where overexploitation leads to their extinction. Hardin gave the example of a farmer who takes his cows to pasture and only considers the non-negative net benefit of using the pasture for free, which will deplete the land. In the end, everyone will lose because they acted rationally but individualistically. Like Nash's thesis, the article was a critique of Adam Smith's hypotheses. According to Hardin, "ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all" (1968, p. 1244).

Hardin correctly argued that the tragedy of the commons could be solved with an adequate exclusion mechanism. However, contrary to what is usually referred to in mainstream economic thought, the questionable privatization of the common good was only one of several proposals he presented in his famous paper, although he always based his analysis on the assumption that all people were selfish *homo economicus*. Hardin recognized that privatization could generate inequity but justified it by arguing that "injustice is preferable to total ruin" (Hardin, 1968, p. 1247).

Garrett Hardin was an anti-immigrant white supremacist and his well-known article also argues that people should not be free to decide the number of children they have and those who are biologically superior at managing property and power should inherit more. He also criticizes the welfare state, United States liberals or social democrats, the United Nations and even human rights. He asserts: "If we love the truth we must openly deny the validity of the Universal Declaration of Human Rights" (Hardin, 1968, p. 1246).

Nevertheless, "The tragedy of the commons" is one of the most (poorly) cited articles in history, with the aim of promoting exclusive property rights and the marketization of the commons when, objectively, it did not meet the standard for inclusion in the prestigious journal *Science*.

Over 30 years later, Elinor Ostrom, an unknown political science professor at Indiana University, became the first woman to win the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel, created in 1969 by Swedish central bank economists, for her contributions to the analysis of economic governance. Although Ostrom was not an economist, rarely has the misnamed Nobel Prize in economics been as well-deserved as the one she received in 2009. Ostrom had devoted her academic career to demonstrating how communities that share common resources manage them sustainably, without the need for exclusive property rights or coercive State intervention, but rather through voluntary cooperation and local collective action, which she called "governing the commons" (Ostrom, 1990). Instead of starting from abstract theories, Ostrom drew on multiple case studies from around the world and disproved Hardin and conventional economics, because fortunately we are still *homo sapiens*, the most cooperative beings in nature.

The very definition of what is "common" will vary according to different cultures. For the *sumak kawsay* or good way of living of many Andean Quechua peoples, privatizing water sources would be equivalent to appropriating life itself. From their world view, it is simply unthinkable that water sources

should become a commodity and not be freely accessible. How should these common resources be managed so as to avoid opportunistic behaviour that affects what belongs to everyone? Ostrom presents different types of partnership and management systems, but it is very difficult for virtuous institutions to exist without virtuous people. Thus, ultimately, it is the shared values and the mutual trust among community members that are fundamental.

While Ostrom's contribution was significant and dismantled Hardin's negative determinism, her approach presents a serious problem: the greater the number of people in a community, the more difficult it is to coordinate the management of the commons. Therefore, at least above a certain population size, it is more efficient to have an institutionalized representation of the community that decides, coordinates and executes the administration of common goods. In modern society, this is called the State.

V. *Economicus* versus *sapiens*

Externalities are the most widespread manifestation of interdependence. Hardin's example of the use of pasture generates negative externalities for other users and, at its extreme, causes the tragedy of the commons or results in no one being able to enjoy that good. It is already known that the neoclassical conceptual solution is to create markets through the establishment of adequate property rights that enable exchanges and achieve the internalization of externalities through the price system. In another seminal paper, Coase (1960) proposed what would later become known as the Coase theorem: regardless of who has these property rights, with low transaction costs, exchanges will lead to Pareto efficiency. In the example of the smoker and the non-smoker, it does not matter whether the non-smoker has the right to clean air or the smoker has the right to smoke; the important thing is that they can negotiate without incurring major costs and thus reach Pareto efficiency. The way in which property rights are granted has crucial distributional effects, but in terms of efficiency, it is sufficient that prices internalize externalities.

As mentioned above, the world is actually a universe of multiple large transaction costs, such that in the presence of externalities, the free market will not usually lead to an efficient situation. Moreover, beyond the fundamental distribution problem, there are other unavoidable ethical questions linked to this way of seeking the famous invisible hand. Taking Coase's original example, let us imagine a factory spewing smoke in a neighbourhood and, moreover, let us assume that the population of this neighbourhood lives in extreme poverty. The "internalization of externalities" means that, if the neighbourhood has the right to clean air, the "efficient" solution would be for those living there to let themselves be subjected to pollution in exchange for payment. Furthermore, no one should intervene for the sake of "consumer sovereignty" even though a wealthy neighbourhood would not even allow the construction of a polluting factory. What the devotees of the invisible hand fail to understand is that this example is no longer about free exchange; instead, it is conditioned by poverty, and is therefore no longer about the supremacy of the consumer, but rather about the supremacy of misery. Not everything can become a commodity.

The good news is that there are also positive externalities, such as the beautiful view of the neighbour's garden across the street. In a world of *homo economicus*, this type of good will only be provided individually if its benefit is greater than the cost to the respective agent. The bad news is that, if it exists, its provision will be inefficient, because if that neighbour could be compensated for the benefit he or she is providing to others, the garden would probably be bigger or better. Knowing that its benefits extend to the entire locality, the neighbourhood committee could ask each beneficiary to provide this compensation to the neighbour, but if everyone is *homo economicus* and knows that exclusion from the garden's benefits is impossible, no one will offer the fee voluntarily. This is known as the free rider problem, relating to someone who deliberately tries to enjoy the benefits of a collective good or service without having participated in its costs. This problem also arises with the anarcho-capitalists and their private armies: if everyone has to be defended equally in an armed conflict, a *homo economicus* would never contribute voluntarily to defence. Another example is the

dishonest person who does not pay the condominium cleaning fee because, as long as others pay, he or she will benefit from having it cleaned. The free rider problem may involve collective goods that are impossible or costly to make excludable, that is, "public goods". In game theory terms, for *homo economicus*, being a free rider would be the "rational" thing to do and is another type of Nash equilibrium, where the non-cooperative solution leads to the worst of all worlds: the non-provision —or suboptimal provision— of public goods.

As we have seen, when faced with recurring situations, *homo economicus* agents will understand that without cooperation everyone will lose, but they must be persuaded that others will act as they do. If they believe that others are spontaneous cooperators, their best strategy will be to not cooperate, which means that cooperation among *homo economicus* is based on mutual distrust, as discussed above. Adam Smith's invisible hand is also a paradoxical form of cooperation, putting *homo economicus* in competition with everyone else, presumably to achieve the best possible social outcome. On the surface, good things are achieved in all these contexts. However, much more is lost, such as mutual trust and pursuit of the common good, virtues that are fundamental to life in society.

The market solution to achieve Pareto efficiency in the presence of externalities is often technically impossible or absurdly costly, and, in trying to commodify everything, it becomes morally disgraceful or socially ridiculous. Fortunately, the poor do not accept being subjected to pollution against payment; neighbours volunteer to improve the neighbourhood garden; public goods, such as national defence, exist thanks to social contracts that establish a central authority in charge of executing, at the institutional level, collective action for the common good; condominiums are clean because their inhabitants have a sense of cooperation or, if they do not act out of integrity, they will do so given the cost of the shame of not cooperating; and attractive blonde women generally do not need mechanisms —much less market mechanisms— to avoid being harassed, because this would be socially and even legally penalized. The explanation for all this is that people are not *homo economicus*, but rather *homo sapiens* with virtues, a great spirit of cooperation, capable of mutual trust, subject to social scrutiny and with intrinsic values such as dignity.

The basic problem with neoclassical economics, at the heart of which is market theory, is that it assumes that we are all individualistic, ambitious, competitive and amoral *homo economicus*, when in fact we are much nicer *homo sapiens.* Therefore, many goods and services are generated and managed outside the market, with collective action based on cooperation and the logic of the common good rather than on competition and personal gain.

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The nexus between outward foreign direct investment and exports: evidence from developing countries[1]

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Abstract

This research analyses how outward foreign direct investment (OFDI) by emerging nations affects the investing countries' exports, examining the diversity in this relationship by categorizing developing nations by income (low-income, lower-middle-income and upper-middle-income) and by region (Africa, Asia and the Pacific and Latin America and the Caribbean). The research uses fixed and random effects on unbalanced data from 64 developing nations between 1990 and 2019. The results show that export performance in developing countries is significantly enhanced by OFDI. There is a supplementary impact of OFDI on exports from the middle-income and upper-middle-income classes of emerging nations. Results at the regional level show that this additional impact is greater in Asia and the Pacific than in other developing regions. In Latin America and the Caribbean, conversely, OFDI substitutes for domestic exports, and the region's contribution to total global OFDI is smaller and more variable than that of other regions.

Keywords

Foreign direct investment, investments, exports, emerging markets, developing countries, economic development, macroeconomics, econometric models, Latin America

JEL classification

F41, E24, F21, D22

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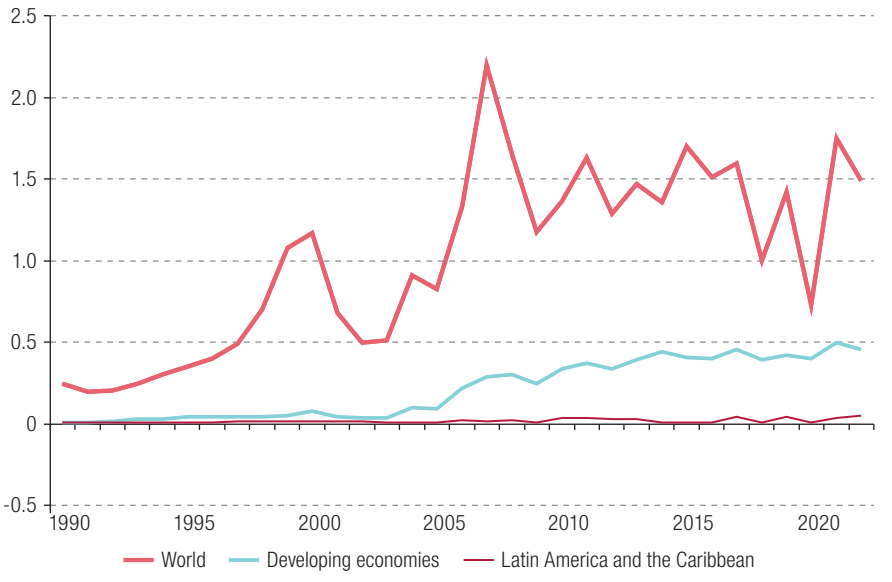
I. Introduction

Foreign direct investment (FDI) refers to investment coming into a country from outside, whereas FDI by the country abroad is called outward foreign direct investment (OFDI). Foreign investment has consequences for both the home and host nations. Historically, rich nations have been portrayed as the exclusive sources of FDI, particularly for emerging markets. This implies that the domestic economies of industrialized nations are also affected by direct investment in developing countries. The impact of OFDI on the home nation is now seen as a more crucial phenomenon than formerly. In 1995, OFDI remained associated with the developed countries of the world, with developing countries only supplying 4% of the total, but developing nations subsequently invested more abroad, accounting for 27% of total world OFDI in 2014 (UNCTAD, 2015). The 2023 figures for FDI show a boom for developing countries, and for the Latin American and Caribbean region specifically, with increases to 51% and 4% of the global total, respectively, in the wake of the economic stresses caused by coronavirus disease (COVID-19) there as in other regions around the globe (UNCTAD, 2023).

Figure 1 shows the volume of OFDI from developing countries and from Latin America and the Caribbean specifically. OFDI has a variety of effects on emerging nations' domestic economies. First, when the effect of capital outflows on the local job market is considered, it is clear that locating part of the production structure abroad means fewer jobs at home (Crescenzi, Ganau and Storper, 2022). However, Slaughter (2000) argues that domestic employment benefits from OFDI owing to supervisory obligations stemming from foreign investment. OFDI also affects productivity. To reduce costs and boost output, businesses throughout the world are increasingly pooling resources from many nations (Desai, Foley and Hines, 2005). Lastly, OFDI has an impact on the home nation's technology. When a nation begins investing abroad, it often learns new technologies that it then introduces at home (Liu and others, 2016). While OFDI has a variety of consequences for domestic performance, the impact on exports is particularly noteworthy, given the centrality of exports to emerging countries.

Figure 1
World, developing economies and Latin America and the Caribbean: outward foreign direct investment, 1990–2020
(Billions of dollars)



Source: United Nations Conference on Trade and Development (UNCTAD), *World Investment Report 2022, International Tax Reforms and Sustainable Investment*, Geneva, 2022.

How OFDI affects exports from the home nation varies greatly from country to country, depending on factors that include the nature of the local economy and the underlying motivations of investing companies. For instance, the impact of a capital outflow will be different in nations with plentiful natural resources and those with scarce ones. The effects of OFDI entailing the relocation of manufacturing to other countries are extremely contextual. Previous research identifies three primary motivations for OFDI: exploring new markets, improving operational efficiency and acquiring strategic assets (Dunning, 1993).

When motivated by a desire to maximize output per unit of input costs, home country companies outsource manufacturing to countries with lower production costs as a supplement to trade. OFDI increases domestic investment by boosting the export of capital and intermediate products from the home nation to the foreign country (Hejazi and Pauly, 2003). There is no initial impact on domestic output.

Market-seeking OFDI, meanwhile, is designed to serve the host country's home market and nearby markets. Such investments are intended to improve access to foreign markets and thence boost sales of goods and services in these markets. When OFDI replaces exports from the home economy or when a local company relocates its manufacturing facilities to another country, the result is less investment in the home country. While OFDI may reduce the volume of exports of finished products, it can increase the volume of exports of intermediate items by the parent company in the home nation to the firm's subsidiaries abroad. The overall effect is unclear.

The third motivation, the acquisition of strategic assets, reflects a need to acquire resources and assets that are not readily accessible in the home market but are crucial to the success of the company's long-term plans. Access to cutting-edge information and tools may help domestic businesses increase output and branch out into uncharted territory, which might have a favourable effect on investment levels.

Although a number of studies have looked at how OFDI affects exports for both individual companies and whole industries, most of them have concentrated on more industrialized nations rather than developing ones. Furthermore, the overall effect of OFDI on home nation export performance is not conclusively shown by the available information. Depending on the type of relationship between OFDI and domestic exports, the empirical literature suggests that OFDI may be either complementary (Head and Ries, 2001; Mullen and Williams, 2011; Padilla Pérez and Gomes Nogueira, 2016; Ahmad, Draz and Yang, 2016) or substitutional (Bojnec and Fertő, 2014; Bhasin and Paul, 2016). Most of these studies only include industrialized nations or very specific categories of nations. When it comes to emerging nations, there is a dearth of data in the empirical literature. Even if developing nations' proportion of global OFDI is growing, they still rely heavily on exports to bring in cash. To fill this knowledge vacuum, then, the present study looks at how OFDI affects exports from developing countries. An unbalanced sample of 64 developing nations covering the period from 1990 to 2019 was taken and divided into three categories based on income: low-income (20 countries), lower-middle-income (30 countries) and upper-middle-income (14 countries). We have also examined the link in nations spanning three continents (Africa, Asia and the Pacific and Latin America and the Caribbean).

The study results will make it easier to understand the behaviour of OFDI and its influence on the domestic exports of developing nations, which will be of use to policy reviewers, academics and contributors to the empirical literature. The developing nations most affected by international investment will also be highlighted in this study. Policymakers in developing nations will be equipped to make better judgements about investment prospects abroad, and accessible capital structures will be identified so that valuable investment flows may be attracted. As a result of this study, it will be clearer which locations and income brackets might benefit from exploring OFDI as a means of increasing exports.

There are five distinct parts to this analysis. A comprehensive literature review will be found in section II. The OFDI profile of developing countries is discussed in section III. Section IV sets out the econometric data and methodology. Section V includes the discussions and empirical results. Section VI offers some policy suggestions and concludes.

II. Literature review

Opponents of OFDI argue that it is harmful to local economies because it sends employment and productive capital abroad. The evidence, however, reveals that OFDI has both positive and negative impacts on domestic economies. For several decades, the effects of OFDI on exports have been the subject of a large body of theoretical and empirical research. The complementary impacts of OFDI on exports are distinguished from substitution-type effects in the theoretical literature. Both Mundell (1957) and Buckley and Casson (1981) postulated scenarios in which OFDI served as a replacement for exports from the home nation. Because these models place a high premium on exports of finished commodities, they assume that foreign investment can stand in for exports. When intermediate items are included in these models, the outcomes vary. The new trade theory views OFDI and exports as supplementary rather than competing. Svensson (1996) claims that growth in both OFDI and exports of intermediate products occur simultaneously. Vertical FDI, according to the latest theories, should create complementary trade flows of final goods from foreign affiliates to the parent business and of intermediate products within the firm, in headquarters operations for example, as replacements for exports from the home country to the partner countries.

The effects of FDI on a country's exports have been studied empirically at the company, sector and country levels, with various schools of thought emerging. One consequence that is clear from the data is that OFDI can help domestic exporters. Different studies have shown either that OFDI has no impact or that it increases exports from the home nation. Kim and Rang (1997) used cross-sectional data to analyse the connection between OFDI and exports from Japan and the Republic of Korea, finding in both cases that exports were unaffected by OFDI. Similar conclusions were reached by Cantwell and Narula (2001), who found no correlation between OFDI and domestic exports from Malaysia in their research. However, inward foreign direct investment (IFDI) was found to have a great impact on trade. Head and Ries (2001) used panel data on around 932 Japanese production companies over 25 years to analyse the influence of direct investment into different nations on product exports. OFDI and domestic exports were found to be complementary across the whole sample of businesses.

Lim and Moon (2001) analysed data collected from Korean enterprises to investigate the link between Korean OFDI and exports. They used ordinary least squares (OLS) estimates to explore the positive correlation between OFDI and exports from the home nation. Canadian and United States foreign investment and exports, in particular to China and India, were studied by Ghosh and Wang (2011) using cross-country time series data from 1989 to 2001. Increased investment in another nation was cited as a cause of growth in exports to it. Research by Bojnec and Fertő (2014) showed that OFDI had a substitution impact on exports from the home nation. They used the gravity model to study the OFDI and bilateral exports of European member countries of the Organisation for Economic Co-operation and Development (OECD) at the country level and conducted a panel study covering the years 2004–2008 using four distinct econometric methods. According to their findings, OFDI dampens growth in bilateral merchandise exports.

Similarly, Bhasin and Paul (2016) looked at 11 Asia-Pacific nations from 1991 to 2012 to see how OFDI affected domestic exports. Exports and OFDI were shown to be substitutes by means of a panel cointegration and causality test. However, Liu and others (2016) found home nation exports to be heavily reliant on the growth of OFDI. They reached this conclusion by analysing subsets of data from the two primary export and OFDI data sets, using a group of exports from the United States, the OECD nations and China. Their analysis of these two-panel data sets led them to the conclusion that exports rose most rapidly in the early phases of OFDI, with export growth lagging behind OFDI growth as OFDI developed into its mature stage. Ahmed, Draz and Yang (2016), for their part, used

data from 1981 to 2013 for four Association of Southeast Asian Nations (ASEAN) countries to examine the effects of OFDI on those countries' exports, employing an OLS regression model. They determined that in the ASEAN area, the impacts of OFDI on home country exports were mostly of the complementary kind. The effects of OFDI on Costa Rica's domestic economy were studied by Padilla Pérez and Gomes Nogueira (2016), who looked at the specific circumstances of Costa Rican companies with outside operations and identified a favourable correlation notwithstanding the very small size of the country.

Microdata from 552 Chinese manufacturing firms that had invested abroad for various reasons allowed Jia and others (2019) to analyse the impact of OFDI on domestic employment. They applied the difference-in-differences technique to compare two groups of indicators: absolute employment levels and relative employment levels. Overall, they found that OFDI boosted employment whatever its destination. Kapoor and Arora (2022), after disaggregating their data at the country, industry, company and product levels, found that the correlation between OFDI and exports varied. Analyses at the national and business sector levels identified complementary correlations, whereas product-level analyses lent credence to the conventional wisdom.

Overall, the aforementioned research demonstrates three distinct impacts of OFDI on home nation exports. The results of this research are contradictory, with evidence in the literature that OFDI may either boost or reduce domestic exports. The majority of studies cover just one country or a limited number of developing and industrialized nations. Since the proportion of OFDI originating from developing countries has been growing over time, it is crucial to examine OFDI and exports for a large sample of these. Examining whether the correlation between the OFDI and the exports of developing nations changes with a region's development level is equally crucial.

III. Developing countries and outward foreign direct investment

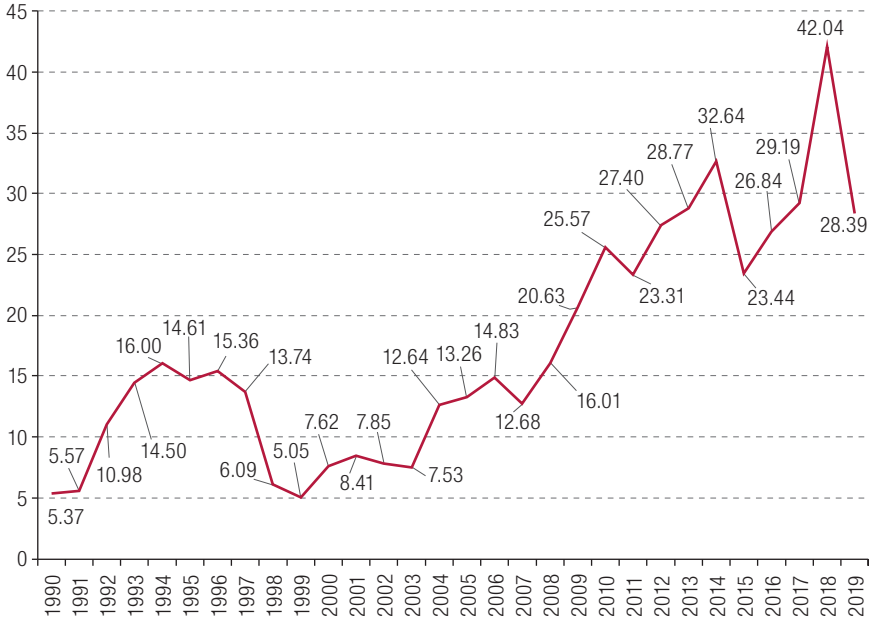
More and more underdeveloped nations are engaging in OFDI, which contributes to the acceleration of globalization. A global total of US$ 1.45 trillion was invested abroad in 2016. In 2017, FDI came in at a record amount of about US$ 1.6 trillion. Revenues from foreign investments were directly affected by the rise in commodity prices. After the Second World War, the industrialized nations of the globe were the main sources of OFDI. The effects of OFDI on the home nations also began to be discussed. Since the 1980s, however, a number of emerging nations have been making significant foreign investments. The uptick in OFDI from such countries meant there was a need for deeper knowledge of the domestic variables behind it. Factors driving investment from developing nations, according to the literature, include the host country's macroeconomic stability, political stability, openness and level of investment in research and technology.

Das (2013) argues that domestic corruption, low per capita incomes and slow economic development are major factors in encouraging OFDI from small developing nations. Natural resources, the accessibility of major markets and the size of the host country's market are other drivers of developing country OFDI (Buckley and others, 2007; Kolstad and Wiig, 2012). According to the *World Investment Report 1995* (UNCTAD, 1995), the percentage of global investment coming from emerging nations more than doubled between 1980–1984 and 1990–1994, from 5% to 10%. In 1995, developing nations were responsible for 15% of all OFDI. Such investment boosts a country's economy because it stimulates the competitiveness of local companies and has other positive effects. However, capital

outflows may also have negative consequences for economies, and although this is recognized, few developing nations have implemented aggressive policies to deal with OFDI. Many of the drivers of greater OFDI from developing nations were summed up in the *World Investment Report 2006* (UNCTAD, 2006). They include a rise in the home country's production costs, improved market and trading conditions and a shift in macroeconomic policy. By 2014, developing nations had increased their foreign investment by 23% to a total of US$ 468 billion, as detailed in the *World Investment Report 2014* (UNCTAD, 2014). The FDI share of this investment rose to 32% in 2014, up from 13% in 2007.

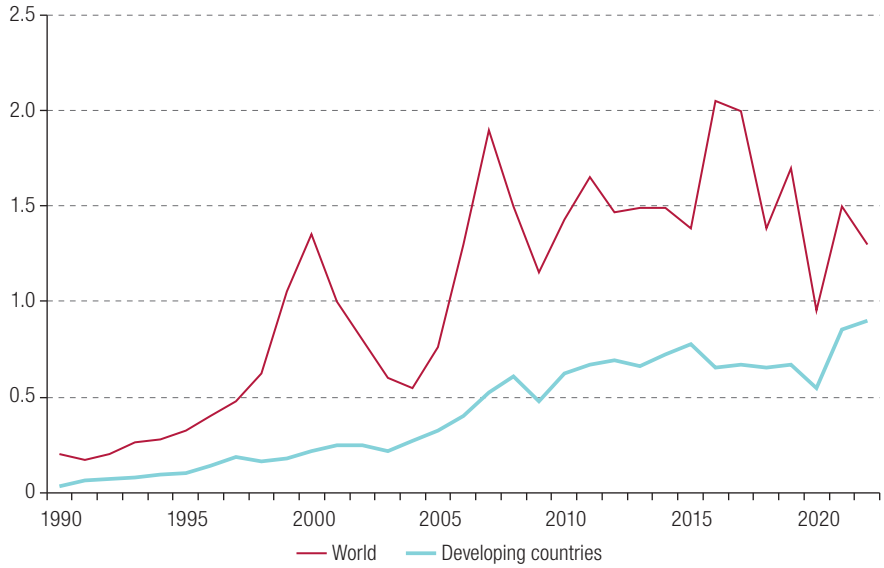
The share of global OFDI from developing countries has been on the rise. Figures 2 and 3 show that they have come to account for a significant portion of overall FDI outflows around the globe, alongside wealthy nations. Greenfield investments have enabled them to increase their share of global output (UNCTAD, 2014). As shown in figure 2, developing nations' proportion of global OFDI has risen steadily from 5.37% in 1990 to 25.57% in 2010 and a record 42% in 2018. However, the percentage of OFDI originating from the low-income category of emerging nations has been lower, owing to severe political and economic upheavals in those countries. Transnational corporations are common in many lower-middle-income and upper-middle-income countries, which are major sources of FDI in many other countries. Owing to massive greenfield projects in areas like steel, electronics and petrochemicals, FDI flows into the manufacturing sector have been on the rise of late (UNCTAD, 2015). Nations in the lower-middle-income and upper-middle-income brackets are increasingly looking to low-cost Asia-Pacific nations as bases for their industrial activity and providing large amounts of FDI.

Figure 2
Share of total world foreign direct investment originating in developing countries, 1990–2019
(Percentages)



Source: United Nations Conference on Trade and Development (UNCTAD), "Investment statistics and trends" [online] www.unctad.org/fdistatistics.

Figure 3
Foreign direct investment originating in developing countries, 1990–2020
(Billions of dollars)



Source: United Nations Conference on Trade and Development (UNCTAD), "Investment statistics and trends" [online] www.unctad.org/fdistatistics.

Table 1 shows the changing pattern of FDI originating in developing nations and regions over time. OFDI has risen most dramatically in Asia and the Pacific. In 2005, the outflow of FDI from the region was a then record US$ 79 billion (see table 1). While services were a primary focus of Asia-Pacific OFDI, a larger proportion of the region's capital outflows went to investments in natural resources and industry. The rapid expansion of the global economy, surging oil consumption and a promising investment climate were the driving forces behind this trend. Although there were fewer worries about geopolitical instability in certain parts of Asia and the Pacific in 2006 than formerly, the trend of increasing OFDI from the region continued. All the major economies and subregions in Asia and the Pacific saw growth. Outflows from the region were mostly driven by China. With the rise of Asia-Pacific transnational corporations, FDI soared to US$ 253 billion in 2007, marking a new high for developing countries. African nations likewise, by expanding their operations both inside and outside the region, increased OFDI to US$ 6 billion in the same year, with South Africa, Egypt, Morocco, Angola and Libya as the leading five countries, with investments in the extraction of raw materials and the expansion of service industries. South Africa played the leading role among these countries.

Brazil and Mexico, the two largest economies in Latin America and the Caribbean, continued to compete with each other for control of gas and oil, steel, mining, cement, food and beverages and other industries that attracted investment from Latin America and the Caribbean. However, a drop in Brazilian outflows led to a reduction in FDI from the region to US$ 52 billion in 2007. According to King Mantilla (2022), research has shown that the net effect of FDI on the balance of payments is influenced by intra-company loans, which are a major driver of FDI proceeds in those economies. Several nations in the region have launched an array of initiatives to foster FDI. The Brazilian State oil corporation, Petrobras, for instance, has expanded its operations to the African continent and the ominican Republic. Extractive sectors were initially the focus of these programmes, but they have now expanded into key areas including agriculture and transportation.

Table 1
Selected regions and economies: outward foreign direct investment
(Billions of dollars)

OFDI	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
World	881	1 323	1 997	1 929	1 101	1 451.4	1 694.4	1 284	1 306	1 354	1 594	1 452	1 601	986	1 314
Developed countries	749	1 087	1 692	1 572	821	989.6	1 237.5	873	834	823	1 173	1 044	1 095	534	917
Developing countries	118	212	253	296	229	400.1	383.8	357	381	468	389	383	467	415	373
Africa	2	8	6	10	5	7	3.5	12	16	13	18	18	12	8	5
Asia and the Pacific	79	141	195	204	210.9	273	280.5	299	335	432	339	363	417	407	328
Latin America and the Caribbean	36	63	52	82	47	119.9	99.7	44	28	23	31	1	38	0.1	42

Source: United Nations Conference on Trade and Development (INCTAD), *World Investment Report*, several issues.

Developed countries' OFDI slowed in 2008. After flows peaked in 2007, the financial crisis and subsequent economic slump in many developed nations impaired and ultimately checked transnational corporations' capacity and willingness to invest in countries outside their own in 2008 and 2009. While FDI flows from emerging countries increased by 3% in mid-2008, they began to dip at the beginning of 2009 as part of a drastic worldwide drop in FDI flows that year. African outbound investment fell by half in 2009 to US$ 5 billion. Asia-Pacific OFDI kept rising in 2009, however. The expansion of China's non-financial FDI abroad was driven by the country's incessant need to replenish its mineral base and by rising OFDI worldwide.

OFDI from China, the Republic of Korea, Singapore and Taiwan Province of China rebounded in 2010. Although the rise in OFDI from developing nations was gradual and modest, it reached a record high of US$ 400.1 billion in 2010, with most of the money being invested within the same area. Global OFDI rose by 17% from 2010 to 2011. Developing country OFDI was US$ 383.8 billion in 2011, down marginally from the previous year. The decline was caused by a combination of factors, including a slowdown in foreign investment growth in emerging Asia and the Pacific and a reduction in capital outflows from Latin America and the Caribbean. Nonetheless, OFDI from emerging and transition economies attained its second-highest level ever.

OFDI from emerging and developing markets increased further in 2014, and vertically integrated businesses headquartered in developing nations spread internationally. A decline in outflows from Latin America and the Caribbean and from Africa was offset by a surge in foreign investment in developing nations by Asia-Pacific multinational corporations. Nearly a third of all FDI came from these multinationals, making them the world's largest foreign investors. Nine of the 20 nations receiving the most FDI were either emerging or transitioning economies. Multinational corporations based in developing countries spent US$ 468 billion on operations abroad in 2014, up 23% from 2013. In 2014, multinational corporations headquartered in emerging Asia and the Pacific increased their foreign investment to US$ 432 billion. This growth was quite extensive, affecting almost every major economy in Asia and the Pacific and adjoining States. That same year, Chinese multinationals invested US$ 143 billion in the East Asia subregion, with this meteoric rise causing the country to become the world's second-biggest investor.

China's outbound investment growth outpaced its inbound investment growth at this time. Nonetheless, OFDI from developing nations as a whole dipped in 2015, with the total amount invested abroad by multinational corporations from developing nations falling by 17% to US$ 389 billion. OFDI from the Asia-Pacific region, which had been the largest investing group in 2014, decreased in 2015. Weak aggregate demand, falling commodity prices and currency depreciation all played a role. OFDI from emerging nations was especially vulnerable owing, among other things, to the slow pace at which new foreign affiliates were opened and acquired. OFDI did increase in a small number of developing nations in 2015, despite the general decline in outflows that year. As an example, China maintained its position as the world's second-largest investor, behind only the United States. China became a major investor in several industrialized countries, chiefly via cross-border ventures. The Latin America and Caribbean region's OFDI increased by 5% as a result of changes in intra-company lending. The global economic slowdown, persistently low aggregate demand and falling earnings for multinational enterprises were all major factors during the 2015 downturn.

OFDI from developing nations fell by 1% in 2016 to US$ 383 billion, after a steeper decline in 2015. This was despite a substantial outflow of FDI from China. However, OFDI from developing nations continued to be substantial, accounting for a major share of FDI from all countries. OFDI shifted its emphasis from maximizing efficiency to expanding into new markets or acquiring new assets. International investment agreements were largely responsible for the increase in OFDI from developing nations, with a wide variety of regional and bilateral agreements being reached.

OFDI from developing nations went into decline in 2017. Investment by Chinese multinationals fell for the second year in a row as a result of government restrictions on investment abroad and heightened scrutiny of inbound investment in the United States and Europe. Foreign investment by Latin American companies experienced its largest decline on record in 2018. Brazil's negative cash outflows and Chile's reduced investment significantly influenced this. As multinational firms continued to channel funds raised on foreign capital markets back to their home countries, the movement of money out of Brazil slowed.

Lower commodity prices, geopolitical concerns and a decline in OFDI from China all contributed to a 19% drop in Asia-Pacific capital outflows to US$ 328 billion in 2018. Because of a decrease in intraregional flows and negative outflows, OFDI from Latin America and the Caribbean totalled just US$ 42 billion.

In general, as a look at recent patterns in developing country OFDI shows, developing economies are continuing to increase their investment in other countries in an effort to integrate into the global economy. Increased market access and domestic competitiveness are two benefits of OFDI. A few nations in the developing world are largely responsible for the rising tide of OFDI, as governments take more active measures to encourage it and provide local enterprises with access to the advantages of investing abroad via measures such as expanding regional agreements. Nonetheless, certain emerging nations' record with outbound investment flows has been quite fragile. It is invariably a financial crisis that ends up undermining them.

Governments should work harder to foster OFDI in order to improve their economies, since this kind of investment boosts a country's competitiveness by strengthening ties between foreign subsidiaries and home businesses. Countries seeking to benefit from FDI and attract money, technology and skilled workers should update their policies with this in view.

IV. Methodology and data

1. Models

This section describes the framework used to investigate the link between OFDI and exports from the investing nation. Various considerations, including transportation costs, the relative size of countries and relative factor endowment, play a role in a firm's choice between exporting and setting up a foreign affiliate, as theorized by Brainard (1997). We concentrate on the model specification that makes exports the dependent variable, OFDI the independent variable and the remaining control factors the explanatory variables. A comprehensive examination of the theoretical and empirical literature underpins our choice of control variables for explaining exports.

To begin, we transform all the numbers into their natural logarithms. Many advantages arise from working with variables expressed in natural logarithm form. Slope parameters of regressors can be easily interpreted in this framework. In relation to a change of 1 percentage point in the regressors, the coefficients of the logged regressors represent partial elasticities of the dependent variable. Putting the variable into logarithmic form may help with the outlier issue.

The following is the equation of the regression model:

$$ln(EPXO)_{it} = \alpha_0 + \alpha_1 ln(OFDI)_{it} + \alpha_2 ln(IFDI)_{it} + \alpha_3\, ln(TOP)_{it} + \alpha_4 ln(EX)_{it} + \alpha_5 ln(RGDP)_{it} + \alpha_6 ln(RGDP_{RW})_{it} + \pi_i + \eta_t + \epsilon_{it} \quad (i = 1, \dots N);\ (t = 1, \dots T) \tag{1}$$

where $EXPO$ denotes exports of goods and services, $OFDI$ outward FDI flows, $IFDI$ inward FDI flows, TOP trade openness, EX the official exchange rate, $RGDP$ real gross domestic product and $RGDP_{RW}$ real gross domestic product in the rest of the world, while ε_{it} is the error term, cross-section-specific effects are represented by τ_i, and η_t represents period-specific effects.

This model is estimated in several steps: first for the full sample of developing countries, then for three subsamples based on development level (low-income, lower-middle-income and upper-middle-income countries) and lastly for the full sample of countries by region (Africa, Asia and the Pacific and Latin America and the Caribbean).

Estimating the effect of OFDI on exports using the model formulated in equation (1) ignores economy size. The effect of OFDI on exports as a percentage of GDP is a more useful metric, since it captures the impact of OFDI on the export sector as a proportion of the domestic economy. In addition to the level form, we thus also consider the following variant of the model:

$$ln(EPXO/RGDP)_{it} = \beta_0 + \beta_1 ln(OFDI/RGDP)_{it} + \beta_2 ln(IFDI/RGDP)_{it} + \beta_3 ln(TOP)_{it} + \beta_4 ln(EX)_{it} + \beta_5 ln(RGDP)_{it} + \beta_6 ln(RGDP_{RW})_{it} + \pi_i + \eta_t + \epsilon_{it} \quad (i = 1, \dots N); (t = 1, \dots T) \tag{2}$$

where $(EXPO/RGDP)$ denotes exports of goods and services relative to real GDP, $(OFDI/RGDP)$ outward FDI flows relative to real GDP and $(IFDI/RGDP)$ inward FDI flows relative to real GDP.

2. Definition of variables

The primary goal of this research is to examine how domestic exports are affected by OFDI. At the same time, the analysis incorporates additional factors that affect domestic exports, including trade openness, the exchange rate, real GDP and other countries' real GDP. Similar factors have been considered in most earlier research, including that by Bojnec and Fertő (2014) and Ahmed, Draz and Yang (2016). Table 2 provides the abbreviations and definitions for all the variables used in the study.

Table 2
Definition of variables

Variable	Abbreviation	Definition
Exports	*EXPO*	Exports of goods and services (current dollars)
Outward foreign direct investment	*OFDI*	Foreign direct investment outflows (current account balance in current dollars)
Inward foreign direct investment	*IFDI*	Foreign direct investment inflows (current account balance in current dollars)
Trade openness	*TOP*	Trade as a percentage of real gross domestic product (GDP)
Exchange rate	*EX*	Official exchange rate (local currency units per dollar, period average)
Real gross domestic product	*RGDP*	Real GDP (constant dollars)
Real gross domestic product (rest of world)	$RGDP_{RW}$	Real world GDP (constant dollars) less home country GDP (constant dollars)

Source: World Bank, "World Development Indicators" [online] https://databank.worldbank.org/source/world-development-indicators.

3. Estimation methodology

Owing to the panel nature of the data, we shall be concentrating on two methods for estimating the panel regression model. Both fixed and random effects models fall within this category. Using these methods, we can regulate the unobserved factors that create the observed individual heterogeneity in the panel data.

The findings may be skewed if panel data are analysed using pooled OLS regression, since this disregards the possibility of bias introduced by the panel data set's inherent individual variability. Independence of the error term ε_{it} is another assumption of OLS. However, owing to subject-level variability, the panel data do not follow this OLS prediction. Therefore, a random or fixed effects approach to estimating the panel regression model should be considered.

The fixed effects method is a well-known way of estimating data panels in the academic literature. The unique qualities of each cross-sectional unit set it apart from all others of the same kind. Models exhibiting these features remain stable over time, and the term i provides an explanation for this in the fixed effects model. This model provides a way of considering how unobserved individual effects could influence the dependent variable. The basic concept is that numerous factors may go unnoticed over the course of the data collection process, and fixed effects account for these overlooked factors. The fixed effects model is useful for minimizing the impact of selection bias owing to missing data by investigating the impact of time and country variables on the results. As defined by Wooldridge (2010), variables that do not appear in the dataset but always influence the dependent variable are omitted variables.

Estimating panel regression models with a random effect is another common method. The random effects model assumes that individual effects (heterogeneity) are independent of all regressors and examines error variance in respect of cross-sections and time frames. The regressor's intercepts and slopes are stable across both people and time periods. It is the precise faults made by each person that differ among people (or time periods) (Park, 2011). If variables are omitted in the data, or if the regressors in the regression and the omitted variables are not associated, the random effects model may provide a way to mitigate the impact of the missing information. It will provide the least biased and most accurate possible estimations of the coefficients.

The fixed effects approach accounts for the connection between regression regressors and unique individual effects, while the random effects approach ignores this connection. A test for choosing between fixed and random effects strategies was proposed by Hausman (1978). The random effects approach is assumed to be beneficial to the model under the null hypothesis in this test, whereas the alternative suggests that the fixed effects approach is beneficial to the model. This test helped us decide between the fixed and random effects models.

4. Data and sources

The following empirical research will use an unbalanced panel data set based on 64 developing nations for which data are available to analyse the effects of OFDI on home country exports from 1990 to 2019. The research uses the World Bank's yearly categorization of developing nations from 1990 to 2019 and additionally categorizes them into three groups based on per capita income: low-income, lower-middle-income and upper-middle-income countries (the World Bank divides countries chiefly by GDP). This research will also attempt to investigate regional variations in this connection by grouping developing nations into three regions: Africa, Asia and the Pacific and Latin America and the Caribbean.

The variables utilized in this study and their definitions are listed in table 2. Exports are what are being measured. Data for the dependent variables and six independent variables (OFDI, IFDI, trade openness, the exchange rate, real GDP and real GDP in the rest of the world) are drawn from the World Development Indicators (WDI) database.

V. Results and interpretations

Equation (1) estimates a model for the impact of OFDI on home country export performance. This analysis is conducted for the full sample of developing countries and for subsamples categorized by development level and geographical location. A transformation was also applied to the level form model

in both the fixed effects and random effects variants, converting it into a form where the variables were relative to real GDP (equation (2)). This allowed us to evaluate the impact of OFDI on exports in a way that took economy size into account across the entire sample of developing nations. The Hausman (1978) specification evaluation was applied to choose the best model from the available static and random effects models. The Hausman test suggests that fixed effects models are more appropriate for estimating overall development, degree of development and regional model classifications in developing nations, whether in level form or relative to real GDP. This implies acceptance of the alternative hypothesis that the fixed effects model is accurate. Tables 3, 4 and 5 present the results of the fixed effects model, illustrating the influence of OFDI on home country exports in developing nations. The tables give the results for emerging economies at both the aggregate level and for subgroupings based on current development status (low-income, lower-middle-income and upper-middle-income countries) and geographical area (Africa, Asia and the Pacific and Latin America and the Caribbean).

Table 3
Selected developing countries (whole sample): fixed effects estimates for the impact of outward foreign direct investment on domestic exports

Independent variable	Dependent variable	
	Exports *(Current dollars)*	Exports *(Percentages of real GDP)*
ln*OFDI*	0.006***	0.008***
ln*IFDI*	-0.0031	-0.0071***
ln*TOP*	0.7712***	0.7123***
ln*EX*	0.0631***	0.0612***
ln*RGDP*	0.0613***	-0.9631***
ln$RGDP_{RW}$	1.4801***	1.4014***
Constant	-22.9618***	-17.9620***
Adjusted R^2	0.9823	0.9736
F-statistic	1 012.13	24 670.50
	(0.0000)	(0.0000)

Source: Prepared by the authors.
Note: ln*OFDI* denotes the logarithm of outward FDI flows, ln*IFDI* of inward FDI flows, ln*TOP* of trade openness, ln*EX* of the official exchange rate, ln*RGDP* of real gross domestic product and ln$RGDP_{RW}$ of real gross domestic product in the rest of the world. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

Table 4
Selected developing countries, by income subgroup: fixed effects estimates for the impact of outward foreign direct investment on domestic exports

Independent variable	Dependent variable					
	Exports *(Current dollars)*			Exports *(Percentages of real GDP)*		
	Low-income	Lower-middle-income	Upper-middle-income	Low-income	Lower-middle-income	Upper-middle-income
ln*OFDI*	0.0021	0.0063***	0.0004	0.0020	0.0079***	0.0124***
ln*IFDI*	-0.0020	-0.059**	0.0069	-0.0068	-0.025***	-0.023**
ln*TOP*	1.0753***	0.8315***	1.0761***	1.0746***	0.5783***	1.0847***
ln*EX*	0.9867***	0.0392	-0.0901	0.9685***	0.0202***	-0.0030
ln*RGDP*	-0.0613***	0.0619***	0.8621***	-1.0316***	-0.774***	-0.0641***
ln$RGDP_{RW}$	-0.0577	1.293***	0.0827***	-0.0642	1.437***	0.0715**
Constant	-4.572***	-25.729***	-7.355***	1.885***	-26.571***	-1.423***
Adjusted R^2	0.9862	0.9988	0.9974	0.9877	0.9570	0.9920
F-statistic	3 561.90	587.83	7 652.19	9 834.32	20 765.15	1 462.09
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Source: Prepared by the authors.
Note: ln*OFDI* denotes the logarithm of outward FDI flows, ln*IFDI* of inward FDI flows, ln*TOP* of trade openness, ln*EX* of the official exchange rate, ln*RGDP* of real gross domestic product and ln$RGDP_{RW}$ of real gross domestic product in the rest of the world. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

Table 5
Selected developing regions: fixed effects estimates for the impact of outward foreign direct investment on domestic exports

Independent variable	Dependent variable					
	Exports *(Current dollars)*			Exports *(Percentages of real GDP)*		
	Africa	Asia and the Pacific	Latin America and the Caribbean	Africa	Asia and the Pacific	Latin America and the Caribbean
ln*OFDI*	0.0061***	0.0004	0.0003	0.0069***	0.0080***	-0.0030
ln*IFDI*	-0.0020	0.0097**	-0.0090***	-0.0079**	0.0154***	-0.0017***
ln*TOP*	0.702***	0.901***	0.976***	0.6950***	0.9012***	0.8921***
ln*EX*	0.5103***	-0.0079	0.0176*	0.5011***	-0.0091	0.0201**
ln*RGDP*	0.0634***	0.307***	0.451***	-0.862***	-0.719***	-0.7281***
ln$RGDP_{RW}$	0.129***	1.728***	0.805***	0.917***	1.398***	0.875***
Constant	-13.571***	-26.478***	-18.124***	-8.945***	-17.982***	-14.124***
Adjusted R^2	0.971	0.993	0.997	0.989	0.986	0.987
F-statistic	498.87	1 836.02	12 986.6	11 443.57	50 143.23	59 984.20
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Source: Prepared by the authors.
Note: ln*OFDI* denotes the logarithm of outward FDI flows, ln*IFDI* of inward FDI flows, ln*TOP* of trade openness, ln*EX* of the official exchange rate, ln*RGDP* of real gross domestic product and ln$RGDP_{RW}$ of real gross domestic product in the rest of the world. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

Considering first how FDI flows out of a country and how it can affect domestic exports, findings for different subgroups of developing nations corroborate the observation for the total sample that the OFDI variable has a considerable positive influence in explaining exports from the home country. Likewise, when the model variables are taken as a percentage of real GDP, the effect is positive and statistically significant for both the lower-middle-income and upper-middle-income groups of developing countries, indicating that OFDI is positively associated with economic growth. This positive and statistically significant impact indicates that the OFDI of a nation boosts domestic exports by way of vertical integration. According to Desai, Foley and Hines (2005), vertically integrated FDI boosts exports of intermediate products from the home nation to the host market, which might account for these complementarities. Companies in the lower-middle-income and upper-middle-income ranges of emerging nations have the financial wherewithal to set up operations abroad, where they may take advantage of cheaper labour and materials. The positive but inconsequential impact of OFDI in the low-income nations group may be attributed to the fact that low-income countries' OFDI is concentrated in the service sector and is thus not likely to have a major impact on exports.

In addition, when developing nations are compared by region, we discover that OFDI has a positive and significant influence on African exports, but when we turn to the model in which the variables are expressed as a percentage of real GDP, we find that it has a positive and significant effect on exports in both Africa and Asia and the Pacific. This is more pronounced in Asia and the Pacific, perhaps because of its higher rate of OFDI in other regions. To obtain more accurate findings and a more transparent view of the different economies, we converted the level form model into a percentage of GDP model in this research. The high volatility of OFDI from Latin America and the Caribbean suggests that the negatively insignificant impact of FDI on home country exports there is due to the fact that the vast bulk of the region's OFDI is simply horizontal or market-seeking FDI to overcome customs obstacles by producing abroad as an alternative to exporting (Dunning, 1993).

Our results hold up well in comparison to those of other investigations, including those by Chen, Hsu and Wang (2012), Qiang (2013), Bojnec and Fertő (2014) and Bhasin and Paul (2016).

The income analysis reveals that, in both the level form model and the model specified in terms of GDP, IFDI into emerging economies proves to be a quite significant negative variable for domestic exports in both the lower-middle-income and upper-middle-income groups. The regional analysis reveals

that Africa and Latin America and the Caribbean are the only emerging world regions where the IFDI coefficient is negatively significant. This negative impact suggests that IFDI leads to the introduction of harsh competition in the reporting economy, which in turn drives out prospective but extremely weak exporters, i.e. that IFDI is flooding the local market and displacing local producers. The low IFDI ratio in low-income developing countries has a negligible impact on domestic exports because of the weak infrastructure and political instability in these nations. Large amounts of IFDI into the extractive sectors of the Asia-Pacific region are having a profoundly favourable impact on the region's export growth. Similar results were found by Tufa and Tashu (2015) and Zhang (2005).

In both the whole sample and its income and geographical subgroups, domestic export volumes are positively correlated with the degree to which an economy is open to trade. This impact shows that the benefits of increased export demand are a direct result of trade liberalization. According to the Santos-Paulino (2002) synopsis, exports expand at a higher rate in more liberal countries. The United States International Trade Commission (USITC, 2003) and Abbas (2014) corroborate the favourable correlation between economic openness and exports.

The exchange rate is a crucial positive factor affecting exports from developing countries. This impact is strongest for emerging nations with low and moderate per capita incomes. In Africa and Latin America and the Caribbean, the exchange rate has the same beneficial impact on exports. A rise in exports is associated with a positive coefficient, suggesting that currency depreciation boosts exports. For emerging nations in the upper-middle-income class and in Asia and the Pacific, the impact of the exchange rate is minimal.

