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The structuralist revenge: economic complexity as an important dimension to evaluate growth and development

A vingança dos estruturalistas: complexidade econômica como uma dimensão importante para avaliar crescimento e desenvolvimento

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RESUMO: Este trabalho traz elementos da literatura de complexidade econômica para as discussões da tradição estruturalista em economia sobre o papel central da manufatura e da sofisticação produtiva no crescimento econômico. Usando dados fornecidos pelo *Atlas da Complexidade Econômica* o presente estudo procurou verificar se a complexidade dos países é importante para explicar convergência e divergência entre países pobres e ricos. A análise econométrica revelou que complexidade das exportações é significativa na explicação de convergência e divergência entre os países. Essencialmente, quanto maior a complexidade da pauta de exportação de países em desenvolvimento, maior é a probabilidade de convergência de renda.
PALAVRAS-CHAVE: Complexidade; desenvolvimento econômico; comércio internacional; Cepal; estruturalismo.

ABSTRACT: This paper brings elements from the economic complexity literature to the discussions of the structuralist tradition on the central role of manufacturing and productive sophistication to economic growth. Using data provided by the *Atlas of Economic Complexity* this study sought to verify if countries' complexity is important to

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explain convergence and divergence among poor and rich countries and, if so, which are the countries that will be able to reduce the income gap compared to developed countries. The econometric analysis revealed that exports and production complexity is significant to explain convergence and divergence among countries.
KEYWORDS: Complexity; core-periphery; economic development; international trade; ECLAC; structuralism.
JEL Classification: B2; B5; B23; O1; O14.

INTRODUCTION

In economics structuralism is principally associated with the so-called Anglo-Saxon or Early Structuralism and the Latin American strand. Both strands base their analyses on the concept of complementarities and poverty traps, linkages, and dualism (Ancochea, 2007). The structuralist view usually stresses that economic development is strongly linked to a radical transformation in the structure of production to suppress obstacles, bottlenecks and other rigidities of underdevelopment. Based on the hypothesis that the industrial structure affects both the rhythm and the direction of economic development, the structuralist literature highlights the importance of industrialisation as a process of structural change necessary to economic development. Structuralists state that without industrialisation, it is not feasible for a country to increase employment, productivity and income *per capita* and, consequently, to reduce poverty. The main argument stresses that the development process involves a production reallocation from low productivity to high productivity sectors where increasing returns to scale prevail. In this theoretical background, economic structuralism has provided many reflections on how economic growth should be understood in a historical perspective of mutual causation in the economic system. While various historical, political and ideological factors contributed to the structuralist view, Keynesian criticism of the neoclassical economics and its argument regarding state interventionism was very important.

Paul Rosenstein-Rodan, Ragnar Nurkse, Arthur Lewis, Albert Hirschman, Gunnar Myrdal and Hollis Chenery are economic thinkers associated with early structuralism or pioneers of development[1]. Their seminal contributions challenged the neoclassical view of market efficiency to promote structural change and recognised particularities through which the manufacturing industry plays a central role to support and propel economic development. A further theoretical contribution comes from Latin American structuralism, which is mainly related to the Economic Commission for Latin America and the Caribbean (ECLAC), whose works merged into a coherent school of thought in late 1950s. In light of historical experiences, the main thoughts presented in this Latin American version are encapsulated in the works of Raul Prebisch and Celso Furtado, focused on the specific challenges faced

[1] See for instance, Blankenburg, Palma & Tregenna (2008) and Ancochea (2007).

by developing countries in a world economy divided in two poles, the "centre" and the "periphery", and their distinctive productive structures (Prebisch, 1949; Furtado, 1964). Problems relating to dualism in international trade, technology disparities, balance of payments constraints and state interventionism were all emphasised.

Broadly speaking, these authors emphasised that productive sectors are different in terms of their potential to generate growth and development. Manufacturing sectors, with high increasing returns, high incidence of technological change and innovations and high synergies and linkages arising from labour division strongly induce Economic Development (Reinert, 2009, p. 9). These are activities where imperfect competition rules, with all its typical features (learning curves, fast technical progress, high R&D spending, economies of scale and scope, high industrial concentration, entry barriers, product differentiation, etc.). This group of high value-added sectors are usually opposed to low value-added sectors typical of poor and middle income countries and its perfect competition market structure (Low R&D content, low technological innovation, perfect information, absence of learning curves, etc.) (Reinert and Katel, 2010, p. 7), therefore, in a structuralist perspective it is also possible to point out the economic policy recommendations for productivity increase from climbing the technological ladder, i.e., moving from low-quality activities to high-quality activities, through technological sophistication of the economy (Bresser-Pereira, 2016). In order to achieve this goal, the construction of a complex and diverse industrial system, subject to increasing returns to scale, synergies and linkages between activities is fundamental (Reinert, 2010, p. 3). The specialisation in agriculture and mining does not allow this type of technological change.

