INDUSTRY, COMPETITIVENESS, EXTERNAL TRADE AND GROWTH ACCELERATION

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ABSTRACT

This paper presents a pioneering theoretical model for the acceleration of economic growth from the junction of elements of the post-Keynesian theory of long-run growth with Neo-Schumpeterian aspects. New findings are presented showing that the growth acceleration of a given country depends primarily on its international competitiveness, given the capacity for imitation and technological innovation, beyond the growth of physical production capacity of the economy and growth acceleration of world income.

Key words: External trade, international competitiveness, growth acceleration.
JEL Classification: C23, F43, O30.

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INDUSTRIA, COMPETITIVIDAD, COMERCIO EXTERIOR
Y ACELERACIÓN DEL CRECIMIENTO

RESUMEN

Este artículo presenta un modelo teórico pionero para la aceleración del crecimiento económico, mediante la unión de elementos de la teoría poskeynesiana del crecimiento a largo plazo con aspectos neoeschumpeterianos. Se presentan nuevas conclusiones que muestran que la aceleración del crecimiento de un país depende principalmente de su competitividad internacional, dada la capacidad de imitación e innovación tecnológica, además del crecimiento de la capacidad de producción física de la economía y de la aceleración del crecimiento de los ingresos del mundo.

Palabras clave: comercio exterior; competitividad internacional; aceleración del crecimiento.
Clasificación JEL: C23, F43, O30.

1. INTRODUCTION

Economic growth has been a subject of crucial importance in the agenda of countries, and to discover its determinants has become strategic for the formulation of public policies to promote sustainable long-run growth. The debate around the 'acceleration' of economic growth is new and still little explored in the economic literature (Hausmann, Pritchett, and Rodrik, 2005), although it is closely related to one of the oldest and important issues of economics —which is economic growth itself.

Adam Smith (1776) argued that economic growth was the result of an interactive and cumulative process based on the division of labor and increasing returns in the industry. In this process, the increasing returns are not confined simply to the factors that increase productivity within certain industries but also related to the production of all industries, which should be viewed as an interconnected whole (Young, 1928; Kaldor, 1966).

In this sense, in order to explain the reason for the differential rates of growth amongst capitalist countries, Kaldor (1966)) presented some "laws" or empirical generalizations, which are also applicable to developing countries. The first law states that there is a strong relationship between manufacturing output and real Gross Domestic Product (GDP) growth. The second law, known as the Kaldor-Verdoorn, reveals that there is a positive relationship between the productivity growth in the manufacturing sector and the growth of manufacturing output because of increasing incomes. Kaldor's third law states that the faster the growth of production in the manufacturing sector, the greater the rate of transfer of workers from the other sectors to this sector; consequently, the productivity and growth of the country's manufacturing sector is greater.

From Kaldor's Laws (1966), we have the foundation of the theory of demand-led growth that considers the existence of restrictions arising from the productive structure, hampering the sustainable expansion of demand consistent with equilibrium in the balance of payments. Indeed, in the long run, there are demand conditions that determine the level of production, so it was believed that it is the availability of production factors and the rate of technological progress that adapt to the increased demand. This idea materialized in the so-called Thirlwall's Law.

Fagerberg (1988) innovatively introduces the debate on the need to incorporate the supply side in the model of export-led growth through technological competitiveness. In order to achieve this, the author assumes the hypotheses of the technological gap model to discuss why the growth rates of countries differ. Indeed, the author finds an equation that determines the market-share of exports[1] as a function of technological factors (scope, capacity for imitation, technological innovation), the capacity of physical production, the growth of relative prices, and external demand.

From the seminal papers developed by Thirlwall (1979) and Fagerberg (1988), we intend to advance in the debate, presenting an original mathematical model of growth acceleration, which includes the supply-side through elements that reflect international competitiveness. In addition, we seek to test the model using the methodology of panel data for a sample of 63 countries between 1997 and 2011.

The choice of these two models as a starting point for our growth acceleration model is justified for three reasons. First, we consider the demand-oriented approach and, specifically, the export-led growth

[1] The same relationship is valid for imports.

approach more suitable to target growth models because exports have a unique character compared to other components of aggregate demand: It is the only component that is truly autonomous, *i.e.*, exogenous to the economic system, and it is the only determinant of demand capable of defraying imports, which could be crucial for the development of a country when it cannot internally produce some goods needed for growth (as capital goods). Second, within this perspective, the Thirlwall model is the first and one of the most fertile models of export-led growth. Third, there is a linkage missing between Thirlwall and the post-Keynesian models with the Neo-Schumpeterian approach —they do not point to causes for the differences between the income elasticities of demand between countries— which can be made from Fagerberg's contributions, explaining the trade specialization pattern and differences between these elasticities through technological aspects.

To achieve the goal presented, the paper is divided into four sections besides this introduction. The second section presents a review of the theoretical and empirical literature about the post-Keynesian and Neo-Schumpeterian approach to long-run growth, especially the growth models with an external constraint and the role of international competitiveness. The next section mathematically develops the model of growth acceleration. In the fourth, an empirical analysis of the determinants of growth acceleration for the countries in the sample, the methods of GMM Difference and GMM System are illustrated (GMM, Generalized Method of Moments). Finally, the last section presents the final remarks.