Both the overall and subgroup effects of real GDP are substantial, although it has a positive influence only in the level form model, with the exception of low-income nations, where it inversely affects exports. However, in the relative form model, the higher negative impact of real GDP is realized at the general level and it is all subgroupings of developing nations. Increased economic activity equals greater aggregate domestic demand and thus fewer resources available for export. Dodaro (1993), Anwer and Sampath (1997) and Sohn (2005) all find similar associations.

Lastly, rest of the world GDP has a very substantial positive influence on exports for all countries in the sample and the income and geographical subgroupings. The reason this variable is good for domestic exports is that demand for exports rises whenever it does. The connection is supported by Bojnec and Fertő (2014). The high adjusted R^2 values suggest that the model estimates have considerable predictive ability. Even when the model is converted into GDP terms, R^2 values remain quite strong. F-statistic p-values suggest that the data support a good fit with the model.

VI. Conclusions and policy implications

Exports have been shown to be positively correlated with OFDI in both absolute terms and as a percentage of real GDP. The findings of the relative form model, however, demonstrate a complementary effect of OFDI on home country exports in the aggregate for developing nations, and are therefore more relevant for understanding the impact of OFDI on home country exports. Low-income nations experience little effect from OFDI, but lower-middle-income and upper-middle-income emerging economies see a positive correlation between OFDI and exports. This synergy might be the result of vertically integrated investment that boosts exports of local intermediate inputs to the market of the host nation. Firms in developing nations with lower-middle to upper-middle levels of income can afford to set up operations abroad, where they can take advantage of the cheaper labour and materials on offer. When looking at the effect of OFDI on exports from developing countries, we find it to have a positive effect on exports from both Africa and Asia and the Pacific, although more complementarity is found in Asia and the Pacific

when the real GDP form model is considered. This is because a significant portion of overall FDI outflows from poor nations originate there, and the region is reaping the rewards in the form of higher exports from the home countries. There are important policy consequences from this research. Our findings will help countries with local enterprises that have both domestic and foreign operations make decisions about OFDI and its influence on exports. A proactive approach to OFDI is necessary for policymakers in developing nations owing to the enormous influence that OFDI has on the performance of exports from those countries' domestic markets. For developing nations to reap the benefits of OFDI in the form of exports, governments must remove obstacles to local enterprises investing abroad.

Policymakers in developing nations will be able to better assess whether or not their country should invest abroad if they compare the impact of OFDI on home country exports across developing countries by their degree of development. Regional enterprises may use this research to determine whether they would benefit more from engaging in vertical FDI, horizontal FDI or technology-sourcing FDI while providing manufacturing services abroad. This study will contribute to the understanding and framing of OFDI policies to enhance developing nations' export performance.

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Annex A1

Developing countries included in the research

Table A1.1
Full sample of countries

1. Algeria	33. Jamaica
2. Angola	34. Jordan
3. Argentina	35. Kenya
4. Bangladesh	36. Lao People's Democratic Republic
5. Benin	37. Libya
6. Bolivia (Plurinational State of)	38. Madagascar
7. Botswana	39. Malawi
8. Brazil	40. Malaysia
9. Bulgaria	41. Mali
10. Burkina Faso	42. Mauritius
11. Burundi	43. Mexico
12. Cabo Verde	44. Morocco
13. Cambodia	45. Namibia
14. Cameroon	46. Niger
15. China	47. Nigeria
16. Colombia	48. Pakistan
17. Congo	49. Panama
18. Costa Rica	50. Papua New Guinea
19. Dominican Republic	51. Paraguay
20. Egypt	52. Peru
21. El Salvador	53. Philippines
22. Eswatini	54. Republic of Moldova
23. Fiji	55. Romania
24. Gabon	56. Russian Federation
25. Ghana	57. Senegal
26. Guatemala	58. Sierra Leone
27. Guinea	59. South Africa
28. Guinea-Bissau	60. Sri Lanka
29. Guyana	61. Thailand
30. Honduras	62. Togo
31. India	63. Türkiye
32. Iran (Islamic Republic of)	64. Venezuela (Bolivarian Republic of)

Source: Prepared by the authors.

Table A1.2
Countries by income level

Low-income countries	Lower-middle-income countries	Upper-middle-income countries
Bangladesh	Algeria	Argentina
Benin	Angola	Botswana
Burkina Faso	Bolivia (Plurinational State of)	Brazil
Burundi	Bulgaria	Costa Rica
Cambodia	Cabo Verde	Gabon
Ghana	Cameroon	Libya
Guinea	China	Malaysia
Guinea-Bissau	Colombia	Mauritius
India	Congo	Mexico
Kenya	Dominican Republic	Panama
Lao People's Democratic Republic	Egypt	Russian Federation
Madagascar	El Salvador	South Africa
Malawi	Eswatini	Türkiye
Mali	Fiji	Venezuela (Bolivarian Republic of)
Niger	Guatemala	
Nigeria	Guyana	
Pakistan	Honduras	
Senegal	Iran (Islamic Republic of)	
Sierra Leone	Jamaica	
Togo	Jordan	
	Morocco	
	Namibia	
	Papua New Guinea	
	Paraguay	
	Peru	
	Philippines	
	Republic of Moldova	
	Romania	
	Sri Lanka	
	Thailand	

Source: Prepared by the authors.

Table A1.3
Countries by region

Africa	Asia and the Pacific	Latin America and the Caribbean
Algeria	Bangladesh	Argentina
Angola	Bulgaria	Bolivia (Plurinational State of)
Benin	Cambodia	Brazil
Botswana	China	Colombia
Burkina Faso	Fiji	Costa Rica
Burundi	India	Dominican Republic
Cabo Verde	Iran (Islamic Republic of)	El Salvador
Cameroon	Jordan	Guatemala
Congo	Lao People's Democratic Republic	Guyana
Egypt	Malaysia	Honduras
Eswatini	Pakistan	Jamaica
Gabon	Papua New Guinea	Mexico
Ghana	Philippines	Panama
Guinea	Republic of Moldova	Paraguay
Guinea-Bissau	Romania	Peru
Kenya	Russian Federation	Venezuela (Bolivarian Republic of)
Libya	Sri Lanka	
Madagascar	Thailand	
Malawi	Türkiye	
Mali		
Mauritius		
Morocco		
Namibia		
Niger		
Nigeria		
Senegal		
Sierra Leone		
South Africa		
Togo		

Source: Prepared by the authors.

Annex A2

Hausman test results

Table A2.1
Hausman test results for the full sample of countries

Dependent variable	Exports *(Current dollars)*	Exports *(Percentage of real GDP)*
Chi-statistic	314.789	234.987
Probability	(0.0000)	(0.0000)

Source: Prepared by the authors.

Table A2.2
Hausman test results by countries' development level

Dependent variable	Exports *(Current dollars)*			Exports *(Percentages of real GDP)*		
	Low-income	Lower-middle-income	Upper-middle-income	Low-income	Lower-middle-income	Upper-middle-income
Chi-statistic	22.76	83.98	29.27	49.68	51.4397	29.64
Probability	(0.0135)	(0.0000)	(0.0000)	(0.0924)	(0.0000)	(0.0000)

Source: Prepared by the authors.

Table A2.3
Hausman test results by region

Dependent variable	Exports *(Current dollars)*			Exports *(Percentages of real GDP)*		
	Africa	Asia and the Pacific	Latin America and the Caribbean	Africa	Asia and the Pacific	Latin America and the Caribbean
Chi-statistic	123.81	179.76	119.32	109.87	139.65	141.65
Probability	(0.0000)	(0.0000)	(0.0000)	(0.0190)	(0.0000)	(0.0000)

Source: Prepared by the authors.

Sustainability and development in the municipalities of the State of Paraná: mapping and analysis using the sustainable city development index of Brazil (IDSC-BR)[1]

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Abstract

In consideration of the importance that the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development have acquired in the economic, social and environmental spheres, this article uses the sustainable city development index of Brazil (IDSC-BR) methodology to map SDG attainment in the 399 municipalities of Paraná. The main findings reveal that the municipalities with the lowest SDG fulfilment scores are concentrated in the central region of Paraná. Analysing the results by the individual Goals, the State performed best with Goal 11, sustainable cities and communities (89.52%), Goal 7, affordable and clean energy (85.11%), and Goal 12, responsible production and consumption (75.64%). At the same time, the Goals where compliance faces the greatest challenges are Goal 15, life on land (16.83%), Goal 14, life below water (26.02%), and Goal 17, partnerships for the goals (33.25%).

Keywords

Cities, sustainable development, 2030 Agenda for Sustainable Development, Sustainable Development Goals, measurement, urban management, municipal government, statistical data, development indicators, Brazil

JEL classification

D63, F63, H75, I31

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I. Introduction

Theories of economic development gained great importance in the political and social spheres after the end of World War II. This was largely on account of the reconstruction efforts undertaken in countries devastated by the war, which revealed a new scenario conducive to a global commitment towards economic stability.

One of the consequences of that global commitment was the creation of the United Nations, founded in 1945 and currently comprising 193 Member States, in order to maintain international peace and security, provide humanitarian assistance, protect human rights and uphold international law.

The United Nations is now undertaking a task that was not envisioned by its founders but derives from decades of global research and analysis: the definition of the 2030 Agenda for Sustainable Development's 17 SDGs, to be achieved between 2016 and 2030 in order to secure a better and more sustainable future for all. Essentially, SDGs address the global challenges the world faces, such as poverty, inequality, environmental damage, climate change, peace and justice.

Those aspirations, on which the Member States of the United Nations embarked in 2015, were embodied in the document *Transforming Our World: The 2030 Agenda for Sustainable Development*: a global plan to achieve, by 2030, a better world for all peoples and nations, by eradicating poverty, protecting the planet's climate and environment, and promoting peaceful and inclusive societies.

In order to achieve SDGs by 2030, local and regional governments must be brought on board as the main actors responsible for pursuing initiatives towards the 2030 Agenda. Performance in pursuit of SDGs is measured by means of indicators, which summarize a range of data and provide inputs for planning and oversight in public management, allowing the achievement of SDGs to be monitored.

In parallel, the sustainable city development index of Brazil (IDSC-BR) was published in March 2021. A tool for assessing progress in meeting SDGs in the country's municipalities, it comprises 88 indicators that report results in such areas as health, poverty, education and equality. IDSC-BR was used to map 770 municipalities, of which only 110 were in Paraná. Since 289 municipalities in the State were omitted from that first study, the aim of this paper is to fill the gap, covering all of Paraná's 399 municipalities and updating the indicators with the data available at the time the study was prepared.

In that context, in order to measure the degree of compliance with SDGs at the municipal level, this study aims to answer the following question: What challenges with SDG compliance in Paraná are revealed by applying the IDSC-BR component indicators to the State's 399 municipalities?

The paper is divided into five sections, including this introduction, in which the subject is presented. The second section briefly reviews the literature and theoretical framework for sustainable development, with some ideas from various economists including, in particular, Amartya Sen, Jeffrey Sachs, Raúl Prebisch and Fernando Fajnzylber. The third section describes the materials and method used in the research and data analysis, the results of which are presented in the fourth section. Lastly, the fifth section offers some final thoughts.

II. Sustainable development

The study of economic development can be divided into three phases. The first, up to 1950, covers a period when the economic literature drew no distinction between the concepts of development and growth. During the second phase, which ran from 1950 to 1990, some differences between those concepts began to emerge. Lastly, in the third phase, from 1990 to the present, a debate is taking place on the idea that economic development is different from sustainable development, because the latter takes account of productive, social and environmental issues (Moretto and Giacchini, 2005, p. 3).

Historically, since 1959, various authors studying economic development have addressed issues and adopted approaches that go beyond exclusively economic matters to deal with issues such as education, public management, political science, sociology, biology and earth sciences. That was the context that saw the emergence of the United Nations and its specialized agencies and the contributions they have made (Barbieri, 2020).

An example of this is found in a study by Sen (1999), which states that development consists of the removal of various types of "unfreedoms" that leave people with little choice and little opportunity of exercising their reasoned agency (Sen, 1999, p. xii). In other words, development is only possible when people are no longer subjected to constraints on their capabilities.

The author gives an example of how the absence of essential freedoms relates directly to economic poverty, which robs people of the freedom to satisfy hunger, or to achieve sufficient nutrition, or to obtain remedies for treatable illnesses, or the opportunity to be adequately clothed or sheltered, or to enjoy clean water or sanitary facilities (Sen, 1999, p. 4).

In the early 1970s, the concept of sustainable development began to take shape from United Nations studies on climate change and environmental degradation. This concept, which aims to reconcile economic development, social development and respect for the environment, is now an essential topic of discussion in a wide range of organizations, including debates on municipal and regional development (Gonçalves, 2005).

Sachs (2005) also emphasizes well-being, stating that making the world a better place is within our reach, and that all people can and should enjoy basic levels of nutrition, health, shelter, water and sanitation, as well as other minimum needs for survival, well-being and agency within society.

The author argues that public authorities should intensify their efforts in five types of investment: human capital (nutrition, health, education), natural capital (biodiversity and ecosystems), infrastructure (water, sanitation, energy), public institutional capital (judicial system, well-managed government services) and knowledge capital (scientific research in various areas) (Sachs, 2005).

In the context of Latin America and the Caribbean, the sustainable development concept has been addressed within the Economic Commission for Latin America and the Caribbean (ECLAC), which was established in Santiago in 1948. One of the five regional commissions of the United Nations, its functions include contributing to the economic development of Latin America and the Caribbean, coordinating actions and strengthening economic ties among the region's countries and with other nations of the world, and implementing and monitoring SDGs in its member States (ECLAC, 2021b).

By 1980, Prebisch had already begun to address the issue of sustainable development, arguing that the socioeconomic model of the "centres" led to the depredation of natural resources and environmental degradation, which underscored the need to adopt an alternative development model specific to Latin America and the Caribbean (ECLAC, 2021c).

In light of the impact of the Club of Rome's report *The Limits to Growth*, Prebisch (1980) analysed sustainable development in the context of the second oil crisis, which took place in 1979. From the environmental perspective, the irrational exploitation of this energy resource would have serious consequences. From the economic point of view, rising oil prices would have a strong inflationary effect that would reduce economic activity in the countries affected —primarily those of the "centre"— due to the unequal distribution of the fruits of the increased productivity of technology (ECLAC, 2021c).

Similarly, Prebisch (1987) noted that the technological progress arrived in the countries of the periphery —and was spread there— more slowly and more unequally. As a result, the penetration of technical progress into activities oriented to exports of primary products became a characteristic of the heterogeneous structure, as a result of which those countries were left on the margins of development (Prebisch, 1987).

The term "structural heterogeneity", introduced in the 1970s by Aníbal Pinto (1970), accurately explains the characteristics of Latin American economies (ECLAC, 2021a). The author's starting point was his discovery that "the fruits of technical progress tended to be concentrated, in terms of the distribution of income both between the classes and between sectors (strata) and between regions of a given country" (Bielschowsky, 2016, p. 23). In other words, developing countries with an uneven penetration of technology reported disparities between sectors and regions, reflecting a heterogeneous economic structure:

> Thus, the distribution of different activities in a nation can lead to regional disparities related to the greater dynamism made possible by the presence of the most productive activities in certain regions, to the detriment of others characterized by activities with a lower degree of economic dynamism. This gives rise to regional contrasts that are frequently found in underdeveloped countries (Santos and Oliveira, 2008, p. 13).

In examining the neo-structuralist phase of ECLAC, Fajnzylber (1992a and 1992b) works from the assumption that a fundamental relationship exists between technical progress, sustainability and competitiveness, which can be made compatible with growth and equity: competitiveness can contribute to both economic growth and equity, but solving the equity problem requires redistributive social public policies.

Therefore, in establishing this link between sustainable development and competitiveness, Fajnzylber argued that production respectful of environmental standards would contribute to productive excellence and, consequently, to international insertion and growth (Torres, 2006).

In response to these issues, the 2030 Agenda and its SDGs address many of the main structural problems facing Latin America and the Caribbean and propose the formation of partnerships to establish new development guidelines that place equality at the centre of the development agenda. They also seek to reduce asymmetries between countries through a global compact for financing and technology transfer, which are highly unequal in Latin America and the Caribbean (United Nations, 2016).

The 2030 Agenda's 17 SDGs are listed on table 1, broken down by their focus and dimensions.

Table 1
Sustainable Development Goals and their dimensions

Focus	Dimension	Goal
People	Social	(1) *No poverty* – End poverty in all its forms everywhere. (2) *Zero hunger* – End hunger, achieve food security and improved nutrition and promote sustainable agriculture. (3) *Good health and well-being* – Ensure healthy lives and promote well-being for all at all ages. (4) *Quality education* – Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. (5) *Gender equality* – Achieve gender equality and empower all women and girls. (6) *Clean water and sanitation* – Ensure availability and sustainable management of water and sanitation for all. (7) *Affordable and clean energy* – Ensure access to affordable, reliable, sustainable and modern energy for all. (11) *Sustainable cities and communities* – Make cities and human settlements inclusive, safe, resilient and sustainable.
Planet	Environmental	(12) *Responsible production and consumption* – Ensure sustainable consumption and production patterns. (13) *Climate action* – Take urgent action to combat climate change and its impacts. (14) *Life below water* – Conserve and sustainably use the oceans, seas and marine resources for sustainable development. (15) *Life on land* – Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
Prosperity	Economic	(8) *Decent work and economic growth* – Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all. (9) *Industry, innovation and infrastructure* – Build resilient infrastructure, promote sustainable industrialization and foster innovation. (10) *Reduced inequalities* – Reduce income inequality within and among countries.
Peace	Political and institutional	(16) *Peace, justice and strong institutions* – Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
Partnerships		(17) *Partnerships for the goals* – Strengthen the means of implementation and revitalize the global partnership for sustainable development.

Source: Prepared by the authors, on the basis of J. Barbieri, *Desenvolvimento sustentável: das origens à Agenda 2030*, Petrópolis, Editora Vozes, 2020.

The icons used to illustrate and publicize the 17 SDGs are shown in diagram 1.

Diagram 1
Sustainable Development Goals

Source: United Nations, "Sobre o nosso trabalho para alcançar os Objetivos de Desenvolvimento Sustentável no Brasil", Brasília, 2021 [online] https://brasil.un.org/pt-br/sdgs.

III. Sustainable city development index of Brazil (IDSC-BR)

In order to monitor SDGs at the local (municipal) level, the Sustainable Cities Institute, through its Sustainable Cities Programme, created the sustainable city development index of Brazil (IDSC-BR).

The IDSC-BR methodology was developed by the Sustainable Development Solutions Network. The index provides a useful and effective tool for public management and political action in Brazilian municipalities (ICS, 2021), which is designed to facilitate the monitoring of the municipalities' progress and challenges in meeting the 2030 Agenda through the use of data and statistics.[2]

The index allows broad assessments of the shortfall in achieving the SDG targets in 770 Brazilian municipalities, based on 88 indicators calculated with the most up-to-date figures (generally from between 2010 and 2019) available at the national level from public and official sources (ICS, 2021).[3]

The construction of the IDSC-BR can be summarized in three stages: (i) correction of outliers at the lower end of the distribution, (ii) normalization of data using the values set as performance targets, in order to ensure comparability between indicators, (iii) aggregation of the indicators within each SDG (mean) and estimation of the overall mean across all SDGs to calculate the final IDSC-BR score (ICS, 2021).

[2] The United Nations Sustainable Development Solutions Network was created in 2012 on instructions from the United Nations Secretary-General. The Sustainable Development Solutions Network mobilizes global scientific and technological expertise to identify practical solutions for sustainable development, including the implementation of SDGs. It works in close collaboration with United Nations agencies, funding institutions, the private sector and civil society (Sustainable Development Solutions Network, 2021).

[3] For a description of the 88 indicators, see ICS (n.d.).

Once the upper and lower limits for each indicator have been identified, the methodology provides for the normalization of the municipalities' data using the following *min-max* formula:[4]

$$x' = \frac{x - min(x)}{max(x) - min(x)} * 100$$

Where x is the raw value, min indicates the lower limit, max indicates the upper limit and x' is the normalized value (ICS, 2021).

Normalization of the values ensures that they are all expressed in ascending order (when higher values indicate better performance) or descending order (when lower values indicate better performance). In this way, the indicators can be compared and analysed: if a municipality scores 50 (i.e. 50%) on an indicator, it is halfway to the optimal (target) value at which a given SDG is deemed fulfilled (ICS, 2021).

Once the value for each indicator has been determined, scores are calculated for each of the 17 SDGs. For this, the arithmetic mean of all that Goal's indicators is used. Lastly, the average of all SDGs is calculated and the result is obtained, expressed by the index per municipality (ICS, 2021).

Index scores range from 0 to 100, with 100 indicating optimal performance. Thus, the difference between a municipality's score and 100 is the distance in percentage points that the municipality needs to travel to attain optimal performance in SDGs (ICS, 2021).

The IDSC-BR consists of 88 indicators that report data for a single year for each indicator, covering the years 2010 and 2019. For this paper, the indicators were updated with the data available for 2020. Primarily because of the large volume of data, the indicators do not have a historical series for comparison; instead, they offer a "snapshot in time". To address that limitation and to ensure a better understanding of the data extraction process, the indicators and the most recent base years used are presented in table A1.1 in the annex.

Another limitation of this paper is that (only) one of the 88 indicators that make up the IDSC-BR is not included in the research. The indicator "percentage of municipality deforested", which corresponds to Goal 13 (Climate Action), could not be applied because the construction method in the description was lacking in clarity. Since Goal 13 uses two indicators, the absence of this indicator does not affect its analysis.

IV. Results

In a first analysis, the indicator results were used to calculate the average score achieved by the municipalities with respect to each SDG.[5]

Next, the ranking of Paraná's municipalities in terms of overall SDG compliance was calculated, as indicated by their final indicator scores: i.e. their final average with respect to all SDGs. The result is shown in table A2.1 in annex A2. Note that the overall scores range from 0% to 100% and that a score of 100% indicates optimal performance in meeting SDGs.

All the data were prepared, formatted and processed using Microsoft Excel, in .xlsx format, while the maps were produced using the QGIS software package.

The results show that Paraná's most sustainable municipality was Capanema, with a score of 68.68%. That result means, in other words, that the city achieved just under three quarters of the optimal SDG attainment level. According to the 2010 census, this municipality —located in the geographical mesoregion

[4] For each indicator's upper and lower limits, see ICS (n.d.).

[5] Owing to the volume of data, the inclusion of a table with all the results obtained was not possible. The file is therefore available for viewing on Google Drive [online] https://drive.google.com/file/d/1OsEHRI1ouWSm_oJPlvU7YDZKyGYclZoZ/view?usp=sharing.

of southwestern Paraná, near Cascavel— has 18,526 inhabitants. Its economy revolves around rural activities, mainly soybean and corn cultivation and livestock raising, with dairy cattle, poultry, pigs and beekeeping (Municipality of Capanema, 2020).

Capanema was notable primarily on account of its outstanding results with the following Goals (see table 2): Goal 12, responsible production and consumption, which covers the indicators for household waste and population served by selective waste collection (maximum score); Goal 15, life on land, covering data on conservation areas for comprehensive protection and sustainable use (maximum score); Goal 11, sustainable cities and communities, with a score of 97.09%, indicating good management of the population and favela households, as well as small numbers of low-income people needing more than an hour to commute to work; Goal 16, peace, justice and strong institutions; and Goal 7, affordable and clean energy, with scores above 90%, indicating good results for homicides and deaths from assault and firearms, and a high number of households with access to electricity.

Table 2
Brazil: final average of sustainable city development index of Brazil (IDSC-BR) for municipalities of Capanema, Rio Branco do Sul and Curitiba, by SDG
(Percentages)

Sustainable Development Goals	Capanema	Rio Branco do Sul	Curitiba
1. No poverty	54.41	56.78	62.72
2. Zero hunger	63.91	39.35	46.19
3. Good health and well-being	59.09	45.97	63.61
4. Quality education	66.77	45.28	59.37
5. Gender equality	64.78	17.99	37.79
6. Clean water and sanitation	55.65	47.18	89.02
7. Affordable and clean energy	90.46	85.03	93.65
8. Decent work and economic growth	65.99	64.16	70.10
9. Industry, innovation and infrastructure	51.47	70.98	54.48
10. Reduced inequalities	72.98	73.18	62.36
11. Sustainable cities and communities	97.09	38.60	34.13
12. Responsible production and consumption	100.00	50.00	100.00
13. Climate action	52.35	0.00	91.62
14. Life below water	50.71	0.00	90.99
15. Life on land	100.00	0.29	67.85
16. Peace, justice and strong institutions	91.94	12.75	15.04
17. Partnerships for the goals	30.06	12.20	44.49
Final average	68.68	38.81	63.73

Source: Prepared by the authors.

In contrast, the least sustainable municipality was Rio Branco do Sul, which scored only 38.81 out of a possible 100 points. The city scored particularly poorly on SDGs related to the environment (untreated wastewater, high levels of carbon dioxide equivalent (CO_2e) emissions per capita and low coverage of conservation areas for comprehensive protection and sustainable use), social peace (high homicide rate, high number of deaths by assault and firearms), means of implementation (low levels of per capita public investment) and gender equality (high rate of femicides).

The economy of the city of Rio Branco do Sul is mainly focused on the extraction of minerals, such as cement and lime, and there are several factories in the municipality. Agricultural activities are also present, including corn and mandarin crops and poultry raising (The Cities, 2021).

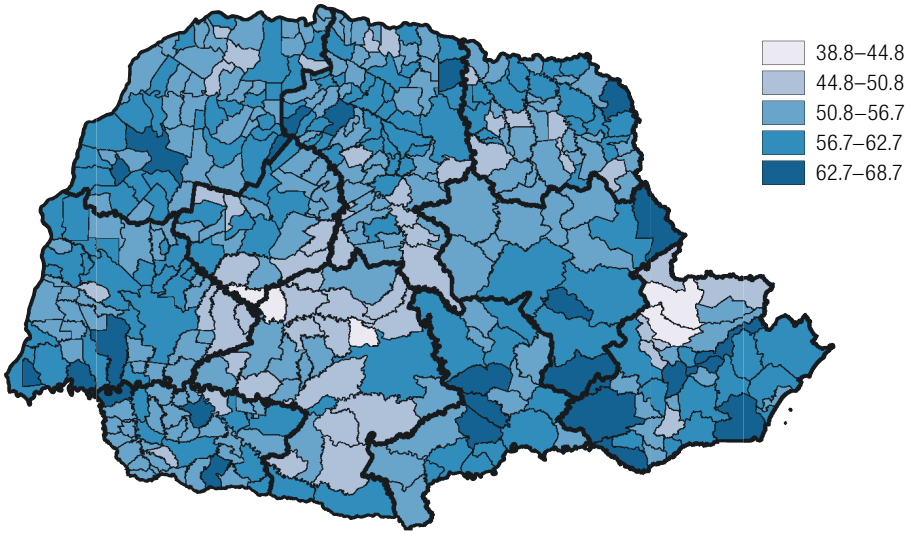
Curitiba, the capital of Paraná, ranked 15th in the ranking with a score of 63.73 out of a possible 100: i.e. slightly above halfway to optimal SDG performance. The capital obtained its best scores with those SDGs that address the environmental dimension: Goal 12, responsible production

and consumption, which covers the indicators for household waste and population served by selective waste collection; Goal 7, affordable and clean energy, given the high number of households with access to electricity; Goal 13, climate action, with low per capita carbon dioxide equivalent (CO_2e) emissions; and Goal 14, life below water, indicating good treatment of wastewater before it reaches the sea, rivers and streams.

In contrast, the capital's worst scores were for Goal 16, peace, justice and strong institutions, which covers indicators relating to homicides and mortality rates from assaults and firearms, and Goal 11, sustainable cities and communities, which records data on the population living in irregular settlements and the number of favela households. These negative results could be related to people migrating in search of work who do not always find adequately paying jobs, which aggravates the municipality's social problems and the city's difficulties in creating and directing public housing policies.

Map 1 shows the results of classifying the municipalities of Paraná's mesoregions by means of a heat map.

Map 1
Brazil: achievement of Sustainable Development Goals in the State of Paraná
(IDSC-BR, percentages)



Source: Prepared by the authors.

Note that 44 of the 399 municipalities in Paraná scored below 50%: in other words, they are not even halfway to achieving the commitments set by the 2030 Agenda. The scores for the remaining 355 municipalities ranged from 50% and 68.7%, indicating moderate levels of compliance and that they still have major challenges to overcome in order to achieve SDGs. No municipality scored more than 80% and, therefore, according to the index's methodology, SDGs cannot be considered fully achieved in any of Paraná's municipalities.

From another perspective, when the municipalities are classified by population size, table 3 shows the averages achieved with respect to each SDG by number of inhabitants. For ease of display, those SDGs with scores below the total average of the 399 municipalities are marked in orange and those above the total average in green.

Table 3
Brazil: achievement of Sustainable Development Goals in municipalities of the State of Paraná, by number of inhabitants
(IDSC-BR, percentages)

Goal	Average of 399 municipalities	Up to 5 000 inhabitants	From 5 001 to 10 000 inhabitants	From 10 001 to 20 000 inhabitants	From 20 001 to 50 000 inhabitants	From 50 001 to 100 000 inhabitants	From 100 001 to 500 000 inhabitants	More than 500 000 inhabitants
Goal 1	51.83	48.18	50.40	53.05	54.35	59.05	58.75	64.63
Goal 2	54.08	54.48	54.98	54.64	52.62	52.40	49.58	44.75
Goal 3	64.39	68.27	66.97	63.04	58.33	58.43	59.75	58.72
Goal 4	62.91	66.22	62.87	61.00	61.48	62.39	61.13	63.27
Goal 5	38.05	46.71	40.01	34.61	29.70	30.23	31.25	36.73
Goal 6	66.42	62.18	63.68	66.56	70.08	79.81	82.65	85.23
Goal 7	85.11	83.79	81.97	85.51	89.64	88.99	90.93	93.96
Goal 8	59.06	58.87	58.41	58.57	59.12	61.11	64.79	67.19
Goal 9	51.27	50.51	50.72	52.13	52.33	52.66	49.29	46.82
Goal 10	74.60	77.08	76.11	73.48	72.01	72.11	69.48	63.39
Goal 11	89.52	94.21	93.02	91.54	86.95	65.02	60.10	43.81
Goal 12	75.64	68.58	75.05	78.04	78.35	77.21	92.74	100.00
Goal 13	43.29	26.81	33.20	47.53	61.75	78.97	81.02	91.05
Goal 14	26.02	3.70	11.37	34.38	54.12	65.55	62.89	89.16
Goal 15	16.83	4.90	11.70	20.70	23.32	31.73	59.69	34.31
Goal 16	53.95	76.00	68.15	43.64	29.80	18.56	14.57	16.08
Goal 17	33.25	34.37	32.83	31.07	33.73	33.43	41.07	43.10

Source: Prepared by the authors.
Note: Scores below the overall average for the 399 municipalities are marked in orange and scores above that average are shown in green.

The results on table 3 can be divided into three groups. The first, comprising the 203 municipalities in the population categories "up to 5,000" and "5,001 to 10,000", which are classified as "small", presented several similar results and so can be grouped together. In broad terms, they were above average with respect to the following Goals: 2, zero hunger; 3, good health and well-being; 5, gender equality; 10, reduced inequalities; 11, sustainable cities and communities; and 16, peace, justice and strong institutions. Similarly, they were below average for the following Goals: 1, no poverty; 6, clean water and sanitation; 7, affordable and clean energy; 8, decent work and economic growth; 9, industry, innovation and infrastructure; 12, responsible production and consumption; 13, climate action; 14, life below water; and 15, life on land. In other words, these municipalities fell short mainly in those SDGs relating to the environment and the economy.

The second group, comprising 87 medium and large municipalities in the population categories "20,001 to 50,000", "50,001 to 100,000", "100,001 to 500,000" and "more than 500,000", also presented a similar pattern in their results. This group ranked above average in the following Goals: 1, no poverty; 6, clean water and sanitation; 7, affordable and clean energy; 8, decent work and economic growth; 12, responsible production and consumption; 13, climate action; 14, life below water; 15, life on land; and 17, Partnerships for the goals. Similarly, they were below average for the following Goals: 2, zero hunger; 3, good health and well-being; 5, gender equality; 10, reduced inequalities; 11, sustainable cities and communities; and 16, peace, justice and strong institutions. This group's results were practically opposite to those of the small municipalities, as their only point in common was with Goal 4, quality education, which was above average in municipalities with more than 500,000 inhabitants and in those with less than 5,000 inhabitants.

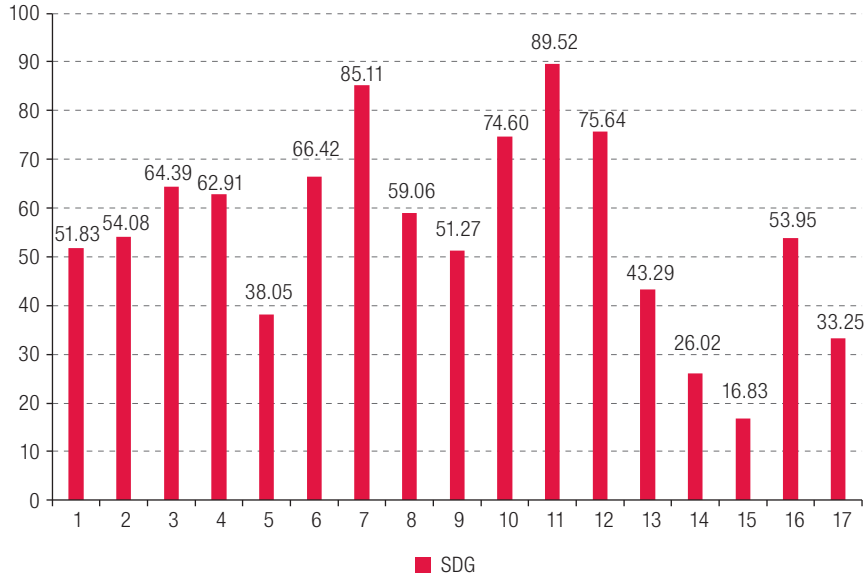
The third group, comprising 109 municipalities in the "10,001 to 20,000" population category, reported variable results, similar to those of the medium and large municipalities but, at the same time,

sharing some characteristics with the small municipalities. They reported shortfalls with the following Goals: 3, good health and well-being; 4, quality education; 5, gender equality; 8, decent work and economic growth; 10, reduced inequalities; 16, peace, justice and strong institutions; and 17, partnerships for the goals. At the same time, they reported scores above the State average for the following Goals: 1, no poverty; 2, zero hunger; 6, clean water and sanitation; 7, affordable and clean energy; 9, industry, innovation and infrastructure; 11, sustainable cities and communities; 12, responsible production and consumption; 13, climate action; 14, life below water; and 15, life on land.

Table 3 therefore makes it clear that population size is a factor to be taken into account in assessing the degree of SDG compliance and that larger municipalities perform better on Goals that are predominantly social (Goal 1, no poverty; Goal 6, clean water and sanitation; and Goal 7, affordable and clean energy), environmental (Goal 12, responsible production and consumption; Goal 13, climate action; Goal 14, life below water; and Goal 15, life on land), economic (Goal 8, decent work and economic growth) and political and institutional (Goal 17, partnerships for the goals).

From the mapping of SDG attainment, presented in figure 1, the three best and the three worst results were extracted: in other words, those where the State of Paraná is closest and farthest from achieving the 2030 Agenda's Goals.

Figure 1
Brazil: achievement of Sustainable Development Goals (SDG) in municipalities of the State of Paraná, by SDG
(IDSC-BR, percentages)

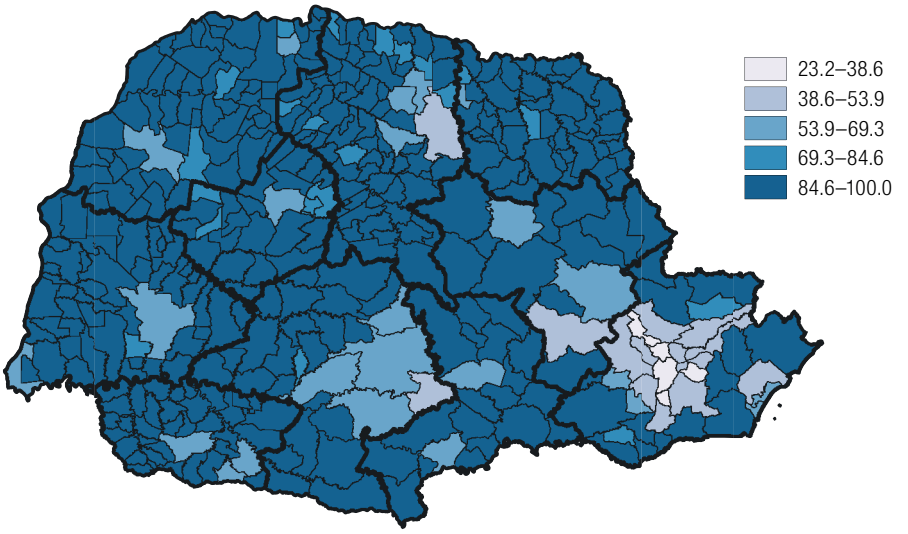


Source: Prepared by the authors.

The three results that came closest to optimal performance in Paraná were the following: Goal 11, sustainable cities and communities (89.52%); Goal 7, affordable and clean energy (85.11%); and Goal 12, responsible production and consumption (75.64%).

The best performance (89.5%) was recorded for Goal 11. The aim of that Goal is to make cities and human settlements inclusive, safe, resilient and sustainable. It covers the measurement of three indicators: "population living in irregular settlements", "favela households" and "percentage of the low-income population with a commuting time of more than one hour". Map 2 illustrates Paraná's attainment of Goal 11.

Map 2
Brazil: achievement of Sustainable Development Goal 11, sustainable cities and communities, in the State of Paraná
(IDSC-BR, percentages)

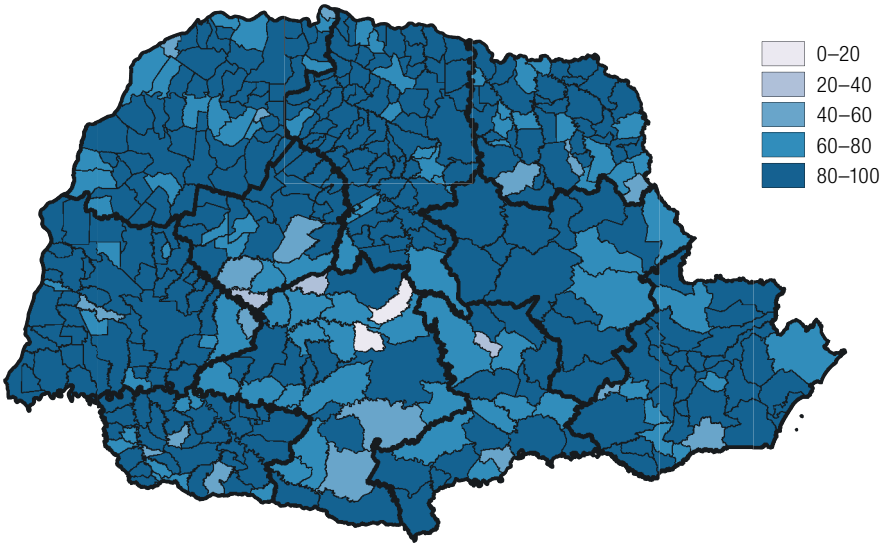


Source: Prepared by the authors.

Map 2 shows that the municipalities with the lowest scores —in other words, those farthest from achieving sustainable development— are located in the Curitiba metropolitan and central-southern mesoregions of Paraná. In the Curitiba metropolitan mesoregion, the negative result could be related to people migrating to the capital and its surrounding areas in search of work and better standards of living who do not always find adequately paying jobs, which aggravates the region's social and housing problems.

The second best score was for Goal 7, which aims to ensure access to affordable, reliable, sustainable and modern energy for all. The measurement uses the indicator "households with access to electricity". Map 3 shows the distribution of this indicator in Paraná.

Map 3
Brazil: achievement of Sustainable Development Goal 7, affordable and clean energy, in the State of Paraná
(IDSC-BR, percentages)

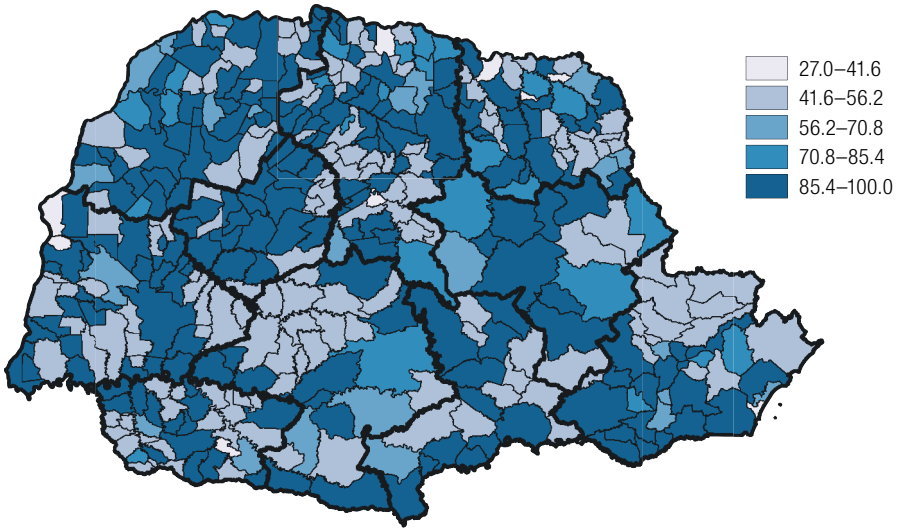


Source: Prepared by the authors.

As can be seen, almost all households in Paraná have access to electricity, which yielded an overall average of 85.1% compliance with Goal 7, the second highest score. The municipalities marked with lighter colours did not reach or were close to the minimum value and, after normalization, are listed with the lowest scores. Since the source of the data for this indicator is the 2010 Census, these values could improve even further following the 2022 Census.

The third best result was for Goal 12, which entails ensuring sustainable consumption and production patterns. It was evaluated by two indicators: "household waste per capita" and "population served by selective waste collection". Map 4 shows the average scores of Paraná's municipalities.

Map 4
Brazil: achievement of Sustainable Development Goal 12, responsible production and consumption, in the State of Paraná
(IDSC-BR, percentages)



Source: Prepared by the authors.

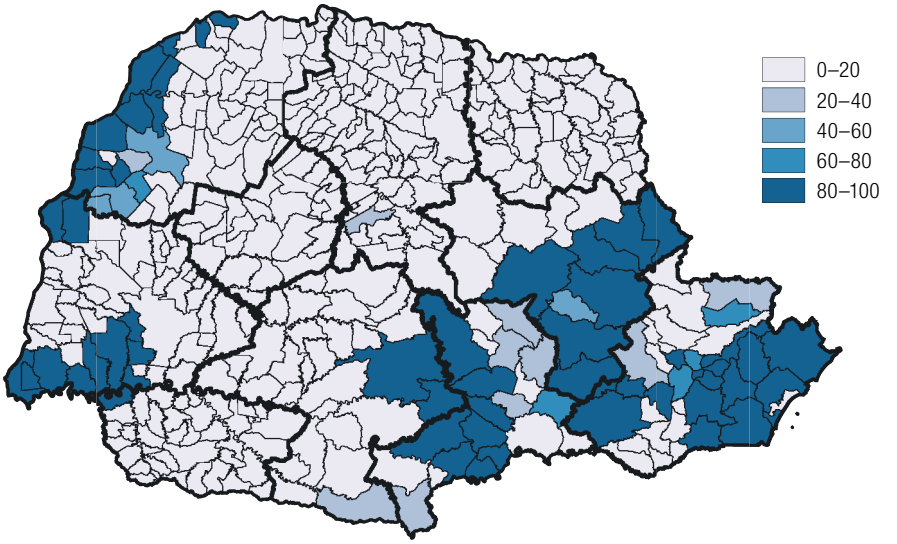
Compliance with this Goal in the State was 75.6%, the third highest average score of all the Goals. Of the indicators used to assess Goal 12, the State's low average score for the indicator "population served by selective waste collection" (54.9%) warrants particular note. This result means that approximately 40% of the municipalities do not have selective waste collection, which is the ideal method for optimizing waste disposal processes and the most appropriate and environmentally friendly way to implement them. Moreover, only 33% of the municipalities cover their entire urban populations with selective collections.

At the same time, the Goals that are farthest from being attained are the following: Goal 15, life on land (16.83%); Goal 14, life below water (26.02%); and Goal 17, partnerships for the goals.

Goal 15 involves protecting, restoring and promoting the sustainable use of terrestrial ecosystems, sustainably managing forests, combatting desertification, and halting and reversing land degradation and biodiversity loss. Only one indicator is used for this Goal: "conservation areas for comprehensive protection and sustainable use" (see map 5).

The State's average score was only 16.8%, one of the lowest results of all SDGs. This is because the indicator only calculates the proportion of the territory occupied by conservation areas for comprehensive protection and sustainable use (municipal, state and federal), which do not exist in all municipalities. Consequently, those municipalities that have conservation areas in their territories achieved the highest scores for Goal 15 and are indicated in dark blue on map 5.

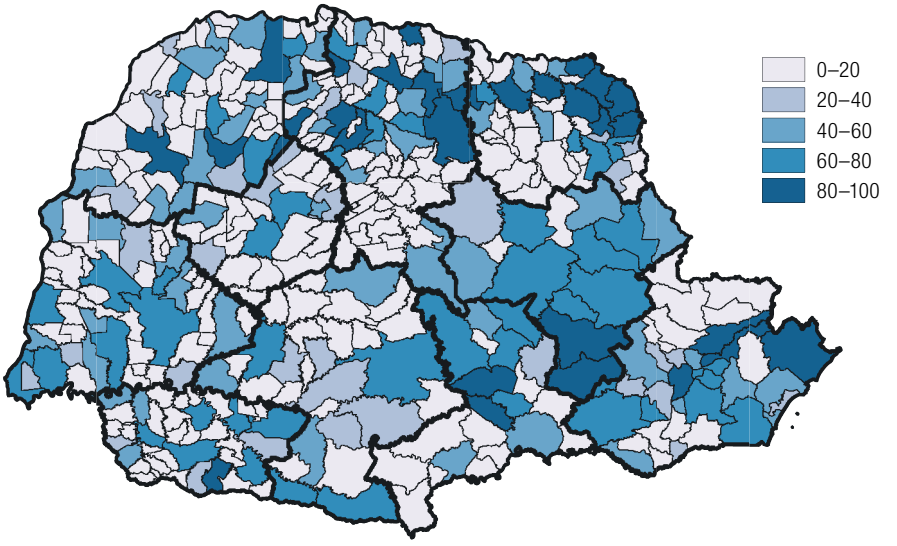
Map 5
Brazil: achievement of Sustainable Development Goal 15, life on land, in the State of Paraná
(IDSC-BR, percentages)



Source: Prepared by the authors.

Goal 14 involves the conservation and sustainable use of the oceans, seas and marine resources for sustainable development. This Goal is addressed by a single indicator that measures the wastewater that is treated before reaching the sea, rivers and streams as a percentage of the total wastewater reaching the sea. The State's overall score was only 26.0%. The results by municipality are shown in map 6.

Map 6
Brazil: achievement of Sustainable Development Goal 14, life below water, in the State of Paraná
(IDSC-BR, percentages)



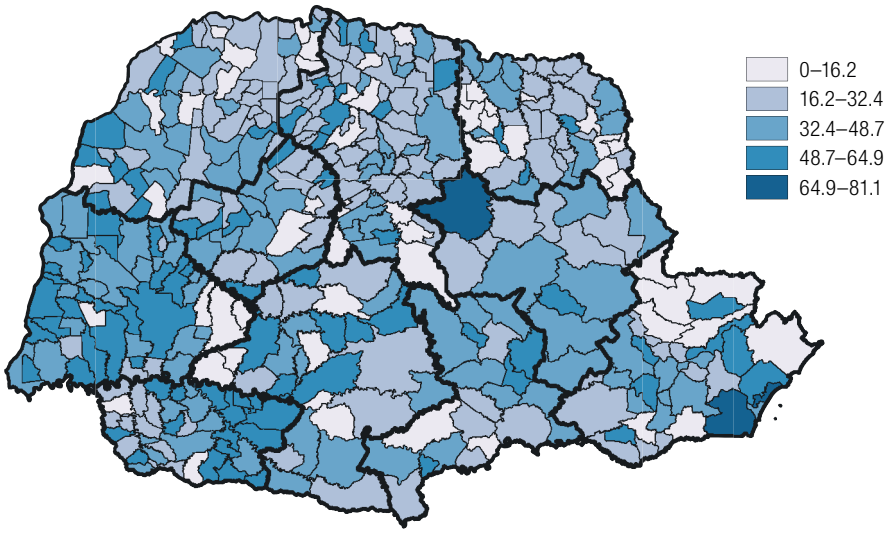
Source: Prepared by the authors.

According to data from the 2013 *Atlas Esgotos*, published by the National Water and Basic Sanitation Agency (ANA, 2013), around a half of Paraná's municipalities (203 of 399) do not treat their wastewater before it reaches the sea, rivers and streams.

The State's government must therefore step up its investments in basic sanitation to provide more connections to the sewage collection network and build sewage treatment plants, in order to achieve the universalization of basic sanitation services for the population of Paraná. That increased investment in wastewater treatment systems could reduce the incidence of microorganism-borne diseases, improve the general public health and bolster environmental conservation.

The geographical distribution of the results for Goal 17 in Paraná is shown in map 7. The score for this Goal —which entails strengthening the means of implementation and revitalizing the Global Partnership for Sustainable Development— was 33.2%. Two indicators were used to calculate the score: "public investment" and "total revenues collected".

Map 7
Brazil: achievement of Sustainable Development Goal 17, partnerships for goals, in the State of Paraná
(IDSC-BR, percentages)



Source: Prepared by the authors.