How could one empirically measure these propositions from classical development economists? Ideally one could study the market structures (perfect versus imperfect competition) of products as revealed in world trade data. From the classification of these structures, one could correlate the product and market structures found with levels of per capita incomes. If the propositions of the classics of development are correct, we should find countries with high per capita income specializing in imperfect competition markets and poor countries specializing in perfectly competitive markets in tradable goods production; something, in fact, easy to see with a quick superficial analysis of current trade patterns, but difficult to show in a more robust way. Despite all the evidence from economic history of several successful stories that followed the recommendations of the classics (Southeast Asia, Japan, etc.) and also of failures, such as Latin America and the Caribbean, one could argue that "hard science type" empirical evidence is still lacking to help reinforce the point of the structuralists. That´s where the *Atlas of Economic Complexity* developed by Hausmann & Hildalgo (2011) fits in: as an empirical breakthrough, able to give support to the propositions of the classical economists who saw productive sophistication as the way for economic development (Bresser-Pereira, 2016). This study is organised as follows. The second section recovers the main insights from the structuralist tradition, in both its Anglo-Saxon and Latin American strand. Third section links the structuralist approach to the complexity methodology de-

veloped by Hausmann & Hildalgo (2011) and seeks to understand through empirical analysis if countries' complexity is important to explain convergence and divergence among poor and rich countries. The fourth section concludes the paper.

THE EARLY STRUCTURALIST APPROACH TO ECONOMIC DEVELOPMENT

In economic theory, many studies associate the emergence of the Early structuralism with the publication of Rosenstein-Rodan's "*Problems of Industrialization of Eastern and South-Eastern Europe*"[2]. In this study, Paul Rosenstein-Rodan assigned particular emphasis to the transformative power of industrialisation in the economic system (Rosenstein-Rodan, 1943). In a similar line of thinking, Nurkse (1953), Lewis (1954), Hirschman (1958), Myrdal (1957) and Chenery (1960, 1979) pointed out that the study of long-term economic growth is a "sector-specific" process and consequently involves an increase of the industry share, which, in turn, provides the highest potential of productivity, spillover effects, forward and backward linkages, as well as technological and pecuniary externalities. Hence, their focuses were essentially on the internal special properties of manufacturing and on the way in which these properties spread to the economy as a whole, stimulating the process of economic growth. Although not always emphasised by the literature, the essence of these classical contributions relied especially on Allyn Young's ideas concerning long-term determinants of economic growth which were further extended in their seminal studies. These pioneers of economic development also focused on the identification of bottlenecks and rigidities that block the industrialisation process in underdeveloped economies.

The Early Structuralist approach to manufacturing is particularly associated with Rosenstein-Rodan's path-breaking research in economic development, which stresses the conditions for economic growth in line with Nurkse (1953). Paul Rosenstein-Rodan and Ragnar Nurkse supported the balanced growth theory based on "classical" arguments concerning long-run determinants of the economic growth, particularly dynamic externalities and increasing returns, as advanced by Allyn Young. This type of argument gave rise not only to the role of demand complementarities and increasing returns (to scale) in manufacturing industries, but also various arguments that justify industrial policy, especially of selective type, on the basis of the existence of interdependence between different activities (Chang et al., 2013). Rosenstein-Rodan (1943) states that a remarkable feature of high-income economies, i.e., developed countries, is a structured and dynamic industrial sector. Unlike developed economies, underdeveloped countries were characterised by the absence of a structured and dynamic industrial sector. As a matter of fact, since industrialisation tends to be concentrated in developed countries, massive and planned

[2] Rosenstein-Rodan (1943).

investments coordinated by the state are *sine qua non* conditions for the creation of a new institutional environment and, consequently, the successful carrying out of industrialisation in underdeveloped countries. In this way, Rosenstein-Rodan (1943) describes what later became known as the "big push theory", i.e., a large-scale development programme geared towards jump-starting the economic growth through the industrialisation process of an underdeveloped economy.

In a similar approach, Nurkse stressed that economic growth is "not a spontaneous and automatic affair"[3]. With this assertion in mind, Nurkse (1953) describes the forces that limit the development process in underdeveloped countries. The so-called "vicious circle of poverty" is illustrated as "a circular constellation of forces tending to act and react upon one another in such a way as to keep a poor country in a state of poverty" (ibid., p. 4). This dynamic, translated in a low level of investment and capital accumulation, operates both on the supply and demand side. In this way, from the supply side a low level of investment arises from the small amount of savings available in the economy as a result of its low income level which, in turn, is a consequence of a low level of productivity. Moreover, low productivity is a direct result of small amounts of capital used in the production process and is related to the low domestic savings presented in the country. From the demand side, similar to Rosenstein-Rodan, the greatest obstacle to development was the atrophy of the domestic market through low demand for goods due to low income level in the economy which, in turn, discourages the formation of capital. The low level of capital used in the production process is associated with a weak level of investments that implies a low level of productivity existing in the country. When the productivity per worker is low, the real income is consequently low and the poverty vicious circle is complete. Additionaly, the author recognises that underdevelopment was linked to the kind of product produced by a specific country and how it was traded in the international market.

In contrast to Nurkse and Rosenstein-Rodan, Hirschman did not support the "balanced growth theory", arguing that imbalances generated between sectors could provide corrective reactions, giving arguments in favour of a theory of "unbalanced growth". According to Hirschman (1958), economic growth is essentially an unbalanced dynamic process, in which successive disequilibria produce the conditions for development in different sectors. In his "unbalanced growth" theory, the productive structure is linked through forward and backward linkages to downstream and upstream industries. These linkages represent physical relations of supply and demand among sectors of the economy. Thus, backward linkages are associated with the magnitude that each sector demands from other sectors of the economy, while forward linkages are associated with the extension that each sector is demanded by other sectors. In this dynamic, manufacturing industry is characterised by both strong backward and forward linkages, enabling this sector to generate higher economies of scale with positive effects in terms of productivity gains and

[3] Nurkse (1953, p. 4).

cost savings in later stages of the production chain. From this perspective, Hirschman focused particularly on the intermediate and capital goods sectors while Rosenstein-Rodan and Nurkse focused essentially on productivity growth in the consumer goods sector. Furthermore, while also concentrating on the role of bottlenecks, external economies and complementarities, Albert Hirschman qualifies the economic development "essentially as the record of how one thing leads to another" involving not only physical relations of supply and demand, but also technological linkages. This leads to the first insights on the concept of spillover effects, which stems from manufacturing to the rest of the economy and is approached by the contemporary economic developmental literature, e.g., the Kaldorian and Neo-Schumpeterian strands.

Like Albert Hirschman, Myrdal (1957) centralised his theory on the understanding that economic development is intrinsically a process in disequilibria, breaking with the neoclassical statement of "stable equilibrium"[4]. Thus, Myrdal's theory of unbalanced growth is centred on the concept of "cumulative causation" to analyse the problem of development inequality among nations. In this dynamic, trade and economic relations between developed and underdeveloped countries are discussed considering effects that arise from this interaction and may negatively ("backwash effect") or positively ("spread effect") impact the development of an underdeveloped economy. Furthermore, according to him, economic development also involves not only economic relationships of supply and demand but also institutional and political structures, denominated non-economic factors, which operating in a process of cumulative causation reveals challenges to be faced by underdeveloped countries[5]. In Myrdal's concept of "circular cumulative causation", the main idea relies on the fact that free market forces would tend generally to increase regional disparities. The assertion made by Myrdal was important because, while international economic inequality grew and became a common concern in many schools of thought, the neoclassical theory of international trade insisted on the idea that there was a gradual equalisation tendency of factor prices and income across countries.

Even focused on social aspects of this cumulative causation, Myrdal's theory provided the fundamental framework for later complementary heterodox theories, such as the Latin American structuralist approach – with a strong influence in Celso Furtado – and the Kaldorian theory which concentrated in the demand-supply relationships in the manufacturing sector. In the context of Latin American development problems, it is important to highlight that ECLAC participated actively in these discussions providing important contributions notably from the works of Raúl Prebisch, Celso Furtado and Aníbal Pinto. Based on this theoretical back-

[4] To Myrdal, neoclassical trade theories were "never developed to comprehend the reality of great and growing economic inequalities and of the dynamic processes of under-development and development" (Myrdal, 1957, p. 51).