Map 7 shows that the three municipalities with the best results (in the range of 64.9% to 81.1%) were Pontal do Paraná, Ortigueira and Guaratuba.

The "public investment" indicator reported a better performance, reaching an average of 50.8% in the State. Data for 2020 indicate that 58 municipalities invested more than 1,000 reais per capita.

However, the "total revenues collected" indicator —which measures revenue collections as a proportion of the municipality's total revenue— reported an average score of 15.6%, which is far from the optimal value suggested to achieve sustainable development. Most of the municipalities therefore rely heavily on support from State and federal transfers.

An analysis of the data reveals that 34 of the 87 indicators measured (39.1%) reported average scores of less than 50%; hence, the municipalities are not even halfway towards achieving their sustainable development commitments. The results for 26 indicators (29.9%) were between 50.0% and 79.9%: a medium level on the scale. This indicates that there are still major challenges to overcome in order to achieve SDGs. Lastly, the scores for 27 indicators (31.0%) in Paraná were over 80.0%; according to

the index's methodology, those indicators can be considered attained. It should be noted that in order to increase their scores in the overall index, municipalities must pay attention to all the indicators: in other words, they must improve in all of the areas evaluated.

V. Conclusions

While the cities still have six years to make progress in pursuit of the 2030 Agenda, the study shows that most municipalities remain far from meeting the targets set in 2015. The ranking itself, shown in table A2.1 of annex A2, confirms this, as Capanema —Paraná's most sustainable municipality— achieved a score of 68.68%, or just under three-quarters of optimal SDG performance.

The results also show that 44 municipalities in Paraná are not even halfway to achieving the commitments established in the 2030 Agenda and that the vast majority of them (355) are ranked at medium levels on the sustainability scale. No municipality scored more than 80% and, according to the index methodology, Paraná's municipalities therefore cannot be considered to have fully achieved SDGs.

The analysis by individual SDG shows that the closest to optimal attainment in the State of Paraná are Goal 11, sustainable cities and communities (89.52%), Goal 7, affordable and clean energy (85.11%), and Goal 12, responsible production and consumption (75.64%), all of which exceeded the upper limit of the third quartile (75%). Likewise, SDGs that entail the most difficulties and have the furthest way to go to meet the commitments set in the 2030 Agenda are Goal 15, life on land (16.83%), Goal 14, life below water (26.02%), and Goal 17, partnerships for the goals (33.25%).

Another finding from the study is that population size is a factor that should be taken into account in assessing SDG compliance, since larger municipalities tend to perform better with those SDGs that essentially address issues affecting society (Goal 1, no poverty; Goal 6, clean water and sanitation; and Goal 7, affordable and clean energy), the environment (Goal 12, responsible production and consumption; Goal 13, climate action; Goal 14, life below water; and Goal 15, life on land), economic issues (Goal 8, decent work and economic growth) and political and institutional structures (Goal 17, partnerships for the goals).

This finding underscores the problem of heterogeneity in Latin America and the Caribbean, Brazil and Paraná. At the regional level, this was established by the studies of Prebisch (1987) and Pinto (1970). Some studies in Brazil indicate that heterogeneity exists among the nation's States, where, for example, individuals located in certain regions receive public services and professional opportunities that are very different from the country's average (Baião, Cunha and Souza, 2017, p. 585).

According to Basso (2020), Paraná's central region, for example, is unaffected by the State's economic cycles. That region has the smallest municipalities, with the fewest resources and opportunities and, consequently, lower SDG scores. In contrast, according to the results obtained, municipalities with larger populations are more structured and obtained better results in various SDGs of different kinds.

As stated at the beginning of this paper, its limitations include its analysis of only one year for each indicator and the impossibility of using the data to produce a historical series, on account of the large volume of information. Accordingly, the paper addresses a cut-off point in time, which could serve as the starting point in the analysis of the indicators, with the ultimate goal of creating an "SDG Observatory": i.e. a research centre to serve as an information and support tool for government decisions on public policies, so that the government of the State of Paraná can monitor the evolution of the data over time from that point forward.

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Annex A1

Table A1.1
Indicators, sources and data years

Sustainable Development Goals	Indicator	Source	Data year
1. No poverty	Families registered in the Single Register for Social Programmes (CadÚnico) (percentages)	Ministry of Development and Social Assistance, Family and Fight against Hunger/Ministry of Citizenship	2021[a]
	People with incomes of up to one quarter of the minimum wage (percentages)	Brazilian Institute of Geography and Statistics (IBGE) (Census)	2010
2. Zero hunger	Childhood obesity (percentages)	DATASUS	2020
	Low birth weight (percentages)	DATASUS	2019
	Child malnutrition (percentages)	Food and Nutrition Surveillance System (SISVAN)	2020
	Family farmers receiving support from the National Programme for Strengthening Family Agriculture (PRONAF) (percentages)	IBGE – 2017 Agricultural Census	2017
	Farms practicing organic agriculture (percentages)	IBGE – 2017 Agricultural Census	2017
3. Good health and well-being	Vaccine coverage (percentages)	DATASUS	2020
	Screening for hepatitis A, B and C (per 100,000 inhabitants)	DATASUS	2018
	Hospital beds (per 1,000 inhabitants)	DATASUS	2020
	Infant mortality (children aged under 1 year) (per 1,000 live births)	DATASUS	2019
	Maternal mortality (per 1,000 live births)	DATASUS	2019
	Childhood mortality (children aged under 5 years) (per 1,000 live births)	DATASUS	2019
	Neonatal mortality (children aged 0 to 27 days) (per 1,000 live births)	DATASUS	2019
	AIDS mortality (per 100,000 inhabitants)	DATASUS	2019
	Cases of dengue fever (per 100,000 inhabitants)	DATASUS	2020
	Deaths from chronic non-communicable diseases (per 100,000 inhabitants)	DATASUS	2019
	Municipal health budget (in reais per capita)	DATASUS	2019
	Population served by family health teams (percentages)	DATASUS	2015
	Insufficient prenatal care (percentages)	DATASUS	2019
	Basic Health Units (per 1,000 inhabitants)	DATASUS	2020
	Traffic fatalities (per 100,000 inhabitants)	DATASUS	2019
	Sports facilities (per 100,000 inhabitants)	IBGE/Basic Municipal Information Survey (MUNIC)	2018
	Life expectancy at birth (years)	United Nations Development Programme (UNDP)/Institute of Applied Economic Research (IPEA)	2010
	Teenage pregnancy (percentages)	DATASUS	2019
	Cases of tuberculosis (per 100,000 inhabitants)	DATASUS	2020
4. Quality education	Internet access at primary schools (percentages)	National Institute of Educational Studies and Research Anísio Teixeira (INEP) (School Census)	2020
	Schools with proper facilities for persons with disabilities (percentages)	INEP (School Census)	2018
	Schools with resources for specialized educational services (percentages)	INEP (School Census)	2020
	Basic Education Development Index (IDEB) – final years (index)	Ministry of Education/IDEB	2019
	Basic Education Development Index (IDEB) – first years (index)	Ministry of Education/IDEB	2019
	Young people up to 19 years of age with completed secondary education (percentages)	IBGE (Census)	2010
	Teachers with higher level training – early childhood education – public network (percentages)	INEP (School Census)	2020
	Teachers with higher level training – primary education – public network (percentages)	INEP (School Census)	2020

Sustainable Development Goals	Indicator	Source	Data year
4. Quality education	Teachers with higher level training – secondary education – public network (percentages)	INEP (School Census)	2020
	Internet access at secondary schools (percentages)	INEP (School Census)	2020
	Prova Brasil – Portuguese language – final years of primary education – municipal network (index)	Ministry of Education/IDEB	2019
	Prova Brasil – Portuguese language – first years of primary education – municipal network (index)	Ministry of Education/IDEB	2019
	Prova Brasil – mathematics – final years of primary education – municipal network (index)	Ministry of Education/IDEB	2019
	Prova Brasil – mathematics – first years of primary education – municipal network (index)	Ministry of Education/IDEB	2019
	Pupil/teacher ratio in pre-school education (ratio)	INEP (School Census)	2020
	Pupil/teacher ratio in primary education (ratio)	INEP (School Census)	2020
	Pupil/teacher ratio in secondary education (ratio)	INEP (School Census)	2020
	Age/year matching in primary education (ratio)	INEP (School Census)	2020
	Illiteracy among the population aged 15 years and over (percentages)	IBGE (Census)	2010
	Cultural centres and cultural facilities (per 100,000 inhabitants)	IBGE/MUNIC	2018
	Children and adolescents aged from 4 to 17 years attending school (percentages)	IBGE (Census)	2010
5. Gender equality	Young women aged 15 to 24 years neither studying nor working (percentages)	IBGE (Census)	2010
	Women members of municipal councils (percentages)	Superior Electoral Court (TSE)	2016
	Wage inequality by sex (women's wages/men's wages)	IBGE (Census)	2010
	Percentage difference between young women and young men neither studying nor working (percentage points)	IBGE (Census)	2010
	Femicide rate (per 100,000 women)	DATASUS	2019
6. Clean water and sanitation	Water losses (index)	National Sanitation Information System (SNIS)	2019
	Water service population coverage (percentages)	SNIS	2019
	Sewerage system population coverage (percentages)	SNIS	2019
	Domestic waste collection population coverage (percentages)	SNIS	2019
	Illnesses related to inadequate environmental sanitation (per 100,000 inhabitants)	DATASUS	2020
7. Affordable and clean energy	Households with access to electricity (percentages)	IBGE (Census)	2010
8. Decent work and economic growth	Gross domestic product (GDP) per capita (in reais per capita)	IBGE, Municipal GDP	2018
	Employed population aged 5 to 17 years (percentages)	IBGE (Census)	2010
	Unemployment (rate)	IBGE (Census)	2010
	Youth unemployment (rate)	IBGE (Census)	2010
	Young people aged 15 to 24 years neither studying nor working (percentages)	IBGE (Census)	2010
	Employment among persons aged 16 years and older (rate)	IBGE (Census)	2010
9. Industry, innovation and infrastructure	Public infrastructure investment as a proportion of GDP (percentages)	Brazilian Public Sector Accounting and Financial Information System (SICONFI) and IBGE, municipal GDP	2018
	Share of jobs in knowledge-intensive and technology-intensive activities (percentages)	Annual Social Information Report (RAIS)	2019
10. Reduced inequalities	Municipal income held by the poorest 20% (percentages)	Human Development Atlas in Brazil	2010
	Gini coefficient (index)	Human Development Atlas in Brazil	2010
	Relative risk of homicide (black persons/non-black persons)	DATASUS	2019
	Access to basic health care equipment	IBGE, irregular settlements	2019
	Average real income ratio (black persons/non-black persons)	RAIS	2019
	Proportion of black population in irregular settlements (percentages)	IBGE (Census)	2010

Sustainable Development Goals	Indicator	Source	Data year
11. Sustainable cities and communities	Population living in irregular settlements (percentages)	IBGE (Census)	2010
	Favela households (percentages)	IBGE, irregular settlements	2019
	Percentage of the low-income population with a commuting time of more than one hour (percentages)	Human Development Atlas in Brazil	2010
12. Responsible production and consumption	Household waste per capita (annual tons per capita)	SNIS	2019
	Population served by selective waste collection (percentages)	SNIS	2019
13. Climate action	Per capita emissions in carbon dioxide equivalent (CO_2e)	Greenhouse Gas Emissions and Removals Estimation System (SEEG) – Climate Observatory (OC)	2018
	Percentage of municipality deforested (percentages)	MapBiomas	[b]
14. Life below water	Treatment of wastewater before it reaches the sea, rivers and streams (percentages)	*Atlas Esgotos* – National Water Resources Information System (SNIRH)/National Water and Basic Sanitation Agency	2013
15. Life on land	conservation areas for comprehensive protection and sustainable use (percentages)	Ministry of the Environment	2020
16. Peace, justice and strong institutions	Youth homicides (per 100,000 inhabitants)	DATASUS	2019
	Assault deaths (per 100,000 inhabitants)	DATASUS	2019
	Firearms deaths (per 100,000 inhabitants)	DATASUS	2019
	Homicide rate (per 100,000 inhabitants)	Human Development Atlas	2017
	Violence against lesbian, gay, bisexual, transgender, queer and intersex (LGBTQI+) persons (per 100,000 inhabitants)	DATASUS	2019
17. Partnerships for the goals	Public investment (reais per capita)	SICONFI	2020
	Total revenues collected (percentages)	SICONFI	2020

Source: Prepared by the authors, on the basis of official data.

[a] The indicator "families registered in the Single Register for Social Programmes (percentages)" includes information from January to March 2021, as it was not possible to extract data for 2020 during the study period.

[b] The indicator cannot be applied because the construction method in the description is lacking in clarity.

Table A1.2
Brazil: ranking of municipalities in the State of Paraná by attainment of the Sustainable Development Goals
(Sustainable city development index of Brazil (IDSC-BR), percentages)

Municipality	Score	Municipality	Score
Capanema	68.68	Sabáudia	60.95
Rio Azul	68.58	Anahy	60.82
Irati	67.15	Floraí	60.81
Santa Terezinha de Itaipu	67.08	Munhoz de Melo	60.73
Pérola	66.19	Ourizona	60.67
Guaratuba	66.07	Itambé	60.63
São Jorge do Ivaí	65.98	Prado Ferreira	60.57
São José dos Pinhais	65.81	Paranacity	60.55
Céu Azul	65.78	São Miguel do Iguaçu	60.53
Lapa	65.63	Pinhalão	60.41
Quatro Barras	65.48	Icaraíma	60.36
Mallet	65.10	Tupãssi	60.34
Maringá	64.20	São Jorge do Patrocínio	60.31
Serranópolis do Iguaçu	64.11	Mandaguari	60.30
Curitiba	63.73	Andirá	60.27
Renascença	63.52	Guarapuava	60.23
Porto Amazonas	63.34	Porto Vitória	60.10
Palmeira	63.28	Carlópolis	60.04
Rio Negro	63.17	Altônia	60.01
Jussara	63.00	Guaraqueçaba	59.99
Dois Vizinhos	62.97	Ibiporã	59.93
Carambeí	62.94	Paranavaí	59.93
Sertanópolis	62.90	Paranaguá	59.82
Umuarama	62.85	Quatro Pontes	59.81
Ribeirão Claro	62.73	Nova Olímpia	59.69
Sengés	62.73	Tibagi	59.64
Campina Grande do Sul	62.72	Santa Cruz de Monte Castelo	59.61
Arapongas	62.52	Campo Mourão	59.58
Santa Tereza do Oeste	62.46	Astorga	59.56
Ponta Grossa	62.44	Castro	59.56
Floresta	62.41	Rio Bom	59.53
União da Vitória	62.34	Terra Roxa	59.49
Prudentópolis	62.00	Toledo	59.47
Terra Boa	61.98	Tijucas do Sul	59.47
São José dos Pinhais	61.97	Cafezal do Sul	59.45
Mamborê	61.77	Nova Santa Rosa	59.37
Japurá	61.67	Tapejara	59.36
Uraí	61.53	Cambira	59.32
Cornélio Procópio	61.46	Pato Bragado	59.31
Paulo Frontin	61.46	Diamante do Norte	59.27
Ivaté	61.39	Siqueira Campos	59.18
Foz do Iguaçu	61.36	Assaí	59.11
Ampére	61.36	Morretes	59.10
São João	61.35	Flórida	59.07
Araruna	61.29	Cianorte	59.05
Jandaia do Sul	61.29	Capitão Leônidas Marques	59.04
Colombo	61.21	São Tomé	59.01
Cafelândia	61.15	Pitangueiras	59.00
Atalaia	61.10	São João do Triunfo	58.99
Ivatuba	61.04	Ipiranga	58.99

Municipality	Score	Municipality	Score
Campo Largo	58.90	Maripá	57.17
Jaguariaíva	58.89	Paraíso do Norte	57.07
Guaíra	58.89	Imbituva	56.99
Cambará	58.89	Primeiro de Maio	56.92
Londrina	58.88	Goioerê	56.90
Paula Freitas	58.78	Santo Antônio da Platina	56.85
Santa Mariana	58.78	Santa Cecília do Pavão	56.82
Palmas	58.72	Novo Itacolomi	56.76
Corbélia	58.72	Conselheiro Mairinck	56.66
Uniflor	58.70	Rebouças	56.63
Alto Paraná	58.67	Kaloré	56.60
Joaquim Távora	58.62	Lupionópolis	56.57
Alto Paraíso	58.62	Piên	56.54
Tamboara	58.60	São Pedro do Iguaçu	56.53
Jaguapitã	58.60	Abatiá	56.52
Apucarana	58.59	Sertaneja	56.51
Ubiratã	58.57	Rondon	56.50
Chopinzinho	58.54	Pitanga	56.47
Guaporema	58.53	Lobato	56.46
Marechal Cândido Rondon	58.29	Doutor Camargo	56.42
São Pedro do Paraná	58.27	Palotina	56.37
Iporã	58.24	Telêmaco Borba	56.34
São Mateus do Sul	58.15	Farol	56.32
Boa Esperança	58.13	Salto do Itararé	56.31
Cidade Gaúcha	58.10	Piraquara	56.29
Ivaiporã	58.07	Piraí do Sul	56.28
Pato Branco	58.02	Bela Vista do Paraíso	56.25
Paiçandu	57.97	Santa Amélia	56.24
Matinhos	57.94	Barra do Jacaré	56.22
Califórnia	57.89	Mandaguaçu	56.21
Borrazópolis	57.88	Teixeira Soares	56.15
Agudos do Sul	57.83	Rolândia	56.03
Itaipulândia	57.82	Santa Isabel do Ivaí	56.00
Matelândia	57.80	Cruzeiro do Iguaçu	56.00
Porecatu	57.80	Pranchita	55.99
Nova Aurora	57.75	Santa Inês	55.96
Antonina	57.74	Santa Fé	55.96
Colorado	57.73	Ribeirão do Pinhal	55.96
Foz do Jordão	57.72	Vera Cruz do Oeste	55.95
Realeza	57.65	Santa Izabel do Oeste	55.94
Clevelândia	57.63	Enéas Marques	55.89
Campo do Tenente	57.60	Rosário do Ivaí	55.83
Alto Piquiri	57.60	Medianeira	55.79
Iguaraçu	57.59	Guamiranga	55.77
Iracema do Oeste	57.57	Marialva	55.76
Bandeirantes	57.55	Ivaí	55.74
Guapirama	57.52	Congonhinhas	55.74
Francisco Beltrão	57.49	Salgado Filho	55.73
Mariópolis	57.37	Jaboti	55.72
Nova Santa Bárbara	57.28	Fernandes Pinheiro	55.67
Jataizinho	57.28	Loanda	55.63
Perobal	57.23	Marilena	55.63
Araucária	57.22	Bom Jesus do Sul	55.57
Cascavel	57.18	Ângulo	55.41

Municipality	Score	Municipality	Score
Quatiguá	55.41	Balsa Nova	53.92
Douradina	55.40	Santo Inácio	53.89
Inácio Martins	55.37	Barbosa Ferraz	53.85
Mercedes	55.36	Tomazina	53.83
São Pedro do Ivaí	55.35	Boa Vista da Aparecida	53.80
Almirante Tamandaré	55.35	Santa Lúcia	53.72
Planalto	55.31	Presidente Castelo Branco	53.71
Santa Helena	55.30	Manoel Ribas	53.71
São Carlos do Ivaí	55.24	Francisco Alves	53.70
Mariluz	55.24	Florestópolis	53.55
Miraselva	55.18	Leópolis	53.54
Pontal do Paraná	55.15	Formosa do Oeste	53.51
Esperança Nova	55.13	Bela Vista da Caroba	53.49
Cruz Machado	55.12	Quedas do Iguaçu	53.48
Paranapoema	55.11	Tuneiras do Oeste	53.46
Cruzeiro do Oeste	55.05	Três Barras do Paraná	53.46
Assis Chateaubriand	55.02	Itaguajé	53.43
Figueira	55.02	São João do Caiuá	53.42
Santo Antônio do Paraíso	55.01	Nova América da Colina	53.40
Juranda	55.01	Bom Sucesso do Sul	53.38
Barracão	54.98	Jesuítas	53.33
Guaraci	54.92	Itambaracá	53.32
Nossa Senhora das Graças	54.91	Imbaú	53.28
Ariranha do Ivaí	54.81	Porto Barreiro	53.27
Pérola d'Oeste	54.81	Virmond	53.21
Nova Prata do Iguaçu	54.79	Porto Rico	53.16
Nova Londrina	54.76	Terra Rica	53.10
Jacarezinho	54.76	Braganey	53.05
São Manoel do Paraná	54.75	Nova Cantu	52.94
Cambé	54.74	Mauá da Serra	52.94
Itapejara d'Oeste	54.74	Salto do Lontra	52.93
Antônio Olinto	54.74	Jardim Olinda	52.86
Iguatu	54.73	Verê	52.86
Fênix	54.71	Jardim Alegre	52.84
Peabiru	54.68	Reserva	52.84
Engenheiro Beltrão	54.66	Boa Esperança do Iguaçu	52.75
Coronel Vivida	54.58	Sulina	52.74
Nova Esperança do Sudoeste	54.57	Sarandi	52.72
Contenda	54.53	Nova Esperança	52.72
Lidianópolis	54.47	Ramilândia	52.72
Amaporã	54.47	Tapira	52.64
Quarto Centenário	54.44	São João do Ivaí	52.62
Arapuã	54.42	Vitorino	52.62
Entre Rios do Oeste	54.38	Laranjeiras do Sul	52.52
Flor da Serra do Sul	54.31	São José da Boa Vista	52.50
Marmeleiro	54.29	Missal	52.45
Mirador	54.23	Ibaiti	52.44
Fazenda Rio Grande	54.13	Marilândia do Sul	52.29
Saudade do Iguaçu	54.12	Santo Antônio do Caiuá	52.27
Marumbi	54.11	Tunas do Paraná	52.23
Arapoti	54.11	Santo Antônio do Sudoeste	52.20
Lunardelli	54.07	Catanduvas	52.11
Nova Aliança do Ivaí	54.05	Santa Mônica	52.09
Quinta do Sol	53.97	Pinhal de São Bento	52.09

Municipality	Score	Municipality	Score
Cantagalo	52.07	Cândido de Abreu	49.67
Bituruna	52.02	Wenceslau Braz	49.12
Corumbataí do Sul	51.99	Candói	49.00
Brasilândia do Sul	51.98	Roncador	48.68
Sapopema	51.93	Planaltina do Paraná	48.62
Lindoeste	51.90	Cruzmaltina	48.51
Inajá	51.77	Rio Bonito do Iguaçu	48.44
Indianópolis	51.77	Mandirituba	48.41
São José das Palmeiras	51.75	Honório Serpa	48.40
Santana do Itararé	51.66	Cafeara	48.39
Querência do Norte	51.62	Campina da Lagoa	48.34
Ventania	51.57	Iretama	48.29
Diamante d'Oeste	51.57	Manfrinópolis	48.24
Luiziana	51.54	Itaúna do Sul	48.17
Ibema	51.53	Boa Ventura de São Roque	48.12
Maria Helena	51.49	Espigão Alto do Iguaçu	47.96
Alvorada do Sul	51.41	Adrianópolis	47.85
Faxinal	51.30	Moreira Sales	47.85
Mangueirinha	51.27	Goioxim	47.79
Xambrê	51.25	Janiópolis	47.67
General Carneiro	51.25	Centenário do Sul	47.59
Nova Laranjeiras	51.23	Bom Sucesso	47.46
Quitandinha	51.21	Marquinho	47.28
Rancho Alegre d'Oeste	51.14	Campo Bonito	47.23
Ortigueira	51.10	Santa Maria do Oeste	46.71
Curiúva	50.94	Mato Rico	46.55
Bocaiúva do Sul	50.77	Jundiaí do Sul	46.36
Campo Magro	50.61	Nova Tebas	45.77
Ouro Verde do Oeste	50.53	Pinhão	45.59
Rio Branco do Ivaí	50.50	Guaraniaçu	45.57
Rancho Alegre	50.49	Doutor Ulysses	45.44
São Sebastião da Amoreira	50.45	Diamante do Sul	45.42
Cruzeiro do Sul	50.30	Itaperuçu	45.27
Turvo	50.30	Coronel Domingos Soares	44.93
Japira	50.29	Palmital	44.87
Reserva do Iguaçu	50.26	Guairaçá	44.79
Nova Fátima	50.16	Cerro Azul	43.66
Tamarana	50.11	Campina do Simão	42.77
São Jerônimo da Serra	50.05	Laranjal	42.61
Grandes Rios	49.99	Altamira do Paraná	41.23
São Jorge d'Oeste	49.99	Rio Branco do Sul	38.81
Godoy Moreira	49.74		

Source: Prepared by the authors.

Determinants of inward foreign direct investment in Colombia: an empirical analysis[1]

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Abstract

This research delves into the determinants of inward foreign direct investment (FDI) in Colombia in the context of the economic integration promoted by recent governments. Colombia's trade liberalization has sought not only to boost trade flows but also to make the country more attractive to FDI in a framework of fiscal discipline and a stable economic environment conducive to economic growth, albeit characterized by challenging institutional conditions. Government reforms have revitalized FDI inflows into Colombia, with the oil and mining sectors receiving the largest influx of new capital investments. This paper contributes to the literature by using an augmented gravity model approach to analyse the determinants of FDI inflows into Colombia between 2007 and 2020. We find that stable government policies and the rule of law have been key factors in increasing FDI in Colombia, and that bilateral investment treaties are of particular importance as drivers of FDI into the country.

Keywords

Foreign direct investment, economic integration, economic policy, investment promotion, competitiveness, econometric models, Colombia

JEL classification

F21, F36, O16, O54, C10

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I. Introduction

Colombia is one of the leading economies in Latin America and is considered an economically open country with one of the best business environments in the region for foreign investors, especially in energy-related sectors (The Economist Intelligence Unit, 2013; World Bank, 2022; Abreo, Bustillo and Rodríguez, 2022). Colombia is characterized by its fiscal discipline and sound monetary policy aimed at controlling inflation, which has made it possible to attain a stable macroeconomic environment with high economic growth rates even at times of global economic crisis (Park Madison Partners, 2013). Although Colombia has experienced relatively rapid economic growth in recent years, this is mainly because the energy sector has expanded by more than other economic sectors (e.g., the manufacturing sector has had a negative performance), thereby reinforcing the observation that the positive performance of Colombia's macroeconomic indicators depends mainly on the exploitation of natural resources and the high prices of raw materials on international markets (Botta, Godin and Missaglia, 2016).

The Colombian economy began to open up in 1990 with the implementation of the so-called trade opening process. In the field of international trade, Colombia went from an import substitution system to a process of reducing both tariff and non-tariff trade barriers. Regarding openness to international investment, Colombia has made major efforts to create a legal framework that promotes these flows. Ramirez and Quintero (2019) point out that in the late 1980s, legislation was passed on vital matters such as the removal of double taxation and the reduction of taxes on remittances. They also draw attention to the International Investment Statute, issued in 1991, which provided a national legal framework liberalizing foreign investment in the country and establishing rules for the creation of special economic zones. According to Velosa (2019), there were substantial legal modifications to this investment framework in the following years, focused on making Colombia more attractive to FDI. In 1999, the constitution was reformed and financial compensation was introduced for expropriation measures irrespective of circumstances. In 2005 and 2006, legislation was passed to enhance the legal stability of FDI in Colombia and abolish a 7% tax on revenues sent abroad by investors. Lastly, in 2017, as part of the effort to promote foreign investment in the energy sector, new modifications were introduced in the general FDI regime to make foreign investment in Colombia even more attractive.

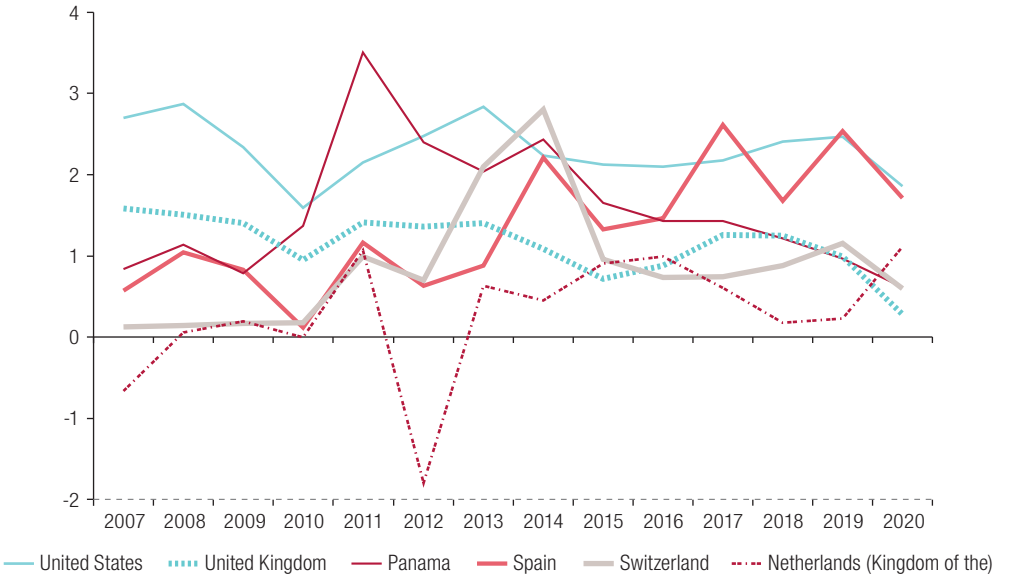
These reforms aided in the revitalization of inward FDI in Colombia, especially in the oil and mining sectors, which received the largest inflows (Velosa, 2019). Botta, Godin and Missaglia (2016) point out that FDI inflows represented less than 3% of GDP between 1990 and 2004, but that since 2005 they have been significantly higher. Concerning some particular characteristics of FDI inflows into Colombia, Buitrago and Leon (2015) indicate that these have helped to finance the country's balance-of-payments deficit. They also state that foreign companies repatriate 70% of their profits (99% in the oil sector). Furthermore, they point out that the ratio between the value of FDI inflows and the dividends generated by these investments represents an outflow of economic resources greater than the inflow of FDI; nevertheless, they confirm that FDI inflows into Colombia have had a positive impact on GDP growth.

This paper investigates the determinants of inward FDI in Colombia in the context of recent governments and their promotion of economic integration. It uses an augmented gravity model to examine the characteristics of FDI inflows into Colombia between 2007 and 2020. Some authors have conducted studies to identify the determinants of FDI inflows into Colombia. Ramirez and Quintero (2019) establish that although the unemployment rate and the interest rate are important factors in attracting FDI flows to Colombia, these flows are certainly determined by international economic dynamics related to the expansion and diversification processes of transnational companies, for which developing countries are attractive markets. The authors conclude that Colombia does not actually determine the attraction of FDI inflows. Garavito, Iregui and Ramírez (2014), in their empirical study on the determinants of FDI inflows into Colombia at the firm level, identify some salient characteristics of this type of investment in local companies. They affirm that the probability of receiving FDI flows is small for companies that are

not part of the oil industry and for small and medium-sized companies regardless of their economic sector. They also state that the probability of receiving FDI flows is greater when companies carry out international trading activities.

Figure 1 exhibits the performance of net FDI inflows into Colombia by main countries of origin from 2007 to 2020. It is essential to mention that despite the challenges related to the internal armed conflict that has existed in Colombia since the second half of the twentieth century, Colombia was South America's third-largest recipient of FDI between 2000 and 2016 with 11% of the total, behind only Brazil (53%) and Chile (15%) (Velosa, 2019). Figure 1 shows that most of the main origin countries for FDI inflows into Colombia are European. It also shows that the United States and Spain have been the largest investors in Colombia over recent years. Investment from Panama declined steadily from 2011, while that from countries such as the United Kingdom and, in particular, Switzerland and the Netherlands showed considerable volatility over the period analysed. Lastly, other countries that invest substantially in Colombia are not shown in the chart. They include Caribbean countries such as Bermuda, the British Virgin Islands and the Cayman Islands that have been or are considered tax havens by some international institutions. Similarly, countries in the region such as Chile and Mexico also make significant investments in Colombia.

Figure 1
Colombia: net inward foreign direct investment by main countries of origin, 2007–2020
(Billions of dollars)

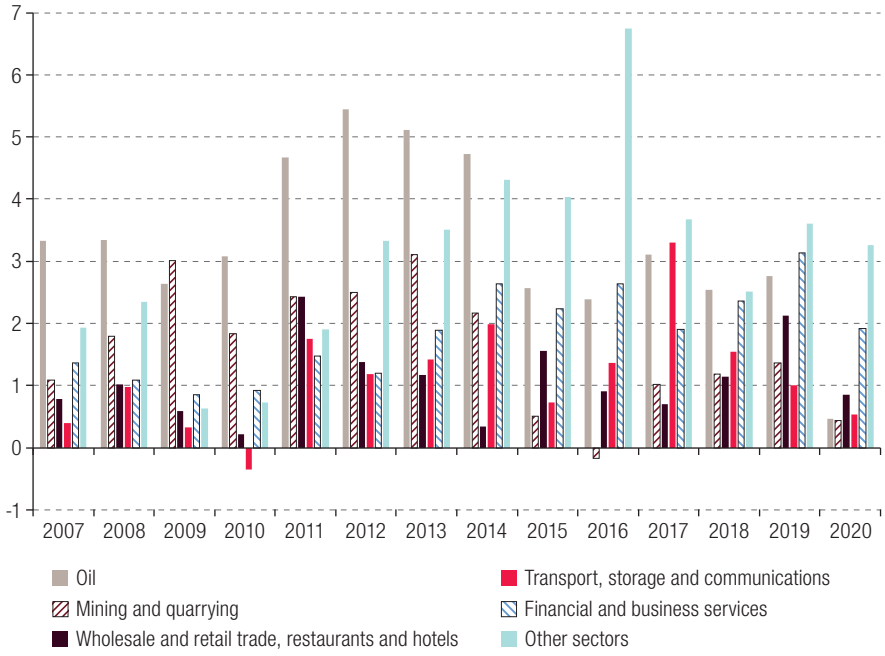


Source: Prepared by the authors on the basis of Banco de la República, *Inversión extranjera directa en Colombia - Actividad económica, 2021* [online] https://www.banrep.gov.co/es/estadisticas/inversion-directa.

Figure 2 shows net FDI inflows into Colombia from 2007 to 2020 by economic sector. The oil sector was the main recipient of net inward FDI in most of the periods studied, being surpassed only in 2016, 2019 and 2020 by the financial and business services sector. The mining and quarrying sector was the country's second-largest recipient of net inward FDI between 2007 and 2013. It is important to highlight that the large FDI flows into these two sectors in the reference period coincided with a period in which the prices of these commodities, especially that of a barrel of oil (Nyangarika, Mikhaylov and Tang, 2018), reached record highs. By 2013, these sectors' share in the composition of FDI inflows into the country had declined, in line with international trends. The great importance of the oil sector and the mining and quarrying sector in FDI inflows into Colombia is also reflected in the composition

of the country's export basket, as they contributed 63.3% of exports in 2018 at constant dollar prices (Abreo, Bustillo and Rodríguez, 2022). Nevertheless, the composition of inward FDI in Colombia has altered considerably since 2014, owing to the fact that the financial and business services sector has positioned itself as one of the two largest recipients. Moreover, FDI inflows into the "other sectors" category grew strongly in 2016, owing to a very substantial increase in investment in the electricity, gas and water sectors. Lastly, according to Banco de la República (2020), FDI inflows into Colombia decreased by 35.1% in 2020 from the previous year, with the sectors worst affected being oil and mining with a drop of 42.8%, because of the effects of the coronavirus disease (COVID-19) pandemic on the global economy. Declines were also large, but less so, in other economic sectors.

Figure 2
Colombia: net inward foreign direct investment by sector, 2007–2020
(Billions of dollars)



Source: Prepared by the authors on the basis of Banco de la República, *Inversión extranjera directa en Colombia - Actividad económica, 2021* [online] https://www.banrep.gov.co/es/estadisticas/inversion-directa.

II. Literature review

A number of economists have argued that inward FDI is an important component of economic development, particularly in emerging countries (Denisia, 2010), of which Colombia is one, where it produces critical growth benefits. In addition, technical spillovers, employment and competitiveness have been shown to be related to inward FDI (Asiedu, 2002). Caves (1992) concludes that the efforts made by different countries to attract FDI are motivated by the potential positive effects on the domestic market in relation to factors such as technology, know-how, employment and production. Some more recent literature takes issue with these findings, examples being Navaretti and Venables (2004) and Crespo and Fortuna (2007), who argue that the spillovers are not always positive. However, Borensztein, De Gregorio and Lee (1998) and Daude and Stein (2007) argue that FDI contributes more to economic growth than domestic investment.

Blomström, Kokko and Zejan (1994) argue that FDI plays a key role in increasing the competitiveness of local businesses. However, it is important to note that the positive effect of FDI may vary from sector to sector (Hirschman, 1958). In addition, a number of studies have tried to explain why companies invest their capital abroad. Vernon (1966), in his product life cycle theory, postulates that when an innovative product reaches maturity in the source country, organizations undertake FDI abroad. Dunning (1977) argues that firms use FDI to overcome geographical and cultural differences between markets and also that FDI takes place between countries with differences in factor endowments. However, the latter assertion has been challenged by the new trade theory (NTT), which argues that horizontal integration involving FDI is carried out between developed economies with similar factor endowments to take advantage of economies of scale (Dorakh, 2020).

Unlike trade, FDI flows do not have a single theoretical model associated with them. Dorakh (2020) suggests that these flows are best understood using a variety of theories, most derived from neoclassical trade theory together with NTT and industrial organization theory. The determinants of FDI differ over time and between country pairs and regions, and the explanations for them are variously associated with conceptual frameworks encompassing factor endowments, production and international capital movements. In the more recent literature, FDI has been examined in relation to specific institutional and industrial policies in both the host and the sending countries (Dorakh, 2020).

Gravity models are viewed as a robust empirical method for examining trade between countries while taking into account distance and economic size. The general gravity model deals with bilateral trade flows and was first applied by Tinbergen (1962). Anderson and Van Wincoop (2003) argued that relative trade costs must be accounted for if an accurate model was to be created because "trade between two regions depends on the bilateral barrier between them relative to average trade barriers" (Anderson and Van Wincoop, 2003, p. 176). Accordingly, multilateral trade resistance (MRT) terms are introduced to reflect the relative trade costs of two countries, with inward MRT measures capturing the ease with which importers can access the market and outward MRT measures capturing exporters' ease of market access (Yotov and others, 2016).

Less common is the use of gravity models to examine FDI between countries in a way that takes trade, size and distance into account. Dorakh (2020) examines the increase in FDI in countries acceding to the European Union (EU), while attempting to estimate how much EU membership promotes FDI in these countries. He finds that FDI in the EU, when combined with international trade, fosters deeper links between member and non-member countries and that infrastructure, production and labour quality play important roles in attracting it. The author therefore confirms that the gravity model is the best-fitting model for estimating the determinants of bilateral FDI flows. According to Baldwin and Taglioni (2011), GDP may be a reasonable proxy for both consumer- and producer-driven demand shifts in the role of trade in vertical specialization, and this reasoning can be adapted to the analysis of FDI flows. GDP should be less good at proxying for the underlying demand shifters. We would thus expect the origin country's GDP and the destination country's GDP to have diminished explanatory power when value chain trade is important, as it is likely to be where FDI is concerned.

Frenkel, Funke and Stadtmann (2004) argue that economic size, risk and economic growth drive the level of FDI flows, while the distance factor negatively influences them. Other studies on the determinants of FDI flows have also considered variables other than those traditionally used in gravity models. This is the case with the study by Alfaro and others (2004), who argue that high-quality financial institutions attract higher FDI flows. Similarly, Asiedu (2006) identifies factors such as infrastructure, inflation, the legal system and the investment framework as determinants of FDI flows. Aleksynska and Havrylchyk (2013) even suggest that countries with institutional weaknesses can attract FDI when they have an abundance of natural resources, as Colombia does. Almfraji and Almsafir (2014) survey

the literature and find general evidence that FDI exerts positive effects on the host country's economic growth. All this indicates that relevant studies take account of gravity variables additional to those considered in the basic gravity model.

Overall, FDI is one of the most important variables explaining economic growth and thence economic development. Lastly, this review suggests that the factors driving FDI vary from country to country (Mishra and Jena, 2019) and depend on the characteristics of both the home and the host country.

III. Data

Following the FDI literature (Brainard, 1997; Dellis, Sondermann and Vansteenkiste, 2017; Wong and Tang, 2011), we use the values for net FDI inflows as a dependent variable. To deal with negative flows without losing the information conveyed by such values, we replace negative values with zero values as explained below. These values are provided by Banco de la República (2021) in current dollars. Additionally, we account for cultural and geographical aspects such as distance, contiguity, a common language and a shared landlocked situation. These variables come from the Gravity and GeoDist databases provided by the Centre for International Prospective Studies and Information (CEPII) and are also included in the Bilateral Longitudinal Observations and Country Statistics (BLOCS) database (Wu and others, 2022).

We also consider variables linked to economic and trade integration, such as whether the countries involved are OECD members, whether there is a preferential trade agreement (PTA) (this variable covers any type of trade agreement) and whether the parties share a bilateral investment treaty (BIT). These last two variables are constructed with data from the Ministry of Commerce, Industry and Tourism of Colombia (2022). It should be noted that although some PTAs include a chapter on investment, we construct the BIT variable by considering whether there is an individual bilateral investment treaty between the pair of countries, regardless of whether there is a specific investment chapter in their PTA.

Additionally, we include variables connected to economic and trade performance. First, the GDP variable for the origin and destination countries is taken as a measure of their economic size. Second, Colombian exports and imports (included in the model individually) are used to determine whether there is a relationship between the FDI flows captured by Colombia and the trade flows generated from the country to its partners and vice versa. We also include variables related to labour productivity in the origin and destination countries, using World Bank data to construct a ratio between GDP and the country's labour force on the basis of new trade theory (NTT). Lastly, the model considers variables related to the institutional quality or governance of Colombia as a host country for FDI, in view of the argument made by Acemoglu, Gallego and Robinson (2014) that the institutional quality of nations is a determinant of their development. The variables taken, in view of the country's difficult political conditions, are the rule of law indicator and the political stability and absence of violence/terrorism indicator provided by the World Bank's Worldwide Governance Index (WGI). Other institutional variables provided by the World Bank were included in the econometric study but turned out to be statistically insignificant. Table 1 gives more details of the variables included in the gravity equation.

Lastly, it is relevant to point out that the choice of the period analysed (2007–2020) was conditioned by the limited statistical information available from the Colombian central bank on FDI inflows into the country. Additionally, the 204 partners included in the study are the countries with which Colombia traded goods in the period analysed.

Table 1
Model variables

Variable	Variable code	Description	Updated	Source	Expected sign
Foreign direct investment$_{jCol}$	FDI$_{jCol}$	FDI inflows from Colombia's partners to Colombia in current dollars	February 2022	Central Bank of Colombia	
Log distance$_{jCol}$	LogDIST$_{jCol}$	Logarithm of distance in kilometres between Colombia and its partners	January 2022	Centre for International Prospective Studies and Information (CEPII)	-
Common language$_{jCol}$	COMLANG$_{jCol}$	Colombia and its partners share a common official or primary language	January 2022	CEPII	+
Contiguity$_{jCol}$	CONTIG$_{jCol}$	Shared physical border between Colombia and its partners	January 2022	CEPII	+
Landlocked$_{jCol}$	LANDLOCKED$_{jCol}$	Colombia and its partners alike are landlocked	January 2022	CEPII	-
Organisation for Economic Co-operation and Development$_{Col}$	OECD$_{Col}$	Colombia is a member of OECD	March 2022	OECD	+
Organisation for Economic Co-operation and Development$_{j}$	OECD$_{j}$	Colombia's partner is a member of OECD	March 2022	OECD	+
Preferential trade agreement$_{jCol}$	PTA$_{jCol}$	Colombia and its partners share a preferential trade agreement	January 2022	CEPII	+
Bilateral investment treaty$_{jCol}$	BIT$_{jCol}$	Colombia and its partners share a bilateral investment treaty	January 2022	Ministry of Commerce, Industry and Tourism	+
Log gross domestic product$_{Col}$	LogGDP$_{Col}$	Logarithm of Colombian gross domestic product in constant dollars	January 2022	CEPII	+
Log gross domestic product$_{j}$	LogGDP$_{j}$	Logarithm of partner countries' gross domestic product in constant dollars	January 2022	CEPII	+
Log Colombian exports$_{Colj}$	LogCOLEXP$_{Colj}$	Logarithm of Colombian exports to its partners in current dollars	March 2022	International Monetary Fund (IMF)	+
Log Colombian imports$_{jCol}$	LogCOLIMP$_{jCol}$	Logarithm of Colombian imports from its partners in current dollars	March 2022	IMF	+
Log labour competitiveness$_{Col}$	LogLABCOMP$_{Col}$	Logarithm of labour competitiveness in Colombia	February 2022	Calculated by the authors from World Bank data (GDP/ labour force)	+
Log labour competitiveness$_{j}$	LogLABCOMP$_{j}$	Logarithm of labour competitiveness in Colombia's partners	February 2022	Calculated by the authors from World Bank data (GDP/ labour force)	+
Log rule of law$_{Col}$	LogRULELAW$_{Col}$	Rule of law in Colombia	March 2022	World Bank	+
Log political stability$_{Col}$	LogPOLSTABIL$_{Col}$	Political stability and absence of violence/terrorism	March 2022	World Bank	+

Source: Prepared by the authors.
Note: "Col" denotes Colombia and "j" the partner country.

IV. Methodological approach

The empirical research implements a relevant, robust and effective econometric approach to capture the characteristics that support or hinder FDI inflows into Colombia: the gravity model. The theoretical and empirical basis of the model was developed by Anderson and Van Wincoop (2003), who then went on to contribute to some of its most important advances. According to Frankel, Stein and Wei (1997), the model establishes that the volume of bilateral trade is proportional to the size of the economies involved, and also that physical distance between them is detrimental to their trade. The gravity model has been widely applied to establish the factors that stimulate or hinder the evolution of various economic variables. It has been used in areas as diverse as transport, local trade, tourism and investment policies, among others (Giuliano, Chakrabarti and Rhoads, 2015). It has also been employed by a wide variety

of authors to understand the behaviour of FDI flows between pairs of countries (e.g., Anderson, Larch and Yotov, 2016; Baltagi, Eggery and Pfaffermayr, 2008; Bénassy-Quéré, Coupety and Mayer, 2007; Bergstrand and Egger, 2007; Egger and Pfaffermayr, 2004; Helpman, 2006).

Although FDI patterns also display gravity characteristics, applied empirical methods have traditionally focused on trade gravity model estimations and have examined FDI in only a limited way. The most influential paper in this area comes from Baier and Bergstrand (2007), who first designed a panel data FDI analysis and showed that an instrumental variable approach was not sufficient owing to the endogeneity issue.[2] FDI models present the same challenges and biases to be avoided as are identified in the trade literature. For this paper, we extended the earlier literature and applied FDI gravity model recommendations derived from more recent work (Anderson, Larch and Yotov, 2016; Baier, Yotov and Zylkin, 2019). Specifically, we used an estimation of the structural FDI gravity model for Colombia as shown in equation (1).

$$FDI_{jCol} = exp(\beta_0 LogDIST_{jCol} + \beta_1 COMLANG_{jCol} + \beta_2 CONTIG_{jCol} + \beta_3 LANDLOCKED_{jCol} + \beta_4 OECD_{Col} + \beta_5 OECDD_j + \beta_6 PTA_{jCol} + \beta_7 BIT_{jCol} + \beta_8 LogGDP_{Col} + \beta_9 LogGDP_j + \beta_{10} LogCOLEXP_{Colj} + \beta_{11} LogCOLIMP_{jCol}) n_{jcol} \quad (1)$$

where *j* denotes the FDI sending country and the variables are as shown in table 1.

We also measured the effect of labour competitiveness in attracting FDI flows to Colombia. Following Álvarez and others (2018), the LABCOMP variable is related to labour productivity, proxied by GDP per worker (labour force). The authors point out that a positive sign for this coefficient denotes lower margin requirements and also greater labour competitiveness. The inclusion of a productivity proxy variable in our model is relevant because of the type of investment that FDI involves and the impact that countries' level of labour competitiveness can have in attracting or generating these monetary flows. The specification that includes the labour competitiveness variable is embodied in equation (2).

$$FDI_{jCol} = exp(\beta_0 LogDIST_{jCol} + \beta_1 COMLANG_{jCol} + \beta_2 CONTIG_{jCol} + \beta_3 LANDLOCKED_{jCol} + \beta_4 OECD_{Col} + \beta_5 OECD_j + \beta_6 PTA_{jCol} + \beta_7 BIT_{jCol} + \beta_8 LogGDP_{Col} + \beta_9 LogGDP_j + \beta_{10} LogCOLEXP_{Colj} + \beta_{11} LogCOLIMP_{jCol} + \beta_{12} LogLABCOMP_{Col} + \beta_{13} LogLABCOMP_j) n_{jcol} \quad (2)$$

Considering the implications and perceptions of the economic context in a country receiving flows of FDI from foreign companies, we also propose the use of two additional variables provided by the World Bank, included separately in the model to avoid correlation problems. The first variable is the rule of law, which relates to the business environment in the receiving country. According to Gani and Scrimgeour (2016), this variable represents the strength of the law and is critical to investment and economic performance. Its inclusion in the model allows us to present equation (3).

$$FDI_{jCol} = exp(\beta_0 LogDIST_{jCol} + \beta_1 COMLANG_{jCol} + \beta_2 CONTIG_{jCol} + \beta_3 LANDLOCKED_{jCol} + \beta_4 OECD_{Col} + \beta_5 OECD_j + \beta_6 PTA_{jCol} + \beta_7 BIT_{jCol} + \beta_8 LogGDP_{Col} + \beta_9 LogGDP_j + \beta_{10} LogCOLEXP_{Colj} + \beta_{11} LogCOLIMP_{jCol} + \beta_{12} LogLABCOMP_{Col} + \beta_{13} LogLABCOMP_j + \beta_{14} LogRULELAW_{Col}) n_{jcol} \quad (3)$$

Equation (4), the last, captures the effect of the political stability and absence of violence/terrorism variable. This variable represents perceptions of the likelihood of political instability and violence, including terrorism. We believe it to be fundamental in the attraction of FDI flows to a country like Colombia, which has been experiencing an internal armed conflict for more than 50 years. Colombia has been in a

[2] The type of matrix proposed (one FDI recipient and many FDI sending countries) means that it is not possible to include a time dummy variable. See Gashi, Hisarciklilar and Pugh (2017).

post-conflict situation since 2016 and the signing of a peace agreement with the country's main armed group, the Revolutionary Armed Forces of Colombia – People's Army (FARC-EP); similar agreements are currently being negotiated with several armed groups in the country.

$$FDI_{jCol} = exp(\beta_0 LogDIST_{jCol} + \beta_1 COMLANG_{jCol} + \beta_2 CONTIG_{jCol} + \beta_3 LANDLOCKED_{jCol} + \beta_4 OECD_{Col} + \beta_5 OECD_j + \beta_6 PTA_{jCol} + \beta_7 BIT_{jCol} + \beta_8 LogGDP_{Col} + \beta_9 LogGDP_j + \beta_{10} LogCOLEXP_{Colj} + \beta_{11} LogCOLIMP_{jCol} + \beta_{12} LogLABCOMP_{Col} + \beta_{13} LogLABCOMP_j + \beta_{14} LogPOLSTABIL_{Col}) n_{jcol} \quad (4)$$

Observations in which the dependent variable takes a value of zero pose a problem for log-linear estimation; as the log of zero is undefined, zero FDI flows will drop out of the estimation (Bacchetta and others, 2012). We therefore resort to the Poisson pseudo-maximum likelihood (PPML) estimator proposed by Santos Silva and Tenreyro (2006). They argue that the PPML approach is able to include zero values in the dependent variable, and also takes account of possible endogeneity and other econometric drawbacks such as heteroskedasticity. Moreover, the PPML estimator has been widely used in recent studies for the consistency of its results (Egger and Nigai, 2015), since it yields smaller and more appropriate coefficients than the ordinary least square (OLS) estimator (Santos Silva and Tenreyro, 2006). The authors' explanation for this is that if the parameters of log-linearized models are estimated by OLS, they will be biased under heteroskedasticity, and if the errors are heteroskedastic, the transformed errors will be correlated with the covariates.