[5] See also Ho (2004).

ground, the basic analytical components of ECLAC and other Latin American structuralists were grounded in historical methodology, the study of domestic determinants of economic growth and technological progress, as well as an evaluation of arguments in favour and against state intervention. Through a sharp critique of neoclassical economics and its idea that specialisation based on comparative advantages, whatever its nature, was a superior solution for economic growth, the Latin American structuralist school gave life to an important interpretation where the productive structure matters to the pace and scope of the development process. Comparing commodity-producer economies and industrialised countries, Prebisch (1949) noted that productivity was essentially higher in the manufacturing sector than in primary activities. This dichotomy in levels of productivity between the productive structure of developed (centre) and underdeveloped (periphery) countries, the so-called structural heterogeneity, was also analysed by Furtado (1959, 1961) and Pinto[6] (1965, 1970).

For Furtado (1961), the mainspring of capitalist development is technological progress through a process of incorporation and diffusion of new techniques with a consequent increase in production and productivity[7]. Therefore, underdevelopment is seen as a partial and blocked version of development, either because of the uneven spread of technical progress or the limited transmission of productivity gains to wages. According to him, in developed countries, dynamic growth is headed by technical progress while in underdeveloped countries it is determined primarily by external demand for imports. While the centre countries internalised new technology by developing an industrial capital goods sector and by spreading the improved technology to all economic sectors, the periphery remained dependent on imported technology which in turn was mainly confined to the primary export sector. Consequently, a sizeable low-productivity pre-capitalist sector continued to survive in the periphery producing a continuous surplus of labour and consequently keeping wages low. Without the processes of industrialisation, the asymmetry between the centre and periphery would not only perpetuate but also deepen.

While various writers contributed to the Latin American structuralist paradigm, Prebisch's original ideas were pivotal in launching a critical perspective on the neoclassical approach to the mutual profitability of free trade between developed and developing countries, whose influence was very remarkable in Latin America. In his thinking, a key structural economic characteristic of peripheral economies refers to the deterioration in their terms of trade over time due to different income-elasticity of demand – also known as "dynamic disparity of demand". Thus, contrary to what

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[6] Although the concept of structural heterogeneity was a central element in works of Raúl Prebisch or in Celso Furtado in the form of "dualism", it was with Aníbal Pinto that the concept of structural heterogeneity solidifies during the 1970s. See for instance Pinto (1970, 1971, 1976).

[7] In a complementary approach, Tavares (1972, p. 50) highlights the problem to create technical progress endogenously and the consolidation of a diversified productive structure with increasing share of national content in domestic production.

the comparative advantage theory suggested, prices of primary products produced and exported by peripheral countries, such as in Latin America, tended to present an antagonistic evolution when compared to prices of manufactured products exported by industrialised countries. This means that the centre's imports of primary products from periphery rise at a lower rate than its national income, while the periphery's imports of manufactured goods from the centre grow at a faster rate than its income. Since demand for manufactured goods increases more rapidly than the demand for primary goods, the well-known Engel's law, there is a tendency to deteriorate the terms of trade of those economies specialised in the production and export of primary goods in comparison to central industrialised economies.

ECONOMIC COMPLEXITY, GROWTH AND DEVELOPMENT

Despite of many historical evidences regarding a vast range of successful development strategies based on the manufacturing sector as source of sustainable economic growth, there still remains a lack of robust empirical content to reinforce the structuralist approach. In this context the recent *Atlas of Economic Complexity* developed by Hausmann & Hildalgo et al. (2011) emerge as important empirical innovation, able to provide support to propositions of the structuralist view that states production sophistication as a central way to overcome underdevelopment. Hausmann & Hildalgo et al. (2011) used computational, network and complexity techniques to create a simple model for comparison of trade data across countries, able to measure a country's productive sophistication or "economic complexity". Starting from an analysis of a given country's exports basket, they can indirectly measure its productive sophistication. The methodology devised to build the economic complexity indices using Big Data culminated in an atlas that collects extensive material on countless products and countries over 50 years starting in 1963.

The two basic concepts used to measure whether a country is economically complex are the ubiquity and diversity of the products in its exports basket. If a given economy is capable of producing non-ubiquitous, rare and complex goods, this indicates the presence of a sophisticated productive structure. This measure obviously involves a scarcity problem, particularly of natural resources like diamonds and uranium, for example. Non-ubiquitous goods can be divided into those with high technological content, which are therefore difficult to produce (airplanes), and those that are highly scarce in nature, such as diamonds, which are therefore naturally non-ubiquitous. To control for this issue of scarce natural resources in complexity measurements, the authors of the *Atlas* use an ingenious technique: they compare the ubiquity of the product made in a given country with the diversity of the exports of countries that also produce and export this good. To illustrate: Botswana and Sierra Leone produce and export something that is rare and therefore non-ubiquitous, rough diamonds. On the other hand, their exports are extremely limited and undiversified. These, then, are instances of non-ubiquity without complexity. At the opposite end of the ubiquity spectrum we could mention image-