We also estimate the gravity model with FDI inflows, which means that some observations may be negative values (divestments). Since the PPML estimator cannot work with negative values, we have the option of discarding them or setting them to zero. Discarding them would leave the estimate with a greater bias than if they were set to zero (Welfens and Baier, 2018): considering that negative FDI values imply disinvestment operations and hence non-contribution to capital formation in the receiving country, the negative investment flows can be assimilated to zero values (Guerin and Manzocchi, 2009). We also estimate our model with another approach which posits that negative values for FDI flows should be replaced by US$ 1 (see annex A1). In this connection, Dorakh (2020) states that negative FDI flows have an economic meaning and therefore cannot be discarded or replaced by zero values, since this would mean that there was no investment relationship between the countries. The author argues that setting negative FDI flows to US$ 1 instead of zero would result in a more robust estimate. Nevertheless, we follow the recommendation of Welfens and Baier (2018), although we provide the results with both techniques and find them to be similar.

Lastly, Yotov and others (2016) emphasize endogeneity issues when it comes to obtaining reliable estimates for the effect of PTAs on trade: PTA dummies may be correlated with unobservable cross-sectional investment costs. The authors argue that a reverse causality may operate, because a country may be more likely to enter into a trade agreement with another country when they already trade a substantial amount. Thus, to fully take into consideration the effects of investment agreements, we also include BITs between investing countries and Colombia.

V. Results

Table 2 gives the results of the proposed models when the variables shown in table 1 are implemented. Model 1 includes common gravity model variables known as control variables, such as distance, common language, contiguity and a landlocked situation. As expected, the distance variable shows a negative sign, meaning that, as with international trade in goods, the distance variable is a factor that is detrimental to FDI inflows into Colombia. If Colombia shares a physical border with a partner, its FDI inflows are 232% higher. This result is explained by a 37% increase in FDI inflows from Panama to Colombia in

the period analysed. Conversely, if Colombia's partner is a landlocked country, its investment flows to Colombia will decrease by 72.33%, while the common language variable is insignificant in this model. Variables related to trade and investment integration schemes also yield significant results.

Table 2
Estimation results

Variable	Model (1)	Model (2)	Model (3)	Model (4)
Log distance$_{jCol}$	-1.446***	-1.142***	-1.150***	-1.142***
	(-0.441)	(-0.358)	(-0.357)	(-0.358)
Common language$_{jCol}$	0.077	1.042**	1.072**	1.038**
	(-0.554)	(-0.505)	(-0.508)	(-0.505)
Contiguity$_{jCol}$	1.200**	1.057	1.04	1.056
	(-0.582)	(-0.733)	(-0.734)	(-0.734)
Landlocked$_{jCol}$	-1.285**	-0.947***	-0.921***	-0.943***
	-(0.569)	(-0.322)	(-0.322)	(-0.321)
Organisation for Economic Co-operation and Development$_{Col}$	-0.389*	-0.165	0.357**	-0.033
	(-0.204)	(-0.139)	(-0.147)	(-0.14)
Organisation for Economic Co-operation and Development$_{j}$	2.322***	1.328**	1.267**	1.327**
	(-0.43)	(-0.541)	(-0.538)	(-0.543)
Preferential trade agreement$_{jCol}$	-1.505***	-0.954**	-0.920**	-0.954**
	(-0.409)	(-0.443)	(-0.446)	(-0.445)
Bilateral investment treaty$_{jCol}$	1.456***	1.272***	1.269***	1.281***
	(-0.388)	(-0.431)	(-0.43)	(-0.433)
Log gross domestic product$_{Col}$	-0.072	-1.793***	-1.587**	-0.66
	(-0.418)	(-0.646)	(-0.632)	(-0.85)
Log gross domestic product$_{j}$	0.308**	0.716***	0.744***	0.714***
	(-0.136)	(-0.151)	(-0.153)	(-0.151)
Log Colombian exports$_{Colj}$	0.269	0.338***	0.338***	0.340***
	(-0.172)	(-0.101)	(-0.1)	(-0.1)
Log Colombian imports$_{jCol}$	-0.055	-0.037	-0.047	-0.038
	(-0.092)	(-0.101)	(-0.103)	(-0.1)
Log labour competitiveness$_{Col}$		1.755**	1.016	0.527
		(-0.764)	(-0.778)	(-0.998)
Log labour competitiveness$_{j}$		0.521***	0.539***	0.522***
		(-0.13)	(-0.132)	(-0.13)
Log rule of law$_{Col}$			2.800***	
			(-1.014)	
Log political stability$_{Col}$				-0.415**
				(-0.176)
Constant	21.697**	55.997**	33.496	17.001
	(-9.16)	(-23.36)	(-22.082)	(-30.227)
Observations	2 053	1 965	1 965	1 965
R-squared	0.635	0.692	0.696	0.693
Reset test	0.0391	0.9472	0.9924	0.9832

Source: Prepared by the authors.
Note: Robust standard errors in parentheses. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

OECD membership reduces Colombia's FDI inflows by 32.22%, calling into question the country's accession to the organization in 2020 as a measure to make it more attractive to FDI. However, if Colombia's partner is an OECD member, FDI inflows increase greatly: by 972.56%. The COVID-19 pandemic in 2020 may have had an additional confounding effect, but it is unlikely to have been that large. Investment decisions are generally made early in the year and executed over the following months, so that investment decisions implemented in 2020 are unlikely to have been overly biased downward by the pandemic. The variable that reflects whether Colombia and its partners have a trade agreement

exhibits a negative effect on FDI inflows into the country, contradicting some studies which affirm that these agreements promote FDI flows between the countries involved. However, it is in line with findings by Wu and others (2022) that more recent trade agreements have had very different institutional characteristics and thus diverse effects on trade patterns.

The BIT variable exhibits a powerfully positive effect (328.88%) on FDI inflows into Colombia, positioning it as a fundamental factor in explaining why this type of investment is attracted to the country. Moreover, and as expected, the partner's GDP has a positive impact on FDI inflows into Colombia, supporting the theoretical foundations of the gravity model. The Colombian GDP, Colombian exports and Colombian imports variables are insignificant in model 1. Last but not least, the result of the reset test (the specification error test of the regression equation) suggests that the model would be improved by adding omitted variables.[3]

Model 2 includes two new variables related to labour productivity in Colombia and its partners as potential promoters of inward FDI in Colombia. In this model, control variables such as distance and a landlocked situation exhibit an influence on Colombian FDI inflows much as in model 1, although with smaller magnitudes. The common language variable has a strongly positive effect (183.48%) on FDI inflows, however, while the contiguity variable becomes insignificant in this model. This is explained by the fact that FDI flows to Colombia from the countries sharing a border with it declined drastically in the period under study, with the exception of Panama. The Colombian OECD membership variable also becomes insignificant. Variables such as whether Colombia's partner is an OECD member and whether the country pair shares a PTA or BIT show effects similar to those in model 1, but with smaller magnitudes.

Additionally, the Colombian GDP variable becomes significant in this model, with a large negative effect (500.74%) on FDI inflows. This suggests that an increase in the country's GDP is detrimental to those flows, contradicting the theoretical foundations of the gravity model and the literature indicating that FDI is an important driver of economic growth. This contradictory result is explained by the structure of the panel data (one host country and many investor countries) and is related to the size of Colombia's GDP. The impact of the partner's GDP variable is positive and greater (71.6%) than in the previous model for FDI inflows into the nation. This confirms earlier findings by Rothgeb (1988), who identified a positive correlation in Latin America between FDI inflows and economic growth, especially in the construction, transport and telecommunication sectors. We further confirm findings by Li and Liu (2005) of a positive correlation between FDI and economic growth due to their positive influence on human capital, captured here via labour productivity.

Concerning the Colombian exports and Colombian imports variables, the effect of the former on FDI inflows turns positive in this model (33.8%), while that of the latter remains insignificant. Furthermore, the inclusion of a proxy for the labour competitiveness of Colombia and its partners shows the increase in Colombia's labour productivity benefiting its FDI inflows by 175.5% and the increase in the partner's labour productivity benefiting Colombian FDI inflows by 52.1%. However, the most relevant aspect of the inclusion of the labour competitiveness variable is that the reset test is highly significant (0.947), which suggests that model 2 is very well specified.

Model 3 yields very similar results to model 2. In this model, however, the Colombian labour competitiveness variable became insignificant, while the labour competitiveness of Colombia's partners shows a greater effect on FDI inflows into Colombia. The influence of the rule of law variable on Colombian FDI inflows is great (280%), which suggests that the strength of the business environment is a critical factor in attracting investment to Colombia. The reset test in this model displays the best specification (0.9924) of all the models proposed in this study.

[3] One of these omitted variables is the possibility that Colombia is a tax haven. We have not found any expository evidence that Colombia is acting as a tax haven for neighbouring countries and therefore exclude this possibility from explicit consideration in our analysis.

Lastly, model 4 also has very similar coefficients to model 3. This model addresses an aspect that has particularly influenced the evolution of Colombia since the second half of the twentieth century, namely violence and terrorism, and yields an unexpected result: a negative effect (-41.5%) for the political stability and absence of violence/terrorism variable on Colombian FDI inflows. This result suggests that when the perception of this variable improves, FDI inflows to Colombia decrease. The model yields a very high result for the reset test, which further supports our findings.

VI. Discussion

The findings obtained by estimating the proposed models allow us to delve into the characteristics of inward FDI in Colombia.

Regarding the control variables, most of the proposed models show a common language benefiting Colombian FDI inflows, unlike the contiguity variable, which has an adverse effect on them. These results explain why some of the largest investors in Colombia are Spain, Mexico and Chile. Additionally, the statistical significance of the landlocked (negative sign) and Colombian exports (positive sign) variables bears out the claim by Garavito, Iregui and Ramírez (2014) that FDI inflows to Colombia favour companies which carry out foreign trade activities, since these activities are generally impaired when countries are landlocked.

Concerning the variables related to trade integration, investment and economic size, the first thing to note is the remarkable effect on FDI in Colombia when the partner is an OECD member. This finding is confirmed by the fact that the main investors in the country are members of the organization. The PTA variable exhibits an adverse impact on FDI inflows into Colombia, which contradicts the argument of Büthe and Milner (2008) that trade agreements are associated with a liberal foreign economic policy and therefore should indirectly promote FDI flows. However, the finding is consistent, in particular, with those obtained by Abreo, Bustillo and Rodríguez (2022) regarding the negative effect of FTAs on Colombian goods exports, showing that this type of agreement is detrimental not only to exports of goods but also to FDI inflows into the country. Colombian policymakers should, though, treat the BIT variable as a particularly crucial determinant in the attraction of FDI to the country, since in each of the proposed models this variable emerges as one that can be managed and controlled to some extent by governments, unlike the other determinants measured. The prominent positive impact of the BIT variable on Colombian FDI inflows is in line with the empirical findings of Egger and Pfaffermayr (2004), who affirm that investment agreements facilitate FDI flows, something that is confirmed by the entry into force of 2,227 BITs since 1959 (United Nations, 2022).

Furthermore, the partner's labour competitiveness variable proved statistically significant and highly positive in all the models it was included in. This suggests that an increase in labour productivity in Colombia's partners should increase investment flows to the country. However, only in model 2 are Colombian labour competitiveness and the labour competitiveness of the partner country significant at the same time, and the effect on FDI attraction is found to be substantial when variables such as the rule of law and political stability and absence of violence/terrorism are not included. This result should be noted by public policymakers focused on improving labour productivity in the country, because it suggests that labour productivity is a key variable in the attraction of inward FDI, and labour productivity in Colombia, according to OECD (2019), is declining.

The results relating to perceptions of the business environment provided by the rule of law variable and its effects on Colombian FDI inflows show that the strength of the law is a critical underpinning of these flows. This finding is supported by the introduction of a series of legal reforms in recent decades (Ramirez and Quintero, 2019; Velosa, 2019) to provide a more attractive legal environment in respect of contract enforcement, property rights and law enforcement, which allows the effectiveness of these

measures in attracting FDI flows to Colombia to be verified. The finding is also partially supported by those obtained by Abreo, Bustillo and Rodríguez (2021), who identify the rule of law variable as a leading positive factor in Colombian exports.

However, the findings for the effect of the political stability and absence of violence/terrorism variable, contradicting the usual assumptions, denote an almost natural relationship between terrorism and violence and the attraction of FDI inflows, calling into question the effectiveness of improvements in the perception of political stability in recent years (especially the peace agreement reached with the largest guerrilla group in the country and the region at the time, the Revolutionary Armed Forces of Colombia – People's Army (FARC-EP), during the last government of former President Juan Manuel Santos) in attracting FDI to the country. Maher (2015) argues that violence by right-wing paramilitary groups and by the national army (as supporters of foreign investment) against guerrillas and civilians can facilitate the entry of foreign investment into a country, with Colombia being an example. This claim both extends and calls into question those of Caves (1992) about the positive effects of FDI on an economy, with the argument that in countries with violent contexts such as Colombia, there is actually a positive relationship between FDI inflows and increased violence. While seemingly contradicting the literature, these results are to be expected given the conflict situation(s) in Colombia and the various alliances that have emerged between paramilitary groups, foreign companies and political actors. These alliances have been described in detail in the study by Grajales (2017), which corroborates our empirical finding of a link between violence and increased economic activity. To go into the methodology used to calculate these alliance indicators would produce a different type of study, and we leave it to further research. Lastly, the results obtained in relation to the combined influence of the rule of law variable and the political stability and absence of violence/terrorism variable might also be considered contradictory, since it could be supposed that these indicators were complementary to a certain extent and that their evolution should have a high correlation, but from the results obtained we can affirm that this is not the case.

Lastly, two domestic issues are worth analysing as relevant for future FDI inflows into Colombia. First, the recent enactment of the so-called Total Peace legislation provides a broad legal framework for the government to carry out individual or collective peace processes with various illegal armed actors. Its objective is to achieve a comprehensive peace that allows for the construction of an inclusive and general peace environment (Office of the President of Colombia, 2022). Second, the growing recent uncertainty surrounding the energy transition policies proposed by the current President could affect the fuels industry, the country's largest. The proposal provides for the possibility of ceasing to grant new licences for oil exploration and eventual exploitation, Colombia's main source of foreign exchange (Government of Colombia, 2022). These two issues, along with others, could be crucial determinants of FDI inflows into the country in the coming years.

VII. Conclusions

This study provides some facts concerning the characteristics of FDI inflows into Colombia, using a gravity model of the relationships between Colombia and 204 countries. It includes variables that, to differing degrees, determine the attraction of FDI inflows by Colombia. These are incorporated into four models that, by employing an augmented specification of the traditional gravity model, identify the extent to which the variables included promote the entry of investment flows into Colombia.

Although most of the variables included show the expected effects on FDI inflows into Colombia, we would like to highlight some important items of evidence. First, FDI inflows into Colombia are notably higher when the partner is an OECD member. Conversely, they are lower when a PTA is in force between Colombia and the country concerned. The BIT variable has a substantial impact on the attraction of FDI to Colombia. This could be the most promising factor for boosting FDI inflows to the nation by

means of government agreements. Its key characteristic is that, unlike other variables that exhibit a capacity to promote FDI inflows into Colombia, such as labour productivity, the level of exports and Colombia's and the partner's GDP, improvements in which depend on multiple factors, the BIT factor can be achieved through the determination of the Colombian government via a focus on foreign policy actions to sign investment agreements.

The rule of law variable, as expected, is shown to have an extremely large effect on the attraction of FDI in Colombia, suggesting that any improvement focused on strengthening the law and protecting foreign investments will facilitate and promote inward investment into the country. Conversely, the finding for the political stability and absence of violence/terrorism variable is that the amount of inward FDI in Colombia increases when violence and terrorism intensify. This finding may help us to understand the complexity of the armed conflict in Colombia and its endemic relationship, in this case, with FDI inflows. This means that the so-called Total Peace legislation of the government of the current Colombian President, Gustavo Petro, which aims to build peace processes with various illegal armed actors on the right and left of the political spectrum, while its implications for the evolution of the country's internal armed conflict are currently unknown, is likely to condition FDI inflows, considering the significant effect of institutional variables on the attraction of FDI to Colombia. Lastly, further research could examine the characteristics of FDI inflows into Colombia by economic sector to identify the factors that facilitate or hinder this type of investment in the different areas of the country's economy.

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Annex A1

Table A1.1
Model estimation results

Variable	Model (1)	Model (2)	Model (3)	Model (4)
Log distance$_{jCol}$	-1.446***	-1.142***	-1.150***	-1.142***
	(-0.441)	(-0.358)	(-0.357)	(-0.358)
Common language$_{jCol}$	0.077	1.042**	1.072**	1.038**
	(-0.554)	(-0.505)	(-0.508)	(-0.505)
Contiguity$_{jCol}$	1.200**	1.057	1.04	1.056
	(-0.582)	(-0.733)	(-0.734)	(-0.734)
Landlocked$_{jCol}$	-1.285**	-0.954**	-0.920**	-0.954**
	(-0.569)	(-0.443)	(-0.446)	(-0.445)
Organisation for Economic Co-operation and Development$_{Col}$	-0.389*	1.272***	1.269***	1.281***
	(-0.204)	(-0.431)	(-0.43)	(-0.433)
Organisation for Economic Co-operation and Development$_{j}$	2.322***	-1.793***	-1.587**	-0.66
	(-0.43)	(-0.646)	(-0.632)	(-0.85)
Preferential trade agreement$_{jCol}$	-1.505***	0.716***	0.744***	0.714***
	(-0.409)	(-0.151)	(-0.153)	(-0.151)
Bilateral investment treaty$_{jCol}$	1.456***	0.338***	0.338***	0.340***
	(-0.388)	(-0.101)	(-0.1)	(-0.1)
Log gross domestic product$_{Col}$	-0.072	-0.037	-0.047	-0.038
	(-0.418)	(-0.101)	(-0.103)	(-0.1)
Log gross domestic product$_{j}$	0.308**	-0.947***	-0.921***	-0.943***
	(-0.136)	(-0.322)	(-0.322)	(-0.321)
Log Colombian exports$_{Colj}$	0.269	-0.165	0.357**	-0.033
	(-0.172)	(-0.139)	(-0.147)	(-0.14)
Log Colombian imports$_{jCol}$	-0.055	1.328**	1.267**	1.327**
	(-0.092)	(-0.541)	(-0.538)	(-0.543)
Log labour competitiveness$_{Col}$		1.755**	1.016	0.527
		(-0.764)	(-0.778)	(-0.998)
Log labour competitiveness$_{j}$		0.521***	0.539***	0.522***
		(-0.13)	(-0.132)	(-0.13)
Log rule of law$_{Col}$			2.800***	
			(-1.014)	
Log political stability$_{Col}$				-0.415**
				(-0.176)
Constant	21.697**	69.813***	47.311**	30.816
	(-9.16)	(-23.36)	(-22.082)	(-30.227)
Observations	2 053	1 965	1 965	1 965
R-squared	0.635	0.692	0.696	0.693
Reset test	0.0391	0.9472	0.9924	0.9832

Source: Prepared by the authors.
Note: See table 1 for details of the model variables. Robust standard errors in parentheses. Negative FDI values are replaced by the value 1. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

Annex A2

Table A2.1
List of countries and territories included in the study

Afghanistan	Brazil	Democratic People's Republic of Korea	Guatemala	Libya	Netherlands (Kingdom of the)	Saint Lucia	Timor-Leste
Albania	British Virgin Islands	Democratic Republic of the Congo	Guinea	Lithuania	New Zealand	Saint Vincent and the Grenadines	Togo
Algeria	Brunei	Denmark	Guyana	Luxembourg	Nicaragua	Samoa	Tonga
American Samoa	Bulgaria	Dominica	Haiti	Macao	Niger	San Marino	Trinidad and Tobago
Andorra	Burkina Faso	Dominican Republic	Honduras	Madagascar	Nigeria	Sao Tome and Principe	Tunisia
Angola	Burundi	Ecuador	Hong Kong, China	Malawi	Norfolk Island	Saudi Arabia	Türkiye
Anguilla	Cambodia	Egypt	Hungary	Malaysia	North Macedonia	Senegal	Turkmenistan
Antigua and Barbuda	Cameroon	El Salvador	Iceland	Maldives	Norway	Serbia	Turks and Caicos Islands
Argentina	Canada	Equatorial Guinea	India	Mali	Oman	Seychelles	United Arab Emirates
Armenia	Cape Verde	Eritrea	Indonesia	Malta	Pakistan	Sierra Leone	United Kingdom
Aruba	Cayman Islands	Estonia	Iran (Islamic Republic of)	Marshall Islands	Palau	Singapore	United States
Australia	Central African Republic	Ethiopia	Iraq	Mauritania	Panama	Slovakia	Uganda
Austria	Chad	Faeroe Islands	Ireland	Mauritius	Papua New Guinea	Slovenia	Ukraine
Azerbaijan	Chagos Archipelago	Fiji	Israel	Mexico	Paraguay	Solomon Islands	Uruguay
Bahamas	Chile	Finland	Italy	Micronesia (Federated States of)	Peru	Somalia	Uzbekistan
Bahrain	China	France	Jamaica	Moldova	Pitcairn	South Africa	Vanuatu
Bangladesh	Comoros	French Polynesia	Japan	Mongolia	Philippines	Spain	Venezuela (Bolivarian Republic of)
Barbados	Congo	Gabon	Jordan	Montenegro	Poland	Sri Lanka	Viet Nam
Belarus	Cook Islands	Gambia	Kazakhstan	Montserrat	Portugal	Sudan	Yemen
Belgium	Costa Rica	Georgia	Kenya	Morocco	Qatar	Suriname	Zambia
Belize	Cote d'Ivoire	Germany	Kuwait	Mozambique	Republic of Korea	Sweden	Zimbabwe
Benin	Croatia	Ghana	Kyrgyzstan	Myanmar	Romania	Switzerland	
Bermuda	Cuba	Gibraltar	Lao People's Democratic Republic	Namibia	Russian Federation	Syrian Arab Republic	
Bolivia (Plurinational State of)	Curaçao	Greece	Latvia	Nauru	Rwanda	Tajikistan	
Bonaire, Sint Eustatius and Saba	Cyprus	Grenada	Lebanon	New Caledonia	Saint Helena	Tanzania	
Botswana	Czechia	Guam	Liberia	Nepal	Saint Kitts and Nevis	Thailand	

Source: Prepared by the authors on the basis of World Bank, *Countries and Economies* [online] https://data.worldbank.org/country.

Smart diversification strategies differentiated by countries' complexity

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Abstract

This paper evaluates production diversification trajectories and proposes an empirical rule for diversification in pursuit of increased economic complexity. It concludes that the growth gains from complexity are greatest in the early stages of economic development. Less complex countries, having limited productive capabilities, diversify into products that are relatively uncomplex and similar to their existing production structure, and this is an obstacle to economic growth. Countries of medium complexity are more willing to implement bold strategies, which makes them more competitive in more complex products. Principal component analysis was used to construct the diversification rule, which proved most accurate at formulating diversification strategies involving products similar to existing production structures. This result shows that production sophistication strategies are most useful when they take account of the productive limitations of economies.

Keywords

Economic development, structural adjustment, economic conditions, productivity, production diversification, economic analysis, econometric models

JEL classification

O10, O11

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I. Introduction[1]

The questions of why some nations are richer than others and what characterizes a successful development process come up repeatedly in the economic debate. The importance of this discussion lies in the fact that most developing economies have not managed to escape from middle-income status, despite remarkable economic growth in the first decade of the twenty-first century (Jankowska, Nagengast and Perea, 2012, p. 9).

In studies of structural change, the way productive resources are allocated between sectors is identified as critical for economic growth (Kuznets, 1966). According to McMillan, Rodrik and Verduzco-Gallo (2014), Asian countries were able to boost economic growth during their development process by directing the flow of labour towards high-productivity sectors, generally of an industrial and technological character. Moreover, as Jankowska, Nagengast and Perea (2012) show, countries that escaped the middle-income trap in the post-war era of the twentieth century initiated a process of structural change in which they moved away from primary sectors and into manufacturing.

Structural change is not an automatic process, however, and it is therefore essential for resources to be allocated appropriately to different sectors (McMillan, Rodrik and Verduzco-Gallo, 2014). Authors are currently debating the idea of smart specialization, according to which a region's productive potential must be considered in policies to select the most promising sectors for economic development, with a view to identifying opportunities for enhancing competitiveness in high value added activities (Balland and others, 2019, p. 2). Thus, although high-productivity sectors may generate greater growth returns, countries differ in their opportunities for increasing competitiveness.

According to the economic complexity methodology (Hidalgo and Hausmann, 2009; Hausmann and others, 2011) and the product space methodology (Hidalgo and others, 2007), a country's production structure reveals what it is capable of producing competitively. The complexity measures proposed by Hidalgo and Hausmann (2009) are indicators of the amount of knowledge embedded in a country's production structure. In turn, the measures of proximity between products proposed by Hidalgo and others (2007) indicate how easy it is to use existing knowledge for the competitive production of each of the goods that the economy does not yet produce. While Hausmann and others (2011) present evidence that complexity predicts future per capita income growth, Balland and others (2019) show that proximity to competitive sectors increases the likelihood that a region will become competitive in the production of a given good.

Setting out from this proposition, a number of recent papers have used measures of complexity and proximity to identify sectors that are promising for economic development. Examples include studies such as Hausmann, Santos and Obach (2017) on Panama, Romero and Freitas (2018) on Brazil and Romero and Silveira (2019) on the Brazilian States.

Hausmann and others (2011) argue that the relationship between complexity and growth decreases as incomes rise. So far, however, there has been no research to ascertain whether this relationship changes significantly in countries with different levels of complexity. Again, since the work by Hidalgo and others (2007), little research has been done on patterns of production diversification in different countries, even as the material published on related diversification has grown (Hidalgo and others, 2018).

Against this background, the present article has three objectives: (i) to estimate the impact of complexity on per capita GDP growth in countries with different levels of complexity; (ii) to analyse patterns of structural change in low-, medium- and high-complexity countries whose complexity increased in the period between 1980 and 2010; and (iii) to propose a rule for identifying products that hold out promise for diversification in each country at each level of complexity, based on a set of indicators weighted using principal component analysis (PCA).

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The rest of the article is divided as follows. Section II sets out the theoretical framework used, section III presents the econometric analyses of the relationship between complexity and per capita GDP growth, section IV analyses countries' patterns of production diversification, section V formulates the proposed rules for production diversification and section VI presents the final conclusions.

II. Economic development and structural change

According to Rodríguez (2009, p. 46), economic development consists of a set of concomitant and compatible changes in the sectoral and subsectoral composition of the structures of goods and services production and labour force occupation, resulting in a continuous, orderly increase in their size and complexity. Different sectors have differing potential to generate increasing returns to scale, innovation, and productivity gains (Kaldor, 1970; Thirlwall, 2005). Modern sectors, as they are called, have a large technological component and higher productivity. Economic development can therefore be understood as an ongoing structural shift into more modern sectors (Hirschman, 1958; Kaldor, 1966; Kuznets, 1966; Prebisch, 1950; Furtado, 1964).

In assessing the development trajectories of nations, Jankowska, Nagengast and Perea (2012) point to low productivity as one of the main factors preventing some nations from achieving a sustained growth trajectory. Here, the structuralist theory of the Economic Commission for Latin America and the Caribbean (ECLAC) has contributed to the understanding of structural change by formalizing the concept of the centre-periphery system, whereby the centre and the periphery are historically differentiated by the patterns of assimilation and diffusion of technical progress in their production structures (Prebisch, 1950; Marcato, 2013; Rodríguez and others, 1995). The result is a structure that is diversified and sectorally homogeneous (in terms of productivity) in the centre and a structure that is specialized and sectorally heterogeneous in the periphery (Rodríguez, 2009, pp. 81–82). The reproduction of this system allots the periphery the role of producing and exporting commodities and the centre the role of producing and exporting industrial goods (Rodríguez, 2009, p. 82).

1. The product space, economic complexity and structural change

According to Hidalgo and Hausmann (2009), the production structure of an economy is determined by the diversity of the productive capabilities available. Hidalgo and others (2007) argue that products are related by the similarity of the productive capabilities needed to produce them (Hausmann and Klinger, 2006; Hidalgo and Hausmann, 2009). Since countries differ in the set of capabilities they have available, they present different possible trajectories of production diversification (Hausmann and others, 2011). Because economic development is related to the complexity of the goods that each country efficiently produces and exports (Hidalgo and others, 2007), it is also highly path-dependent, since the potential for export modernization depends on each country's ability to accumulate new capabilities and combine them with existing ones (Hidalgo and Hausmann, 2009).

Hidalgo and others (2007) use the revealed comparative advantage (RCA) index, formalized by Balassa (1965), to measure which goods countries export competitively (RCA > 1). By means of this indicator, the authors construct a product network using the probability of co-exporting between product categories with RCA: the product space. This co-exporting probability is called proximity. The greater the similarity of capabilities, the closer the products will be within the product space, which is nothing more than a representation of the production structure, taking the export basket of an economy as its basis.

According to Hausmann and others (2011), the production structure of developed countries is characterized by the competitive production of products located mainly in the centre of the product space, where the most sophisticated goods sharing the most characteristics with other products are located. Developing countries, meanwhile, have a production structure specializing in the production of goods at the periphery of the network, occupied by goods that have few connections with other products. Because their capabilities are less sophisticated and required by fewer products, then, developing countries will naturally find it harder to modernize their production structure.

The speed of structural change and production diversification depends on the density of the product space in the vicinity of the product that the country produces and exports competitively (Hausmann and Klinger, 2006). In other words, it depends on the level of similarity, in terms of the capabilities needed, between potential products and the country's current export basket, as captured in the density index developed by Hidalgo and others (2007). Intuitively, the greater a product's density, the closer it is to the current production structure, since it shares a greater number of capabilities with the products exported by the country.

Building on this approach, Hidalgo and Hausmann (2009) and Hausmann and others (2011) have developed the economic complexity methodology, based on what they call the reflections method. The authors begin by producing indicators of country diversification (the number of goods a country exports with RCA) and product ubiquity (the number of countries exporting that product with RCA). The authors show that the diversity and ubiquity measures are inversely related, indicating that more diversified countries competitively produce less ubiquitous goods. As part of the reflections method, the authors combine these two indicators and construct complexity measures: the product complexity index (PCI) and the economic complexity index (ECI). It is then assumed that complex products (higher PCI) have a low degree of ubiquity and are exported by more diversified countries, while complex countries (higher ECI) have a higher degree of diversification and competitively export less ubiquitous goods.

Empirical tests by Hidalgo and Hausmann (2009) and Felipe and others (2012) confirm that these measures yield empirical data which make them good predictors of a country's economic growth and the future complexity of its export basket. Thus, the goal for less developed countries, as part of the process of structural change, is to move away from the periphery of the product space and, by diversifying and learning new skills, to work their way towards the denser and more complex centre of the product network, thereby boosting future economic growth.

2. The relatedness principle and production diversification trajectories

The logic of capabilities is at the root of the relatedness principle. To put it another way, "two activities, such as products, industries, or research areas are related when they require similar knowledge or inputs" (Hidalgo and others, 2018, p. 452). Thus, a country is more likely to start production of a good with RCA the greater the number of related products that the country already exports efficiently (Hidalgo and Hausmann, 2009).

Following this principle, Pinheiro and others (2018) analyse the diversification trajectories of countries in the light of their economies' option set: the set of products they do not yet export with RCA (Pinheiro and others, 2018, p. 9). Starting with a group of 93 countries during the period from 1965 to 2015, the authors show that in almost 93% of cases, nations embark on the export of products that are relatively similar to the average product in their export basket, confirming the principle of relatedness between products in the production diversification trajectory.

According to the authors, however, there are cases, albeit fewer of them, that depart from the principle of relatedness, with countries beginning to export products unrelated to their option set. Thus, within the product space, there are trajectories of unrelated diversification (into products with little relation to the option set) and related diversification (into products with a greater relation to the option set).

Pinheiro and others (2018) have contributed to the literature on productive modernization by developing the relative density index and the product complexity index with the aim of making measures of product relatedness comparable across countries over time. According to the authors, "density estimates the distance between a product and all of the related products, and hence, has the problem that it does not fall within the same range of values for all countries" (Pinheiro and others, 2018, p. 12).

The relative density index relates a country's new exports to its option set in a given year. In equation (1), the term $\langle \omega_{c,t} \rangle_0$ refers to the average density of the option set and $\sigma_0(\omega_{c,t})$ is the standard deviation of the density of this set of products. Cases of related diversification occur when the relative density is positive, i.e. when the product concerned is closer to the production structure than the average option. Otherwise, diversification is unrelated.

$$\widetilde{\omega}_{p,c,t} = \frac{\omega_{p,c,t} - \langle \omega_{c,t} \rangle_0}{\sigma_0 \left(\omega_{c,t} \right)} \tag{1}$$

The relative complexity index analyses the level of complexity of a given product in relation to the average complexity of the option set. The term $\langle PCI_{c,t} \rangle_0$ refers to the average complexity of the products in the option set and $\sigma_0(PCI_{c,t})$ is the standard deviation of the complexity of the products in this same set.

$$\widetilde{PCI}_{p,c,t} = \frac{PCI_{p,c,t} - \langle PCI_{c,t} \rangle_0}{\sigma_0 \left(PCI_{c,t} \right)} \tag{2}$$

The interpretation of these two indicators was clarified when Pinheiro and others (2018) formalized the diversification vector, reflecting the average direction of diversification in a given time period. Intuitively, this two-dimensional vector identifies the direction of diversification in terms of variations in the similarity and complexity of new exports relative to an economy's option set. Basically, the country can diversify into products that are closer to or further from its production structure and into products that are more complex or less complex than the average option.

Applying these indicators to disaggregated international trade data, the authors find that the direction of development and the type of production diversification depend on countries' level of development. In the early stages of development, countries possess a limited set of productive capabilities and therefore specialize in less complex and more similar products. At more advanced stages, countries already have a more diversified set of productive capabilities, so their production structure is closer to that of more complex sectors (Pinheiro and others, 2018, p. 25). Lastly, the study shows that countries are more likely to embark upon unrelated diversification trajectories at intermediate stages of development, when they are close to both more complex and less complex goods.

In summary, according to the study, one of the main dilemmas of diversification arises at intermediate stages: is it best to take bigger leaps in the product space and choose unrelated diversification trajectories or to take small steps in the product space, continuing along the path followed since the early stages of development? Both are possible. According to Pinheiro and others (2018), the unrelated diversification trajectory is associated with higher levels of economic complexity. However, the costs of developing an activity as part of a related diversification process are lower, since the likelihood of success is much greater (Alshamsi, Pinheiro and Hidalgo, 2018).

3. Production diversification strategies

Recognizing the contributions of the product space and economic complexity approaches, some empirical studies have concentrated on the comparative study of countries' sophistication trajectories and on the study of productive modernization strategies.

Hausmann, Santos and Obach (2017) conducted a study of Panama's economy to evaluate production diversification strategies for the country. The authors propose an index containing different global and domestic market components to assess a product's potential. It is divided into three components: strength in Panama today, global market opportunities, and complexity analysis. The first dimension evaluates the performance of Panamanian industry, the second evaluates market opportunities for industries and the third, via an assessment of economic complexity, "captures how complex these industries are, how strategic they are (in terms of access to other complex industries) and their distances —in terms of capabilities— to industries already in place" (Hausmann, Santos and Obach, 2017, p. 35). The authors apply the diversification opportunity score to the provinces of Chiriquí and Darién.

This methodology, combined with economic complexity analysis, has served as a basis for other studies. Romero and Freitas (2018) adapted it to identify the sectors that held out the greatest promise for increasing Brazil's complexity. Likewise taking three dimensions, in this case current capabilities, market opportunities and analysis of gains, and including only products with RCA < 1, the authors developed a decision rule whereby they concluded that, of the 20 products with the greatest potential for increasing the complexity of the Brazilian economy, the top 3 were automobiles, vehicle parts and telephones. The study also found that a rise in Brazil's ECI (in the event of RCA being acquired in the 20 products listed) would lead to an increase of 0.53 percentage points in the growth rate of Brazilian per capita GDP.

Other studies conducted to identify production diversification and sophistication strategies include those carried out by Hartmann (2016) on Türkiye; Hausmann and Chauvin (2015) on Rwanda; Hartmann, Bezerra and Pinheiro (2019) on Paraguay; and, lastly, Queiroz, Romero and Freitas (2023) on the Brazilian States, using employment data. However, there has not yet been a detailed empirical study of the relationship between the characteristics of the production structure and successful experiences of economic modernization, whether based on related or unrelated diversification trajectories. This is the gap that the present paper seeks to fill so as to facilitate the proposal of an empirical rule for increasing the sophistication of economies.

III. Empirical analysis

1. Database

This study used disaggregated international trade data for the empirical analysis of countries' diversification trajectories, following the four-digit Standard International Trade Classification, revision 2. The data were obtained from the Atlas of Economic Complexity database, provided by the Center for International Development at Harvard University, and cover the period from 1962 to 2017. The GDP and per capita GDP data series for the econometric models, both in constant dollars, were obtained from World Bank Open Data.

Considering the diversity of countries and products, and recognizing that not all countries report trade data consistently with the criteria used in the international standards, the database was put through a cleaning process known as the Bustos-Yildirim method in order to produce consistent information. Once the database had been obtained, we applied a new data cleaning process with three criteria similar to those used by Hausmann and others (2011). First, only countries with data available

from 2010 were kept. Second, countries that exported at least US$ 1 billion in 2010 were kept. Third, products whose exports exceeded US$ 10 million in 2010 were kept. Lastly, the observations for Iraq, Macao (China) and Chad were removed from the database because of various concerns about the quality of these countries' or territories' data. Thus, the final sample consisted of 5,661,984 observations, 147 countries and 766 products.

2. Evaluation of production diversification trajectories

To analyse diversification trajectories, it is necessary to establish a methodology for identifying the products that a country begins to export competitively. Time periods of 10 years apiece between 1980 and 2010 will be taken, giving four time intervals for which strategies are distinguished.

A country is taken to have become competitive in the production of a product p between t and t' if $RCA_{cp} < 1$ at t and $RCA_{cp} \geq 1$ at t'. However, as Pinheiro and others (2018) point out, there is a possibility of false positives in the analysis, i.e. export patterns that are not repeated in successive periods over time. Accordingly, like those authors, we adopted a methodology to correct the analysis for false positives, whereby point t' is the reference year and point t ($t = t' - 10$) is the comparison year. The study employs a retrospective criterion whereby country c must have $RCA_{cp} < 1$ at $t - 1$ and a prospective criterion whereby country c must have $RCA_{cp} \geq 1$ at $t' + 1$. This ensures that it genuinely was not a competitive exporter of the good in the comparison year and that it had become one after the reference year.

In this section, countries' diversification trajectories are analysed on the basis of two key characteristics: (i) the similarity between new products and the existing production structure and (ii) the complexity of new products relative to the complexity of the diversification option set.

For this, the indicators of relative density $(\pi_{c,t\rightarrow t'})$ and relative complexity $(\Omega_{c,t\rightarrow t'})$ developed by Pinheiro and others (2018) will be used. Thus, there are four diversification patterns, two of related diversification (RD) and two of unrelated diversification (UD), of which two are associated with complexity above the average for the options (progressive) and two with complexity below the average for the options (regressive):

(i) Progressive RD $(\pi_{c,t\rightarrow t'} > 0$ and $\Omega_{c,t\rightarrow t'} > 0)$

(ii) Progressive UD $(\pi_{c,t\rightarrow t'} < 0$ and $\Omega_{c,t\rightarrow t'} > 0)$

(iii) Regressive RD $(\pi_{c,t\rightarrow t'} > 0$ and $\Omega_{c,t\rightarrow t'} < 0)$

(iv) Regressive UD $(\pi_{c,t\rightarrow t'} < 0$ and $\Omega_{c,t\rightarrow t'} < 0)$

3. The S-curve of the productive sophistication process

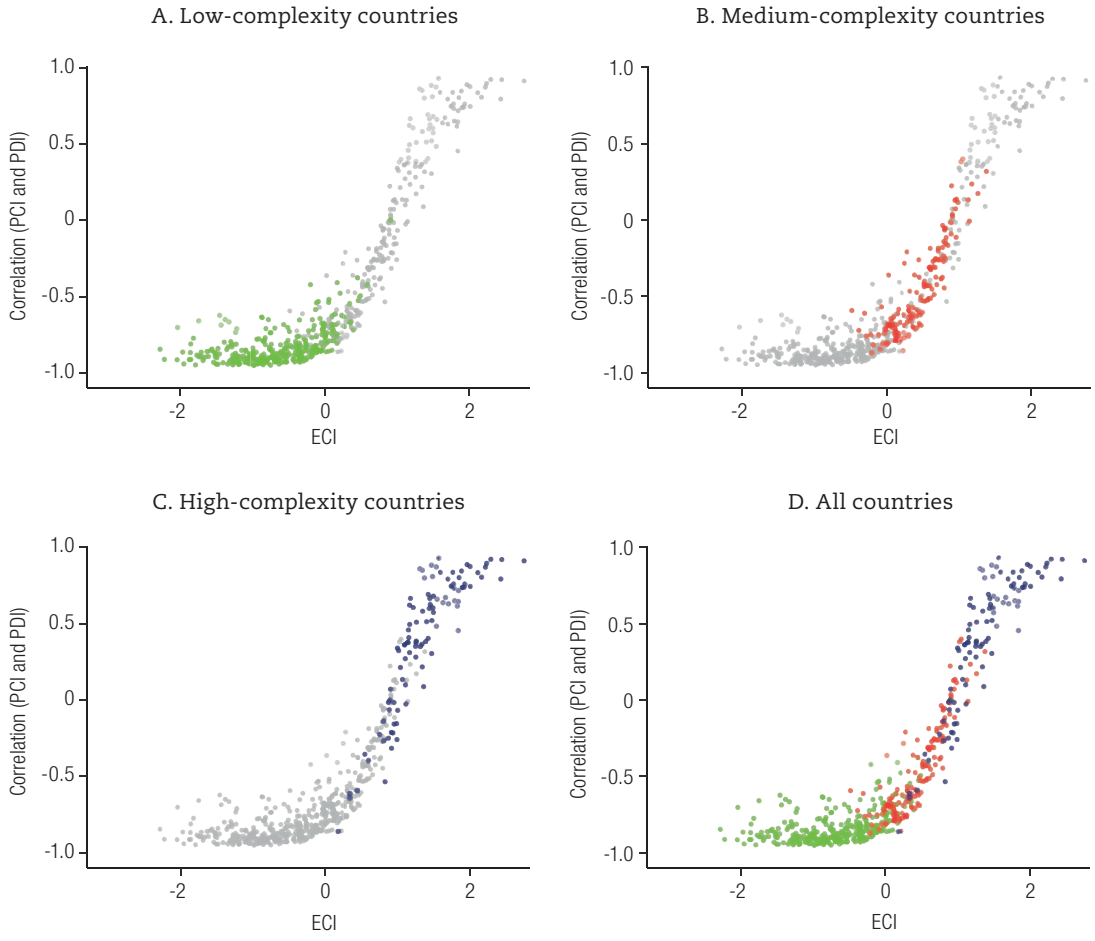
Hartmann and others (2020) use the correlation between product density and product complexity to illustrate the characteristics of each country's production structure. The calculation uses the Pearson correlation coefficient for the diversification option set. A positive value for this index means that more complex products have a higher density, i.e. the country's production structure is closer to more sophisticated products.

With the ECI on the x-axis and the correlation index on the y-axis, the authors construct the S-curve of economic sophistication, and this shows that the direction of diversification (into more or less complex goods) depends on the country's stage of development (Hartmann and others, 2020).

Setting out from this contribution, countries are classified into three different groups by the characteristics of their production structure in 2010. To divide the groups, a Chow test employing 2010 data was used to identify structural breaks in the explanatory relationship between the correlation index

and complexity. Interpreting a positive change in the correlation index as illustrating a country's move towards more sophisticated products, two break points were tested: (i) ECI = 0.0 and (ii) ECI = 1.0. For both, the value of the test statistic indicated the existence of breaks with statistical significance. The 2010 production structure classification was extended to the other years, and this is represented in the S-curve by overlaps between some points. The S-curve of sophistication in this paper thus captures the evolution of the production structure, as represented by the change in the correlation index, between 1980 and 2010 for each group of countries. The lower right panel of figure 1 shows the level of sophistication and the characteristics of the production structure of 122 countries over 10-year intervals between 1980 and 2010.

Figure 1
S-curve of sophistication



Source: Prepared by the authors.
Note: PCI: product complexity index; PDI: product density index; ECI: economic complexity index. The colour green denotes the low-complexity group ($ECI_{2010} \leq 0.0$), red the medium-complexity group ($0.0 < ECI_{2010} < 1.0$) and blue the high-complexity group ($ECI_{2010} \geq 1.0$).

In line with the results presented by Hartmann and others (2020), we found that low-complexity countries (top left panel) had a production structure associated with simpler products. For the most part, this group presented negative values for the correlation index. Moreover, it was observed that the production structure of the least complex countries evolved little in the period from 1980 to 2010, with the green dots remaining concentrated in the zone where the correlation index is less than -0.5 and the ECI is less than 0.0.

The group of countries of medium complexity (upper right panel), despite having a structure more associated with less complex products, is slightly closer to more sophisticated products. It is clear that the production structure of the countries in this group did undergo an evolution compared to the low-complexity group, since the red dots are distributed more vertically in the central zone of the curve, indicating a considerable positive variation in the correlation index between 1980 and 2010.

Lastly, the production structure of high-complexity countries (bottom left panel) is strongly associated with more complex products. As in the medium-complexity group, the distribution of the blue dots is more vertical, indicating that the values of the correlation index for these countries changed significantly between 1980 and 2010. Thus, the high-complexity countries embarked on a trajectory of change in their production structure between 1980 and 2010.

Table 1 presents the estimates for the relationship displayed in the S-curve, in a decennial analysis for the period 1980–2010. The correlation index is the dependent variable, and a positive change illustrates a structural shift towards more sophisticated products. The ECI is the explanatory variable and represents the level of complexity of countries' production structures. The regression was estimated using a two-way fixed effects panel data model.

Table 1
Relationship between stages of development and opportunities for sophistication

Variable	Low-complexity	Medium-complexity	High-complexity
Economic complexity index (ECI)	0.0638***	0.6391***	0.9455***
	(0.0217)	(0.0516)	(0.0950)
Constant	-0.7681***	-0.7492***	-0.6182***
	(0.0191)	(0.0369)	(0.1165)
Observations	272	124	92
Adjusted R^2	0.2167	0.6535	0.7391
F-statistic	4.23	39.74	47.33
p-value	0.0041	0.0000	0.0000

Source: Prepared by the authors.
Note: The model has the index of correlation (product complexity index (PCI) versus product density index (PDI)) as the explained variable. Robust standard errors in parentheses. Statistical significance of the coefficients: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

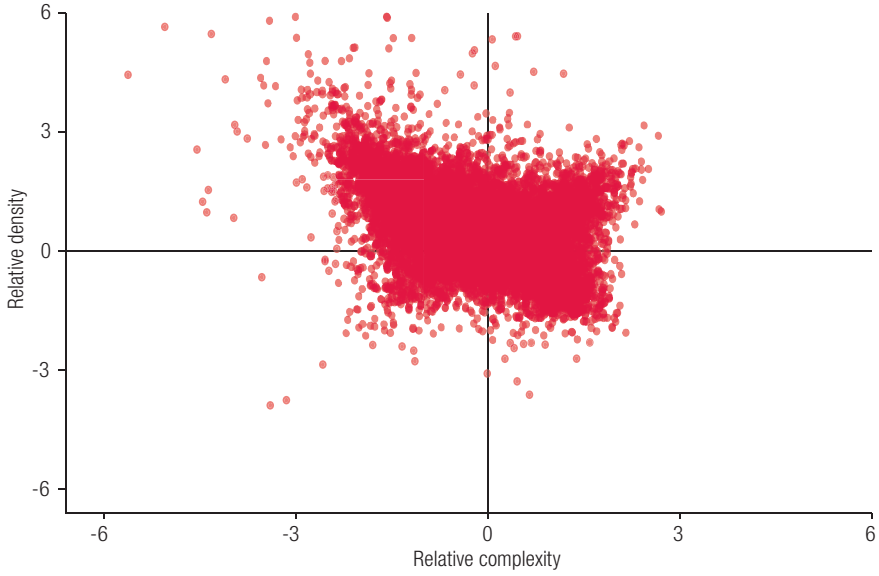
In all three groups, the ECI coefficient is statistically significant at the 1% level. The model for the low-complexity countries has the least explanatory power (21.67%). Nevertheless, in this group, the ECI coefficient has the lowest value (0.0638). Figure 1 shows that the correlation index values of low-complexity countries change little in comparison with those of the other countries. The implication is that low-complexity countries have greater difficulty in initiating the process of structural change while maintaining low levels of economic complexity.

At medium and greater levels of complexity, it becomes viable to have a diversification process that takes the production structure beyond simpler products, as indicated by the considerable increase in the ECI coefficient and the model's explanatory power. When the third group is analysed, it can be seen that the countries classified as highly complex in 2010 evinced the most rapid process of structural change between 1980 and 2010. The value of the ECI coefficient, which was 0.6391 for the medium-complexity group, is 0.9455 in this case. In summary, these results indicate that the countries that were most complex in 2010 experienced a more constant process of structural change between 1980 and 2010, while medium-complexity countries, although developing a more sophisticated production structure, did not sustain as strong a development process as the most complex countries.

4. The U-curve of the production diversification process

Figure 2 shows the relationship between relative density and relative complexity. It can be seen that most new products are in the second quadrant, i.e. are less complex (with negative relative complexity) and closer to the country's production structure (with positive relative density) than the average for the diversification option set.

Figure 2
Relationship between the relative density and relative complexity of new products

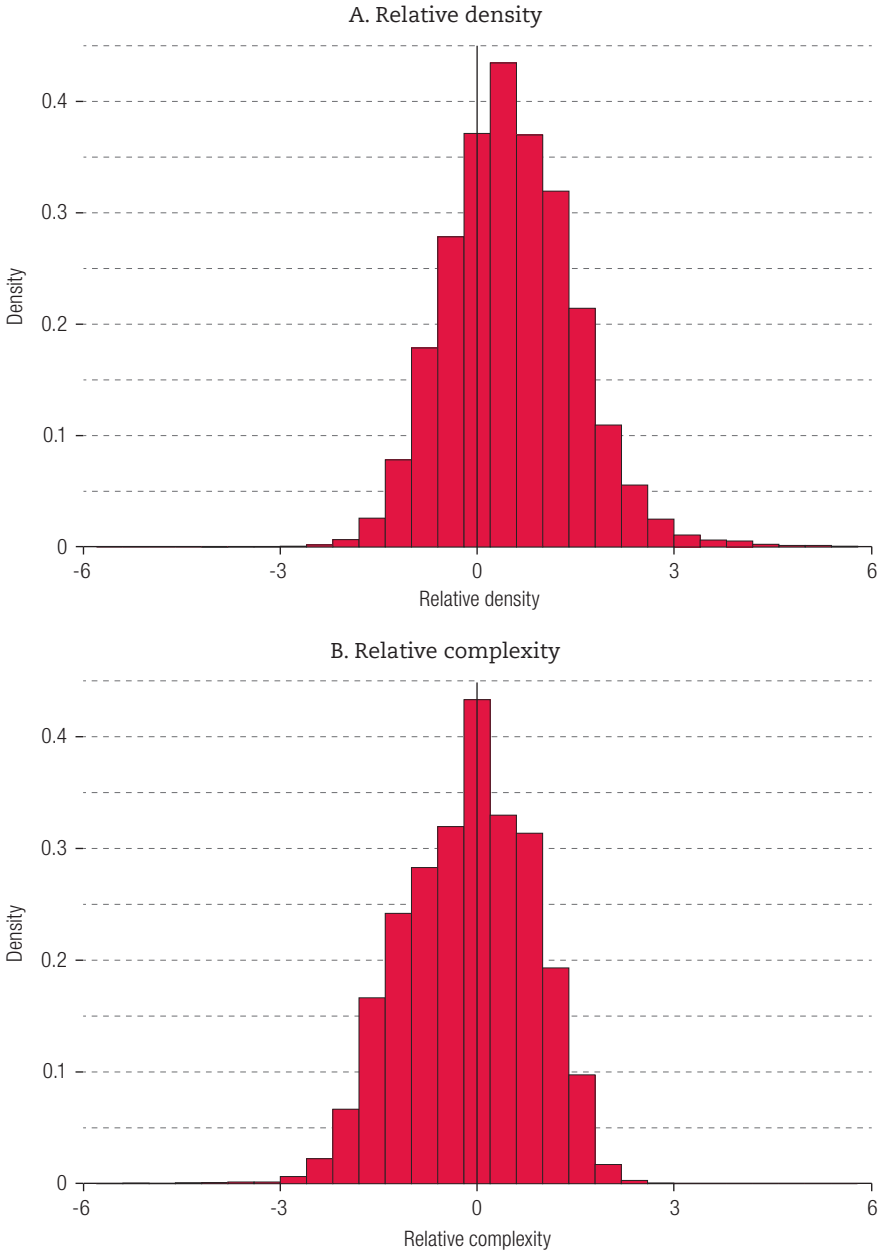


Source: Prepared by the authors.

Analysing the distribution of the relative density indicator (left-hand panel of figure 3) shows that most new products have positive relative density (70.17% of cases). This reinforces the conclusion of Pinheiro and others (2018) that, in general, countries tend to diversify their production into products that are more similar to their existing production structure. As for relative complexity (right-hand panel of figure 3), the statistics are fairly balanced. Approximately 52.34% of cases have a negative relative complexity index value. This balance can be explained by the fact that in the most complex countries, the products closest to the existing production structure are precisely the most sophisticated ones.

Table 2 summarizes the frequency with which each diversification pattern is found. Within the related diversification (RD) pattern, regressive RD accounts for 62.63% of cases and progressive RD for 37.37%. In the unrelated diversification (UD) pattern, progressive UD accounts for 71.84% of the total and regressive UD, which anyway represents a small share of new products (8.40%), accounts for 28.16% of cases. Table 2 reflects the findings of figures 2 and 3: RD is predominant, with RD into products that are less complex than the average option (regressive RD) having a higher frequency.

Figure 3
Distribution (histograms) of relative density and relative complexity values for new products



Source: Prepared by the authors.

Table 2
Diversification strategy
(Numbers and percentages)

Strategy	New products *(Numbers)*	Share of all new products *(Percentages)*
Progressive related diversification	3 775	26.22
Regressive related diversification	6 326	43.95
Progressive unrelated diversification	3 085	21.43
Regressive unrelated diversification	1 209	8.40

Source: Prepared by the authors.

Countries do not follow a single pattern, however. Table 3 details the mix of strategies within each group of countries. Low-complexity countries mostly follow a regressive RD pattern (70.07% of cases), owing to the constraints imposed by an unsophisticated production structure.

Table 3
New product diversification strategies
(Percentages)

Group	Strategy	Share by country group
Low-complexity	Progressive related diversification	8.48
	Regressive related diversification	70.07
	Progressive unrelated diversification	16.55
	Regressive unrelated diversification	4.89
Medium-complexity	Progressive related diversification	24.06
	Regressive related diversification	40.54
	Progressive unrelated diversification	27.91
	Regressive unrelated diversification	7.49
High-complexity	Progressive related diversification	49.57
	Regressive related diversification	17.81
	Progressive unrelated diversification	19.00
	Regressive unrelated diversification	13.61

Source: Prepared by the authors.

When medium-complexity countries are analysed, the shares of progressive UD (27.91%) and progressive RD (24.06%) are quite high. This once again reinforces the conclusions of Pinheiro and others (2018) and Hartmann and others (2020), which are also present in the model presented in table 1: because medium-complexity countries have a production structure that is close to both simple and sophisticated products, they are already in a position to aspire to diversification into more complex products.

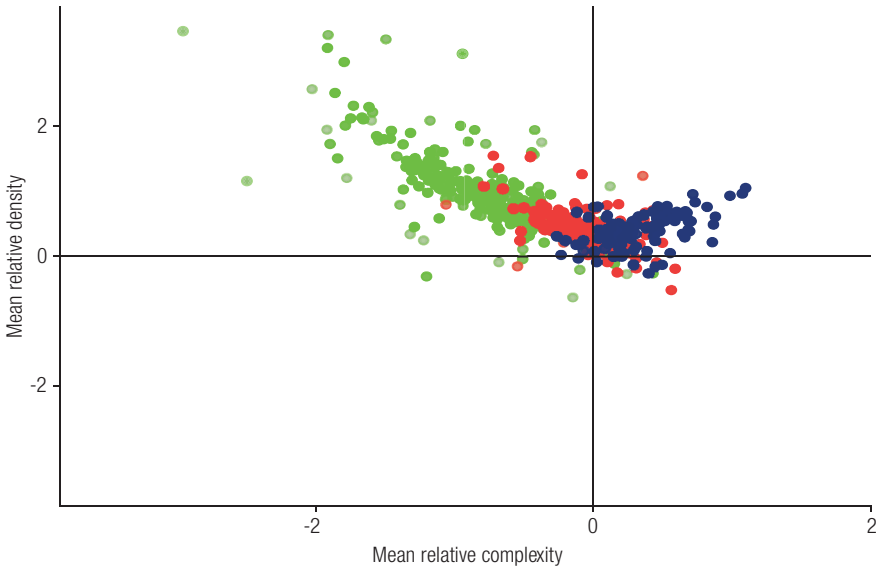
In the case of the most complex countries, progressive RD predominates (49.57%). By taking advantage of a production structure with more sophisticated knowledge and technologies, these countries can sustain a continuing increase in the complexity of this structure.

Calculating the average values of the relative density and relative complexity indices for the set of new products yields the diversification vector (Pinheiro and others, 2018) and thus the diversification trajectory of each group.

Figure 4 shows the U-curve of diversification. As in figure 1 (S-curve of sophistication), each point in figure 4 represents a country in a given year of the 10-year intervals between 1980 and 2010. As anticipated in figure 2, most new products have positive values for the relative density index. It can therefore be understood that, whichever group countries belong to, they tend on average to diversify into products that are relatively similar to those they already produce and export competitively. Average relative density had a positive value in 95.01% of the diversification trajectories analysed in figure 4.

What does seem to vary between diversification trajectories, however, is the average level of complexity of the direction taken. While low-complexity countries tend on average to move towards less complex products, with 95.97% of cases (green dots) being in the second quadrant, high-complexity countries move towards products that are more complex than the average option, with 81.44% of cases (blue dots) being in the first quadrant. Medium-complexity countries, although also mostly positioned in the second quadrant, which contains 59.54% of cases (red dots), are distributed closer to the origin (0.0). An indicator of this is that 34.35% of cases in the group are in the first quadrant, while this value is 1.10% for the low-complexity group.

Figure 4
U-curve of diversification



Source: Prepared by the authors.
Note: The colour green denotes the low-complexity group, red the medium-complexity group and blue the high-complexity group.

The results in table 3 and figure 4 confirm that the process of productive sophistication, and hence economic development, is path-dependent (Hidalgo and Hausmann, 2009). Because they possess a simpler set of capabilities, less complex countries tend to gain competitiveness in simpler and denser sectors, which shows that the difficulty of accumulating and combining more sophisticated capabilities imposes constraints on movements in the product space beyond the periphery. Meanwhile, a more sophisticated set of productive capabilities allows more complex countries to remain in central parts of the product space, maintaining competitiveness in more complex sectors. It is clear, then, that the characteristics of the production structure determine the intensity of countries' structural change (see table 1), the type of diversification strategy they adopt (see table 3) and their diversification trajectories (see figure 4). Consequently, the set of products with potential for economic development will also vary by group.

IV. Econometric tests

1. Econometric specification

One objective of this article is to divide countries into groups by the characteristics of their production structures so as to analyse diversification strategies. Thus, for each group of countries, we used the same specification as Hausmann and others (2011) to test whether economic complexity could explain the dynamics of economic growth.

$$grpcgdp_{i,t} = \beta_0 + \beta_1 lnpcgdp_{i,t} + \beta_2 ECI_{i,t} + \beta_3 natrec_{i,t} + \beta_4 ECI\_lnpcgdp + \mu_i \quad (3)$$

The variable $grpcgdp$ is the annualized growth rate of per capita GDP by 10-year interval, $lnpcgdp$ is per capita GDP at the start of the interval (in logarithms), ECI is the initial level of economic complexity, $natrec$ is natural resource exports[2] as a share of GDP at the start of the interval, $ECI\_lnpcgdp$ is the term for the interaction between the ECI and per capita GDP, and e is the error term.

Hypothetically, β_1 will capture the idea of convergence in economic growth whereby, other things being equal, poorer countries tend to grow at higher rates. By adding in the natural resource export share variable, we try to control for the effect of the wealth produced by natural resource activities, which is not explained by the economic complexity index (Hausmann and others, 2011, p. 30).

A difference from the model proposed and tested by Hausmann and others (2011), however, is that the term for the interaction between the ECI and per capita GDP was dropped in this paper when testing the model by country groups. The interaction term captures the variation in the impact of complexity on per capita GDP growth at different income levels, on the basis that lower-income countries tend to grow faster (convergence hypothesis), for which a particular type of control is required. In this paper, it is assumed that different levels of economic development affect the speed of economic growth and structural change, so that controlling for the level of complexity is more appropriate. Lastly, and again following these authors, a dummy variable was added for each decade to control for factors affecting all countries in that time interval.

2. Results

Table 4 contains the regression results for the model, replicating the tests of Hausmann and others (2011) and covering the decades 1980–1990, 1990–2000 and 2000–2010. Like Hausmann and others (2011), we opted for a stacked data regression with dummy variables for the time intervals in order to capture differences between countries in the effects of complexity on growth.

Table 4
Effects of complexity on growth in 10-year intervals, 1980–2010

Variable	(1)	(2)
Initial per capita GDP, logarithm	-0.0002	-0.0053***
	(0.0010)	(0.0012)
Natural resource export share	0.0097	0.0326*
	(0.0194)	(0.0185)
Initial value of economic complexity index (ECI)	-	0.0341***
		(0.104)
Interaction index (initial value of ECI x initial per capita PIB, logarithm)	-	-0.0025**
		(0.0104)
Constant	0.0100	0.0533***
	(0.0088)	(0.0107)
Observations	255	255
Adjusted R^2	0.0283	0.1643
F-statistic	3.53	9.32
p-value	0.0080	0.0000

Source: Prepared by the authors.
Note: The model has the annualized per capita GDP growth rate as the explained variable. Robust standard errors in parentheses. Statistical significance of the coefficients: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

[2] The definition of natural resources followed the guidelines presented in the statistical appendix of WTO (2010).

On the basis of the results, it is observed that the rise in the ECI and the interaction term increases the explanatory power of the model by about 13.6 percentage points. This explanatory gain is similar to that found by Hausmann and others (2011), which was about 14.9 percentage points. Although the size and statistical significance of the coefficients are similar to those found by those authors, however, model (2) here explains about 27 percentage points less of the variability in growth rates than their model (0.434).

The coefficients of all explanatory variables are significant. The implication is that, controlling for the initial level of per capita GDP and growth in natural resource exports, an increase in the economic complexity index is related to an increase in future per capita GDP growth rates. A gain of 0.1 in the ECI raises the per capita GDP growth rate by about 0.34 percentage points, while the impact of complexity on growth tends to be smaller for richer countries, as indicated by the negative value of the coefficient of the interaction term.

Table 5 contains the regression results for the country groups (without the interaction term). Stacked data regressions were also used for this model, with the inclusion of dummy variables for each 10-year interval. For low-complexity countries, the model has medium explanatory power, explaining 23.49% of the variance in the per capita GDP growth rate. Only the ECI coefficient is found to be significant at 10% at least. For the countries in this group, increases in the complexity of the production structure positively reinforce economic growth.

Table 5
Growth dynamics by country group in 10-year intervals, 1980–2010

Variable	Low-complexity	Medium-complexity	High-complexity
Initial per capita GDP, logarithm	-0.0026	-0.0071***	-0.0190***
	(0.0017)	(0.0020)	(0.0027)
Natural resource export share	0.0165	0.0938**	0.4488***
	(0.0202)	(0.0413)	(0.1372)
Initial value of economic complexity index	0.0088***	0.0160**	0.0059
	(0.0028)	(0.0064)	(0.0052)
Constant	0.0212	0.0675***	0.2005***
	(0.0140)	(0.0159)	(0.0219)
Observations	135	63	57
Adjusted R^2	0.2349	0.1576	0.6478
Time fixed effects	Yes	Yes	Yes
F-statistic	9.22	3.32	21.60
p-value	0.0000	0.0106	0.0000

Source: Prepared by the authors.
Note: The model has the annualized per capita GDP growth rate as the explained variable. Robust standard errors in parentheses. Statistical significance of the coefficients: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

In the case of medium-complexity countries, it is likewise confirmed that the ECI has a positive impact on the growth rate. A gain of 0.1 in the ECI tends to increase the annual per capita GDP growth rate by 0.16 percentage points. For this group, the dynamics of natural resource exports are also a determining factor in explaining the different growth dynamics. It should be noted that the model's explanatory power in this intermediate range of complexity was the lowest for any of the three groups (adjusted R^2 of 0.1576).

In the case of high-complexity countries, lastly, what is striking is that economic complexity is not statistically significant in explaining growth dynamics within the group. Hypothetically, the ECI in this group levels upward, so that factors other than the complexity of the production structure may explain the different growth trajectories of these countries.

V. A proposed production diversification rule

Building on the contributions of Hausmann, Santos and Obach (2017) and following the line of research set out by Romero and Freitas (2018) and Queiroz, Romero and Freitas (2023), the opportunity score methodology will be used to assess which products are promising for economic development, as shown in table 6. However, unlike the studies mentioned, which distribute the weight of the variables equally within each dimension, this study will use the statistical tool of principal component analysis (PCA) to determine the weight of each variable in the calculation of the score, applying PCA to low-, medium- and high-complexity country groups.

Table 6
Dimensions and indicators making up the scores and weightings, by group

Dimension	Weight	Indicators	Country group		
			Low-complexity	Medium-complexity	High-complexity
Current capabilities	1/3	Value exported per product	0.5731	0.5975	0.6364
		Revealed comparative advantage (RCA)	0.1073	0.1561	0.1490
		Compound export growth rate	0.3196	0.2464	0.2146
Market opportunities	1/3	Value imported per product	0.7265	0.9418	0.5360
		Revealed comparative disadvantage (RCD)	0.0204	-	0.0074
		Compound import growth rate	0.2532	0.0582	0.4566
Analysis of gains	1/3	Product complexity index (PCI)	0.4689	0.4276	0.3716
		Product density index (PDI)	0.0562	0.1437	0.2671
		Opportunity gain index (OGI)	0.4749	0.4286	0.3613

Source: Prepared by the authors.

The method consists in constructing particular linear combinations from a set of n original random variables in order to generate a set of principal components that explain as much information as possible within the initial set of variables and observations (Mingoti, 2007). One option for determining the number of components to be used is that proposed by Kaiser (1960), whereby components with a value greater than 1 are chosen, since the components selected should thus contain variances greater than those observed for the original standardized variables. In this paper, however, we kept the n generated components that cumulatively explain at least 80% of the variance within the dimensions. This value of 80% is considered by Manly (2008) to be a high percentage for the sum of the variances of the first components to be chosen in relation to the total variance of all components.

The PCA method will be used to calculate the weight of the variables by dimension, considering only products for which countries do not have RCA. First, the variables are standardized within the database; then, the PCA is performed; lastly, the score is calculated. This method is preferred over the assignment of equal weights to the variables because of its ability to determine the influence of each variable. If an indicator has high variability, the country data in the sample years will vary more, indicating that this indicator is more important for differentiating countries within the original set of n random variables. Thus, instead of being an ad hoc method for assigning weights to the variables, it becomes a method revealed by the data themselves.

Table 6 shows the distribution of the weights of each of the variables used to calculate the score for the groups identified earlier. With a view to basing the proposed rule on successful development experiences, only those countries presenting an increase in the ECI between the periods analysed and only those products making up the diversification option set for each country were kept in the databases of each group when the weighting was calculated.

Within the first dimension, a country's capacity to export a given good is gauged from the amount of the product exported by value, the RCA index (which indicates how competitively it is exported) and the export growth rate[3]. The second dimension captures the market opportunities for a given product on the basis of production bottlenecks. In other words, the higher the value of imports of the good, the revealed comparative disadvantage (RCD) index and the import growth rate, the greater the gains that would accrue to the country from beginning to competitively produce and export it. Developed by Britto and others (2019), the RCD index captures the performance of domestic producers compared to international competitors. The calculation is similar to that for the RCA index, only the value of imports of the product is used instead of the value of exports. If RCD > 1, there is a production bottleneck for that good.

In the third dimension, lastly, we attempt to assess the gains from beginning to competitively produce a good, for which we use the product complexity index (measuring the level of knowledge required to produce the good, i.e. how complex it is), the product density index (measuring the good's similarity to the country's production structure) and the opportunity gain index. This last was developed by Hausmann and others (2011) and measures the opportunities offered by a product that a country is not exploiting in terms of future potential for diversification into a larger number of products and more complex products.

In the case of the medium-complexity group, the PCA initially yielded a negative weight for the RCD index. Since the objective is to obtain weights with positive values for variables that do in fact explain the variability within each dimension, the RCD index was discarded for this group and only the import value and compound import growth rate variables were retained. The most significant differences between the weights are found in the analysis of gains dimension. The product complexity index (PCI) and opportunity gain index (OGI) variables are found to have higher weights in the low-complexity group of countries. In the medium-complexity countries, there is a slight increase in the weight of the product density variable. In the high-complexity countries, lastly, the weights for the analysis of gains dimension are more evenly distributed.

1. Evaluation of the diversification rules

Table 7 describes the average success rates and most recent success rates of the rule by country group. First, to evaluate the rule, the number of new products into which a country diversified was calculated, considering only countries with successful development trajectories, i.e. those whose ECI increased between two periods. The number of new products was then used to establish the list of promising industries. For example, if a country started exporting X new products competitively, the X products with the highest scores were taken. From that number, the success rate was then calculated by ascertaining how many of the new products identified by the rule were in the sectors that actually gained RCA, i.e. of all the products identified by the rule as having potential, how many were in fact export-competitive for the country that began exporting them.

Cut-offs were applied to produce two subsets of products before the success rate of the rule specified in table 6 was calculated. The subsets were of products with relative density and relative complexity above and below the average for the option set. Wherever the rule was successful, furthermore, only products with an RCA index value of between 0.5 and 1.0 were kept, since this range includes products that a country does not export competitively, but which it already produces and has some knowledge of.

[3] The rates of growth in exports and imports were obtained by calculating the annual compound growth rate.

Table 7
Validation of scores by group
(Percentages)

Group	Success rates	Above-average density	Below-average density	Above-average complexity	Below-average complexity
Low-complexity	Average success rate (1980–2010)	**32.00**	27.90	23.30	**36.39**
	Most recent period (2000–2010)	19.86	16.48	20.83	29.89
Medium-complexity	Average success rate (1980–2010)	**33.12**	23.22	23.86	**29.73**
	Most recent period (2000–2010)	32.70	32.10	24.71	31.11
High-complexity	Average success rate (1980–2010)	**33.12**	23.55	**33.94**	19.30
	Most recent period (2000–2010)	43.91	29.01	44.90	27.55

Source: Prepared by the authors, 2023.
Note: The figures in bold indicate the direction of diversification for which the rule was most successful on average over the period.

The figures in bold are the highest average success rates for the density and complexity subsets, and they confirm the results in the descriptive analysis. In the case of low-complexity countries, the rule had a higher average success rate for products with higher density and products with lower complexity than the option set averages. In these cases, countries did actually begin to competitively export one in every three products identified by the rule. The results bear out what has already been found in this paper: there is a tendency to move into products that are relatively similar to the existing production structure, and strategies targeting less complex products seem to be a better fit for existing production limitations, making regressive diversification more prevalent. However, it is observed that the success rates for the most recent period are significantly lower than the average.

In the case of medium-complexity countries, the highest average success rates are also found for products with higher density and products with lower complexity than the option set averages. In the low-complexity group, again, the rule works for one in every three products identified. What is striking is the success rate for the products furthest removed from the production structure: for the most recent period, the success rate for products with a density below the option set average was 32.10%, a value similar to that for the subset of products closer to the production structure. When this result is compared to that for the low-complexity group, and considering that the success rate for the subset with above-average complexity in the most recent period was satisfactory (24.71%), the implication is that progressive unrelated diversification holds out promise for medium-complexity countries from the perspective of the rule constructed.

In the case of high-complexity countries, lastly, the proposed rule is efficient when countries reinforce the ongoing related diversification trajectory with more complex products. Interestingly, the rule was successful in the most recent period for about 4 out of every 10 products identified by it in both the above-average density and above-average complexity subsets. Thus, the rule proved to be more effective in recommending potential products for the development of more complex economies.

It is important to note, however, that the success rate of the rules should not be interpreted as an indicator of their quality. Depending on how rules are structured, it is possible that applying them in full may yield an even higher growth rate than is actually observed. However, the extent to which the rules give the right result is an indication of their feasibility, showing that they do indeed approximate in some degree to relatively successful development trajectories.

VI. Conclusions

This article set out to assess the structural change and growth process in countries at different levels of development. Setting out from the S-curve of sophistication produced by Hartmann and others (2020), the countries were divided into three groups: low-, medium- and high-complexity.

Econometric tests were first carried out to replicate the results found by Hausmann and others (2011) and then similar tests were conducted with the sample split into low-, medium- and high-complexity countries. The contribution of this paper was to replace the term for the interaction between the ECI and initial per capita GDP with estimates by country group, in order to capture dynamics specific to each group according to its complexity (low, medium or high). This investigation revealed that complexity was associated with higher future growth only in low- and medium-complexity countries and that the relationship was strongest in medium-complexity countries. The same results were not observed for high-complexity countries.

In other words, the growth gains from economic complexity appear to be greatest and most significant at the early stages of economic development. At more advanced stages, as the production structure becomes more complex, determinants other than the amount of knowledge embodied in production may have a greater influence on countries' growth trajectories. These findings are consistent with the results of the work by Pinheiro and others (2018), who point out that it is in the initial stages of development that the crucial decision to move towards more diverse and complex economic activities (shooting high) or towards more similar and less complex activities (shooting low) is made, with the former option having greater benefits in terms of advancing the process of structural change and avoiding the middle-income trap. In line with this conclusion, the objective was to assess countries' patterns of structural change by economic complexity group. In analysing the characteristics of the production diversification processes of countries that increased their complexity in each of the groups separately, it was observed that the speed of economic development depended on the set of capabilities embedded in countries' production structures.

The indicators developed by Pinheiro and others (2018) were used to analyse different diversification patterns observed in each group of countries. The analysis indicates that low-complexity countries generally tend to diversify into products that are relatively uncomplex and more similar to the average option. They thus follow a path of diversification that is limited to low-complexity products, which explains why it is difficult for them to initiate the productive modernization process. Medium-complexity countries, although also displaying more cases of regressive related diversification, have a greater capacity to innovate in their production strategies, becoming competitive in products that are more complex than the average option, which boosts economic development. Lastly, high-complexity countries, having a production structure with greater capabilities, maintain constant trajectories of productive modernization through related diversification into products that are more complex than the average option. The finding reinforces the idea that if complexity in this group levels upward, other variables may determine and differentiate growth trajectories between countries.

Lastly, the principal component analysis method was used to identify potential products on the basis of complexity indicators divided into three dimensions: a country's current capabilities, market opportunities in the international market and the potential gains for these products in the event of diversification. The results indicate that potential products vary by group. In analysing the rule's success for countries where complexity increased, we found it to be most efficient when it recommended products that followed the diversification trajectories already adopted by those countries. In other words, convergence with the rule in low- and medium-complexity countries was greatest for the subset of products that were more similar to their existing production structure and less complex than the

average diversification option, while high-complexity countries showed greater convergence in the subset of products that were more similar and more complex than the average option, which is consistent with the result observed in figure 4 (the U-curve of diversification). In these best subsets, the rule was successful for approximately one in every three recommended products in all three groups analysed.

This article therefore substantiates the existence of path dependency in economic development, illustrated by the U-curve of production diversification, and confirms that this path dependency affects diversification strategies. The findings indicate, then, that countries at different levels of development should adopt production diversification policies based on different strategies.

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Does the decision to participate in the labour market affect people's subjective well-being?

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Abstract

This article provides evidence regarding the potential effect of labour participation on life satisfaction. To take into account possible endogeneity in the decision to participate in the labour market, a two-stage least squares estimation is carried out. Hence, an excluded instrument is used for the decision to participate, where the existence of a weak instrument is rejected. Then, to take into account the ordinal nature of the dependent variable, an ordered probit model with a binary endogenous explanatory variable is estimated. This method makes it possible to jointly estimate all the parameters of the model. The results, which are robust to the presence of endogeneity in the decision to participate, show that labour participation does not have an impact on life satisfaction. Regarding the rest of the explanatory variables included in the model, the results are in line with previous empirical evidence.

Keywords

Employment, labour market, workforce, quality of life, measurement, social surveys, econometric models, Chile

JEL classification

I31, I39, J39

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I. Introduction

In recent years, interesting evidence has emerged regarding subjective well-being in Chile. This is due to the incorporation of questions on subjective well-being in surveys, and to growing interest among researchers (Loewe and others, 2014; Montero and Rau, 2015; Montero and Vásquez, 2015; Montero and Rau, 2016; Montero and Miranda, 2020; Montero, Vargas and Vásquez, 2021). There have been several hypotheses regarding the origin of the social unrest of 2019, and rising popular discontent with the country's development conditions was identified as one possibility (Rojas and Charles-Leija, 2022). This has generated increasing interest in different means of approximating the population's level of well-being, to complement the traditional objective development indicators (MSDF, 2021).

Chile is an interesting country to analyse in this regard, as its notable development during the past 30 years has resulted in a significant reduction in the poverty rate (MSDF/UNDP, 2020). However, despite rapid economic growth, access to quality goods and services has not been entirely homogeneous, and persistent inequality (in various dimensions) has led to growing discontent among the population. Thus, it is important to conduct a more detailed analysis to identify the determinants of subjective well-being, in order to generate empirical evidence that complements the design, monitoring and evaluation of public policies.

This article relies on the very innovative Social Well-being Survey, which was conducted in 2021 with the aim of understanding the determinants of subjective well-being. The main objective is to estimate the effect of labour participation on life satisfaction. In principle, one could anticipate a positive effect, in that entry into the labour market allows for more comprehensive personal development, thus expanding future prospects; all of the above would translate into experiencing higher life satisfaction. Conversely, people who do not participate in the labour market would be more restricted, opting for second-order life paths. Nevertheless, and considering the neoclassical model of the labour market, one could equally hypothesize that because people are optimizing their individual preferences on the basis of their individual restrictions, there should be no significant difference in terms of well-being between the two groups. In effect, each person maximizes his or her utility in accordance with his or her constraints, thereby achieving the highest possible level of well-being. For some people, greater well-being may come from active participation in the labour market, while for others, maximization may lead to a decision not to participate.

This question poses a methodological challenge: the decision to participate in the labour market could be endogenous and depend on certain variables, for example personality traits, being the head of the household or having to care for people. Moreover, some of these variables could themselves be determinants of life satisfaction, in which case there is an endogeneity problem: correlation between the model error and the labour participation variable render direct estimates unreliable. In order to take into account the possible endogeneity of labour participation, a two-stage least squares (2SLS) estimation is carried out; having good instruments are critical in this regard. Then, because the dependent variable is ordinal, an ordered probit model with a binary endogenous explanatory variable is estimated.

The resulting estimates show that the decision to participate in the labour market does not have a statistically significant effect on life satisfaction. Thus, public policies that are designed to increase labour participation should aim to facilitate access to higher household income while recognizing that the effect on subjective well-being is negligible. People report being equally satisfied with their lives —keeping everything else constant— regardless of labour market participation.

For the other variables included in the model, the results obtained are similar to those previously identified in the literature. Monetary income has decreasing marginal utility and reference group income has a negative impact on life satisfaction (Card and others, 2012; Montero and Rau, 2016), while the proxy variable for personality traits has a significant effect on life satisfaction (De Neve and others, 2012).

The following section presents a review of the available empirical evidence. Section III presents the methodology utilized. Section IV presents the data used and the results obtained, and section V presents the conclusion.

II. Empirical evidence

There is ample evidence regarding the determinants of life satisfaction, especially for developed countries. It is known, for example, that income has a positive but decreasing impact on life satisfaction. However, evidence on other dimensions, such as years of schooling, has been mixed: in developing countries, a positive effect is shown, while for developed countries, negative effects are sometimes found.[1] For instance, using panel data for Australia, Kristoffersen (2018) finds evidence of a positive effect of schooling on subjective well-being but also shows that the effect is sometimes neutralized by people's current circumstances.

Regarding evidence more directly related to the objective of this article, Frijters, Hasken-De New and Shields (2004), using panel data for Germany, show that participation in the labour market has a positive effect on life satisfaction. In other words, satisfaction increases as a person's employment status improves.

In contrast, Gerdtham and Johannesson (1997) find evidence suggesting that, in Sweden, being unemployed negatively affects life satisfaction. Furthermore, they find that the negative impact is stronger than that of other negative factors (such as being widowed). Also for Sweden, Korpi (1997) presents evidence suggesting that for young people, unemployment has a negative effect on well-being. In addition, "manpower programmes" are placed in an intermediate position, above those who are unemployed but below those who have a job. However, Björklund (1985), also using data for Sweden and employing panel data to control for fixed effects, provides evidence that unemployment does not have a significant impact on mental health.

It is worth highlighting the work of Ochsen and Welsch (2012), who investigate the welfare effects of labour market institutions — specifically, how they are differentiated by sociodemographic subgroup. Using data for 10 European countries for the period 1975–2002, the authors find that more employment protection and a higher benefit replacement rate significantly increase the subjective well-being of the average citizen.

The role of endogeneity is important in the identification of factors that affect the subjective well-being of people. The previous approach can be extrapolated to other variables that could also be endogenous to satisfaction. For example, Ruseski and others (2014) examined the possible endogeneity between sports participation and well-being. A priori, it should be intuitive that physical activity increases satisfaction owing to the feeling of happiness that it produces. However, the endogeneity in this case may be due to the existence of a "sports predisposition". This means that engaging in sports is not random: individuals who do so might be genetically healthier or simply more predisposed to open-air social activities. Both cases are included in an unobservable variable that could also be correlated with the variable of interest.

For Chile, some studies have been carried out to identify the effects of part-time work and the income of the reference group on job satisfaction. For example, Montero and Rau (2015), using country data, evaluate the effect of part-time work on the job satisfaction of women in Chile. Their results show that women who work part time are not less satisfied than those who work full-time. This is unlike evidence for developed countries, which shows that women in part-time employment experience greater job satisfaction (Booth and Van Ours, 2008).

[1] Such results may seem counterintuitive, but they are in fact consistent with the idea that education is associated with higher expectations regarding life circumstances. Thus, education can be associated with greater subjective well-being only to the extent that the ability to meet expectations is improved.

With the aim of evaluating in more detail the effect of the reference group income on job satisfaction, Montero and Vásquez (2015), using data from the first National Survey on Employment, Work, Health and Quality of Life (2009/10), estimate the effect of the reference wages on the job satisfaction of Chilean workers. The authors' estimates control for a variable that measures personality traits, following the methodology proposed by Van Praag, Frijters and Ferrer-i-Carbonell (2003) to take into account the role of the unobservables. Montero and Vásquez (2015) conducted a semi-non-parametric estimation of extended ordered probit models in order to identify the determinants of job satisfaction. Their results show that a 10% increase in the reference group wage would need to be compensated for by a 24.9% increase in the own wage to give the same level of job satisfaction. This shows the enormous importance of the reference group wage for job satisfaction.[2]

Most recently, Montero and Miranda (2020), again for the working population, analyse the domains of life satisfaction using the two-layer model of Van Praag, Frijters and Ferrer-i-Carbonell (2003). Their results show that the most important domains for Chilean workers are family life, leisure, health and work.

To the best of our knowledge, no evidence has been produced that shows the relationship between labour participation and life satisfaction in Chile. This article, therefore, seeks to provide such evidence. Given that the international evidence is mixed, it is worth investigating the effect in question and providing background information for developing economies.

III. Methodology

For the purposes of conceptualizing the discussion, consider the following model:

$$w_i = x_i'\beta + \alpha p_i + u_i \tag{1}$$

where w corresponds to the subjective well-being of the individual, x represents a set of variables that affect people's subjective well-being (e.g. age, gender, education, income and marital status), p is a dummy variable that takes the value 1 if the individual participates in the labour market, and u is a well-behaved stochastic shock.

The proposed model suffers from a problem in that it does not take into account personality traits. It is expected that personality traits are a determinant of subjective well-being and probably also affect the decision to participate in the labour market. Therefore, the model must incorporate a variable that measures personality traits (z), as follows:[3]

$$w_i = x_i'\beta + \alpha p_i + \gamma z_i + u_i \tag{2}$$

The problem is that we do not have a variable that measures personality traits. Therefore, the methodology proposed by Van Praag, Frijters and Ferrer-i-Carbonell (2003) is followed to build a (partial) proxy of personality traits $(\hat{z})$. This procedure is described below.

[2] For developed countries, there is mixed evidence regarding the effect of reference group income on subjective well-being. For example, Drichoutis, Nayga and Lazaridis (2010), presenting evidence for Europe, find that the income of the reference group would have a null impact on the subjective well-being of the population. Previously, Caporale and others (2009) provided evidence of a negative effect for Western European countries and a positive effect for Eastern European countries, which is consistent with the "tunnel effect" of the reference income. Senik (2004) also provides evidence for the existence of the "tunnel effect" in the Russian Federation.

[3] In stricter terms, the model also fails to take into account other variables —in addition to personality traits— that could affect the decision to participate. Normally, the exclusion of these potentially relevant variables is due to the partial availability of data. For example, Powdthavee (2009) shows that, for both genders, the life satisfaction of one partner in a couple has a positive and statistically significant spillover effect on the other partner. In the econometric model, it would be useful to include the subjective well-being of the couple as an explanatory variable. Unfortunately, the Chilean survey does not provide such data.

Consider the existence of "J" domain satisfactions, where the determinants of each of these domains can be modelled as follows:

$$D_j = f(q_j, z) \tag{3}$$

for $j = 1, ..., J$ and where q represents variables affecting the domain satisfaction; z represents other common unobservable variables. The first stage consists of estimating by ordinary least squares (OLS) the J equations (one for each domain) and calculating the residual vectors. The objective is to obtain the part of z that is common to all the residuals, which could be defined as the first principal component of the J x J error covariance matrix. The resulting new variable would be the instrument for z (i.e. $\hat{z}$). The second stage consists of incorporating this new variable —the instrument for personality traits variable— in the estimation of the equation (2). This makes it possible to obtain a (partial) proxy for personality traits.

Strictly speaking, the variable $\hat{z}$ corresponds to a measure of unobserved heterogeneity. It is the best that can be achieved with cross-sectional data, given that the methodology proposed by Van Praag, Frijters and Ferrer-i-Carbonell (2003) is applied using panel data. It should be remembered that, in the context of panel data, one can control for the existence of fixed effects over time.[4] Thus, although $\hat{z}$ may be an imperfect substitute for the fixed effects, it is based on the assumption that there is an element common to all domains that codetermines both life satisfaction (w) and satisfaction with each domain (D_j). However, there may be personality traits that determine some domains more than others and that may not be fully included in this proxy variable. This suggests that the variable $\hat{z}$ can only attenuate the endogeneity bias and that there will be other sources of endogeneity that cannot be taken into account, such as those personality traits that are not constant and that are correlated with life satisfaction and the rest of the domains —and those traits, too, could potentially be correlated with the decision to participate in the labour market.[5]

Going back to equation (2), the simplest and most direct way to estimate the parameters of this model (α, β and γ) is through OLS. However, the main disadvantage of this estimation method is that it does not take into account the ordinal nature of the dependent variable in the model (life satisfaction). This is because subjective well-being is usually measured in surveys through a question asking respondents to evaluate their life satisfaction on the basis of a Cantril scale.

In view of the above, an alternative way to estimate the parameters of this model is through an ordered probit model. Therefore, a random utility model is proposed as follows:

$$w_i^* = x_i'\beta + \alpha p_i + \gamma \hat{z}_i + \epsilon_i \tag{4}$$

where w_i^* is a variable measuring individual subjective well-being (something the econometrician does not observe), and ϵ is a well-behaved stochastic shock. In this context, what is actually observed is satisfaction with life (w), which is self-reported by the individual. The following expression shows what the econometrician observes as a function of the latent variable:

$$w = r \text{ if } c_{r-1} < w^* \leq c_r \tag{5}$$

[4] It should be noted, however, that panel data also poses some difficulties. Indeed, Van Landeghem (2019) provides evidence regarding the existence of the panel effect with data for the United Kingdom. The panel effect describes the fact that people answer differently as they gain more experience in responding to surveys. Evidence of this effect is reported for both overall life satisfaction and domain satisfaction.

[5] In more formal terms, one could posit the existence of the following relationship between the variable "personality traits" and the proxy:

$$z = \varphi_1 \hat{z} + \varphi_2 \hat{z}'$$

where $\hat{z}'$ corresponds to the part of the personality traits that are not incorporated (and that complement) in z. It would be reasonable to expect that $\varphi_1 + \varphi_2 = 1$.

Thus, when $c_2 < w^* \leq c_3$, the individual reports life satisfaction equal to 3 $(w = 3)$. The probabilities associated with each response are shown below:

$$Pr(w = 1) = Pr(w^* < c_1) = F(c_1 - x_i'\beta + \alpha p_i + \gamma \hat{z}_i)$$

Then, for any $w > 1$:

$$Pr(w = r) = F(c_{r+1} - x_i'\beta - \alpha p_i - \gamma \hat{z}_i) - F(c_r - x_i'\beta - \alpha p_i - \gamma \hat{z}_i)$$

And the probability for $w = R$ is:

$$Pr(w = R) = 1 - F(c_r - x_i'\beta - \alpha p_i - \gamma \hat{z}_i)$$

Lastly, the log-likelihood function is constructed as follows:

$$log\,(L) = \sum_{i=1}^{n} \sum_{r=1}^{R} w_{ir} ln\left[Pr\left(w_i = r\right)\right] \quad (6)$$

where w_{ir} is 1 if $w_i = r$, and zero otherwise. The parameters to estimate are the following: α, β, γ and the $c's$.

A final problem to address has to do with the endogeneity of the decision to participate in the labour market. Indeed, it could be that the decision to participate in the labour market is influenced by individual life satisfaction; for example, individuals who are more satisfied with their lives could be more willing to participate in the labour market.[6]

To address this potential problem, it is possible to use instrumental variables to estimate equation (2) through 2SLS. This method requires at least one variable that is strongly correlated with the decision to participate but that does not affect life satisfaction. However, just like OLS, the 2SLS method does not take into account the ordinal nature of the dependent variable. Thus, it is necessary to estimate an ordered probit model with an endogenous explanatory variable (the decision to participate). The derivation of the model and the parameters to be estimated are found in annex A1.

IV. Data and results

The econometric models will be estimated using the results of the Social Well-being Survey (2021). This survey was conducted with a sample that is representative of the national population and was administered during the first half of 2021 to a subgroup of households from the National Socioeconomic Survey (CASEN). It featured a robust set of questions aimed at measuring quality of life in Chile.[7] The survey has 12 modules: characterization, subjective well-being, education, work, income, work-life balance, social relations, civic engagement and governance, health, housing, environmental quality and physical safety.[8]

[6] This would occur because the decision to participate (p) could be correlated with those personality traits that have not been captured by $\hat{z}$.

[7] CASEN is conducted every two or three years in the country and collects information at the household level for different dimensions (e.g. employment, housing, health and income). This survey is a very important tool that allows for better targeting of social policies.

[8] For additional information on this survey, see [online] http://observatorio.ministeriodesarrollosocial.gob.cl/encuesta-bienestar social.

In order to measure subjective well-being, the survey incorporated the question "All things considered, how satisfied or dissatisfied are you with your life at the moment?", which respondents could answer as follows: (i) totally dissatisfied; (ii) dissatisfied; (iii) indifferent; (iv) satisfied; or (v) totally satisfied. The results of this question provide the dependent variable (w) of the models to be estimated below.

Regarding the explanatory variables of the model, in addition to labour participation (p), the following were included: dummy for gender, years of schooling, age (and its square), dummies for marital status, a dummy variable for Indigenous classification, a dummy variable for immigrant, a dummy variable for residing in a rural area, a dummy variable for those who have children, number of friends, a dummy variable for participation in a church, a variable for the quality of the individual's current health,[9] household monetary income and its square, household monetary income of the reference group, and a proxy variable for personality traits $(\hat{z})$.[10]

The monetary income of the reference group is constructed following the methodology proposed by Ferrer-i-Carbonell (2005) and implemented for Chile in Montero and Vásquez (2015) and Montero and Rau (2016); this approach consists of constructing the reference group using information from four variables: age range, level of education, gender and geographical area. The age range was divided into the following categories: 18–29, 30–44, 45–59 and 60–65 years. The level of schooling was divided into the following categories: no schooling or incomplete basic education, complete basic education, incomplete secondary education, complete secondary education, incomplete higher education and complete higher education. The geographical area was divided into North, Centre, South and Metropolitan Region. Grouping the variables for each of the categories gives a total of 192 cells. Then, we proceed to calculate the average household monetary income for every single cell that constitutes the income of the reference group.[11]

For the purposes of this study, the following domains (D) were used in order to construct the proxy variable for personality traits $(\hat{z})$: D_1, satisfaction with the educational level achieved; D_2, satisfaction with income level; D_3, satisfaction with social life; D_4, satisfaction with health; D_5, satisfaction with home; D_6, satisfaction with local environmental situation; and D_7, satisfaction with local safety level. Individuals must rate their level of satisfaction with each of these domains on a scale from 1 to 5.[12]

Table 1 presents the estimates made for each of the domains —see equation (3)—, which allow the vectors of the residuals, and thus the principal component, to be obtained. To carry out the OLS estimation of the model for each domain, the following explanatory variables were used: dummy for gender, age (and its square), years of schooling, dummy variable for Indigenous, dummy variable for immigrant, dummy variable for residing in a rural area, household monetary income[13] and number of people in the household. The models also include region fixed effects. It is possible to appreciate that in all the models, there are variables that have a significant impact on the subjective evaluation of the domain. In addition, the R squared values range from 2.3% to 20.4% —reasonable, considering that the data are drawn from a cross section.

Table 2 presents the descriptive statistics of the main variables of the model. The sample comprises people aged 18–65. The first thing that can be noticed is that there is a slight yet statistically significant difference in favour of those who participate in the labour market in terms of life satisfaction. Average life satisfaction is 3.8 on a scale from 1 to 5.

[9] Corresponds to a self-reported score ranging from 1 to 7.

[10] Household monetary income and household monetary income of the reference group are in thousands of Chilean pesos.

[11] This strategy allows the reference group to be built exogenously. It would be very interesting to have self-reported information regarding who people are being compared to. So far, for Chile, this type of information is not available.

[12] (i) Totally dissatisfied; (ii) dissatisfied; (iii) indifferent; (iv) satisfied; (v) totally satisfied.

[13] In thousands of Chilean pesos.

Table 1
Determinants of domain satisfaction: OL

	D_1	D_2	D_3	D_4	D_5	D_6	D_7
Female = 1	-0.0466	-0.292***	-0.241***	-0.238***	0.0439	-0.0418	-0.105**
	(0.0456)	(0.0479)	(0.0477)	(0.0420)	(0.0445)	(0.0467)	(0.0471)
Age	0.00422	0.0333*	-0.0238	-0.0224	0.0299*	-0.0321*	-0.0236
	(0.0176)	(0.0177)	(0.0176)	(0.0154)	(0.0156)	(0.0169)	(0.0166)
Age squared	7.28e-05	-0.000373*	0.000246	9.30e-05	-0.000173	0.000426**	0.000305*
	(0.000189)	(0.000192)	(0.000191)	(0.000169)	(0.000170)	(0.000184)	(0.000182)
Years of schooling	0.134***	0.0286***	-0.0203***	0.0289***	0.0331***	-0.00374	-0.00311
	(0.00621)	(0.00738)	(0.00720)	(0.00642)	(0.00676)	(0.00722)	(0.00657)
Indigenous = 1	-0.00247	0.0526	-0.00506	-0.0670	-0.211***	-0.226***	-0.0507
	(0.0707)	(0.0676)	(0.0695)	(0.0626)	(0.0778)	(0.0700)	(0.0740)
Immigrant = 1	0.156*	-0.0809	-0.0475	0.102	-0.265***	0.402***	0.566***
	(0.0847)	(0.0963)	(0.0999)	(0.0839)	(0.0942)	(0.0893)	(0.0987)
Lives in a rural area = 1	0.198***	0.152***	0.0267	0.0389	0.127**	0.419***	0.413***
	(0.0535)	(0.0564)	(0.0612)	(0.0531)	(0.0528)	(0.0622)	(0.0627)
Monetary income	5.24e-08***	1.87e-07***	4.82e-09	5.78e-08***	1.00e-07***	4.86e-08**	5.77e-08***
	(1.48e-08)	(2.69e-08)	(2.34e-08)	(1.53e-08)	(1.66e-08)	(1.92e-08)	(1.79e-08)
Number of people in the household	-0.00241	-0.0181	0.0425***	0.00339	-0.0260*	0.0130	-0.0254
	(0.0154)	(0.0169)	(0.0155)	(0.0143)	(0.0158)	(0.0168)	(0.0155)
Constant	1.257***	1.851***	4.084***	4.068***	2.244***	3.242***	2.910***
	(0.410)	(0.407)	(0.405)	(0.349)	(0.359)	(0.391)	(0.375)
R squared	0.204	0.105	0.023	0.076	0.070	0.055	0.088
Observations	5 999	5 999	5 999	5 999	5 999	5 999	5 999

Source: Ministry of Social Development and Family, "Encuesta de Bienestar Social", Santiago, 2021 [online] https://datasocial.ministeriodesarrollosocial.gob.cl/portalDataSocial/ebs.