processing medical devices (X-ray equipment) which practically Japan, Germany and the United States (complex countries) alone can manufacture and export; these are non-ubiquitous complex products. In this case the export composition of Japan, USA and Germany is extremely diversified, indicating that these countries are highly capable of making many different things. In other worlds, non-ubiquity with diversity means "economic complexity". On the other hand, countries with highly diverse export composition made up of ubiquitous goods (fish, meat, fruits, ores, etc.) do not show high economic complexity; they produce and export what all others can do. Diversity without non-ubiquity means lack of economic complexity.

One of the main virtues of such economic (ECIs) and product complexity (PCI) indicators is the fact that they operate based on quantitative measures obtained from linear algebra calculations to arrive at their results. There is no account of qualitative issues relating to the production and exports of those goods. That is, no judgment is made as to what is regarded as complex or non-complex. Along these lines, the authors rate several countries and arrive at robust correlations among income per-capita levels, inequality and economic complexity (Hausmann et al. 2011 and Hartman et al. 2015). Japan, Germany, Switzerland and Sweden are always ranked among the top ten countries in terms of complexity. Economic development may be treated as the mastery of more sophisticated production techniques, which usually lead to output of higher value added per worker as argued by classic development authors. This is what economic complexity indicators ingeniously capture from measures of ubiquity and diversity of exports from various countries. The *Atlas*' results are in line with predictions from classical development economists regarding specialization patterns in world trade: rich countries tend to specialize in producing manufactured goods, poor countries in commodities; an aspect we will explore in greater depth ahead.

In this sense, the *Atlas of Economic Complexity* offers yet another important empirical contribution: by calculating the probability of products being jointly exported by several countries, the *Atlas* also creates an interesting measure of the productive knowledge embedded in products and of the local capabilities needed for their production; the "product space" (Hidalgo et al., 2007). The greater the probability of two products being co-exported, the greater their "proximity" and the more indication that they contain similar characteristics and therefore require similar productive capabilities for production; they are "siblings" or "cousin" products. The co-exportation indicator ultimately serves as a measure of each product's "productive connection", that is, an indication of the productive ties linking various products as a result of their shared requirements for production. Highly connected goods are therefore loaded with knowledge and technological potential; they are "hubs of knowledge", whereas those with low connectivity have low knowledge multiplication potential. To illustrate: countries that make advanced combustion engines probably have engineers and knowledge that enable them to produce a series of similar and sophisticated things. Countries that only produce bananas or other fruit have limited knowledge and are probably incapable of making more complex goods. It is important to emphasize that the difficulty observing these

differences arises from our inability to directly measure and capture such local productive skills. What one observes in international trade are the products, not countries' ability to produce them.

Some examples from the *Atlas of Economic Complexity* illustrate the point: machinery in general and cars are highly "connective" and complex in terms of knowledge content, and are therefore "hubs of knowledge"; iron ore and soybeans have very low connectivity and are non-complex. Manufactured goods stand out from other kinds of goods in terms of complexity and "connectivity". Commodities in general lack these characteristics. Empirically, the *Atlas* clearly shows that manufactured goods are generally characterized as more complex and connected whereas commodities emerge as non-complex and non-connected goods. Out of the 34 main communities of goods in the *Atlas* calculated by their network compression algorithm (Rosvall and Bergstrom, (2007), one finds that machinery, chemicals, airplanes, ships and electronics stand out as the more complex and connected goods (hubs of knowledge). On the other hand, gemstones, oil, minerals, fish and shellfish, fruit, flowers, and tropical agriculture show very low complexity and connectivity. Grains, textiles, construction material and equipment and processed food occupy an intermediate position between more and less complex and connected goods.

Complexity and growth: empirical evidence

In the economic growth literature there are two empirical approaches to analyse countries' GDP per capita convergence and divergence. The sigma-convergence approach refers to the reduction of countries' GDP per capita dispersion. Essentially, countries' income are compared in two periods and, if the dispersion is reducing, one can conclude that there has been convergence; instead, if the dispersion is increasing, there has been divergence of income among countries. On the other hand, the beta-convergence approach compares the growth rate of poor countries' and rich countries' GDP per capita. If poor countries are growing faster than rich ones, there has been GDP per capita convergence, but if rich countries are growing faster one can conclude that there has been divergence. Although being conceptually not so precise as the first approach, the second approach has some advantages. By using controls in econometric regressions, in the beta-convergence approach it is possible to differentiate conditional convergence from unconditional convergence. One of the simplest way of measuring convergence in this approach is by regressing countries' GDP per capita (in log) on their output growth, as in equation (1). If the beta coefficient is statistically significant and negative it means that the higher are countries' GDP per capita the lower are their growth rate, and hence there is unconditional convergence.

$$growth_{i,t} = \alpha + \beta \ln (GDPpc_{i,t-1}) + u_{i,t} \quad (1)$$

However, in this approach it is possible to add control variables such as presented in equation (2). These controls enable us to analyse the existence of conditional convergence – or convergence when all other variables remain unchanged.