Note: The sample comprises individuals aged 18–65. Estimates include region fixed effects. Standard deviations are in parenthesis. D_1, satisfaction with education level; D_2, satisfaction with income level; D_3, satisfaction with social life; D_4, satisfaction with health; D_5, satisfaction with home; D_6, satisfaction with local environmental situation; D_7, satisfaction with local safety level. * 10% significance level, ** 5% significance level, *** 1% significance level.

Table 2
Descriptive statistics

Variable	All	Labour participation = 0 (1)	Labour participation = 1 (2)	Difference (1) - (2)
Life satisfaction (on a scale from 1 to 5)	3.878	3.775	3.915	-0.140***
Female = 1	0.511	0.696	0.444	0.251***
Years of schooling	12.609	11.384	13.050	-1.666***
Age	39.590	39.408	39.656	-0.247
Has partner = 1	0.420	0.394	0.429	-0.035
Indigenous = 1	0.101	0.107	0.099	0.008***
Immigrant = 1	0.069	0.040	0.080	-0.040***
Lives in a rural area = 1	0.115	0.142	0.105	0.037***
Has children = 1	0.675	0.681	0.674	0.008
Number of friends	3.273	2.945	3.391	-0.445***
Current health status (from 1 to 7)	5.485	5.349	5.534	-0.185***
Church attendance = 1	0.136	0.149	0.132	0.018***
Income	1 162.871	854 715	1 273.764	-419.049***
Reference income	1 163.581	923 545	1 249.961	-326.416***
Labour participation = 1	0.735	n/a	n/a	

Source: Ministry of Social Development and Family, "Encuesta de Bienestar Social", Santiago, 2021 [online] https://datasocial.ministeriodesarrollosocial.gob.cl/portalDataSocial/ebs.

Note: The sample comprises individuals aged 18–65. Income refers to household monetary income (in thousands of Chilean pesos). Reference income refers to household monetary income of the reference group (in thousands of Chilean pesos). * 10% significance level, ** 5% significance level, *** 1% significance level.

In line with the characteristics of the Chilean labour market, the majority of the people who do not participate are women (69.6%). In addition, with respect to gender, the sample is very well balanced (51% women).

In terms of human capital, there is a significant difference (almost two years of schooling) in favour of the population that participates in the labour market. This makes sense, as those who have invested the most in human capital seek to appropriate the associated profitability.

Regarding age, there are no differences between the two groups. Nor are there differences in terms of the incidence of the Indigenous population. Immigrants, however, account for 4% of non-participants but 8% of participants. This is in line with the considerable migration that the country has experienced in recent years, where most people who migrate do so with the hope of finding a job.

In addition, there is a difference in favour of those who do not participate in the labour market in terms of the rural population (14% compared to 10%). There are no differences between the two groups in terms of the presence of children, while relevant differences were found in terms of number of friends, health status (self-reported) and church attendance.

A difference of 49% can be seen in favour of labour market participants in terms of household monetary income. This is precisely the reason why countries design and promote policies to encourage the incorporation of the most vulnerable people into the labour market. In fact, labour market access is a foundational component of most anti-poverty programmes.

An interesting aspect to observe is the monetary income of the reference group. As can be seen, for labour market participants, the reference group income and household monetary income are similar. However, for those who do not participate, reference group income is 8% higher than household income.

Table 3 shows estimates of the econometric model presented in equations (2) and (6). Columns 1 and 2 show OLS estimates (equation (2)) and columns 3 and 4 show ordered probit model estimates (equation (6)). The models in columns 1 and 3 do not control for the proxy variable for personality traits $(\hat{z})$; columns 2 and 4 do.

Table 3
Dependent variable: life satisfaction

Variables	OLS		Ordered probit	
	1	2	3	4
Labour participation = 1	0.116**	0.0885**	0.128**	0.101*
	(0.0474)	(0.0443)	(0.0582)	(0.0593)
Female = 1	-0.0470	-0.0392	-0.0491	-0.0423
	(0.0633)	(0.0620)	(0.0780)	(0.0826)
Years of schooling	0.0255***	0.0330***	0.0307***	0.0436***
	(0.00805)	(0.00724)	(0.00971)	(0.00950)
Age	0.00394	0.000903	0.00233	-0.00170
	(0.0134)	(0.0128)	(0.0169)	(0.0174)
Age squared	-4.55e-05	-2.53e-05	-2.38e-05	3.31e-07
	(0.000148)	(0.000141)	(0.000187)	(0.000191)
Has partner = 1	0.114*	0.138**	0.155*	0.205**
	(0.0668)	(0.0643)	(0.0847)	(0.0879)
Divorced = 1	0.0193	0.0524	0.0326	0.0842
	(0.0634)	(0.0588)	(0.0772)	(0.0780)
Widower = 1	0.0406	0.0318	0.0663	0.0536
	(0.115)	(0.123)	(0.130)	(0.153)
Indigenous = 1	0.00892	0.0102	-0.0207	-0.0215
	(0.0539)	(0.0498)	(0.0676)	(0.0677)
Immigrant = 1	-0.213***	-0.179***	-0.257***	-0.230***
	(0.0682)	(0.0653)	(0.0850)	(0.0887)

Variables	OLS		Ordered probit	
	1	2	3	4
Lives in a rural area = 1	0.0147	0.0231	0.0369	0.0503
	(0.0574)	(0.0519)	(0.0705)	(0.0689)
Indigenous = 1 and lives in a rural area = 1	-0.0547	-0.0950	-0.0623	-0.122
	(0.109)	(0.0992)	(0.133)	(0.132)
Female = 1 and has partner = 1	0.0390	-0.0311	0.0250	-0.0673
	(0.0777)	(0.0743)	(0.0991)	(0.102)
Has children = 1	-0.0221	-0.00597	-0.0215	-0.00423
	(0.0402)	(0.0384)	(0.0514)	(0.0532)
Income	0.000120***	0.000122***	0.000169***	0.000185***
	(2.33e-05)	(2.06e-05)	(3.53e-05)	(3.35e-05)
Income squared	-4.67e-09***	-3.77e-09***	-6.19e-09**	-5.43e-09**
	(1.56e-09)	(1.19e-09)	(2.46e-09)	(2.21e-09)
Reference income	-8.75e-05*	-0.000108**	-0.000107*	-0.000143**
	(4.88e-05)	(4.47e-05)	(6.33e-05)	(6.27e-05)
Number of friends	0.0117***	0.00613	0.0167***	0.00978
	(0.00426)	(0.00401)	(0.00623)	(0.00617)
Current health status (from 1 to 7)	0.171***	0.0706***	0.213***	0.0925***
	(0.0153)	(0.0160)	(0.0181)	(0.0200)
Church attendance = 1	0.0919**	0.0919**	0.107*	0.115*
	(0.0444)	(0.0416)	(0.0588)	(0.0599)
Personality traits $(\hat{z})$	n/a	0.230***	n/a	0.320***
		(0.0126)		(0.0178)
c_1	n/a	n/a	-0.591	-1.480***
			(0.395)	(0.410)
c_2	n/a	n/a	0.580	-0.216
			(0.394)	(0.409)
c_3	n/a	n/a	0.955**	0.195
			(0.394)	(0.409)
c_4	n/a	n/a	2.568***	1.955***
			(0.396)	(0.410)
Constant	2.407***	3.008***	n/a	n/a
	(0.319)	(0.307)		
Observations	5 999	5 999	5 999	5 999
R squared	0.117	0.225	0.0541	0.112

Source: Ministry of Social Development and Family, "Encuesta de Bienestar Social", Santiago, 2021 [online] https://datasocial.ministeriodesarrollosocial.gob.cl/portalDataSocial/ebs.

Note: The sample comprises individuals aged 18–65. Standard deviations are in parenthesis. Income refers to household monetary income (in thousands of Chilean pesos). Reference income refers to household monetary income of the reference group (in thousands of Chilean pesos). * 10% significance level, ** 5% significance level, *** 1% significance level.

The OLS estimates show that that the labour participation variable has a positive and statistically significant effect on life satisfaction. That is, those who participate in the labour market have 0.116 and 0.0885 more points of life satisfaction, respectively, than those who do not participate. It should be noted that these effects even exceed the effect of schooling. This means that by participating, people obtain not only income but also a better life. Regarding the rest of the explanatory variables incorporated in the model, there are several aspects that should be highlighted. For example, the variable $\hat{z}$ is statistically significant in the model. As expected, income has a positive but decreasing effect on life satisfaction.[14]

[14] Using these results, you can calculate the monetary income at which the highest level of life satisfaction is reached. For Chile, it is found that a monthly household monetary income of 16,180,371 Chilean pesos is associated with the maximum level of life satisfaction. Considering the average size of households in Chile and the exchange rate at the time of writing, this translates into an annual value of US$ 60,430 per person. This value is below that reported by Kahneman and Deaton (2010), who found that after US$ 80,000, the income no longer has an effect on life satisfaction in the United States. However, for a correct comparison, these values should be expressed in purchasing power parity.

The effect of the monetary income of the reference group also stands out. Conceptually, the effect of the reference group on subjective well-being can be positive or negative, depending on the predominant effect: if the information effect predominates, there will be a positive impact, but if the comparison effect predominates, the impact will be negative (Senik, 2004). The estimates show that, controlling for the proxy for personality traits, the monetary income of the reference group has a negative effect on life satisfaction. The conclusion, therefore, is that the comparison effect is predominant. This result is in line with previous evidence for Chile.

With respect to the results of the ordered probit model, the interpretation of the marginal effects is not so direct. Columns 3 and 4 of table 3 show the estimated coefficients of the model $(\hat{\beta})$. At this point, it is important to discuss the interpretation of the sign of the parameter of interest, for instance $\hat{\beta}_j$. Let us assume that $\hat{\beta}_j > 0$; thus, the partial effect is negative for the first category (i.e. $w = 1$) and positive for the last category (i.e. $w = 5$). However, what happens in the middle cells (i.e. $w = 2, 3, 4$) is ambiguous and must be calculated.

The results show that the decision to participate (when controlled for $\hat{z}$) has a positive effect on the probability that the individual has the highest satisfaction with life $(w = 5)$. However, this effect is statistically significant only at 10%. The interpretation for the rest of the explanatory variables, which have positive associated coefficients, follows the same logic. For example, a greater number of years of schooling increases the probability that the individual will report being very satisfied with life $(w = 5)$. Meanwhile, immigrants (negative coefficient) are more likely to report being totally dissatisfied with life $(w = 1)$. Table A2.1 shows the marginal effects of each explanatory variable for each of the categories of the dependent variable.

As already discussed, the current estimates may have an endogeneity problem to the extent that the decision to participate in the labour market (p) could depend on life satisfaction (w). In particular, it could depend on personality traits not captured by $\hat{z}$,[7,8] and therefore remain in the model error (u in equation (2)).

In order to take this possibility into account, the following is proposed. First, the model of equation (2) will be estimated through 2SLS. This requires (at least) one instrumental variable (Q) that meets two characteristics: exclusion $(cov(Q, u) = 0)$ and relevance $(cov(Q, p) \neq 0)$. As a second strategy, and since 2SLS does not respect the ordinality of the explanatory variable, the model proposed in equation (6) will be estimated, which will allow simultaneous estimation of all the parameters of the model.

The instrument proposed to implement the 2SLS method is a dummy variable for head of household (Q_1). The model that is developed to estimate the decision to participate will be based on the covariates of the main model (x and $\hat{z}$) and the excluded instruments (Q_1). This instrument should not be correlated with the part of the personality traits not taken into account $(\hat{z}')$, but it must be correlated with the decision to participate in the labour market.

In the context of the CASEN survey, it is the family, rather than the institution conducting the survey, that designates the head of household. In that sense, it can be concluded that it is not necessary to be employed, to be older or to have more earnings to be considered the head of household. Moreover, the head of household could be self-appointed. Therefore, being a head of household should not have an impact on life satisfaction. People who live alone are automatically designated as the head of household. This does not mean that heads of household necessarily participate in the labour market, but it does increase the probability. The conceptual suitability of the instrument having thus been justified, statistical evidence in its favour is presented below.

The first exercise that must be carried out in the context of this estimator is to evaluate the weakness of the instrument. In that regard, the weak identification test (Cragg-Donald Wald F statistic) shows that the instrument is strong $(F = 65.595)$; this is an initial indication of a non-weak instrument,

but it is not enough. For greater formality, the Stock and Yogo (2005) test should be analysed. We reject the null hypothesis of a weak instrument for all levels of significance from Stock and Yogo test critical values (19.93 10% maximal IV size).

Lastly, the Anderson and Rubin test is implemented to evaluate the exclusion restriction. The test is fully robust to the presence of a weak instrument. The p-value of the test is 0.197; therefore, the null hypothesis of exogeneity of the instrument is not rejected (Andrews, Stock and Sun, 2019).

Statistical evidence in favour of the chosen instrument having been provided, the 2SLS estimator is implemented. For this, all the explanatory variables of the main model, in addition to the excluded instrument, were used as an instrument for the decision to participate in the labour market.

The 2SLS estimates appear in table 4. The first result to highlight is that participation $(\hat{p})$ does not have a significant effect on life satisfaction, unlike what was observed when endogeneity was not controlled for (columns 1 and 2 of table 3). Interestingly, the 2SLS results exhibit larger standard errors than OLS. In effect, the comparison between tables 3 and 4 reveals that although the coefficient associated with participation changes sign, the standard error increases from 0.0443 to 1.353. This loss of precision is common in 2SLS estimates.

The rest of the explanatory variables of the main model maintain their significance. For example, schooling has a positive effect, monetary income has a positive but decreasing effect, and reference income has a negative effect (the comparison effect predominates over the information effect), although the coefficient associated with this variable is not statistically significant.

As mentioned above, the second strategy consists of estimating the model while taking into account the ordinal nature of the dependent variable. For this, an ordered probit model with an endogenous dichotomous dependent variable (the decision to participate, p) is used. Then, equation (1A) (see annex A1) is estimated by maximum likelihood. This estimation method makes it possible to jointly estimate all the parameters of the model: those of the main equation (w) and those of the secondary equation (p). The following variables were included as determinants of labour participation: dummy for gender, years of schooling, age (and its square), dummies for marital status, a dummy variable for Indigenous classification, a dummy variable for immigrant, a dummy variable for residing in a rural area, a proxy variable for personality traits, a variable that indicates the quality of the individual's current health, a dummy variable that indicates church attendance, dummy for head of household, number of hours dedicated to caregiving, and non-labour income.

The results for the life satisfaction equation appear in the main equation column of table 5. The auxiliary equation column contains the results of the participation equation. It should be remembered that the reported coefficients do not correspond to the marginal effects of the explanatory variable.

Again, the first result that should be highlighted is that the labour participation variable (p) is no longer statistically significant in the model (even when it retains its sign). Therefore, the decision to participate in the labour market does not have an effect in terms of life satisfaction. This result is consistent with previous 2SLS estimates. The proxy for personality traits maintains its effect on life satisfaction. It should also be noted that the correlation coefficient of the errors of both models $(\hat{\rho}_{\epsilon v})$ is not statistically significant.

Table 4
Dependent variable: life satisfaction (2SLS), controlling for the potential endogeneity of the labour participation decision

Variables	
(p̂)	-1.509
	(1.353)
Female = 1	-0.207
	(0.157)
Years of schooling	0.0528***
	(0.0186)
Age	0.0363
	(0.0342)
Age squared	-0.000511
	(0.000450)
Has partner = 1	0.241**
	(0.116)
Divorced = 1	0.0882
	(0.0811)
Widower = 1	0.102
	(0.175)
Indigenous = 1	0.0462
	(0.0703)
Immigrant = 1	-0.0911
	(0.105)
Lives in a rural area = 1	-0.0213
	(0.0708)
Indigenous = 1 and lives in a rural area = 1	-0.0875
	(0.127)
Female = 1 and has partner = 1	-0.407
	(0.333)
Has children = 1	-0.0624
	(0.0645)
Income	0.000191***
	(6.49e-05)
Income squared	-6.45e-09**
	(3.11e-09)
Reference income	-7.35e-05
	(6.08e-05)
Personality traits *(ẑ)*	0.245***
	(0.0205)
Number of friends	0.00691
	(0.00452)
Current health status (from 1 to 7)	0.0827***
	(0.0203)
Church attendance = 1	0.118**
	(0.0516)
Constant	2.861***
	(0.337)
Observations	5 999
R squared	0.176

Source: Ministry of Social Development and Family, "Encuesta de Bienestar Social", Santiago, 2021 [online] https://datasocial.ministeriodesarrollosocial.gob.cl/portalDataSocial/ebs.

Note: The sample comprises individuals aged 18–65. Standard deviations are in parenthesis. Income refers to household monetary income (in thousands of Chilean pesos). Reference income refers to household monetary income of the reference group (in thousands of Chilean pesos). The excluded instrument is a dummy variable for head of household. * 10% significance level, ** 5% significance level, *** 1% significance level.

Table 5
Dependent variable: life satisfaction, ordered probit model with a binary endogenous explanatory variable[a]

Variables	Main equation (ordered probit for *w*)	Auxiliary equation (probit for *p*)
Labour participation = 1	0.163	n/a
	(0.208)	
Female = 1	-0.0320	-0.488***
	(0.0860)	(0.137)
Years of schooling	0.0425***	0.0790***
	(0.0107)	(0.00811)
Age	-0.00326	0.0743***
	(0.0180)	(0.0213)
Age squared	2.03e-05	-0.00104***
	(0.000202)	(0.000236)
Has partner = 1	0.203**	0.326**
	(0.0891)	(0.134)
Divorced = 1	0.0844	0.0162
	(0.0782)	(0.117)
Widower = 1	0.0519	0.212
	(0.152)	(0.170)
Indigenous = 1	-0.0222	0.118
	(0.0679)	(0.115)
Immigrant = 1	-0.238***	0.281**
	(0.0888)	(0.138)
Lives in a rural area = 1	0.0529	-0.123
	(0.0693)	(0.0814)
Indigenous = 1 and lives in a rural area = 1	-0.122	-0.0557
	(0.132)	(0.173)
Female = 1 and has partner = 1	-0.0560	-0.733***
	(0.111)	(0.154)
Has children = 1	-0.00348	n/a
	(0.0533)	
Income	0.000185***	n/a
	(3.35e-05)	
Income squared	-5.44e-09**	n/a
	(2.21e-09)	
Reference income	-0.000142**	n/a
	(6.28e-05)	
Personality traits *($\hat{z}$)*	0.320***	0.0299
	(0.0181)	(0.0209)
Number of friends	0.00974	n/a
	(0.00617)	
Current health status (from 1 to 7)	0.0918***	0.0333
	(0.0202)	(0.0237)
Church attendance = 1	0.114*	0.0530
	(0.0599)	(0.0821)
Head of household = 1	n/a	0.113
		(0.0703)
Number of hours dedicated to caregiving	n/a	-0.00769**
		(0.00372)
Non-labour income	n/a	1.85e-05
		(3.16e-05)
Constant	n/a	1.052**
		(0.499)

Variables	Main equation (ordered probit for *w*)	Auxiliary equation (probit for *p*)
c_1	-1.468***	n/a
	(0.412)	
c_2	-0.203	n/a
	(0.411)	
c_3	0.207	n/a
	(0.410)	
c_4	1.966***	n/a
	(0.411)	
$\hat{\rho}_{\epsilon v}$	-0.0378	
	(0.125)	
Pseudo *R* squared	0.114	
Observations	5 997	

Source: Ministry of Social Development and Family, "Encuesta de Bienestar Social", Santiago, 2021 [online] https://datasocial.ministeriodesarrollosocial.gob.cl/portalDataSocial/ebs.

Note: The sample comprises individuals aged 18–65. Standard deviations are in parenthesis. Income refers to household monetary income. Reference income refers to household monetary income of the reference group. All income is expressed in thousands of Chilean pesos. * 10% significance level, ** 5% significance level, *** 1% significance level.

[a] Labour participation decision is endogenous.

The results associated with the participation equation are in line with previous evidence. In the ordered probit model, the coefficients do not correspond to the marginal effects. However, the sign of the reported coefficient determines the sign of the marginal effect —for example, that women are less likely to participate, that there is a concave profile in the relationship between participation and age (consistent with the individual's life cycle), and that schooling has a positive effect on the probability of labour market participation. As expected, the number of hours dedicated to caregiving negatively affects the probability of participation.

Another interesting result associated with the participation equation has to do with the proxy variable for personality traits $(\hat{z})$. The coefficient associated with this variable is not statistically significant, which means that the decision to participate depends on sociodemographic characteristics, while personality traits appear not to play a role.

In summary, the estimates provide evidence that there is a problem of endogeneity in the labour participation variable.[15] Once it is controlled for this problem, the labour participation variable ceases to have a significant impact on life satisfaction. This also highlights the fact that personality traits (as represented by proxy variable $\hat{z}$), although important in explaining life satisfaction (w), are irrelevant in terms of the decision to participate (p). As for the rest of the variables included in the model, the results are in line with previous evidence.

V. Conclusion

In this article, we have provided robust evidence that the decision to participate in the labour market has no effect on life satisfaction. This result is interesting, first, because there is little evidence (to our knowledge) regarding this effect for developing countries, such as Chile, and second, because the available empirical evidence, which mainly pertains to developed countries, is rather mixed. One possible conclusion is that individuals optimize their preferences in accordance with their constraints. In this context, it can be noted that those individuals who optimally decide to participate in the labour market are in a similar situation, in terms of subjective well-being, to those who optimally decide not to participate.

[15] However, as can be seen from the results presented in table 5, the estimated coefficient for the parameter $\rho_{\epsilon v}$ is not statistically significant. This parameter measures the degree of correlation between the errors of both equations of the model.

To arrive at these results, an effort has been made to take into account the possible endogeneity of the decision to participate in the labour market. To that end, a 2SLS estimation was carried out, and an ordered probit model was also estimated, which allows all the parameters of the model to be estimated jointly by means of the maximum likelihood estimator.

Given its potential implications for public policy, the finding that labour participation does not have an impact on life satisfaction should be viewed with caution. Countries actively promote labour participation, as it is a powerful tool in the fight against overcoming poverty. Furthermore, monetary income is a robust variable in terms of its positive effect on subjective well-being, as has been widely observed in the happiness economics literature. For example, in Chile, there are various policy proposals aimed at increasing what has historically been a low rate of labour participation among women (Contreras and Plaza, 2010; Contreras, De Mello and Puentes, 2011; Medrano, 2009). The results presented here must therefore be kept in perspective and should complement the design of public policies, furnishing policymakers with a clear understanding of the different dimensions in which policies affect the population.

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Annex A1

Consider again the latent variable model for life satisfaction:

$$w_i^* = x_i'\beta + \alpha p_i + \gamma \hat{z}_i + \epsilon_i$$

Now, if the labour participation variable is endogenous, then it will be modelled as follows:

$$p^* = m'\delta + v$$

where p^* represents the utility associated with participating in the labour market, and m is a vector that contains the explanatory variables for said utility.

Then the econometrician observes $p = 1$ if $p^* > 0$ and $p^* = 0$ if $p^* \leq 0$. Moreover, $m = [x, \hat{z}, m_1]$ where x and $\hat{z}$ are exogenous covariates, and m_1 are the excluded instruments. It is assumed that (ϵ, v) are independent of m_1 and distributed as a bivariate normal with mean equal to zero, $var(\epsilon) = 1$, $var(v) = \tau^2$ with correlation equal to $\rho_{\epsilon v}$. Under the assumption of joint normality, the following holds:

$$\epsilon = \theta v + e$$

with:

$$\theta = \frac{\rho_{\epsilon v}}{\tau^2}$$

From these assumptions it is possible to start building the probabilities that will be part of the function log-likelihood. Therefore:

$$Pr(w = 1|p = 1, m) = Pr(w|v > -m'\delta, m)$$
$$Pr(w = 1|p = 1, m) = Pr[Pr(w|v, m)|v > -m'\delta, m]$$

Then, we proceed to integrate $Pr(w|v, m)$ over the density of $v|v > -m'\delta$, which is a normal truncated distribution:

$$f = (v \mid v > -m'\delta) = \frac{\emptyset(v)}{\Phi(m'\delta)}$$

Through the use of standard statistical properties, the following is known:

$$E(w \mid v, m) = Pr(w = 1 \mid v, m) = \Phi\left(\frac{c_1 - x_i'\beta - \alpha - \theta v}{\sqrt{1-\rho_{\epsilon v}^2}}\right)$$

Thus:

$$Pr(w = 1 \mid p = 1, m) = P_{1,1} = \int_{-m'\delta}^{\infty} \Phi\left(\frac{c_1 - x_i'\beta - \alpha - \theta v}{\sqrt{1-\rho_{\epsilon v}^2}}\right) \frac{\emptyset(v)}{\Phi(m'\delta)} dv$$

For simplicity, consider the following definition:

$$\Phi(c_j)\left(\frac{c_j - x_i'\beta - \alpha - \theta v}{\sqrt{1-\rho_{\epsilon v}^2}}\right)$$

Thus, the rest of the probabilities are given by the following:

$$Pr(w=2 \mid p=1,m) = P_{2,1} = \int_{-m'\delta}^{\infty} \left[\Phi(c_2) - \Phi(c_1)\right] \frac{\emptyset(v)}{\Phi(m'\delta)} dv$$

$$Pr(w=3 \mid p=1,m) = P_{3,1} = \int_{-m'\delta}^{\infty} \left[\Phi(c_3) - \Phi(c_2)\right] \frac{\emptyset(v)}{\Phi(m'\delta)} dv$$

$$Pr(w=4 \mid p=1,m) = P_{4,1} = \int_{-m'\delta}^{\infty} \left[\Phi(c_4) - \Phi(c_3)\right] \frac{\emptyset(v)}{\Phi(m'\delta)} dv$$

$$Pr(w=5 \mid p=1,m) = P_{5,1} = \int_{-m'\delta}^{\infty} \left[1 - \Phi(c4)\right] \frac{\emptyset(v)}{\Phi(m'\delta)} dv$$

Then, the exercise is replicated to build the probabilities for $p = 0$. Note the following:

$$Pr(w=1|p=0,m) = Pr[Pr(w|v,m)|v < -m'\delta, m]$$

Therefore:

$$Pr(w=1 \mid p=0,m) = P_{1,0} = \int_{-\infty}^{-m'\delta} \Phi\left(\frac{c_1 - x_i'\beta - \theta v}{\sqrt{1-\rho_{\epsilon v}^2}}\right) \frac{\emptyset(v)}{1-\Phi(m'\delta)} dv$$

Again, consider the following simplification:

$$\Phi(c_j)\left(\frac{c_j - x_i'\beta - \theta v}{\sqrt{1-\rho_{\epsilon v}^2}}\right)$$

The probabilities are given by the following expressions:

$$Pr(w=2 \mid p=0,m) = P_{2,0} = \int_{-\infty}^{-m'\delta} \left[\Phi(c_2) - \Phi(c_1)\right] \frac{\emptyset(v)}{1-\Phi(m'\delta)} dv$$

$$Pr(w=3 \mid p=0,m) = P_{3,0} = \int_{-\infty}^{-m'\delta} \left[\Phi(c_3) - \Phi(c_2)\right] \frac{\emptyset(v)}{1-\Phi(m'\delta)} dv$$

$$Pr(w=4 \mid p=0,m) = P_{4,0} = \int_{-\infty}^{-m'\delta} \left[\Phi(c_4) - \Phi(c_3)\right] \frac{\emptyset(v)}{1-\Phi(m'\delta)} dv$$

$$Pr(w=5 \mid p=0,m) = P_{5,0} = \int_{-\infty}^{-m'\delta} \left[1 - \Phi(c_4)\right] \frac{\emptyset(v)}{1-\Phi(m'\delta)} dv$$

In this way, the log-likelihood can be constructed:

$$l(\delta,\beta,\alpha,c_j,\rho_{\epsilon,v},\tau) = \sum_{i=1}^{n} \begin{bmatrix} w_{i1}p_i ln(P_{1,1}) + w_{i2}p_i ln(P_{2,1}) + w_{i3}p_i ln(P_{3,1}) + w_{i4}p_i ln(P_{4,1}) + \\ w_{i5}p_i ln(P_{5,1}) + w_{i1}(1-p_i) ln(P_{1,0}) + w_{i2}(1-p_i) ln(P_{2,0}) + \\ w_{i3}(1-p_i) ln(P_{3,0}) + w_{i4}(1-p_i) ln(P_{4,0}) + w_{i5}(1-p_i) ln(P_{5,0}) \end{bmatrix} \quad (1A)$$

where $w_{ij} = 1$ if $w_i = j$ and equal to zero otherwise, for $j = 1, 2, 3, 4, 5$. This is the function that is maximized to find the estimates of the population parameters.

Annex A2

Table A2.1
Marginal effects for ordered probit: life satisfaction

Variables	*P(w = 1)*	*P(w = 2)*	*P(w = 3)*	*P(w = 4)*	*P(w = 5)*
Labour participation = 1	-0.00278*	-0.0144*	-0.00713*	-0.00316	0.0275*
	(0.00169)	(0.00842)	(0.00421)	(0.00198)	(0.0161)
Female = 1	0.00116	0.00602	0.00298	0.00132	-0.0115
	(0.00227)	(0.0118)	(0.00582)	(0.00262)	(0.0225)
Years of schooling	-0.00120***	-0.00621***	-0.00307***	-0.00136***	0.0118***
	(0.000306)	(0.00140)	(0.000680)	(0.000418)	(0.00255)
Age	4.67e-05	0.000242	0.000120	5.31e-05	-0.000462
	(0.000478)	(0.00248)	(0.00123)	(0.000544)	(0.00473)
Age squared	-9.09e-09	-4.72e-08	-2.33e-08	-1.03e-08	8.99e-08
	(5.26e-06)	(2.73e-05)	(1.35e-05)	(5.97e-06)	(5.20e-05)
Has partner = 1	-0.00562**	-0.0291**	-0.0144**	-0.00639**	0.0556**
	(0.00248)	(0.0126)	(0.00625)	(0.00318)	(0.0239)
Divorced = 1	-0.00231	-0.0120	-0.00594	-0.00263	0.0229
	(0.00216)	(0.0112)	(0.00550)	(0.00249)	(0.0212)
Widower = 1	-0.00147	-0.00764	-0.00378	-0.00167	0.0146
	(0.00419)	(0.0217)	(0.0108)	(0.00480)	(0.0415)
Indigenous = 1	0.000590	0.00306	0.00151	0.000670	-0.00583
	(0.00186)	(0.00964)	(0.00478)	(0.00215)	(0.0184)
Immigrant = 1	0.00633**	0.0328***	0.0162***	0.00719**	-0.0626***
	(0.00250)	(0.0127)	(0.00629)	(0.00333)	(0.0240)
Lives in a rural area = 1	-0.00138	-0.00716	-0.00354	-0.00157	0.0137
	(0.00191)	(0.00982)	(0.00488)	(0.00215)	(0.0187)
Indigenous = 1 and lives in a rural area = 1	0.00334	0.0173	0.00857	0.00380	-0.0330
	(0.00367)	(0.0188)	(0.00932)	(0.00421)	(0.0358)
Female = 1 and has partner = 1	0.00185	0.00960	0.00475	0.00210	-0.0183
	(0.00282)	(0.0146)	(0.00721)	(0.00325)	(0.0278)
Has children = 1	0.000116	0.000602	0.000298	0.000132	-0.00115
	(0.00146)	(0.00759)	(0.00375)	(0.00166)	(0.0145)
Income	-5.07e-06***	-2.63e-05***	-1.30e-05***	-5.76e-06***	5.01e-05***
	(1.10e-06)	(4.93e-06)	(2.50e-06)	(1.69e-06)	(9.01e-06)
Income squared	1.49e-10**	7.73e-10**	3.83e-10**	1.69e-10**	-1.47e-09**
	(6.31e-11)	(3.17e-10)	(1.58e-10)	(7.99e-11)	(6.00e-10)
Reference income	3.92e-06**	2.03e-05**	1.01e-05**	4.45e-06**	-3.88e-05**
	(1.81e-06)	(9.09e-06)	(4.44e-06)	(2.02e-06)	(1.69e-05)
Number of friends	-0.000269	-0.00139	-0.000689	-0.000305	0.00266
	(0.000172)	(0.000883)	(0.000437)	(0.000203)	(0.00167)
Current health status (from 1 to 7)	-0.00254***	-0.0132***	-0.00652***	-0.00289***	0.0251***
	(0.000621)	(0.00287)	(0.00148)	(0.000973)	(0.00544)
Church attendance = 1	-0.00315*	-0.0164*	-0.00809*	-0.00358*	0.0312*
	(0.00169)	(0.00861)	(0.00424)	(0.00205)	(0.0163)
Personality traits *(ẑ)*	-0.00880***	-0.0456***	-0.0226***	-0.01000***	0.0870***
	(0.00116)	(0.00302)	(0.00182)	(0.00253)	(0.00458)
Observations	5 999	5 999	5 999	5 999	5 999

Source: Ministry of Social Development and Family, "Encuesta de Bienestar Social", Santiago, 2021 [online] https://datasocial.ministeriodesarrollosocial.gob.cl/portalDataSocial/ebs.

Note: The sample comprises individuals aged 18–65. Standard deviations are in parenthesis. The marginal effect was calculated at the average value of the explanatory variables. Income refers to household monetary income (in thousands of Chilean pesos). Reference income refers to household monetary income of the reference group (in thousands of Chilean pesos). * 10% significance level, ** 5% significance level, *** 1% significance level.

External debt and exchange-rate misalignment in Brazilian firms: developments and risks from 2000 to 2018[1]

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Abstract

This article investigates the effects of exchange-rate misalignment on the earnings of 201 Brazilian non-financial listed companies over the period 2010–2018. A measure of exchange-rate misalignment was constructed by compiling information on the value of currency derivative contracts and generating a new database. The results indicate that exchange-rate devaluation has a negative differential effect for firms that have borrowed in foreign currency, including exporting firms. Controlling for variables that protect firms with foreign currency debt, we find that the differential effect of devaluation is negative for firms with larger foreign currency liabilities and positive for those with larger foreign currency assets or greater hedging. These results are robust to different specifications.

Keywords

External debt, foreign exchange, foreign exchange rates, financial policy, business enterprises, profit, corporate debt, competitiveness, macroeconomics, Brazil

JEL classification

G11, G32, F31, F34

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I. Introduction

Two decades ago, a substantial number of emerging economies abandoned fixed or quasi-fixed exchange-rate regimes in favour of floating regimes. In the major economies of Latin America, this change of regime took place between 1998 and 2001, almost always in the context of crises. Since then, the new exchange-rate regime has proved to have a number of virtues. However, the promise of relatively well-behaved exchange rates that would respond moderately to changes in fundamentals (Friedman, 1953) did not materialize. On the contrary, sharp and severe exchange-rate movements have been quite frequent in the recent history of these economies.

The behaviour of Brazil's exchange rate during the floating regime was no exception. The 2010s were characterized by great volatility against the United States dollar, including two episodes that looked in several respects like currency crises. In the first, which occurred at the time United States monetary policy began to normalize in 2013 (a period known as the "taper tantrum"), the exchange rate depreciated by 21% over 11 months. The second, severer episode saw a depreciation of just upward of 70% over a 14-month period (from September 2014 to October 2015). Some economists have suggested that one reason the economy struggled to emerge from the 2015–2016 recession was the negative impact of the exchange-rate depreciation in this latter period on firms' earnings and ability to invest (Pastore, 2017; Rocca, 2016). However, given that many firms have access to currency derivatives and many are exporters, it is possible to argue that Brazilian firms may have adapted to exchange-rate volatility and become less vulnerable to possible exchange-rate misalignments.

There is a need for a more complete diagnosis of the impact of exchange-rate movements on firms' performance. The present article aims to contribute to this diagnosis by employing a database that incorporates flow and stock information at the firm level and indicators developed with a view to more precisely measuring any exchange-rate misalignment affecting firms. These measurements are then used to estimate the impact of exchange-rate movements on the performance of Brazilian firms in the period prior to the coronavirus disease (COVID-19) pandemic.

Specifically, the study sets out to determine whether exchange-rate devaluation had a differential effect on firms with larger foreign currency liabilities, firms with greater net currency exposure, firms with less currency hedging, and non-exporting firms as against exporting firms. To this end, we constructed a special database from the quarterly accounting information of a set of 201 Brazilian non-financial listed companies for the period 2000–2018, comprising not only company characteristics and measures of profitability, but also detailed information on foreign currency derivatives and assets provided by Economatica and, in the case of non-standardized financial statements, by the Securities and Exchange Commission.

The results indicate that exchange-rate movements did have a negative differential effect on the profitability of Brazilian firms with larger foreign currency liabilities, suggesting a balance sheet effect during the period analysed. The balance sheet effect was also significant for firms with greater net currency exposure. With respect to the level of currency hedging, the results confirm the positive effect of such hedging on firms' profitability, although it was weaker for exporting firms. This result (the weaker balance sheet effect for exporters) was to be expected, since exporting firms benefit from a natural hedge.

The article is divided into five sections including this introduction. The second section discusses some findings and arguments presented in the recent literature on the balance sheet and competitiveness effects of an exchange-rate devaluation. The third section presents the database, the profitability and currency exposure measures, the variables used and the underlying model employed in the estimations. The results are presented in the fourth section, followed by final considerations in the fifth.

II. The competitiveness effect and the balance sheet effect: a literature review

Sudden large exchange-rate depreciations are generally unpredictable and, for that reason, tend to impair the performance of firms whose foreign currency liabilities are not adequately hedged with foreign exchange assets or derivatives.[2] An unanticipated depreciation leads to both an increase in the stock of external debt (as measured in domestic currency) and a reduction in firms' net worth. While the first effect reduces profits and thus firms' source of domestic funding, the second reduces access to credit for firms facing borrowing constraints. In both cases, investment is often compromised, contributing to a slowdown in the country's economy. This is the essence of the so-called balance sheet effect, which appears to have been the main cause of the crises suffered by the dynamic and seemingly robust economies of Asia in the late 1990s (Krugman, 1999; Aghion, Bacchetta and Banerjee, 2001 and 2004).

The balance sheet effect may or may not offset the positive consequences of an exchange-rate devaluation for the profits and competitiveness of exporting firms and those competing with imports. In the tradition of open economy macroeconomics, and in the Mundell-Fleming model in particular, this competitiveness effect was considered to be the main consequence of an exchange-rate devaluation.

With two opposing forces at work, namely the competitiveness effect and the balance sheet effect, the final outcome should be determined empirically rather than theoretically. This is because the net result of an exchange-rate depreciation on profits and investment will depend on companies' degree of exchange-rate misalignment, the price elasticity of exports and imports and other variables affecting the magnitude of the two effects mentioned, all of which vary across countries and over time. Moreover, the growth rate of the economy is the macroeconomic variable with the largest effect on profits (and investment). Consequently, the economic growth rate needs to be controlled for when studying the balance sheet effect on the basis of data for a period in which it was highly variable.[3]

Unsurprisingly, a large empirical literature on the subject has been produced over the last two decades.

The empirical literature on the so-called balance sheet effect in emerging economies is inconclusive. Although many studies use fairly similar methodologies, the results are divergent, irrespective of whether country-specific or multi-economy datasets are used.

While it is possible that these divergent results will be reconciled as methodologies and information improve, it is also very possible that part of the difference in outcomes is simply due to the fact that the various studies deal with different economies and different periods and that the balance sheet effect is indeed differentiated, as argued above, because it depends on country- and period-specific factors.

The studies by Bleakley and Cowan (2002 and 2008) that served as a benchmark for much of the subsequent literature used a sample of 450 non-financial firms in five Latin American economies in the 1990s and obtained results supporting the conclusion that firms with more dollar debt did not invest less than their peers with less dollar debt or with local currency debt following episodes of exchange-rate devaluation.

In some of the specifications estimated, the authors actually found that firms with higher foreign currency debt invested more than their peers after an episode of exchange-rate depreciation. According to the authors, one possible explanation for this was that the firms with the highest dollar debts were

[2] Cowan, Hansen and Herrera (2005) examine this hypothesis for Chile over the period 1995–2003. They construct a measure of the deviations of actual depreciations from those implied by dollar futures contracts and conclude that most of the large depreciations in the period studied were unanticipated.

[3] The growth rate is controlled for in some of the models presented in section IV. To take one significant example of the relationship between profits and growth in Brazil, the average return on equity among the sample of 201 companies in the database declined from 11.2% in the period 2004–2010 (when the economy grew at a rate of 4.5% a year) to 5.4% between 2011 and 2018 (when growth slowed to 0.7% a year).

those that exported (exporting leads firms to borrow in dollars as a hedge), and a depreciating exchange rate benefited their export revenues. Exporting provides a "natural hedge", and for these firms the competitiveness effect more than offsets the balance sheet effect following an exchange-rate devaluation.

Álvarez and Hansen (2017), using a methodology similar to that of Bleakley and Cowan (2008) and a sample of Chilean firms for the period 2004–2014, shared this conclusion. The authors determined that Chilean firms' profits were unaffected by exchange-rate depreciations, indicating that they were matching their foreign currency liabilities with foreign currency assets or exports. However, they arrived at a result that seemed to conflict with this, namely that exchange-rate depreciation affected investment, indicating that the so-called balance sheet effect did affect investment, although not profitability. The authors did not attempt to explain this apparent contradiction, but one possible cause is that although short-term cash flow may be protected from depreciations (which thus do not affect profits), the reduction in net worth resulting from the increase in the domestic currency value of foreign currency liabilities could, in a context of borrowing constraints, limit the availability of funds for investment.

At first glance, the results presented by Cowan, Hansen and Herrera (2005) for Chilean firms also pointed to a balance sheet effect. The authors indicated that firms with higher external debt had a lower investment rate than others following an exchange-rate depreciation. According to the authors, however, this effect was offset by foreign currency assets. In other words, they concluded that Chilean firms had adequately hedged their currency exposure with assets and derivatives.

Caballero (2018), drawing on a monumental sample of 6,917 firms from 15 emerging economies, concluded that there was a significant balance sheet effect and provided evidence that firms did not offset their foreign currency liabilities with dollar revenues from exports or by using derivatives. However, the author's use of a vast sample of countries meant that a number of variables had to be sacrificed. For example, the author used information on securities debt (the stock of bonds denominated in foreign currency) as a proxy for foreign currency liabilities. In many economies, including Brazil, foreign currency debt owed by firms to banks and suppliers is a substantial part of external debt, which could compromise the results.

A more recent strand in the literature seeks to ascertain why firms might suffer exchange-rate misalignments and be vulnerable to the balance sheet effect. Using a sample of firms from 18 emerging economies between 2014 and 2016, Bruno and Shin (2018) found that firms took advantage of favourable international financial market conditions to issue foreign currency bonds, using the proceeds to purchase financial assets in local currency. In other words, firms became misaligned by taking on foreign debt with the aim of engaging in activities similar to carry trades and were therefore exposed to losses in the event of exchange-rate depreciation. Similarly, Caballero, Panizza and Powell (2016) found that a 10% increase in bond issuance was associated with an 8% increase in firms' net assets. Commenting on this literature, Du and Schreger (2016) found strong evidence that the decision to borrow in dollars was not motivated by hedging considerations (on the part of exporters, for example), so that firms were probably left vulnerable to exchange-rate depreciations.

Although the literature on the balance sheet effect in Brazil is fairly sparse, some studies for different periods have found evidence of some cases. Drawing on a sample of about 260 Brazilian firms for the period 1990–2002, Bonomo, Betina and Pinto (2004) found evidence for the balance sheet effect, a result that remained statistically significant after controlling for the impact of the exchange rate on investment via exports and imports of inputs.

Garcia, Janot and Novaes (2008) conducted the most detailed research known to us for Brazil, in terms of both the variables and the methodology used; however, it is limited to the effects of the 2002 currency crisis. Using the difference-in-differences method, the authors found a negative effect from the sharp movement in the exchange rate that year outweighing the competitiveness effect.

Using a much smaller sample of Brazilian firms (about 100) for the period 2003–2014, Valle and others (2017) concluded that foreign currency debt did have a negative effect on profits and investment after an exchange-rate devaluation (balance sheet effect). They also added an interesting point that had apparently gone unnoticed in the discussion of the topic: the negative correlation between the exchange rate and the terms of trade means that, in the event of an exchange-rate devaluation associated with a decline in the terms of trade, external debt increases in reais, but export revenues do not increase proportionally because while each dollar exported brings in more reais, export prices (for commodity exporters) decrease, reducing the value of the natural hedge.

With the literature briefly reviewed above as a backdrop, the strategy adopted for this paper concentrates on two points. First, the decision was taken not to address the effects on investment in order to prioritize the effects on earnings, specifically on a differentiated set of profitability measures.

This decision means that the balance sheet effect is not fully captured in the model estimated. In the first place, the model captures the negative effect of devaluations on profits due to the increase in the financial costs (measured in reais) of firms with foreign currency debts, whose foreign currency liabilities increase in relative terms. It also captures the increase in interest costs arising from tighter credit conditions, owing to the deterioration in firms' balance sheets associated with the increase in (dollarized) liabilities. However, it does not include the investment effect of any restriction on access to credit. Comparing the effects of devaluations on investment and earnings would allow the contributions of these different components of the balance sheet effect to be distinguished.[4]

In the second place, the paper attempts a more comprehensive exploration of the exchange-rate misalignment giving rise to the balance sheet effect. To this end, in addition to foreign currency debt as the main factor of vulnerability to exchange-rate movements, other firm-level variables such as foreign currency assets and foreign currency derivatives hedging are introduced. This allows the net currency exposure variable to be included as one of the regressors in the model.

III. The database and the models estimated

As mentioned earlier, the specific objective of this paper is to quantify the degree of exchange-rate misalignment among Brazilian firms and to estimate its impact on profitability when an exchange-rate depreciation occurs. In particular, the paper seeks to ascertain whether exchange-rate movements have a differential effect on the profitability of Brazilian firms with foreign currency liabilities. A differential effect on these firms would be an indicator of the so-called balance sheet effect, while the absence of a differential effect would indicate that exchange-rate movements affect firms with and without dollar liabilities alike, suggesting that firms with external liabilities protect themselves from exchange-rate movements.

As explained above, to determine the effects of exchange-rate misalignment on Brazilian firms, we constructed a special database in which, alongside characteristics and profitability measures, we collected detailed information on currency derivatives and assets at the firm level. Specifically, we conducted an empirical analysis of the quarterly accounting information of a set of 201 Brazilian non-financial listed companies for the period 2000–2018, drawing on information from Economatica and, in the case of non-standardized financial statements, from the Securities and Exchange Commission. The variables analysed were selected in the light of the objectives described above and included profit and loss variables (net earnings and earnings before interest, taxes, depreciation and amortization (EBITDA), among others) and balance sheet variables (e.g. total assets, equity, total debt and foreign currency debt).

[4] The authors plan to estimate investment effects and perform the decomposition suggested here in a forthcoming paper.

In addition, we surveyed explanatory notes and other accounting documents to construct a measure of exchange-rate misalignment by analysing the value of foreign currency assets, foreign currency liabilities (often unreported, but necessary to complete the balance sheet data) and currency derivative contracts. Sometimes hedging data were not provided or only the value of currency derivative gains or losses was reported and not the value of the underlying contracts, so the information had to be disregarded. Despite these exclusions, it was possible to obtain reasonably complete and consistent information on the value of foreign currency assets and derivative hedges, as well as a breakdown by currency of companies' debt. Since the information was presented in different documents and in a non-standardized form, this analysis entailed a major effort of data collection and systematization, but it did furnish us with a new dataset of unpublished information of considerable value to our study.

An important variable for this research that proved unobtainable were foreign trade flows by company. Brazil's Federal Internal Revenue Secretariat prohibits the disclosure of export and import figures by firm (because of purported confidentiality issues), so that only qualitative information was available, i.e. whether the firm exported or imported in a given period. For this reason, foreign trade variables took the form of dummy variables.

Regarding the representativeness of the sample, it was possible to retain a substantial set of companies despite the necessary purging of the sample base. We had to exclude 71 companies from the set of non-financial companies listed on the B3 stock exchange, for reasons ranging from a lack of information vital to the proposed analysis to protracted situations of court-supervised corporate reorganization. Corporate mergers and spin-offs also posed a difficult problem. Where possible, we attempted to construct artificial firms by aggregating the data of demerged firms following the demerger and combining the data of merged firms from before the merger. Often, however, this proved impossible and observations had to be discarded. Still, the 201 firms that remained in the sample retained 89% of the total assets of B3-listed non-financial firms in 2018. Moreover, their external liabilities represented 60% of the total external debt of non-financial firms (on average), according to the Central Bank of Brazil's external sector statistics (international investment position account).

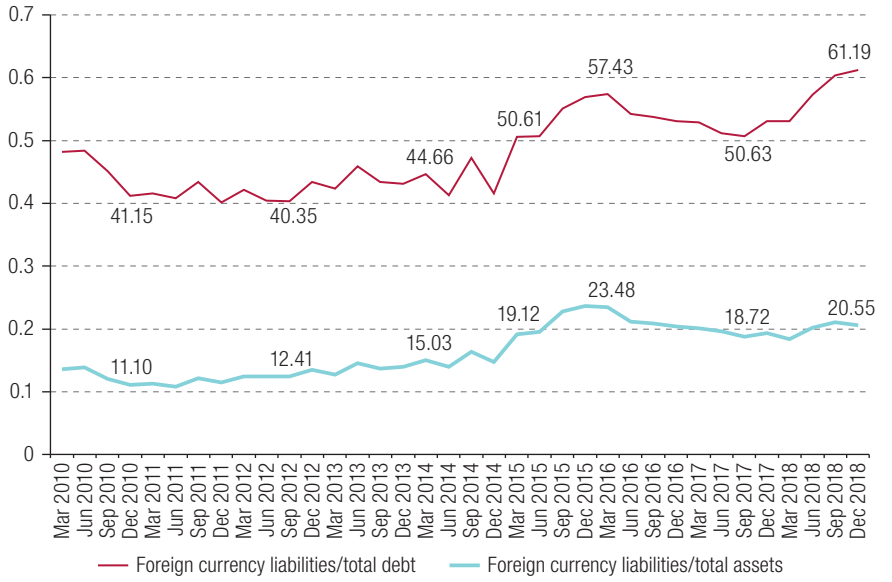
Lastly, the use of quarterly information allowed for a quite large sample with the additional advantage of capturing the effects of exchange-rate fluctuations within the annual period. However, to avoid distortions arising from high volatility in the quarterly values of the flow variables (e.g. profits and financial expenses), including volatility resulting from accounting procedures, these values had to be computed as four-quarter moving averages. The stock data taken for each period t were the mean of the values for the four quarters included in t. Descriptive statistics for the variables are presented in annex A1.