Again, in this analysis, if one finds a statistically significant negative beta coefficient one can conclude that there is conditional convergence because low-income countries are growing faster than high-income countries if all other variables remain unchanged.

$$growth_{i,t} = \alpha + \beta \ln (GDPpc_{i,t-1}) + \gamma Z_{i,t} + u_{i,t} \quad (2)$$

In our analysis we go beyond this approach and evaluate whether the beta coefficient changes according to countries' exports complexity. Essentially, we try to understand if countries' complexity is important to explain convergence and divergence among poor and rich countries and, if so, which are those countries that will be able to reduce the income gap to developed countries and which are those that will probably remain poor. The most appropriate econometric technique to tackle this issue seems to be *heterogeneous regressions*[8]. The Economic Complexity Index (ECI) will not be used as a control variable in the baseline equation, but as a variable of heterogeneity. Since our dataset consists of countries with different degrees of complexity, we can add an interaction term between GDP per capita and ECI to the regression model in order to capture the impact of exports complexity on conditional and unconditional convergence. Therefore, the partial effect of GDP per capita on growth, that is, the coefficient of the interaction term, varies according to countries' exports complexity. This estimate may shed light on some important issues in the current debate concerning the effectiveness of promoting export sophistication for boosting growth.

The baseline model

Let us begin by analysing the impact of GDP per capita on output growth without considering the heterogeneous effect provided by the inclusion of the ECI on the regression. The model to be estimated follow the basic structure of the model presented in equations (1) and (2). However, because output growth impact positively on GDP per capita, we use a System GMM estimator (Brundel and Bond, 1998) to instrumentalise the dependent variables. This estimator extends the standard Arellano and Bond (1991) GMM estimator by utilising lagged differences as instruments for equations in level and lagged levels as instrument for equations in first difference. Hence, there is no need to find exogenous regressors as instruments for the GDP per capita, for the variables used as controls and for the variables used to assess the heterogeneous effects.Thereby, the following model is estimated:

$$growth_{i,t} = \alpha + \delta\, growth_{i,t-1} + \beta_1 \ln (GDPpc_{i,t-1}) + \gamma Z_{i,t} + u_{i,t} \quad (3)$$

where Z is a matrix of control variables.

[8] See Agung (2014, pp. 278-285) for a detailed presentation of this method and prior applications. Woodridge (2002, pp. 170-171) presents an example of this method for a panel data model.

Differently from equations (1) and (2), where the coefficient of ln ($GDPpc_{i,t-1}$) refers to the convergence coefficient, in dynamic panels, where a lagged variable of the dependent variable is included in the regression, it works a short-term coefficient. However, as we are interested on the long-term relationship, the coefficient under consideration to analyse convergence is β:

$$\beta = \frac{\beta_1}{1-\delta} \quad (4)$$

Time series for income growth are taken from the Penn World Table 8.1, as well as some variables used as control such as government expenditure as a share of GDP and population growth. There is a number of variables that can be used to explain growth. In order to enhance comparability, we decided to take into account government expenditure as a share of GDP, population growth and exports as a share of GDP. Neoclassical growth models use 'government expending (%GDP)' as a proxy for government burden. These models argue that government can be a heavy burden on the economy when they impose high taxes, promote inefficient programs, do not eliminate unnecessary bureaucracy, and distort market signals. The proxy commonly used to account for the government burden is the ratio of government current expenditures to GDP. They argue that excessive government consumption is mostly used to maintain the bureaucracy's payroll. However, neoclassical economists, by and large, also acknowledge the importance of public investments on health, education, and security to promote growth. The 'population' is included as an explanatory variable that accounts for the growth of the labour force. Finally, exports as a share of GDP is used as a proxy to export-orientation. This work consists of a sample of 147 countries and covers the period 1979-2011. Our estimates were done based on four-year period averages. This is a standard procedure in panel data analysis, as it reduces the effects caused by unit roots. Table 1 presents the results for the regressions without controls (unconditional convergence) and with controls (conditional convergence):