1. Net currency exposure and evidence from the database

The data indicate that the combined foreign currency debt of the 201 companies in the sample grew between 2010 and 2018 as a proportion of both the total assets and the total debt of the companies in the sample, which, as mentioned above, accounted for a large share of all listed companies and of the external debt of all Brazilian companies (see figure 1). Much of this growth can undoubtedly be attributed to successive exchange-rate depreciations over the period analysed.

Although foreign currency debt is often used in the literature as a measure of firms' exchange-rate vulnerability, it is actually a very incomplete and often misleading proxy for firms' true currency exposure, as it does not provide information on their foreign currency assets or derivatives position. For this reason, we constructed a measure of exchange-rate misalignment that much better reflects the true risk firms are exposed to in the event of exchange-rate movements.

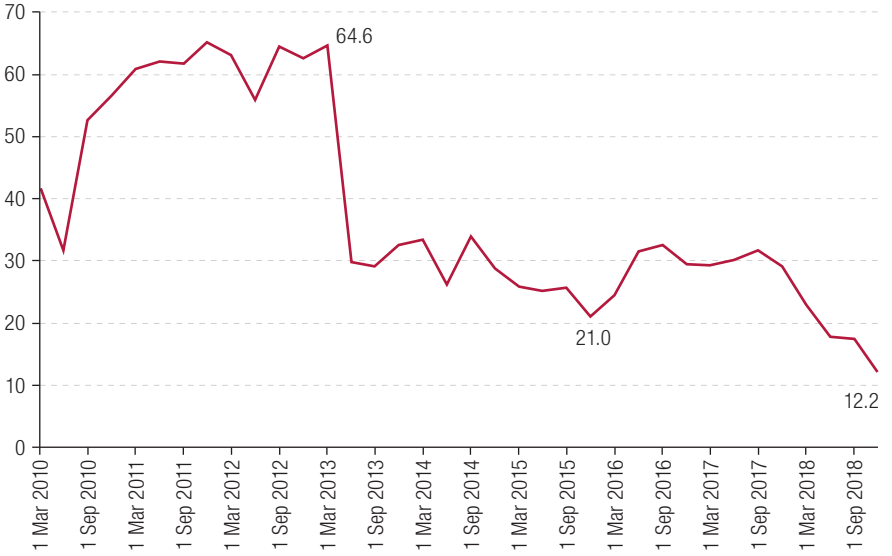
Figure 1
Brazil: foreign currency liabilities as a share of total assets and total debt of a sample of 201 non-financial listed companies, 2010–2018
(Percentages)



Source: Prepared by the authors, on the basis of Economatica and the Securities and Exchange Commission (CVM).

This measure, which we have called "net currency exposure", is foreign currency liabilities subtracted from foreign currency assets and foreign currency positions purchased via currency derivatives. On this measure, contrary to what the trend in foreign currency liabilities suggests, firms' level of exchange-rate misalignment progressively declined over the decade to approximately 12% of total debt by the end of the period (see figure 2).

Figure 2
Brazil: net currency exposure from foreign currency liabilities in a sample of 201 non-financial listed companies, 2010–2018
(Percentages)



Source: Prepared by the authors, on the basis of Economatica and the Securities and Exchange Commission (CVM).

Greater use of currency hedging might seem to be at odds with the increase in the cost of such hedging over the period analysed. However, at least in the case of short-term transactions, for which there is a more liquid market, the increase in the cost of hedging as measured by the "dollar premium" on dollar futures contracts only reflects the increased risk of exchange-rate devaluation. In other words, the obverse of the increase in hedging costs in the 2010s was the increase in the expected cost of the alternative (not hedging). Souza (2022), using data on the currency derivative contracts of Brazilian B3-listed firms for the period 2011–2021, accordingly showed that currency hedging strategies yielded gains on average for the firms adopting them.

In sum, the decrease in exchange-rate misalignment over the decade is not surprising and may have been the result of firms weighing the costs and benefits of currency hedging. It should also be noted that the measure in this paper is likely to overestimate the true currency exposure of firms, because part of the foreign currency debt of exporting firms is hedged against exchange-rate movements by net exports. Since Brazil's net exports were positive throughout the period 2010–2018, it is possible that firms were perfectly aligned from an exchange-rate perspective at the end of the period under consideration. Unfortunately, the lack of information on exports and imports by firm meant that we were unable to estimate this more precisely.

The data collected allow some observations to be made about the firms in the sample. First, given the expected importance of natural hedging, it is worth noting that an average of about 60% of the firms with foreign currency debt over the period analysed were exporters and therefore had some kind of natural hedge from foreign currency revenues, although the value of this hedge depended on the difference between the value of each firm's exports and imports, and this information is not available.

Second, it is important to note that the pooled debt and currency hedging data presented in figures 1 and 2 may conceal large differences between firms. For example, two thirds of the 201 firms in the sample (i.e. 136 on average) had foreign currency liabilities over the decade analysed. Of these, 49% hedged up to 25% of their foreign currency liabilities with derivatives contracts, 17% hedged between 25% and 75%, and 43% hedged 75% or more.

Foreign currency liabilities are more commonly hedged with foreign currency assets than with derivatives. The majority of firms (67%) hedge only a small portion of their liabilities (less than 25%) with foreign currency assets. A minority (14%) use foreign currency assets to hedge a large portion (over 75%) of their liabilities.

In short, the aggregate data conceal quite disparate situations among firms, and these may account for the effects of an exchange-rate depreciation on the performance of the aggregate if, for example, there is asymmetry between the impact of the gains and losses from exchange-rate movements.

2. The model estimated

The possible differential effects of a real exchange-rate movement on various measures of corporate profitability were estimated for firms with and without net currency exposure (measured as the difference between foreign currency liabilities and the sum of foreign currency assets and the purchased value of currency derivative contracts). By having both types of firm in the sample and classifying them into exporters and importers, it was possible to control for changes in profitability that might be associated with macroeconomic movements, as opposed to those arising from firms' exchange-rate exposure.

Since exports serve as a natural hedge against exchange-rate depreciations, firms' status as exporters or non-exporters was also controlled for.

The base model for this paper follows the one proposed by Álvarez and Hansen (2017):

$$Y_{it} = \alpha_i + FXD_{it-1}(\alpha + \beta\Delta er_t) + \delta X_{it-1} + \theta Z_t + u_{it}$$

where Y is a measure of profitability, FXD is foreign currency debt (specifically, foreign currency liabilities), er is the real exchange rate between the Brazilian real and the United States dollar, X represents a set of firm-specific controls and Z denotes macroeconomic controls. An important difference with the estimates in this paper is that, while Álvarez and Hansen (2017) use a dummy variable for hedging, the data here provide the actual values of hedging contracts. This allows possible non-linear effects of exchange-rate protection measures on firm profitability to be analysed.

Specifically, this paper centres on the β coefficient, which represents the differential effect of the exchange rate on profitability, in consideration of foreign currency debt. A negative and statistically significant coefficient indicates that the larger the foreign currency debt, the greater the effect of an exchange-rate devaluation on the profitability measure, confirming the balance sheet effect. Meanwhile, a non-significant differential effect indicates that on average firms with larger or smaller foreign currency liabilities were affected alike by the devaluation, indicating that firms acted to protect themselves against devaluations, either through hedging or naturally through exports, and suggesting that there was no balance sheet effect.

The variables actually used in the estimations are described in table 1.

Table 1
Profitability measures and other variables used in estimates

Profitability measures	
EBITDA	Earnings before interest, taxes, depreciation and amortization relative to total assets
Net earnings	Net earnings relative to total assets
ROE	Return on equity
ROIC	Return on invested capital
Other variables used in estimates	
Liabilities	Foreign currency liabilities relative to total assets
Assets	Foreign currency assets relative to total assets
Hedging	Foreign currency hedging relative to total assets
Exposure	Net exposure = (Liabilities - assets - hedging)/Total assets
Δer_t	Logarithmic change in the four-quarter moving average of the real exchange rate between the real and the United States dollar
ΔGDP_t	Logarithmic change in the four-quarter moving average of seasonally adjusted gross domestic product (GDP)
$\Delta Imports_t$	Rate of change in the seasonally adjusted world import volume index

Source: Prepared by the authors.

The first two profitability variables were calculated relative to the value of each firm's total assets reported for the same period, while the other two are also ratios between nominal variables, so that not only the numerators but also the denominators (equity and invested capital, respectively) are affected by inflation. In other words, changes in price indices affect the numerator and denominator equally, and thus cancel each other out, in all four profitability measures. The profitability measures thus represent an index unaffected by price changes. The same is true of the variables *liabilities*, *assets*, *hedging* and *exposure*.

The real exchange rate was calculated as a four-quarter moving average of the nominal exchange rate deflated by Brazil's extended national consumer price index (IPCA).[5] Quarterly real gross domestic product (GDP) (seasonally adjusted volume index) was obtained directly from the quarterly national

[5] In line with the procedure used in most of the literature on the topic, instead of using the conventional calculation of the real exchange rate, we only deflated it by the national price index in the interests of standardization with the other variables.

accounts series published by the Brazilian Institute of Geography and Statistics. Lastly, the seasonally adjusted quarterly merchandise import volume indices (2005 Q1 = 100) of the World Trade Organization (WTO) were used.[6]

For the estimates, the unit root test proposed by Im, Pesaran and Shin (2003) for panel data was applied. The null hypothesis of a unit root was rejected for all variables, which were thus considered stationary for the estimations (see results in table A1.2 of annex A1).

With the data represented in a panel of 201 firms observed over the period 2010–2018, the models were estimated using the ordinary least squares method with fixed effects for the firms.

IV. Results

In a first stage, we sought to ascertain whether exchange-rate movements differentially affected firms with foreign currency debt. To control for individual firm-level effects, all the models were estimated with fixed effects, while standard errors were adjusted for heteroskedasticity and autocorrelation. The results are presented in table 2 (debt-only model). To analyse the results obtained, we should briefly consider here the expected signs of the coefficients in the equations for the different measures of profitability.

Table 2
Results of foreign currency debt models

Dependent variable	All firms				Exporting firms			
	EBITDA	Net income	ROE	ROIC	EBITDA	Net income	ROE	ROIC
C	0.057705	-0.020276	0.052371	0.048912	0.084113	0.013388	0.051316	0.048104
	[0.0077]***	[0.0100]**	[0.0099]***	[0.0057]***	[0.0034]***	[0.0046]***	[0.0165]***	[0.0036]***
$Liabilities_{t-4}.\ \Delta er_t$	-0.671549	-3.10743	-1.544706	0.9093	0.258137	-0.666504	-3.979288	0.541674
	[0.3974]*	[0.7636]***	[1.3462]	[0.4044]**	[0.2659]	[0.2958]**	[1.4375]***	[0.1934]***
Δer_t	0.011155	0.286275	-0.078589	-0.246871	-0.046792	-0.134884	0.037214	-0.172715
	[0.0900]	[0.1982]	[0.2107]	[0.0895]***	[0.1156]	[0.1446]	[0.1875]	[0.0901]*
$Liabilities_{t-4}$	0.140998	0.086087	0.182637	0.009597	0.004156	-0.059947	0.116939	-0.008052
	[0.0444]***	[0.0513]*	[0.1200]	[0.0675]	[0.0200]	[0.0245]**	[0.1644]	[0.0220]
Observations	5 751	6 022	5 914	6 005	3 016	3 171	3 103	3 169
Adjusted R-squared	0.2024	0.0645	0.1336	0.1237	0.3891	0.3875	0.1308	0.2598
F-statistic	8.2236	3.045	5.4899	5.175	15.5464	16.0808	4.5104	9.3604
Prob(F-statistic)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Source: Prepared by the authors.
Note: White standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Regarding the indicators with net earnings in the numerator (net income/assets and return on equity (ROE)), these measures represent the difference between income and expenses, with the latter including both operating and financial expenses. For this reason, they tend to be negatively affected by any increase in domestic currency-denominated interest payments ensuing from an exchange-rate devaluation, so that the coefficient should have a negative sign. This outcome ought to be unambiguous for the net income dependent variable, but not necessarily for ROE. Indeed, since the equity of firms with foreign currency debts should contract when there is a devaluation, the ROE measure (which has equity in the denominator) may present an ambiguous result, given that both the numerator and the denominator contract with devaluation. Where these first two measures are concerned, in other words, a stronger balance sheet effect (if any) on the net income/assets variable is to be expected.

[6] See WTO (n.d.).

With regard to the earnings before interest, taxes, depreciation and amortization (EBITDA) and return on invested capital (ROIC) variables, a firm's result includes both earnings and financial expenses. This means that, in principle, devaluation should not have a negative differential effect on companies with more foreign currency debt.

The beta coefficient estimated represents the differential effect of a devaluation on the various profitability measures. In the sample containing all companies, devaluation is found to produce a statistically significant differential effect for three of the four profitability measures: net income, EBITDA and ROIC. When an exchange-rate devaluation occurs, there is a negative differential effect on the net earnings of firms with foreign currency debt and, as expected, the greater the debt, the greater the impact (balance sheet effect). In the case of ROIC, also as expected, the differential effect is positive, since this measure includes financial income. Among the model results presented in table 2, only in the case of EBITDA is the sign of the coefficient not the expected one.

The coefficients for exchange-rate movements in isolation, irrespective of the level of foreign currency liabilities, indicate the possible effect of an exchange-rate devaluation on profitability measures when foreign currency debt is zero.

In the case of exporting firms, while exchange-rate devaluation did have a negative differential effect on the profitability measures, this was found to be smaller for the net income of exporting firms than of all firms. As mentioned, exports provide a natural hedge against exchange-rate movements.

We also checked whether exchange-rate devaluation had a differential effect depending on the level of net currency exposure, measured as the difference between foreign currency liabilities and the sum of foreign currency assets and the purchased value of currency derivative contracts. The results are presented in table 3.

Table 3
Model results for net currency exposure

Dependent variable	All firms				Exporting firms			
	EBITDA	Net income	ROE	ROIC	EBITDA	Net income	ROE	ROIC
C	0.059203	-0.022867	0.051008	0.048926	0.082813	0.013266	0.045846	0.050076
	[0.0073]***	[0.0111]**	[0.0058]***	[0.0057]***	[0.0022]***	[0.0027]***	[0.0107]***	[0.0034]***
$Exposure_{t-4}.\Delta er_t$	-1.95642	-5.000682	-2.341707	1.343516	0.413077	-0.8630	-8.632429	0.672557
	[0.8292]**	[0.9606]***	[1.7506]	[0.7270]*	[0.2137]*	[0.2146]***	[2.3554]***	[0.2686]**
Δer_t	0.046017	0.343453	-0.267726	-0.298298	0.014472	-0.088957	-0.225004	-0.166851
	[0.1180]	[0.2215]	[0.1982]	[0.0955]***	[0.0976]	[0.1089]	[0.1752]	[0.1054]
$Exposure_{t-4}$	0.096136	0.091496	0.349993	0.056043	0.066162	0.007115	0.21759	0.096291
	[0.0591]	[0.0571]	[0.1059]***	[0.0981]	[0.0167]***	[0.0189]	[0.1837]	[0.0274]***
Observations	4 243	4 418	4 339	4 404	2 198	2 297	2 253	2 296
Adjusted R-squared	0.3928	0.083	0.1758	0.1017	0.497	0.4533	0.1871	0.2687
F-statistic	15.595	3.1043	5.8716	3.6233	19.0869	16.7344	5.2848	7.9683
Prob(F-statistic)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Source: Prepared by the authors.
Note: White standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

As expected, it was found that, on average, firms with greater net exposure were differentially affected by an exchange-rate devaluation. The differential effect was statistically significant and negative for these firms' net income, the preferred measure of profitability in this paper.

For exporting firms, the differential effect on net income was smaller, in absolute number terms, than that estimated for the sample of all firms. The differential effect on EBITDA was positive and significant for the sample of exporting firms. An exchange-rate devaluation increases the revenues of firms that

are net exporters without affecting operating expenses, raising profitability as measured by EBITDA. In contrast, net income is negatively affected by higher financial costs when there is an exchange-rate devaluation and the company has a positive net exposure.

Lastly, we sought to analyse whether an exchange-rate devaluation had differential effects when associated with the level of currency hedging, liabilities and assets separately. The results are presented in table 4.

Table 4
Model results for foreign currency liabilities, assets and hedging

Dependent variable	All firms				Exporting firms			
	EBITDA	Net income	ROE	ROIC	EBITDA	Net income	ROE	ROIC
C	0.058638	-0.021079	0.062494	0.050392	0.084563	0.019692	0.056147	0.052667
	[0.0080]***	[0.0113]*	[0.0119]***	[0.0068]***	[0.0024]***	[0.0027]***	[0.0206]***	[0.0036]***
$Liabilities_{t-4}.\ \Delta er_t$	-2.098985	-5.117687	-0.780767	1.411363	0.450721	-0.617229	-6.742197	0.706289
	[0.8717]**	[0.9769]***	[1.7451]	[0.7931]*	[0.2017]**	[0.2238]***	[2.5564]***	[0.2658]***
$Assets_{t-4}.\ \Delta er_t$	3.444796	4.37346	-14.341085	-0.304638	-0.860182	-0.276664	-5.756039	0.140102
	[1.4612]**	[1.2632]***	[5.2190]***	[1.3653]	[0.3429]**	[0.5797]	[8.4122]	[0.4400]
$Hedge_{t-4}.\ \Delta er_t$	1.689724	3.18858	4.997618	0.330964	-0.545262	1.648387	10.551523	0.384984
	[0.8033]**	[0.7463]***	[1.5394]***	[0.6034]	[0.2524]**	[0.3003]***	[2.4618]***	[0.3207]
Δer_t	0.03744	0.397119	-0.165512	-0.354283	0.026152	-0.107312	-0.08693	-0.224882
	[0.1357]	[0.2656]	[0.2383]	[0.1062]***	[0.1112]	[0.1206]	[0.2471]	[0.1203]*
$Liabilities_{t-4}$	0.098459	0.08676	0.3396	0.04944	0.058107	-0.019288	0.186391	0.08376
	[0.0627]	[0.0606]	[0.1184]***	[0.1050]	[0.0157]***	[0.0207]	[0.2068]	[0.0275]***
$Assets_{t-4}$	-0.088986	-0.177326	-1.08239	-0.07827	-0.09219	-0.107952	-0.491503	-0.115933
	[0.0527]*	[0.0577]***	[0.4558]**	[0.0932]	[0.0327]***	[0.0444]**	[0.5495]	[0.0462]**
$Hedge_{t-4}$	-0.081039	-0.107409	-0.317261	-0.091532	-0.076222	-0.051791	-0.218928	-0.127274
	[0.0480]*	[0.0451]**	[0.1039]***	[0.0662]	[0.0333]**	[0.0310]*	[0.1603]	[0.0440]***
Observations	4 243	4 418	4 339	4 404	2 198	2 297	2 253	2 296
Adjusted R-squared	0.3922	0.0822	0.1801	0.1011	0.4962	0.4547	0.1904	0.2681
F-statistic	15.2577	3.0389	5.9116	3.5517	18.4521	16.3136	5.2378	7.7261
Prob(F-statistic)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Source: Prepared by the authors.
Note: White standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

It can be seen that exchange-rate devaluation had a statistically significant differential effect on three of the four profitability measures. As expected, the differential effect was negative for firms with greater foreign currency liabilities and positive for firms with greater hedging. On the asset side, the differential effect was positive, as expected, for three of the four profitability measures, the exception being ROE, possibly reflecting the ambiguous effects of an exchange-rate devaluation on this variable.

In the case of exporting firms, the differential effect for those with larger foreign currency liabilities was significant on all four profitability measures and negative, as expected, for net income and ROE. In the case of net income, in particular, the differential effect of an exchange-rate devaluation was smaller in absolute number terms for exporting firms, indicating that these firms were less vulnerable on average to an exchange-rate devaluation when they had foreign currency liabilities.

Cowan, Hansen and Herrera (2005) argue that the positive differential effect for firms with larger foreign currency assets and hedging should at least partially offset the negative differential effect for firms with foreign currency liabilities. The results obtained do not support this. In particular, for the sample of all firms, when foreign currency assets and hedging are controlled for, the ratios for net income and EBITDA are greater in absolute number terms than the values observed in table 2.

1. Robustness analysis: macroeconomic controls

To check whether the results obtained were internally robust, the specification of the models was modified by introducing controls for the macroeconomic environment. Specifically, we controlled for changes in the level of domestic economic activity (real change in GDP) and world demand (change in the volume of world imports). We found that the results did not change significantly and remained robust after the inclusion of the macroeconomic controls.

Table 5 presents the results for the differential effect of an exchange-rate movement on firms with foreign currency debt. It can be seen that, for the sample of all firms, the coefficients of the main profitability measures selected, EBITDA and net earnings, remain similar, although the differential effect on EBITDA is no longer statistically significant. For exporting firms, the differential effect of an exchange-rate movement remains statistically significant for three of the four profitability measures (the same ones as when changes in GDP were not controlled for), and the values of the coefficients are also similar. The effect of changes in world imports was neither significant nor numerically important.

Table 5
Model results for foreign currency debt, controlling for GDP

Dependent variable	All firms				Exporting firms			
	EBITDA	Net income	ROE	ROIC	EBITDA	Net income	ROE	ROIC
C	0.010417	-0.051815	0.049685	0.020457	0.086184	0.003143	0.035746	0.043126
	[0.0158]	[0.0207]**	[0.0190]***	[0.0154]	[0.0035]***	[0.0052]	[0.0192]*	[0.0060]***
$Liabilities_{t-4}.\Delta er_t$	-0.468387	-3.008685	-3.727566	0.699823	0.257397	-0.732257	-4.036402	0.507089
	[0.3005]	[0.7620]***	[1.3277]***	[0.4268]	[0.2338]	[0.3158]**	[1.4420]***	[0.1894]***
Δer_t	0.137032	0.406934	0.059871	-0.16837	0.050402	0.092346	0.144919	-0.045684
	[0.0873]	[0.1976]**	[0.2102]	[0.0693]**	[0.0598]	[0.0700]	[0.2046]	[0.0658]
$Liabilities_{t-4}$	0.221933	0.159341	-0.000104	0.06105	0.046056	-0.010632	0.112285	0.021545
	[0.0467]***	[0.0382]***	[0.1092]	[0.0881]	[0.0173]***	[0.0279]	[0.1707]	[0.0235]
ΔGDP_t	2.53726	1.541578	0.719538	1.318793	2.233325	2.80565	-0.285939	1.681872
	[0.6065]***	[0.8440]*	[0.8861]	[0.4803]***	[0.1941]***	[0.2788]***	[1.2254]	[0.3641]***
$\Delta Imports_t$					-0.003352	-0.000353	0.004973	-0.000562
					[0.0009]***	[0.0013]	[0.0031]	[0.0018]
Observations	5 751	6 022	5 914	6 005	3 016	3 171	3 103	3 169
Adjusted R-squared	0.2023	0.0644	0.1344	0.1245	0.4017	0.4058	0.1306	0.2636
F-statistic	8.1825	3.0318	5.4997	5.1853	16.1043	17.0353	4.451	9.3996
Prob(F-statistic)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Source: Prepared by the authors.
Note: White standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

The differential effect of an exchange-rate devaluation according to the level of net currency exposure, controlling for the macroeconomic environment, is presented in table 6. In the sample of all firms, the result of controlling for changes in GDP, although statistically significant for three of the four profitability measures, did not substantially change the differential effect of an exchange-rate devaluation. The effect of an exchange-rate devaluation (when exposure is zero) becomes positive and statistically significant for ROE, indicating a competitiveness effect for firms with no net currency exposure.

In the case of exporting firms, the differential effect does not alter significantly when changes in GDP and world imports are controlled for. As mentioned above, it remains negative and statistically significant for net earnings and positive and significant, as expected, for EBITDA.

Lastly, we analyse whether the introduction of macroeconomic controls modifies the differential effects of an exchange-rate devaluation when associated with currency hedging, liabilities and assets separately. The results are presented in table 7.

Table 6
Model results for net currency exposure, controlling for GDP

Dependent variable	All firms				Exporting firms			
	EBITDA	Net income	ROE	ROIC	EBITDA	Net income	ROE	ROIC
C	0.058234	-0.019319	0.045325	0.04593	0.090417	0.010131	0.055951	0.041288
	[0.0072]***	[0.0110]*	[0.0055]***	[0.0053]***	[0.0037]***	[0.0043]**	[0.0194]***	[0.0069]***
$Exposure_{t-4}.\ \Delta er_t$	-1.955036	-4.991498	-2.33874	1.332235	0.472087	-0.810924	-8.599479	0.708695
	[0.8294]**	[0.9544]***	[1.7519]	[0.7255]*	[0.1996]**	[0.2119]***	[2.3588]***	[0.2673]***
Δer_t	0.083268	0.216148	-0.069113	-0.18998	0.081311	0.07066	-0.23602	0.004271
	[0.1094]	[0.1814]	[0.1321]	[0.0715]***	[0.0421]*	[0.0450]	[0.1417]*	[0.0740]
$Exposure_{t-4}$	0.096756	0.088804	0.354874	0.058249	0.079514	0.018635	0.224711	0.104125
	[0.0593]	[0.0575]	[0.1066]***	[0.0978]	[0.0173]***	[0.0179]	[0.1836]	[0.0265]***
ΔGDP_t	0.526774	-1.596536	2.538219	1.358107	2.05716	2.308366	1.091204	1.810258
	[0.3937]	[0.8198]*	[0.7764]***	[0.4332]***	[0.2151]***	[0.2116]***	[1.1734]	[0.4226]***
$\Delta Imports_t$					-0.003909	-0.000851	-0.003883	0.001242
					[0.0010]***	[0.0012]	[0.0045]	[0.0018]
Observations	4 243	4 418	4 339	4 404	2 198	2 198	2 198	2 198
Adjusted R-squared	0.3927	0.083	0.1772	0.1023	0.514	0.514	0.514	0.514
F-statistic	15.5136	3.0939	5.8925	3.6276	20.0441	20.0441	20.0441	20.0441
Prob(F-statistic)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Source: Prepared by the authors.
Note: White standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table 7
Foreign currency liabilities, assets and hedging model results, controlling for GDP

Dependent variable	All firms				Exporting firms			
	EBITDA	Net income	ROE	ROIC	EBITDA	Net income	ROE	ROIC
C	0.056752	-0.014867	0.053506	0.045455	0.087051	0.011155	0.063958	0.039311
	[0.0080]***	[0.0113]	[0.0128]***	[0.0066]***	[0.0046]***	[0.0046]**	[0.0226]***	[0.0075]***
$Liabilities_{t-4}.\ \Delta er_t$	-2.097425	-5.101601	-0.773983	1.39537	0.488775	-0.598927	-6.722016	0.714897
	[0.8703]**	[0.9679]***	[1.7263]	[0.7880]*	[0.1694]***	[0.2177]***	[2.5593]***	[0.2655]***
$Assets_{t-4}.\ \Delta er_t$	3.45533	4.370947	-14.396222	-0.297226	-0.769531	-0.288225	-5.650937	0.059947
	[1.4611]**	[1.2570]***	[5.1882]***	[1.3668]	[0.3562]**	[0.5906]	[8.4768]	[0.4318]
$Hedge_{t-4}.\ \Delta er_t$	1.671175	3.287474	4.847426	0.254385	-0.638275	1.450051	10.584186	0.163176
	[0.8098]**	[0.7665]***	[1.5739]***	[0.5895]	[0.2452]***	[0.2623]***	[2.4464]***	[0.3286]
Δer_t	0.07854	0.257283	0.029452	-0.242757	0.10108	0.058944	-0.105204	-0.041204
	[0.1285]	[0.2223]	[0.1737]	[0.0817]***	[0.0580]*	[0.0596]	[0.2214]	[0.0964]
$Liabilities_{t-4}$	0.102296	0.075054	0.358999	0.058699	0.097982	0.017195	0.201298	0.113509
	[0.0636]	[0.0611]	[0.1196]***	[0.1048]	[0.0161]***	[0.0199]	[0.2139]	[0.0292]***
$Assets_{t-4}$	-0.065413	-0.247576	-0.982013	-0.022179	-0.05074	-0.044665	-0.485242	-0.05314
	[0.0483]	[0.0694]***	[0.4623]**	[0.0922]	[0.0362]	[0.0449]	[0.5597]	[0.0452]
$Hedge_{t-4}$	-0.067832	-0.147399	-0.261798	-0.059597	-0.048973	-0.018526	-0.208213	-0.098357
	[0.0459]	[0.0468]***	[0.1082]**	[0.0637]	[0.0318]	[0.0307]	[0.1655]	[0.0431]**
ΔGDP_t	0.568473	-1.702568	2.415173	1.357745	2.150126	2.283921	0.934932	1.868676
	[0.4171]	[0.8232]**	[0.8281]***	[0.4345]***	[0.2355]***	[0.2356]***	[1.5132]	[0.4586]***
$\Delta Imports_t$					-0.003995	-0.000867	-0.003548	0.001098
					[0.0010]***	[0.0012]	[0.0048]	[0.0018]
Observations	4 243	4 418	4 339	4 404	2 198	2 297	2 253	2 296
Adjusted R-squared	0.3922	0.0822	0.1813	0.1017	0.5136	0.4701	0.1899	0.2755
F-statistic	15.1803	3.0296	5.9254	3.5553	19.4147	17.0393	5.1568	7.8706
Prob(F-statistic)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Source: Prepared by the authors.
Note: White standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

We find that the statistically significant differential effect of an exchange-rate devaluation on three of the four profitability measures is still present when changes in GDP are controlled for. As expected, the differential effect is negative for firms with larger foreign currency liabilities and positive for firms with larger foreign currency assets or greater hedging.

In the case of exporting firms with greater foreign currency liabilities, as before, the differential effect is significant and negative for only two of the four profitability measures, net earnings and ROE, and positive for EBITDA and ROIC. Once again, we find a substantially smaller differential effect from an exchange-rate devaluation on net income in absolute number terms, indicating that exporting firms with foreign currency liabilities are less vulnerable to an exchange-rate devaluation.

V. Conclusions

This paper has sought to investigate the effects of exchange-rate misalignment on the earnings of Brazilian non-financial firms between 2010 and 2018, using a sample of 201 Brazilian non-financial listed firms. Its main contribution derives from the use of a specially constructed database containing detailed and hard-to-access information on currency derivatives and assets. Following what is a standard econometric strategy in the literature on the so-called balance sheet effect in emerging economies, we obtained results that corroborate those of previous studies on Brazil.

The main finding was that, when an exchange-rate devaluation occurs, there is a negative differential effect on firms with foreign currency debt and greater exchange-rate exposure, even when they are exporters, although in this case the effect is smaller. By including in the equation some variables that protect firms with foreign currency debt from the effects of devaluation, we obtained the expected result: the differential effect is negative for firms with larger foreign currency liabilities and positive for firms with larger foreign currency assets or a higher level of hedging. These results were consistent across different specifications.

It is important to note that the effects of an exchange-rate devaluation in a given economy cannot be generalized, because they depend on factors such as external debt and trade ratios, as well as firms' currency hedging strategies, which vary between countries and over time. We have presented evidence that the degree of exchange-rate misalignment among Brazilian firms declined substantially over the 2010s.

This last consideration suggests future lines of research to be pursued with this paper as a starting point. A first task is to divide the period into phases characterized by different levels of exchange-rate misalignment and recalculate the effect of exchange-rate depreciations on profits in these subperiods. A second suggestion for future research is to study a specific episode of severe exchange-rate devaluation, such as the depreciation of some 70% around 2015, using the difference-in-differences method. Lastly, given the importance of the export and import variables in determining the degree of exchange-rate misalignment, and in view of the lack of firm-level data for Brazil, one possible way forward would be to group firms into sectors for which these data are available.

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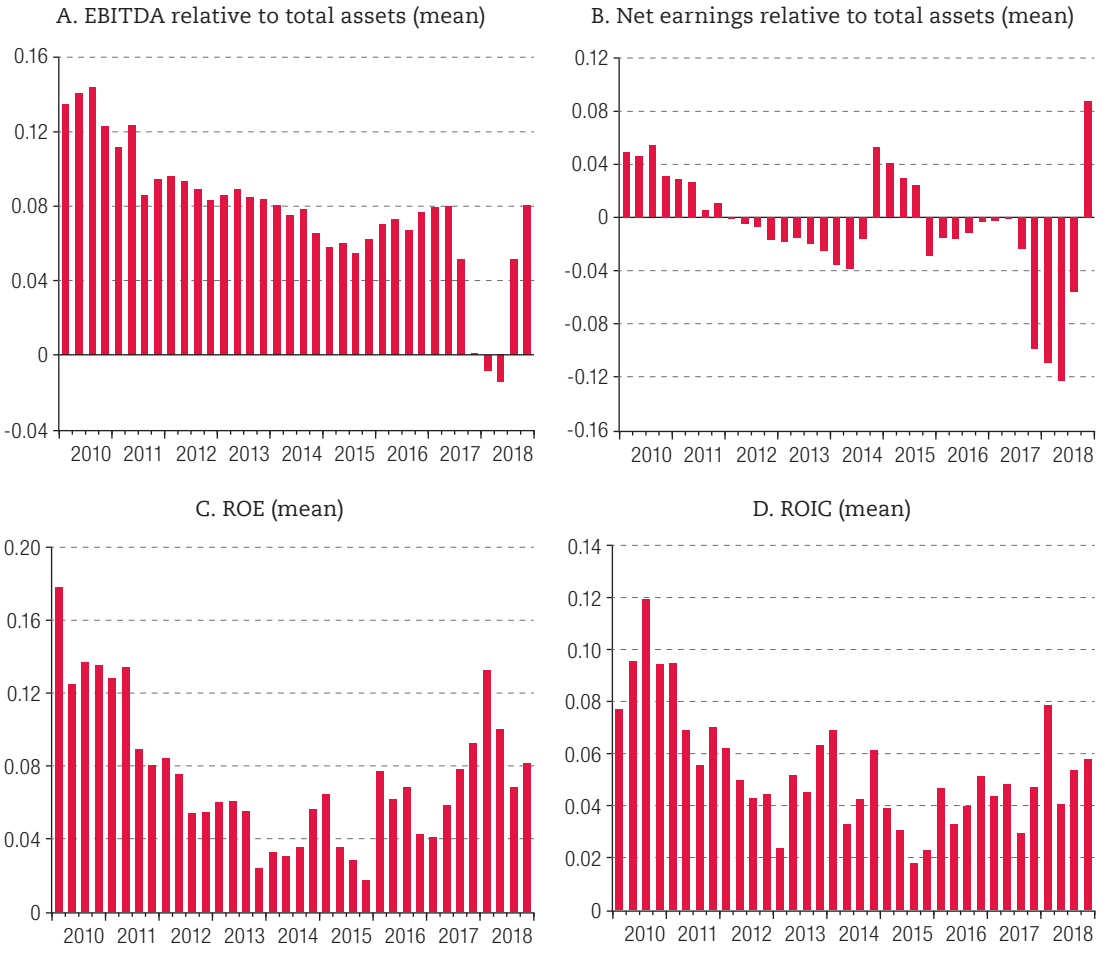
Annex A1

Table A1.1
Descriptive statistics

Sample: all firms								
	EBITDA	Net income	ROE	ROIC	Assets	Liabilities	Hedging	Net exposure
Mean	0.0771	-0.0041	0.0584	0.0510	0.0169	0.0768	0.0186	0.0413
Median	0.0913	0.0256	0.0797	0.0557	0.0000	0.0078	0.0000	0.0000
Maximum	2.6142	12.4243	2.9512	4.6221	0.3903	1.6513	0.6936	1.6513
Minimum	-1.6142	-8.1933	-2.9842	-4.5758	0.0000	0.0000	-0.3471	-0.5454
Standard deviation	0.1721	0.5376	0.4188	0.2811	0.0459	0.1354	0.0606	0.1143
Observations	3 735	3 735	3 735	3 735	3 735	3 735	3 735	3 735
Sample: exporting firms								
	EBITDA	Net income	ROE	ROIC	Assets	Liabilities	Hedging	Net exposure
Mean	0.0871	0.0137	0.0565	0.0565	0.0279	0.1089	0.0273	0.0538
Median	0.0905	0.0229	0.0699	0.0535	0.0000	0.0345	0.0000	0.0011
Maximum	0.9754	0.6266	2.9512	1.5617	0.3903	0.7675	0.6936	0.7614
Minimum	-1.0531	-1.2648	-2.9842	-1.5894	0.0000	0.0000	-0.3471	-0.5454
Standard deviation	0.0935	0.1074	0.4262	0.1200	0.0576	0.1476	0.0726	0.1178
Observations	1 947	1 947	1 947	1 947	1 947	1 947	1 947	1 947

Source: Prepared by the authors.

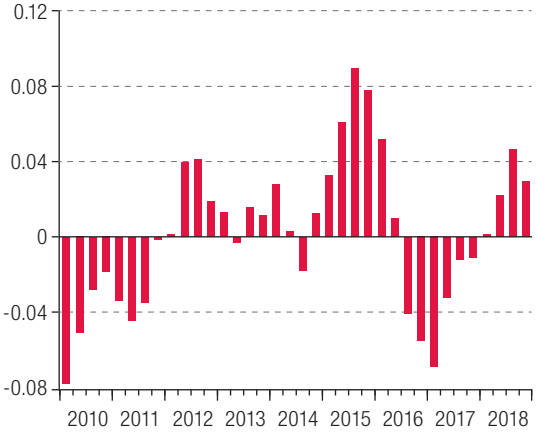
Figure A1.1
Brazil: profitability measures, 2010–2018



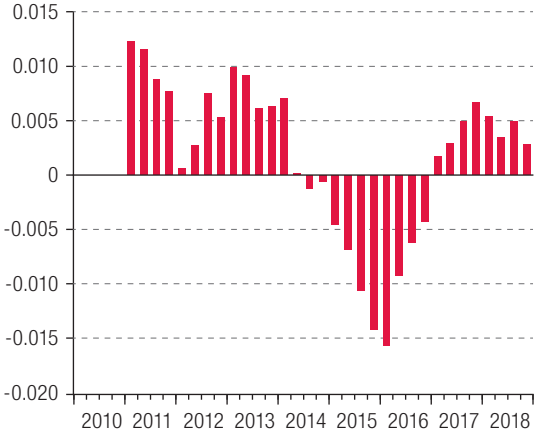
Source: Prepared by the authors.

Figure A1.2
Brazil: macroeconomic variables, 2010–2018

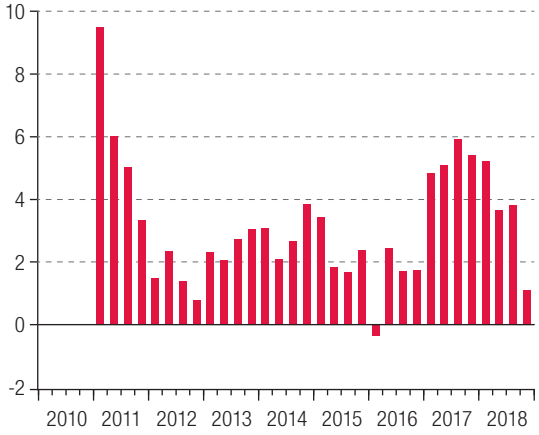
A. Real exchange rate of Brazilian real to United States dollar (changes in moving average)



B. Real seasonally adjusted GDP (changes in moving average)



C. Seasonally adjusted world import volume index (rates of change)



Source: Prepared by the authors.

Table A1.2
Unit root tests

Null hypothesis: individual unit root with individual effects and linear trend			
Variable	Statistic	p-value	Conclusion
EBITDA	-4.3673	0.0000	Null hypothesis of unit root rejected
Net income	-3.0665	0.0011	Null hypothesis of unit root rejected
ROE	-1.5368	0.0622	Null hypothesis of unit root rejected
ROIC	-3.2228	0.0006	Null hypothesis of unit root rejected
Liabilities	-5.9119	0.0000	Null hypothesis of unit root rejected
Assets	-7.0674	0.0000	Null hypothesis of unit root rejected
Hedging	-3.0250	0.0012	Null hypothesis of unit root rejected
Exposure	-28.1913	0.0000	Null hypothesis of unit root rejected
Δer_t	-16.1975	0.0000	Null hypothesis of unit root rejected
ΔGDP_t	-15.9391	0.0000	Null hypothesis of unit root rejected
$\Delta Imports_t$	-38.6561	0.0000	Null hypothesis of unit root rejected

Source: Prepared by the authors, on the basis of K. Im, M. Pesaran and Y. Shin (2003), "Testing for unit roots in heterogeneous panels", *Journal of Econometrics*, vol. 115, No. 1, Amsterdam, Elsevier.

Support for technological innovation in the Brazilian machinery and equipment sector since the 2000s: analysis based on the Innovation Survey (PINTEC)

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Abstract

This article analyses how technological innovation has evolved in the machinery and equipment sector in Brazil, comparing innovation by firms that benefited from government schemes to support innovation versus those that did not. The data used were from six editions of the Innovation Survey (PINTEC) and a special tabulation prepared by the Brazilian Institute of Geography and Statistics (IBGE). The results indicate that the industrial and science, technology and innovation policies of the 2000s had positive effects in the sector: firms' innovative activities were boosted by government support instruments and increased more than innovation by companies that did not receive this support. The systematized data also enable the identification of some failings in these sector support programmes.

Keywords

Industrial development, industrial enterprises, technological innovations, industrial policy, machine tool industry, productivity, development policy, programmes of action, industrial statistics, industrial surveys, Brazil

JEL classification

L52, O31, O38

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I. Introduction

There is no consensus in the economic literature on industrial policies as a centrepiece of economic development policies. Opinions diverge on several aspects, such as the scope of policies (correcting market failures or creating markets), their orientation (horizontal versus vertical or sectoral measures) and the type of support (subsidies or targeted financing).

These divergences notwithstanding, countries have frequently used industrial policies (explicitly or implicitly) as an economic development strategy (Suzigan and Furtado, 2010; Cherif and Hasanov, 2019). More recently, industrial policy practices have been pursued more explicitly, whether in response to the 2008 financial crisis or as a stimulus for investments in Industry 4.0 (Chang and Andreoni, 2016). Latin America generally, and Brazil in particular, also saw a return to industrial policies in the 2000s (Peres, 2005).

From 2004, the Brazilian economy devised new industrial support instruments, which covered the period up to 2014. Machinery and equipment was one of the sectors afforded priority in industrial policy plans throughout this period, because its ability to supply other sectors of the economy and incorporate technical progress into production processes made it strategic for industrial growth and development. Technological innovation was a main focus of attention in these plans, with various support instruments implemented over the period.

Given the importance of the machinery and equipment sector for Brazil's growth and development, this article's main aim is to analyse how technological innovation indicators evolved over the duration of industrial policies, and to gauge the importance of public support for innovation in this sector. To this end, it analyses the innovative activities by firms in the machinery and equipment sector that benefited from government schemes to support innovation, compared with non-beneficiaries. It uses the data available from the last six editions of the Innovation Survey (PINTEC) of the Brazilian Institute of Geography and Statistics (IBGE), from 2003, 2005, 2008, 2011, 2014 and 2017, and other data obtained from a special tabulation prepared by IBGE (2020) specifically for this study. Given the difficulties of establishing causal links between industrial policies and innovation indicators, this study is exploratory in nature.

The article takes the hypothesis that the various government support instruments supported innovation by companies in the machinery and equipment sector, which evolved more positively than firms in the same sector that did not receive this support.

This article has two sections, in addition to this introduction and concluding remarks. The following section presents the analytical framework and briefly describes the industrial policies implemented since the 2000s, focusing on the sector under analysis. Section III considers how public support for innovation has evolved and analyses the technological innovation indicators relevant to the machinery and equipment sector from the last six PINTEC surveys, which form the core of the article.

II. Industrial and technological innovation policies since the 2000s: analysis of the Brazilian machinery and equipment sector

The Brazilian economy saw a series of industrial policy and productive development plans between 2004 and 2014. After almost 25 years of scant State involvement in industrial development since the balance of payments crisis of the 1980s and the economic opening of the 1990s, Brazil ran into a serious economic crisis that stemmed, in a number of ways, from the loss of importance of industry in the country's gross domestic product (GDP).

In the 1980s, despite the crisis, a certain consensus remained regarding the importance of active industrial policy to restart Brazil's economic development. Although guided by no overarching principle, various steps were taken: the Ministry of Science and Technology was established, providing visibility and resources to the area, and the Informatics Act was passed, although in practice it did not achieve the institutional substance or level of resources that had been envisaged[1] (Costa, 1994).

In the 1990s, a vision contrary to State intervention in industrial development prevailed in the economic policy arena (Erber and Cassiolato, 1997). In the context of the changes made in the Brazilian economy during this period in the direction of liberalization and inflation stabilization, the Real Plan, the use of high exchange rates and high interest rates were particularly prejudicial to the manufacturing industry and contributed to accelerating deindustrialization (Nassif and Feijó, 2013).

The plans of the 2000s aimed primarily to reverse this process and resume support for industrial and productive development. These plans were: the Industrial, Technological and Foreign Trade Policy in 2004, the Productive Development Policy in 2008, and the Greater Brazil Plan in 2011 (Laplane and Laplane, 2017; De Toni, 2015). These plans were based on evolutionary and neo-Schumpeterian theory, especially with regard to the innovation systems approach (Salerno and Daher, 2006; Schapiro, 2014; Stein and Herrlein, 2016).

This approach made these plans different from past industrial policies in several ways. The most important, for the purposes of this work, is the deliberate linkage of industrial and innovation policy.[2] Particularly since 2007, with the launch of the Action Plan on Science, Technology and Innovation, and later with the National Science, Technology and Innovation Strategy 2012–2015, boosting business innovation became one of the main aims, and various channels for articulation were constructed between the business sector and science and technology institutions.

Another major difference with respect to previous plans was the aim of more openness to external markets through exports. All the plans included specific measures aimed at the export sector —such as financing from the National Bank for Economic and Social Development (BNDES)— as well as institutional changes, such as the establishment of the Brazilian Trade and Investment Promotion Agency (Apex-Brasil). The expansion of exports, in general, and of micro and small businesses in particular, was also among the main objectives of the Productive Development Policy and the Greater Brazil Plan.

Support for small businesses was another factor that set the industrial policies of the 2000s apart from earlier ones. A large array of taxation- and financing-related measures were adopted to support Brazilian small businesses, especially in the area of innovation, led mainly by the Studies and Projects Financing Entity.

In relation to the topic of this article, an important feature of industrial policy plans was that the measures were geared towards specific sectors: what are known as "vertical" policies. This was particularly the case for measures under the Industrial, Technological and Foreign Trade Policy, which had four priority sectors (semiconductors, software, pharmaceutical products and medicines, and capital goods) and areas with good future prospects (biotechnology, nanotechnology and renewable energies). The Productive Development Policy, meanwhile, was aimed at 25 sectors organized into three blocs based on their competitive position. The machinery and equipment sector fell into the category of schemes to maintain competitiveness (along with the wood and furniture, leather and footwear, and plastics sectors, among others). Lastly, the Greater Brazil Plan organized sectors in a different way: 19 priority sectors divided into five blocs. The machinery and equipment sector was included in the bloc termed mechanical, electrical, electronic and health systems.

[1] The most controversial aspect of the Informatics Law (1984) was the establishment of a market reserve for national microcomputer companies. This law has been reformulated several times since the 1990s, and market reserve ended in 1992. This discussion exceeds the scope of this article. See, among others, Costa (1994) and Garcia and Roselino (2004).

[2] The inseparability of industrial policy and innovation policy in the current context is the subject of several recent studies, especially using the neo-Schumpeterian approach. See Baptista (2000).

The sectoral reorganization of the Productive Development Policy and the Greater Brazil Plan reflected the needs of the productive sector, given that the sectors included in the Industrial, Technological and Foreign Trade Policy did not represent a very large share of the Brazilian industrial structure. The expansion to more sectors through the Productive Development Policy and later the Greater Brazil Plan ultimately diluted selectivity, especially in relation to those highly technologically dynamic sectors capable of driving industrial policy transformation (Stein and Herrlein, 2016).

There follows a description of the main measures aimed at the machinery and equipment sector under each of the industrial policy plans. They consisted of new tax incentives for research and development (R&D) activities, investment exemptions, financial grants, and financing for R&D projects and the acquisition of machinery and equipment.

1. Industrial, Technological and Foreign Trade Policy

During the time that the Industrial, Technological and Foreign Trade Policy was in force, three main measures were introduced to strengthen the machinery and equipment sector: (i) facilitating the acquisition of machinery and equipment in all segments of the economy through the National Industry Modernization Programme and expanding the scope of the Fund for Financing the Acquisition of Industrial Machines and Equipment (FINAME) and other funds, with a view to creating demand and strengthening Brazilian producers; (ii) creating a financing line by BNDES for the design, production and purchase of commissioned goods (turn-key, main contractor, engineering services); and (iii) creating international marketing initiatives, with contracts between the productive sector and Apex-Brasil for prospecting and trade intelligence for the sector, as well as the participation of Brazilian producers in the industry's major international fairs (Salerno and Daher, 2006).

Efforts were made to reduce taxes on investment, production and exports by eliminating the tax on processed products for machinery and equipment and establishing tax equality between imported and domestically produced products, although the Contribution to the Financing of the Social Security System (COFINS) was applied to imported goods. In addition, firms that exported at least 80% of their production were exempted from payments to the Social Integration Programme and the Civil Servant Investment Programme, known as PIS/PASEP, as well as to COFINS, for purchases of machinery and equipment (Cano and Silva, 2010).

The Industrial, Technological and Foreign Trade Policy was supported by the Innovation Act (No. 10973), adopted in 2004, which provided measures to support scientific and technological research in the productive area, mainly by offering more flexible channels of interaction with universities and research centres.

In addition, legislation known as the Asset Act (No. 11196), adopted in 2005, granted tax incentives to firms investing in research, development and technological innovation. This legislation was important for fostering productive and technological development in the machinery and equipment sector because, according to the National Association for Research and Development of Innovative Companies (ANPEI, 2018), its guaranteed benefits included a 50% deduction in the tax on processed products for the purchase of machinery and equipment for R&D.

However, although the Industrial, Technological and Foreign Trade Policy included wide-ranging measures, both horizontal and vertical, and impacted key sectors for the development of Brazilian industry, it failed to achieve its main objectives. The policy was hampered by the effects of tight macroeconomic policy, precarious economic infrastructure and a fragile science, technology and innovation system, and a weak coordination and implementation process. Despite the difficulties, its main merit was to have laid more solid foundations for later industrial policies with a renewed focus on industrial development (Suzigan and Furtado, 2006; Cano and Silva, 2010).

2. Productive Development Policy

The machinery and equipment sector —mass-manufactured or custom-made— also had a prominent place in the Productive Development Policy, in the category of programmes for strengthening competitiveness. In view of its great growth potential, and given the aim of increasing fixed investment to 21% GDP by 2010, the goals set for the machinery and equipment sector were: (i) investments of US$ 11.5 billion for 2008–2010; (ii) an increase in spending on research, development and innovation from 1.32% to 2.0% of net sales; and (iii) an increase in exports from US$ 16.7 billion to US$ 22.3 billion by 2010. These goals sought mainly to increase the competitive potential of the machinery and equipment industry through the market conquest strategy, managed by the Ministry of Development, Industry and Foreign Trade, which began to act as the coordinator of the various measures aimed at productive development (IEDI, 2011).

In the custom machinery and equipment segment, the strategy, also under the purview of the Ministry of Development, Industry and Foreign Trade, was to increase competitiveness and foreign market share through specialization. The targets were to increase research, development and innovation spending from 0.55% to 0.80% of net turnover and raise exports to US$ 4.4 billion by 2010 (from US$ 2.9 billion in 2007). Like mass manufacturing, custom manufacturing had great growth potential, chiefly thanks to investments under the Growth Acceleration Programme, set up in the same period to expand economic infrastructure.

According to ABIMAQ (2008), the Productive Development Policy made progress to varying degrees in several areas and thus met some of the requirements included in the scope of the programme, such as expanding productive capacity through investment promotion measures and tax relief, the 20% cut in the average basis spread on all BNDES financing lines, the reduction of the financial intermediation rate and the restructuring of the Credit Rights Investment Funds for the members of the Brazilian Association of the Machinery and Equipment Industry (ABIMAQ), set up to benefit smaller companies, which represented more than 60% of the firms in the sector.

Although the Productive Development Policy failed to achieve its main objectives, it did produce significant improvements, such as increased business spending on R&D. The impact on economic activity of the crisis that broke out in 2008 in the United States economy (subprime mortgage crisis) imposed severe constraints on the domestic and external macroeconomic outlook and threatened the country's financial stability. Accordingly, the Productive Development Policy took on an increasingly countercyclical role to combat the international crisis —especially through the ambitious action of BNDES to expand lending to the productive sector— and had less to do with fostering structural change (Stein and Herrlein, 2016). In the machinery and equipment sector, the main adverse effects reflected the impossibility of keeping up growth in investment in the wake of the crisis.

Despite falling short of its aims, the Productive Development Policy is considered to have underpinned progress in coordinating industrial policy instruments and increasing their coverage (Laplane and Laplane, 2017). In this regard, Stein and Herrlein (2016) have drawn attention to the importance of reducing the tax on processed products across a wide range of sectors, extending accelerated depreciation for new investments, reducing the PIS/PASEP and the COFINS repayment window for the purchase of machinery and equipment and, perhaps most importantly, BNDES financing and loans.

3. Greater Brazil Plan

The strategic agenda for the machinery and equipment sector was designed to achieve three main objectives, namely: (i) increase apparent consumption and reduce the import ratio, (ii) increase exports, and (iii) make the machinery and equipment industry more competitive. In this regard, the Greater Brazil

Plan had the same the strategic objectives for the sector as the Productive Development Policy, which speaks to the importance of industrial policy consolidation and continuity, in the sense of restructuring and strengthening certain lines of action without changing the direction of previous plans.

According to ABIMAQ (2011a), the Greater Brazil Plan package, which included changes in tax exemptions, financing, innovation and trade protection, had the merit of placing issues of competitiveness, innovation and industrial density on the Brazilian agenda. However, ABIMAQ had already emphasized the need to define a clear strategy for the future of Brazilian industry, and stated that the Greater Brazil Plan also had deficiencies, such as an excessive number of targets and a lack of tools and effective mechanisms to achieve the objectives proposed. It also cited delays in rolling out the measures, especially in relation to regulation and standardization processes, given that the problems facing the industry required long-term solutions and stable standards.

In his analysis of the institutional context of the Greater Brazil Plan, Schapiro (2014) concludes that its problems were associated with weaknesses in the political-institutional context, both in the technical-administrative and political spheres. Schapiro argued that industrial policy still suffered from a "decision-making cacophony" caused by a "hollow institutional context", since decision-making was not centralized in a single State agency and it involved representatives from several ministries. This also aggravated the problem of fragmented industrial sector representation, since there were several bodies responsible for industrial policy. Application of the Greater Brazil Plan therefore suffered from a problem of intragovernmental coordination.

Generally speaking, although industrial policy plans provided important measures for Brazilian industry from the 2000s onward, difficulties arose in coordinating instruments and, especially, in ensuring continuity. The institution-building that began with the Industrial, Technological and Foreign Trade Policy was complicated by subsequent plans, either by their very design (such as the large number of sectors targeted by the Productive Development Policy and the Greater Brazil Plan and the difficulties of interinstitutional coordination) or by external difficulties with the effects of the 2008 crisis.

The positive and negative aspects of these plans have been evaluated in studies of diverse scope and using different evaluation methodologies. Although it is outside the scope of this article to take stock of these studies, some of their findings contribute to the analysis of specific policies for the machinery and equipment sector, in the following section.

In their analysis of the sectoral changes achieved by the three plans, Stein and Herrlein (2016) find that they ultimately distorted the purpose of industrial policy strategic decisions and leaned towards horizontal measures throughout, to the detriment of vertical policies or transformation of the productive structure, as would be expected from a neo-Schumpeterian policy. This converges with Schapiro's (2014) perspective on the Greater Brazil Plan, which also signals the predominance of the "Brazil cost" agenda (centred on tax reduction) over the Schumpeterian or transformative agenda. It also converges with Ulhôa, Botelho and Avellar (2019). Using data from federal government budget execution, they found that public resource allocation was not consistent with industrial policy being at the core of public policy financing over the period of the policies. Conversely, they did point to increasing industrial policy articulation with innovation policy, as the most significant public spending increase occurred in science and technology, which more than doubled in the period.

The following section, which forms the core of this article, presents a dataset that systematizes the evolution of science, technology and innovation indicators to give an exploratory picture of the effects of industrial policy plans in that sector, which benefited from support measures over the entire period owing to its extraordinary importance for industrial growth and development. This section offers an evolutionary analysis of government support for innovation in the sector using indicators relating to innovation efforts by beneficiary firms compared to non-beneficiaries, starting in the 2000s.

III. Evolution of public support for innovation in Brazil's machinery and equipment sector: analysis of PINTEC results

In pursuit of its main objective, this work analysed the data available from the PINTEC surveys carried out from the 2000s onward, namely, the surveys of 2003 (2001–2003 triennium), 2005 (2003–2005 triennium), 2008 (2006–2008 triennium), 2011 (2009–2011 triennium), 2014 (2012–2014 triennium) and 2017 (2015–2017 triennium), as well as the data obtained by means of a special tabulation carried out by IBGE (2020), exclusively for this work.[3]

For the analytical purposes of this study, PINTEC data were grouped by the latest classification used by the Brazilian Micro and Small Business Support Service, with the exception of microbusinesses. In this definition, small firms are those that have between 10 and 99 employees, medium-sized firms have 100–499 employees, and large firms have 500 or more.

In PINTEC, the manufacture of machinery and equipment falls into category 28 of the National Classification of Economic Activities (CNAE), which encompasses the manufacture of machinery and equipment, including mechanical components, parts and pieces for industrial and agricultural activities, mineral extraction and construction, transportation and lifting of freight and passengers, and for ventilation, refrigeration, thermal installations or other similar activities. Category 28 of the Classification thus covers much of the capital goods sector or industry.

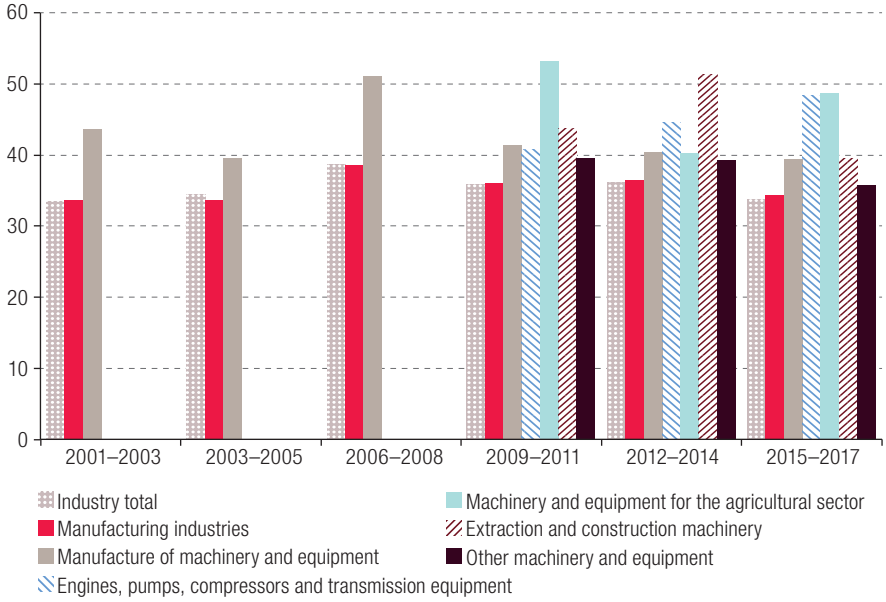
1. Characteristics of innovation in the machinery and equipment sector based on PINTEC data for the period 2001–2017

The innovation rate was the first of the indicators selected to analyse the evolution of technological innovation in the machinery and equipment sector. This indicator is obtained by dividing the total number of firms that made innovations by the total number of firms in the research sample. Figure 1 shows the innovation rate of Brazilian companies in the machinery and equipment sector in the period 2001–2017. The data show that the sector's innovation rate exceeds the rate for the manufacturing industry overall and the total rate for the industry throughout the period analysed.

This result is as expected, because of the sector's need to keep up with the pace of competition, for which it is essential to invest in innovation in general and in R&D in particular. Furthermore, as noted in the previous section, industrial policy plans had selected machinery and equipment as a strategic sector, so that it benefited from various programmes aimed at expanding innovation. However, the sector's innovation rate fell between the 2003 and 2005 PINTEC surveys, from 43.50% to 39.35%. In the 2008 survey it recovered notably, to 51%, but a downtrend occurs again in the later editions (2011, 2014 and 2017), in which innovation rates were 41.31%, 40.33% and 39.24% respectively. This represents 11.76 percentage points less than in 2008, a fall consistent with the trend seen in the sector overall.

[3] Although the industrial and innovation policies were implemented from 2004, the 2003 survey was used to trace the historical evolution of the indicators.

Figure 1
Brazil: innovation rate of firms that engaged in innovation in the machinery and equipment sector, 2001–2017
(Percentages)



Source: Prepared by the authors, on the basis of Brazilian Institute of Geography and Statistics (IBGE), special tabulation of the Survey of Innovation (PINTEC), 2020.

The fluctuations in this and other indicators analysed may be attributed to instability experienced over the period, both nationally and internationally. On the domestic front, between 2003 and 2010 Brazil experienced its longest growth cycle since the 1980s, with average annual GDP growth of 4.1%, notwithstanding this period included the worst phase of the international crisis that broke out in 2008. The main drivers of this growth cycle were increased public investment, rapid credit growth, real minimum wage gains and public policies involving higher social spending, as well as strong growth in the export sector in a context of global trade growth (Laplane and Laplane, 2017). However, the lagged effects of the international crisis starting in 2011, together with the difficulties in forming a strong institutional fabric for industrial and innovation policy over the period, produce results that sometimes suggest improvements and sometimes deterioration in the indicators, making it difficult to establish causal links. In addition, during the period covered by the 2017 PINTEC edition (2015–2017), Brazil suffered a political and economic crisis and changes in the underpinnings of industrial and innovation policy.

Continuing the analysis of general indicators on innovation, figure 2 shows the innovative effort obtained from the ratio between spending on innovation and net sales revenues. In the machinery and equipment sector, the innovative effort indicator went from 3.26% in the 2003 PINTEC survey to 4.15% in 2005, the highest level ever recorded by the survey. However, looking at the indicator over the entire period, a drop is seen between the 2008 and 2011 surveys, from 3.01% to 2.10%. There is an upturn in the 2014 survey (2.17%), following by another drop in 2017 (1.66%), considerably below the 2005 figure. Thus, the downtrend seen in the case of the innovation rate occurs in the innovative effort indicator as well.

Figure 2 also shows a disaggregated analysis of innovative effort by innovative companies in the sector in the 2011, 2014 and 2017 PINTEC surveys.[4] The subsectors spending the most on innovative activities as a percentage of their net sales revenues were mining and construction machinery,

[4] Disaggregated sectoral analysis of innovative firms in the machinery and equipment sector is available only from the 2011 PINTEC survey onward.

with 3.20% in 2011 and 2.43% in 2014, followed by machinery and equipment for agriculture, with 3.20% in 2011 and 2.25% in 2014. However, both these subsectors recorded their lowest results in 2017, in line with the drop for industry in general and for the machinery and equipment industry in particular.

Figure 2
Brazil: total innovative effort in the machinery and equipment sector, 2001–2017
(Percentages)

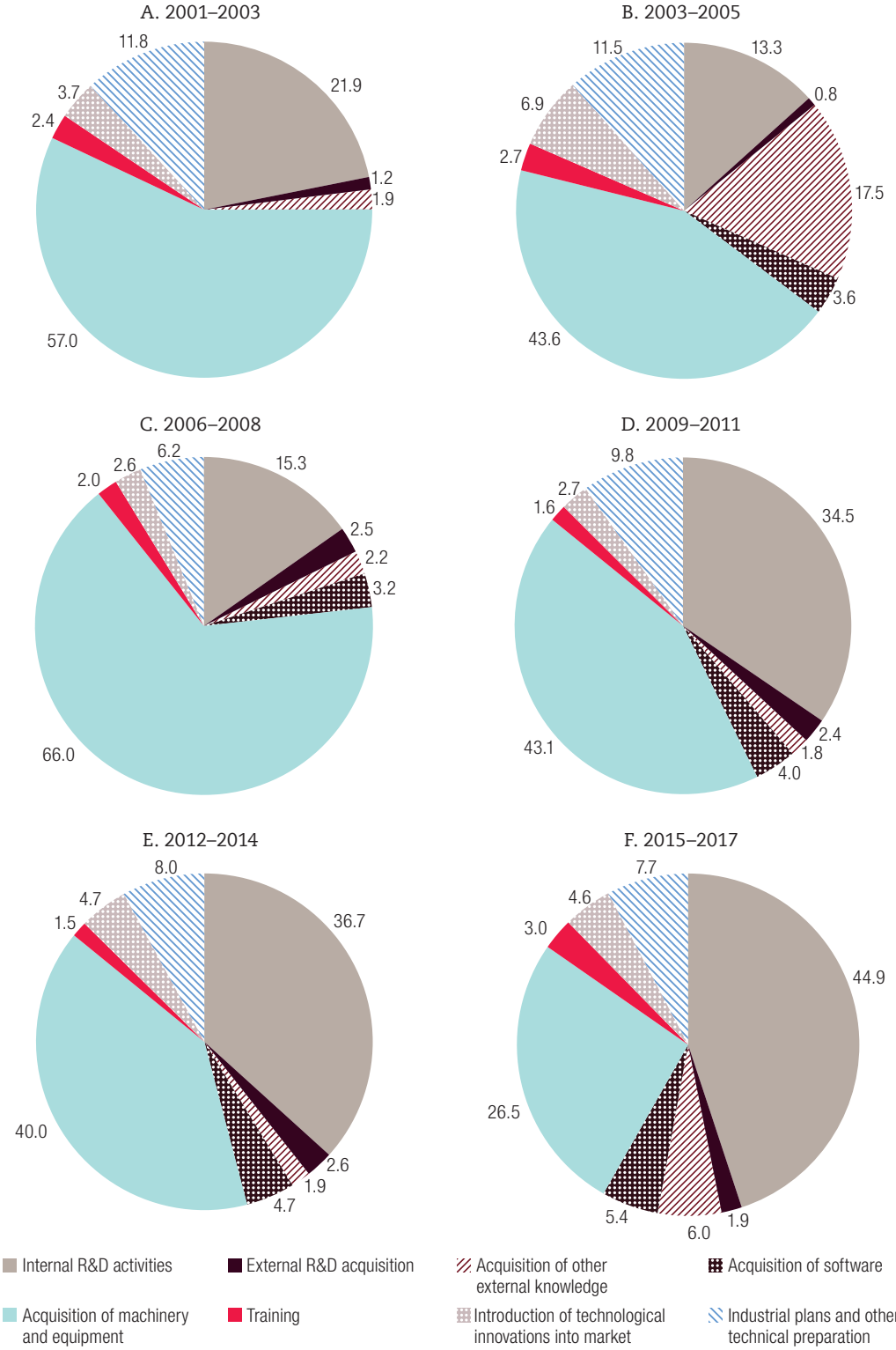
Source: Prepared by the authors, on the basis of Brazilian Institute of Geography and Statistics (IBGE), special tabulation of the Survey of Innovation (PINTEC), 2020.

The data on innovative effort and the innovation rate show different trends between the subsectors making up the machinery and equipment sector. Given the substantial rise that occurred in the growth rate of imports, albeit at different rates from one subsector to another,[5] this would seem to indicate a loss of competitiveness, especially in relation to progress by China. There are thus indications that the sector has undergone a process of specialization that has strengthened subsectors linked to agriculture and construction. This hypothesis seems to be corroborated by Brazil's specialization in commodities, together with its investment in the agro-industrial system and significant growth in civil construction in the 2000s, largely driven by public policies (such as *Minha Casa, Minha Vida*). However, this aspect requires more in-depth studies that are beyond the scope of this article.

To round out the analysis of innovative activities in the machinery and equipment sector, figure 3 shows the percentage of different expenditures between 2001 and 2017. For most of the period, the innovative behaviour of the sector was based predominantly on the acquisition of machinery and equipment. Although this share has fallen successively, going from 66% in the 2008 PINTEC survey to 26.5% in 2017, its predominance shows that the acquisition of technology embedded in machinery and equipment was the main innovative activity within expenditure on innovation by firms in the sector over the entire period —with the exception of the 2017 PINTEC survey, where it ranked second.

[5] Proportion of imports by subsector: components for the machinery and equipment industry (18.3%); machinery for the manufacturing industry (16.8%); machinery for consumer goods (21.2%); infrastructure and basic industry (17.2%); machinery for logistics and civil construction (15.9%); agricultural machinery and tools (2.1%); machinery for oil and renewable energies (0.3%), and other machinery (8.3%) (ABIMAQ, 2011b).

Figure 3
Brazil: expenditure on innovation by firms in machinery and equipment sector that engaged in innovation in products or processes, 2001–2017
(Percentages)



Source: Prepared by the authors, on the basis of Brazilian Institute of Geography and Statistics (IBGE), special tabulation of the Survey of Innovation (PINTEC), 2020.

The percentage of expenditure going to internal R&D activities increased from 21.9% in 2003 to 44.9% in 2017, making it the main component within the structure of spending on innovation by firms in the sector. This was the first time in the survey's historical series that R&D spending reached this figure, which supports the inference that industrial policy subsidies in the 2000s, especially the tax incentives for R&D activities, drove a rise in investments in internal R&D by companies. Although no methodologies were used to establish causal links, this is understood as an important indication that the industrial policy stimulus of the 2000s produced positive outcomes, in addition to showing effectively stronger linkage with science, technology and innovation policies, under which several tools were used to increase business spending on R&D, as discussed by Ulhôa, Botelho and Avellar (2019).

Although external R&D acquisition figures among the lowest percentages of spending on innovative activities, even coming last in the 2003, 2005 and 2017 surveys, it increased in general over the period, rising from 1.2% in 2003 to 2.6% in 2014. Similarly, software acquisition, treated as an innovation activity since the 2005 survey, rose from 3.6% in 2005 to 5.4% in 2017.

From this perspective, because Brazilian industry suffers from a technological gap with respect to the world's most innovative economies, it is reasonable to expect lower external R&D and software acquisition because of the limited diffusion of new technologies, whereas the acquisition of machinery and equipment is higher because of purchases of new machines with embedded technology that bring firms new or significantly improved products and processes.

The following subsection analyses the outcomes of public policies to support the machinery and equipment sector based on data tabulated by IBGE.

2. Characteristics of public policy support for innovation in the machinery and equipment sector

According to the data from the 2003 PINTEC survey, a total of 2,354 firms in the sector engaged in innovations, of which 16.14% obtained financing from innovation support schemes. In the 2005 survey, the number of innovative firms in the sector that obtained government financing rose slightly to 17.32%. This percentage rose to 25.25% in the 2008 survey, and held steady in 2011, but the number of beneficiary firms fell in absolute terms. The 2014 survey showed the highest percentage hitherto, with 34.80% benefitting from government aid. At the same time, although the total number of innovative firms fluctuated over the period, the lowest number was recorded in the 2017 survey: 2,189, of which 26.18% received government financing (see table 1).

Table 1
Brazil: innovative firms in machinery and equipment sector, beneficiaries and non-beneficiaries of innovation support programmes, by company size, 2001–2017
(Percentages)

Period	Machinery and equipment sector							
	Total number of firms		Firm size					
			Small		Medium-sized		Large	
	Beneficiary	Non-beneficiary	Beneficiary	Non-beneficiary	Beneficiary	Non-beneficiary	Beneficiary	Non-beneficiary
2001–2003	16.14	83.86	79.74	85.31	13.16	12.11	7.11	2.58
2003–2005	17.32	82.68	71.12	86.32	20.25	10.87	8.61	2.81
2006–2008	25.25	74.75	85.03	88.38	10.63	9.64	4.34	1.98
2009–2011	25.78	74.22	71.95	89.42	20.97	9.80	7.09	0.79
2012–2014	34.80	65.20	73.51	83.61	19.68	14.95	6.81	1.44
2015–2017	26.18	73.82	74.35	87.93	18.67	10.58	6.98	1.49

Source: Prepared by the authors, on the basis of Brazilian Institute of Geography and Statistics (IBGE), special tabulation of the Survey of Innovation (PINTEC), 2020.

The rise in the share of companies in the sector receiving public support is thought to be due to expansion of programmes and the diversification of innovation support instruments within the framework of the Industrial, Technological and Foreign Trade Policy, the Productive Development Policy and the Greater Brazil Plan. However, with the gradual dismantling of support instruments, fuelled by the fiscal crisis that worsened during the period of the Greater Brazil Plan, public support for innovation was also progressively dismantled, as is evident in the results of the 2017 PINTEC survey. It also warrants remarking that almost all the surveys showed a lower percentage of beneficiary firms in the machinery and equipment sector than in industry in general, which indicates that public resource allocation did not strictly follow sectoral priorities.

The size of beneficiary firms varied between survey years, with no clear trend. For the period as a whole, medium-sized companies showed the largest gain in share of support programmes, while the share of small firms fell from 79.74% in 2001 to 74.35% in 2017 and that of large firms slipped slightly from 7.11% to 6.98% of total beneficiaries.

Considering that a series of support instruments in the arena of industrial and innovation policies were allocated to the small and medium-sized enterprises (SMEs) segment, with the aim of integrating these firms better into the Brazilian productive structure, it may be inferred that these instruments reached medium-sized companies more significantly. As mentioned earlier, this is a major difference from previous industrial policy plans, which primarily targeted large companies.

A number of points used to analyse business innovation have been adopted in the specialized literature to compare beneficiaries and non-beneficiaries of innovation support schemes. The study by Avellar and Botelho (2015) presents a set of innovative effort and performance indicators for different sizes of beneficiary and non-beneficiary firms, broken down by fiscal and financial incentive schemes. Based on these criteria, IBGE prepared tables 2 and 3 for this study, showing indicators of innovative effort and performance for small, medium-sized and large firms in the machinery and equipment sector, both beneficiaries and non-beneficiaries of public assistance for innovation in the period 2001–2017.

A pattern has been identified in the indicators of innovative effort by innovative firms: medium and large innovative beneficiary firms show higher indicators of innovative effort (spending on R&D, spending on innovative activities, proportion of employees with complete higher education, continuous R&D and partnerships) than non-beneficiary innovative firms throughout the period, with the exception of the 2005, 2008, 2011 and 2014 PINTEC surveys, in which the indicator on partnerships was lower in large firms.

Conversely, the innovative effort indicators of beneficiary small innovative companies fluctuated over the period: sometimes these were higher than for non-beneficiaries and sometimes lower. However, small firms showed higher average expenditure on R&D and innovative activities, as well as a larger share of firms receiving public assistance for innovation than non-beneficiaries.

With regard to outcome indicators —such as productivity, innovative firms, product, process and organization innovation, and strategic protection[6]—, the medium-sized and large beneficiary firms mostly showed higher indicators than non-beneficiaries, with the exception of the productivity indicator, which showed predominantly lower results across all company sizes, especially small firms. However, although most of the outcome indicators of the small beneficiary firms were higher than those of non-beneficiaries, some survey years showed fluctuations, with lower indicators, especially in the product innovation indicator.

Although some indicators of beneficiary firms were lower than for non-beneficiaries, analysis of the whole set of innovation outcome indicators shows that they were positive overall, especially the percentage of innovative firms between beneficiaries and non-beneficiaries. Throughout the period, beneficiary firms of any size scored significantly higher on these indicators than non-beneficiaries.

[6] PINTEC does not enquire into patent protection, so strategic protection was taken as an outcome indicator because it is the most similar to the usual patent indicator. Strategic protection encompasses complexity of product design, industrial secret and time advantage over competitors, among other aspects.

Table 2
Brazil: indicators of innovative effort by firms in machinery and equipment sector, beneficiaries and non-beneficiaries of public assistance for innovation, by firm size, 2001–2017

Period	Variable	Indicators of innovative effort by innovative firms											
		Small				Medium-sized				Large			
		Beneficiaries	Average or percentage	Non-beneficiaries	Average or percentage	Beneficiaries	Average or percentage	Non-beneficiaries	Average or percentage	Beneficiaries	Average or percentage	Non-beneficiaries	Average or percentage
2001–2003	R&D spending *(Thousands of reais)*	6 936	22.9	95 901	57.0	19 299	386.0	42 839	179.2	112 728	4 175.1	86 155	1 689.3
	Spending on innovation *(Thousands of reais)*	89 626	295.8	343 654	204.1	93 838	1 876.8	194 828	815.2	589 551	21 835.2	352 089	6 903.7
	Employees with higher education *(Number)*	37	12.2%	262	15.6%	184	368.0%	194	81.2%	546	2 022.2%	472	925.5%
2003–2005	R&D spending *(Thousands of reais)*	13 837	49.2	81 895	50.3	30 505	381.3	28 739	140.2	109 632	3 224.5	106 444	2 008.4
	Spending on innovation *(Thousands of reais)*	90 487	322.0	1 539 635	945.7	141 101	1 763.8	137 335	669.9	392 370	11 540.3	484 570	9 142.8
	Employees with higher education *(Number)*	344	122.4%	635	39.0%	178	222.5%	175	85.4%	509	1 497.1%	458	864.2%
2006–2008	R&D spending *(Thousands of reais)*	17 603	29.0	49 341	26.4	22 627	297.7	32 543	159.5	224 158	7 230.9	46 572	1 108.9
	Spending on innovation *(Thousands of reais)*	757 203	1 245.4	563 369	301.1	163 050	2 145.4	270 695	1 326.9	581 488	18 757.7	238 917	5 688.5
	Employees with higher education *(Number)*	81	13.3%	153	8.2%	123	161.8%	102	50.0%	440	1 419.4%	106	252.4%
2009–2011	R&D spending *(Thousands of reais)*	41 109	86.2	179 416	105.1	65 179	468.9	53 494	286.1	400 262	8 516.2	11 158	743.9
	Spending on innovation *(Thousands of reais)*	207 959	436.0	746 661	437.4	389 551	2 802.5	237 793	1 271.6	558 506	11 883.0	33 293	2 219.5
	Employees with higher education *(Number)*	79	16.6%	668	39.1%	138	99.3%	168	89.8%	1 260	2 680.9%	34	226.7%
2012–2014	R&D spending *(Thousands of reais)*	83 068	122.2	129 945	89.7	168 680	926.8	75 551	291.7	559 410	8 879.5	24 525	981.0
	Spending on innovation *(Thousands of reais)*	331 256	487.1	531 361	366.7	394 058	2 165.2	444 403	1 715.8	1 040 430	16 514.8	94 210	3 768.4
	Employees with higher education *(Number)*	342	50.3%	234	16.1%	303	166.5%	200	77.2%	913	1 449.2%	31	124.0%
2015–2017	R&D spending *(Thousands of reais)*	31 634	74.3	45 884	32.3	169 312	1 582.4	97 351	569.3	428 744	10 718.6	69 449	2 894.0
	Spending on innovation *(Thousands of reais)*	146 719	344.4	338 816	238.4	248 729	2 324.6	299 306	1 750.3	568 561	14 214.0	272 882	11 370.0
	Employees with higher education *(Number)*	130	30.5%	169	11.9%	430	401.9%	182	106.4%	874	2 185.0%	106	442.0%

Source: Prepared by the authors, on the basis of Brazilian Institute of Geography and Statistics (IBGE), special tabulation of the Survey of Innovation (PINTEC), 2020.

Table 3

Brazil: indicators of innovative outcomes in firms in machinery and equipment sector, beneficiaries and non-beneficiaries of public assistance for innovation, by firm size, 2001–2017

Period	Variable	Outcome indicators for innovative firms											
		Small				Medium-sized				Large			
		Beneficiaries	Percentage	Non-beneficiaries	Percentage	Beneficiaries	Percentage	Non-beneficiaries	Percentage	Beneficiaries	Percentage	Non-beneficiaries	Percentage
2001–2003	Labour productivity *(Thousands of reais)* (Net sales revenue/Employees)	100.09	-	82.39	-	128.58	-	136.15	-	215.35	-	228	-
	Innovative firms *(Number)*	303	80.8	1 684	38.3	50	87.7	239	49.8	27	100.0	51	73.9
	Product innovation *(Number)*	95	31.4	173	10.3	11	22.0	32	13.4	12	44.4	23	45.1
	Process innovation *(Number)*	215	71.0	1 137	67.5	41	82.0	172	72.0	24	88.9	42	82.4
	Strategic protection *(Number)*	90	29.7	238	14.1	16	32.0	46	19.2	16	59.3	26	51.0
2003–2005	Labour productivity *(Thousands of reais)* (Net sales revenue/Employees)	105.15	-	143.88	-	165.46	-	171.90	-	212.60	-	268.50	-
	Innovative firms *(Number)*	281	90.4	1 628	32.9	80	100.0	205	56.0	34	100.0	53	79.1
	Product innovation *(Number)*	43	15.3	371	22.8	18	22.5	44	21.5	22	64.7	26	49.1
	Process innovation *(Number)*	228	81.1	864	53.1	60	75.0	133	64.9	26	76.5	39	73.6
	Strategic protection *(Number)*	54	19.2	218	13.4	12	15.0	23	11.2	16	47.1	25	47.2
2006–2008	Labour productivity *(Thousands of reais)* (Net sales revenue/Employees)	126.37	-	141.05	-	233.68	-	240.57	-	342.28	-	343.85	-
	Innovative firms *(Number)*	608	97.3	1 871	42.9	76	98.7	204	51.3	31	96.9	42	77.8
	Product innovation *(Number)*	94	15.5	362	19.3	23	30.3	46	22.5	18	58.1	17	40.5
	Process innovation *(Number)*	509	83.7	1 338	71.5	66	86.8	153	75.0	28	90.3	34	81.0
	Strategic protection *(Number)*	104	17.1	108	5.8	28	36.8	55	27.0	21	67.7	17	40.5
	Organization innovation *(Number)*	601	96.2	2 929	67.1	76	98.7	312	78.4	30	93.8	45	83.3
2009–2011	Labour productivity *(Thousands of reais)* (Net sales revenue/Employees)	126.84	-	180.55	-	246.32	-	244.66	-	404.07	-	341.23	-
	Innovative firms *(Number)*	477	77.6	1 707	34.5	139	94.6	187	44.1	47	95.9	15	34.88
	Product innovation *(Number)*	64	13.4	812	47.6	48	34.5	58	31.0	27	57.5	4	26.67
	Process innovation *(Number)*	428	89.7	1 074	62.9	127	91.4	150	80.2	39	83.0	10	66.67
	Organization innovation *(Number)*	335	54.5	3 504	70.8	139	94.6	317	74.8	42	85.7	26	60.47

Period	Variable	Outcome indicators for innovative firms											
		Small				Medium-sized				Large			
		Beneficiaries	Percentage	Non-beneficiaries	Percentage	Beneficiaries	Percentage	Non-beneficiaries	Percentage	Beneficiaries	Percentage	Non-beneficiaries	Percentage
2012–2014	Labour productivity *(Thousands of reais)* (Net sales revenue/Employees)	146.35	-	220.72	-	300.59	-	297.45	-	531.89	-	359.11	-
	Innovative firms *(Number)*	680	96.5	1 449	28.3	182	98.9	259	54.0	63	100.0	25	69.44
	Product innovation *(Number)*	217	31.9	387	26.7	67	36.8	71	27.4	39	61.9	11	44.00
	Process innovation *(Number)*	678	99.7	1 300	89.7	169	92.9	214	82.6	51	81.0	19	76.00
	Strategic protection *(Number)*	119	17.5	319	22.0	120	65.9	152	58.7	48	76.2	19	76.00
	Organization innovation *(Number)*	661	93.8	3 447	67.3	174	94.6	365	76.0	59	93.7	32	88.89
2015–2017	Labour productivity *(Thousands of reais)* (Net sales revenue/Employees)	225.42	-	187.28	-	435.28	-	311.17	-	654.32	-	426.69	-
	Innovative firms *(Number)*	426	99.0	1 421	31.1	107	99.1	171	42.5	40	100.0	24	72.73
	Product innovation *(Number)*	28	6.5	144	3.2	50	46.3	58	14.4	22	55.0	11	33.30
	Process innovation *(Number)*	367	85.4	1 077	23.6	86	79.6	120	29.9	34	85.0	20	60.61
	Strategic protection *(Number)*	138	32.1	414	9.1	84	77.8	101	25.1	25	62.5	12	36.36
	Organization innovation *(Number)*	408	94.9	2 718	59.5	100	92.6	289	71.9	38	95.0	26	78.79

Source: Prepared by the authors, on the basis of Brazilian Institute of Geography and Statistics (IBGE), special tabulation of the Survey of Innovation (PINTEC), 2020.

It is important to note that, among the firms receiving support from innovation support schemes, a substantially larger number of small firms than medium-sized and large firms benefited from government incentives for innovation. However, the large beneficiary firms present the best effort and outcome indicators. This was to be expected, given the greater investment capacity of large enterprises and their greater expenditure on innovation-related activities in general, and R&D in particular.

Analysis of how innovative effort and performance indicators have evolved suggests that industrial policy and support for innovation in Brazil since the 2000s influenced these positive outcomes in the machinery and equipment sector: in general, innovative firms that received government innovation assistance show higher indicators than non-beneficiaries. However, more research is needed to determine whether public support made them more innovative or, conversely, they were already more innovative and thus better able to access public assistance.

It should be noted, however, that the indicators followed a growth trajectory until the 2014 PINTEC survey, which was then broken in the 2017 survey, whose figures are mostly lower than in 2014, mainly for beneficiary firms. As Botelho and Avellar (2021) show, the drop across practically all innovation indicators, captured especially in the 2017 PINTEC data, signals the abandonment of industrial and innovation policies in Brazil.

To complement the analysis of support for innovation in the machinery and equipment sector, table 4 presents data on the evolution of the programmes that were in place between 2001 and 2017. In addition to the different types of programme —such as tax incentives, financing, subsidies and participation in public schemes for technological and scientific development, among others— an indicator was calculated to measure the percentage of innovative firms with government assistance, obtained by the total number of innovative firms receiving government assistance divided by the total number companies engaging in innovation.

As described above, the percentage of innovative firms in the machinery and equipment sector receiving some form of government innovation support more than doubled during the period studied. Analysis of the different types of programmes shows that financing for the purchase of machinery and equipment was the main instrument of government support for innovation used by firms in the machinery and equipment sector, in all the PINTEC surveys. The number of firms in the sector using this tool more than doubled over the period, from 304 between 2001 and 2003 to a peak of 669 between 2011 and 2014. However, a drastic decrease was seen in the 2017 PINTEC survey, which showed only 215 firms benefiting from the programme, the lowest number for the entire period.

According to Botelho and Avellar (2021), the main tools of industrial and innovation policy were already being dismantled by 2014, when the economic crisis in Brazil intensified. Furthermore, with the change of government in 2016, support for industry and innovation lost ground on the public policy agenda, and has not regained it since.

Despite this drop, this result is not unexpected since, as shown in figure 3, the sector's innovation is based predominantly on the acquisition of new machinery and equipment, with the exception of the last PINTEC survey, where R&D spending was the most prominent. In this regard, it is worth noting that BNDES has played a historic role in developing the machinery and equipment sector in Brazil. Support through lines of credit and programmes to facilitate the acquisition of machinery and equipment by all segments of the economy —through FINAME, the National Industry Modernization Programme and the Investment Support Programme (PSI)— was one of the pillars for advancing innovation support and thus contributed to strengthening the sector.[7]

[7] The important role of BNDES in the design and implementation phases of industrial and innovation policies is documented in Ferraz, Marques and Alves (2015). These authors show that the mechanical, electrical, electronic and health systems in the Greater Brazil Plan (which encompass the machinery and equipment sector) were the areas that obtained most BNDES disbursements aimed at meeting industrial policy objectives.

Table 4
Brazil: firms in machinery and equipment sector receiving government support through public innovation support programmes, 2001–2017
(Numbers)

Sector activity	Tax incentives		Subsidies[a]	Financing			Public procurement[b]	Other support programmes[c]
	Research and development (R&D)	Informatics Act		R&D		Machinery and equipment		
				In partnership	No partnership			
2001–2003								
Industry total	204	239	-	-	399	3 947	-	1 149
Manufacturing industries	203	239	-	-	399	3 902	-	1 110
Manufacture of machinery and equipment (National Classification of Economic Activities (CNAE))	15	10	-	-	10	304	-	108
2003–2005								
Industry total	249	431	-	-	450	3 883	-	2 129
Manufacturing industries	206	324	-	-	369	3 712	-	1 952
Manufacture of machinery and equipment (CNAE)	20	22	-	-	24	280	-	105
2006–2008								
Industry total	491	747	310	580	382	5 559	-	2 981
Manufacturing industries	438	703	204	524	318	5 435	-	2 680
Manufacture of machinery and equipment (CNAE)	30	8	4	6	17	502	-	174
2009–2011								
Industry total	1 219	754	439	713	594	11 760	-	3 642
Manufacturing industries	1 036	618	313	497	383	11 185	-	3 071
Manufacture of machinery and equipment (CNAE)	103	7	20	51	28	436	-	196
Engines, pumps, compressors and transmission equipment	21	1	4	6	7	100	-	10
Agricultural machinery and equipment	21	-	8	6	5	127	-	89
Extraction and construction machinery	8	1	-	2	-	14	-	6
Other machinery and equipment	53	4	8	37	16	196	-	92

2012–2014								
Sector activity	Tax incentives		Subsidies[a]	Financing			Public procurement[b]	Other support programmes[c]
	R&D	Informatics Act		R&D		R&D		
				In partnership	In partnership			
Industry total	1 684	611	361	834	483	14 240	959	3 857
Manufacturing industries	1 351	457	233	651	369	13 047	604	3 238
Manufacture of machinery and equipment (CNAE)	133	29	16	49	51	669	51	281
Engines, pumps, compressors and transmission equipment	30	-	-	9	7	64	-	18
Agricultural machinery and equipment	22	8	5	18	21	114	10	75
Extraction and construction machinery	10	-	2	6	2	23	-	7
Other machinery and equipment	72	21	10	16	21	467	40	181
2015–2017								
Sector activity	Tax incentives		Subsidies[a]	Financing			Public procurement[b]	Other support programmes[c]
	R&D	Informatics Act		R&D		R&D		
				In partnership	In partnership			
Industry total	1 861	507	491	930	516	5.086	1 008	2 916
Manufacturing industries	1 481	386	290	805	413	4.851	829	2 665
Manufacture of machinery and equipment (CNAE)	184	9	22	131	26	215	82	174
Engines, pumps, compressors and transmission equipment	37	2	7	4	2	43	-	12
Agricultural machinery and equipment	67	3	1	51	3	83	-	3
Extraction and construction machinery	9	-	4	1	-	5	-	3
Other machinery and equipment	71	3	9	75	21	83	82	156

Source: Prepared by the authors, on the basis of Brazilian Institute of Geography and Statistics (IBGE), special tabulation of the Survey of Innovation (PINTEC), 2020.

[a] PINTEC did not count subsidy programmes until the 2008 survey.

[b] The public procurement programme began to be counted separately with the PINTEC survey of 2014; previous surveys treated this programme as part of the "Other support programmes" category.

[c] The "Other support programmes" category includes support provided to researchers in the firm —for example, through the Human Resources Development Programme for Strategic Activities in Support of Technological Innovation (RHAE-Innovation) of the National Council for Scientific and Technological Development (CNPq)— and venture capital.

The BNDES FINAME programme, created in the 1960s, was reformulated on several occasions and remains one of the most traditional public policies aimed at the machinery and equipment sector. FINAME disbursements increased during the period of the industrial policy plans and came to represent on average some 30% of the total resources extended by BNDES between 2010 and 2014, when both total and FINAME-related bank disbursements began to trend downward (BNDES, 2023).

The National Industry Modernization Programme was launched in 2004, but did not last long and was abolished in 2007 to make way for the new Growth Acceleration Programme measures. The Investment Support Programme was launched in 2009 and operated through BNDES on-lending, including within the scope of FINAME. Later, starting in 2011, it was also operated by the Studies and Projects Financing Entity. Grants under the Investment Support Programme increased up to 2016, and have decreased each year since (National Treasury, 2023).

The second instrument of government support for innovation that stood out in all the PINTEC surveys was the category of "Other support programmes", which include scholarships offered by the Research Support Foundations (FAP) and the Human Resources Development Programme for Strategic Activities in Support of Technological Innovation (RHAE-Innovation) of the National Council for Scientific and Technological Development (CNPq). This outcome may be understood as an indication that, to a certain extent, greater coordination has been achieved between industrial and innovation policy, as proposed by the Industrial, Technological and Foreign Trade Policy, the Productive Development Policy and the Greater Brazil Plan.

The public procurement programme, which was included under "Other support programmes" in previous surveys, has been counted separately since the 2014 PINTEC survey. This number of beneficiary firms under this programme rose from 108 in 2001–2003 to 281 in 2011–2014, but fell to 174 in 2015–2017, consistent with the pattern seen in other programmes.

Tax incentives for R&D activities, provided for in the Asset Act, were also an important component of the programmes. It was the third most used resource by firms in the sector over the period and benefited nearly 15 industrial firms between 2001 and 2003, rising to 184 in 2015–2017. The continuous rise in the number of firms benefiting during the period has to do with the fact that this incentive is aimed at large enterprises that tend to show more stable spending on innovation activities. In fact, this trend was repeated across all firms that benefited from the legislation, as their numbers have grown continually since it was adopted in 2006 (from 130 to 1,476 firms in 2017), according to data from the Ministry of Science, Technology and Innovation.

The tax incentive scheme provided under the Informatics Act benefited fewer companies in the sector and was sometimes the least used instrument of all the programmes. The number of beneficiaries increased from 10 in 2001–2003 to 29 in 2011–2014.

Financing for R&D projects, whether or not in partnership with universities or research institutes, also benefited a limited number of firms in the sector. In the first case, the number of beneficiary firms rose from 10 in 2001–2003 to 51 in 2011–2014, then fell back to 26 in 2015–2017. In the second case, the number of beneficiary firms increased from 6 in 2006–2008 to 131 in 2015–2017. The number of projects, in partnership or without, although still low, has increased over the period, with the exception of the 2017 PINTEC survey, when the trajectory of projects carried out in partnership with another entity was reversed.

The resources least used by innovative firms in the sector were financial subsidy programmes, which the PINTEC survey only began to count in the 2008 edition. The number of beneficiary firms rose from around 4 in 2006–2008 to 22 in 2015–2017. Thus, despite progress, this programme remains unrepresentative compared to other innovation support instruments.

In summary, the analysis offered here shows that the main innovation indicators in the machinery and equipment sector evolved positively, especially until the 2014 PINTEC survey, which suggests that the innovation support programmes that started in the 2000s had positive effects, in terms of both the scope and expansion of the instruments involved and the volume of resources and firms benefiting from the programmes. The expansion of tax and financial incentive schemes, support for firm researchers and venture capital, as well as other public support measures, have been important for the financing and growth of innovative activities in the Brazilian machinery and equipment sector.

It bears reiterating that, for almost the entire period, by number of firms, the machinery and equipment sector received less support of any type than the manufacturing industry overall. This speaks explicitly to a point discussed by Suzigan and Furtado (2006), Schapiro (2014), Stein and Herrlein (2016) and Ulhôa, Botelho and Avellar (2019): the fact that, despite important advances over the period, industrial policy failed to secure a place at the heart of the public policy agenda or move towards transforming the productive structure. Given that the machinery and equipment sector is at the centre of all industrial policy plans, government support for the sector could be expected to exceed support for industry overall, but this only occurred in the period 2006–2008.

IV. Concluding remarks

This study analysed the evolution of technological innovation indicators and public support for the machinery and equipment sector during the period of Brazil's industrial and innovation policy plans of the 2000s. Given the significance of the sector, which is extraordinarily important for the future of Brazilian industry, it was included specifically in the Industrial, Technological and Foreign Trade Policy, the Productive Development Plan and the Greater Brazil Plan.

The data presented here show that innovation-related activities by firms in the machinery and equipment sector were boosted by the various government support instruments and evolved positively compared to non-beneficiary firms, thereby confirming the hypothesis of the investigation.

Innovative activities by firms in the sector that benefited from government support programmes for innovation were found to have evolved further than those of non-beneficiary firms (see as a reference the increase in internal R&D activities, which went from 21.9% in 2003 to 36.7% in 2014, and 44.9% in 2017).

The results obtained also indicate positive effects both in terms of the scope of support instruments and their sphere of action, and in terms of the volume of resources and companies benefiting from them, especially through resources made available by BNDES in various financing lines. It should also be noted that the programmes included SMEs, one of the aims of the innovation support policies of the 2000s.

However, the data also showed failings in industrial policy. With regard to machinery and equipment, it is notable that the number of beneficiary firms in the sector was lower than for industry in general.

This is consistent with the results presented in other recent studies, which draw attention to the non-transformative nature of industrial and innovation policy. Although the innovation performance of the machinery and equipment sector underwent a significant shift in 2015–2017, when R&D spending was the top category in total innovation spending, innovation support schemes suffered from interruptions between the first and second governments of Dilma Rousseff, owing mainly to the effects of the international crisis and domestic difficulties such as the fiscal crisis. Thus, industrial policy's lack of a secure place at the heart of the public policy battery, together with the interruptions towards the end of the period, produced results that may be considered partial in relation to its aims.

Despite some positive gains, the deindustrialization process in the Brazilian economy has not been halted. Imports have continued to grow in the machinery and equipment sector, especially of more technologically complex products.

Lastly, certain limitations of this study warrant noting. As is well established in the economic literature, there is no single methodology for evaluating public policies and evaluation methods can be qualitative or quantitative. It is generally understood that the main effects of policies become evident only over longer periods of time, and sometimes they may be different —although not necessarily worse— from those initially expected. In view of these caveats, while this article has contributed to the analysis of industrial and innovation policies for the machinery and equipment sector, it should be complemented with other evaluation methodologies.

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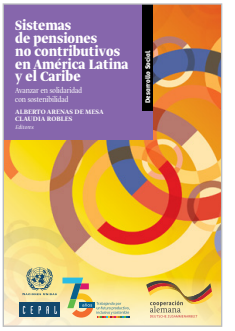

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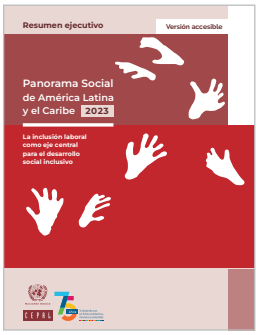

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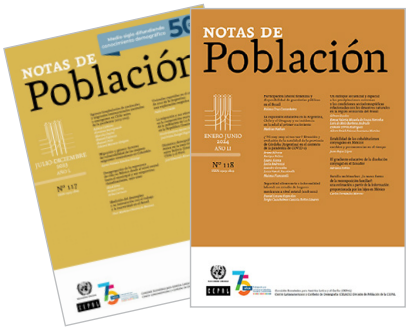

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