Table 1: GDP per capita convergence – baseline model

	(1) *growth*	(2) *growth*
$growth_{t-1}$	-0.000169	-0.0185
	(0.105)	(0.101)
ln ($GDPpc_{t-1}$)	0.0231	0.212
	(0.207)	(0.236)
G/GDP		-0.0603**
		(0.0262)
pop growth		0.879***

		(0.245)
X/GDP		0.00985*
		(0.00574)
Constant	1.424***	-0.0708***
	(1.649)	(2.302)
Long-term impact (β)	0.0231	0.208
	(0.207)	(0.236)
Observations	1237	1237
Number of code	170	170
Hansen test	8.060	9.343
Hansen p-value	0.327	0.229

Standard errors in parenthesis; ***: p<0.01, **: p<0.05, *: p<0.1.
(1): no controls; (2) controlled by population growth, government expenditure as a share of GDP and exports as a share of GDP.
Long term impact: long-term impact of undervaluation on growth rate; calculated based on equation (4).

As can be seen from Table 1, in both estimations the long-term impact of GDP per capita on growth is positive, indicating that there is divergence in countries' income levels. However, they are not statiscally significant different from zero at the 95% significance level, and hence one can conclude that there are neither unconditional nor conditional divergence in countries' income. The inclusion of controls in estimation (2) indicates that other variables may impact on countries growth rate. Government expenses as a share of GDP impact negatively, whilst population growth and exports as a share of GDP impact positively. Nevertheless, the inclusion of these variables does not change the main result of our estimation. The beta-coefficient (the coefficient associated with convergence or divergence) remains statically equal to zero.

Heterogeneous analysis

As discussed before, the ECI reflects the diversification and ubiquity of countries' export basket. The value of this index varies significantly for countries in the same stages of development. As can be seen from Table 2, the ECI of Brazil, Russia, Indonesia and South Africa in 2014 was around zero, whilst this value was negative in Egypt, Argentina and Nigeria. The Chinese ECI, on the other hand, was around 1.0 in 2014, as well as the Mexican, the Thai and the Malaysian indices. Although not so significant, variation is also verified in developed countries. Japan, Germany, Switzerland and South Korea presented a high level of export complexity in 2014

– the ECI was around 2.0, whilst Canada presents a low value, 0.48, and Australia and Saudi Arabia's ECI were negative.

Table 2: Export Complexity Index (ECI) – major economies (1995 and 2014)

Major developed economies			Major developing economies		
	1995	2014		1995	2014
United States	2.049728	1.356961	China	0.205849	1.102516
Japan	3.097456	2.209021	India	-0.12514	0.238223
Germany	2.645996	1.922099	Brazil	0.558866	-0.00237
United Kingdom	2.046284	1.481103	Russia	0.373692	0.051867
France	1.941901	1.291047	Mexico	0.80577	1.040655
Italy	1.763991	1.352926	Indonesia	-0.55073	-0.02842
Canada	1.005954	0.482014	Turkey	-0.04953	0.420847
South Korea	1.133752	1.823794	Argentina	0.001373	-0.21944
Australia	-0.00495	-0.62675	Nigeria	-2.15742	-2.13209
Spain	1.400973	0.824179	Thailand	0.133436	0.940312
Netherlands	1.489492	0.974603	Egypt	-0.59635	-0.17276
Switzerland	2.463272	1.873856	South Africa	0.227118	-0.00416
Saudi Arabia	0.164556	-0.54189	Thailand	0.133436	0.940312

Source: *The Atlas of Economic Complexity*

The main idea behind complexity is that the higher is the economic complexity of a country, the better are its conditions to promote faster growth rates. We analyse this by using heterogeneous regressions. The beta coefficient (the coefficient related to convergence) is replaced by a function of countries' ECI, and hence convergence (or divergence) will not be a parameter but it will depend on countries' export complexity. Firstly, the following model is estimated:

$$growth_{i,t} = \alpha + \delta\, growth_{i,t-1} + \beta_1 \ln(GDPpc_{i,t-1}) + \\ + \beta_2 \ln(GDPpc_{i,t-1})\, ECI_{i,\bar{t}} + \gamma\, Z_{i,t} + u_{i,t} \quad (5)$$

Differently from equation (3), in equation (5) there is an interaction term associated with β_2. This term, which is the multiplication of the log of GDP per capita and the ECI for a given period (which in our analysis is 1995), is the one that enable us to interpret the relation between growth and GDP per capita not

linearly but as a (linear) function of the ECI. The beta coefficient (the long term relationship between GDP per capita and growth) is now given by:

$$\beta = \frac{\beta_1 + \beta_2 ECI_{i,\bar{t}}}{1 - \delta} \qquad (6)$$

From this equation it is clear that the higher is β_2, the higher is the impact of the ECI on the beta coefficient. Thereby, a negative β_2 implies that complexity is positively related with convergence (as a negative β implies convergence), and a positive value for this coefficient implies that complexity is positively related with divergence (as a negative β implies divergence). The results of this estimation (for unconditional and conditional convergence) is presented in Table 3:

Table 3: GDP per capita convergence – heterogeneous model

	(3) *growth*	(4) *growth*
$growth_{t-1}$	-0.0641	-0.0734
	(0.0823)	(0.0762)
ln ($GDPpc_{t-1}$)	0.310	0.0439
	(0.307)	(0.236)
ln ($GDPpc_{t-1}$) * $ECI_{i,\bar{t}}$	-0.0918***	-0.0849**
	(0.0282)	(0.0350)
G/GDP		-0.115***
		(0.0234)
pop growth		0.150
		(0.260)
X/GDP		0.0177***
		(0.00427)
Constant	0.0283	4.886*
	(2.466)	(2.515)
Observations	841	841
Number of code	147	147
Hansen test	12.67	11.60
Hansen p-value	0.0805	0.115

Standard errors in parenthesis; ***: p<0.01, **: p<0.05, *: p<0.1.
(1): no controls; (2) controlled by population growth, government expenditure as a share of GDP and exports as a share of GDP.

Although the term associated with GDP per capita is not statistically significant different from zero at the 95% level, in both equations the term associated with the interaction of GDP per capita and ECI is negative and statistically different

from zero. It indicates that countries with high export complexity are more capable of reducing the income gap to developed countries than countries with low export complexity. The conditional convergence coefficient can be estimated for each country based on equation (6). In the case of countries which the ECI is close to zero, such as Brazil, Indonesia, South Africa and Russia, the convergence coefficient is calculated ignoring the parameter of the interaction term, such as in equation (4). For these countries, the beta coefficient (the long-term relationship between GDP per capita and growth) is 0.0409, which indicates divergence as the value is positive (although not statically significant). For Egypt, Argentina and Nigeria, the results based on equation (6) indicates that divergence is even more relevant. The beta coefficient calculated based on Egypt's ECI is 0.0546, based on Argentina's index is 0.0583, and it is 0.225 based on Nigerian exports basket. On the other hand, in the case of China, Mexico, Thailand and Malaysia, the results indicate convergence rather than divergence. The beta coefficient calculated based on the Chinese ECI is –0.0461, based on the Mexican index is –0.0414, based on the Thai is –0.0335, and based on Malaysian export basket is –0.0280. From these results it is possible to conclude that exports complexity is important to explain convergence and divergence. If developing countries have export baskets similar to the Chinese in term of complexity, for example, there would be convergence among countries income. However, if their export complexity is similar to Argentina or Nigeria, there would be divergence. Thereby, the higher is the complexity of developing countries export basket, the higher is the probability of income convergence among countries.

CONCLUDING REMARKS

This paper sought to collaborate with the structuralist literature on the central role of manufacturing and productive sophistication to economic growth. Both Anglo-Saxon and Latin American structuralism strands stressed that economic development is narrowly linked to a radical transformation of the productive structure of an economy in favour of the manufacturing sector to overcome underdevelopment. Structuralism states that a dynamic process of industrialisation is a necessary condition for increasing employment, productivity and income per capita and, consequently, reducing poverty. According to this approach, the process of economic development involves a shift of production from low productivity to high productivity sectors where increasing returns to scale prevail. The data provided by the *Atlas of Economic Complexity* strengthen assertions made by structuralist theorists. In other words, it is an empirical breakthrough that supports propositions of classical economists where manufacturing and productive sophistication are the drivers of sustainable and thriving economic dynamism. With these elements in mind this study sought to verify if countries' complexity is important to explain convergence and divergence between poor and rich countries and, if so, which are those countries that will be able to reduce the income gap compared to developed countries and which are those that will probably remain poor. Our empirical results show that export complexity is important to

explain convergence and divergence among countries. The results revealed that when developing countries export baskets are similar in terms of complexity, it generates convergence among countries in terms of income. On the other hand poor exports basket in terms of complexity, such as in Argentina or Nigeria, causes divergence in terms of income. The higher the complexity of developing countries export basket, the higher the probability of income convergence with high income countries.

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