2. GROWTH ACCELERATION: A REVIEW OF EMPIRICAL LITERATURE

The modern growth theory has its origin in the seminal contributions of Harrod (1939) and Domar (1947), which are an attempt to extend the long-run results obtained by John Maynard Keynes in his *General Theory of Employment, Interest and Money* (1936). From these studies, several others appeared and helped in understanding the determinants of economic growth and its acceleration over time. To avoid an exhaustive review of the various theoretical and empirical models available in the literature, including distinct theoretical matrices, we will present a brief review of the recent debate on the issue of growth acceleration.

This debate began with a study published by Hausmann, Pritchett, and Rodrik (2005), which raised several issues, giving a new impetus to the discussion. The main issue is that growth accelerations tend to be highly unpredictable since the episodes are not related to conventional determinants and cases of economic reform, as these have not produced the expected results in terms of long-run growth acceleration.

The authors define long-run growth acceleration as a sustained change in economic growth for at least eight years; however, they set a filter to identify and distinguish those moments when countries experience growth acceleration. In order to classify the period as growth acceleration, the authors look at the following conditions: 1) $\Delta g_{t,t+n} \geq 3.5$ per year, the growth rate of the country should be higher or equal to 3.5% per year; 2) $\Delta g_{t,n} \geq 2.0$per year, growth still must be 2% higher than the previous eight years; and, 3) $y_{t+n} \geq \max(y_i)$, $t \geq i$, economic growth is higher than the previous peak period. In other words, the authors exclude episodes of full economic recovery, given that the level of real output of the economy should be higher at the end of acceleration than in all previous years of the acceleration. The idea is that the growth acceleration will be sustainable if greater than or equal to 2%; otherwise, the acceleration is not sustainable.

Hausmann, Pritchett, and Rodrik (2005) used data taken from the Penn World Tables to examine some international experiences of accelerated economic growth that lasted at least eight years since 1950 and showed that the trend of growth accelerations is positively related to depreciation of the real exchange rate, and to increases in investment and external trade. Moreover, the authors have demonstrated that changes in the political regime and economic reforms are statistically significant in explaining growth accelerations, while external shocks tend to produce accelerations that eventually fail (Hausmann, Pritchett, and Rodrik, 2005).

According to Jong-A-Pin and Haan (2008), a promising line of research is to examine the economic, political and institutional aspects that accompany growth acceleration, *i.e.*, changes in growth patterns. Since the publication of the seminal paper, this unconventional approach to identify periods of acceleration has influenced related articles such as Ostry, Zettelmeyer, and Berg (2007), Dovern and Nunnenkamp (2007), Jones and Olken (2008), Jong-A-Pin and Haan (2008), Xu (2011) among others.

Although this recent literature has been very fertile, many studies' derivative of the Kaldorian theory argue that exports may have a central role in explaining the pace of long-run growth. It was believed that for a given country to potentiate the acceleration of its growth, it should expand its production capacity to take advantage of the global economic acceleration. Moreover, technological progress helps explain the competitiveness gains of an economy, which would allow relaxing the external constraints to economic growth. Therefore, an apparent gap in the recent debate is the relationship between the above variables, the changes of the elasticities of external trade, and the long-run growth acceleration. However, the debate will initially be presented around the models of demand-led growth, which has its origin in Thirlwall's (1979) seminal paper and in some of the main Neo-Schumpeterian contributions on the determinants of long-run economic growth.

3. POST-KEYNESIAN AND NEO-SCHUMPETERIAN APPROACHES ON THE LONG RUN ECONOMIC GROWTH

3.1. The Thirlwall's Law: An introduction

The growth model developed by Thirlwall (1979) attempts to explain the different growth rates between countries through an analysis of demand. According to the author, it is possible to explain the reason for countries having similar export growth rates to present different rates of economic growth. The growth rate of a country can only be increased; without that, the balance of payments deteriorates with the expansion of imports. Thus, Thirlwall called attention to the income elasticity of demand, due to the imports required with growth differing between countries, since some countries would have to force the demand before others so that there would be equilibrium in the balance of payments.

Thirlwall's Law can be described in the following expression: The balance of payments equilibrium growth rate is equal to the growth rate of the volume of exports divided by the income elasticity of demand for imports. Therefore, the restriction to the expansion of demand and of economic growth is in the balance of payments. The growth rate of a country is constrained by the size of its income elasticity of imports relative to the rate of expansion of its exports.

Indeed, the trade pattern and the productive structure of the economy set the ratio of the elasticities exposed in the equation and, consequently, the economic growth of the country. However, such a Kaldorian/Keynesian conception does not denote the reasons for the asymmetries of the productive sectors, *i.e.*, it cannot endogenize income elasticities of demand for exports and imports. In this sense, the Neo-Schumpeterian theory goes beyond trying to show that the growth pattern of an economy is related to the technological aspects involved in the production process.

3.2. Technology and international competitiveness: A Neo-Schumpeterian approach

The post-Keynesian view of growth does not deeply address the issue of income elasticities of demand for exports and imports in determining the long-run growth rate. In this sense, it is believed that Neo-Schumpeterians advance in trying to show the reasons for the asymmetry of the growth patterns of an economy, which are related to its international competitiveness, which, in turn, relates to the technological specialization pattern.

Although there are several definitions of competitiveness within and outside the Neo-Schumpeterian approach with a different focus, both micro and macroeconomic, the concept underlying this article has a more macroeconomic character related to the capacities of national economies presenting satisfactory economic performances and centered on the capacity of a national economy to act in international trade.

Mathis, Mazier, and Rivaud-Danset (1988) point out that competitiveness is the ability to push back the limits of external constraints. For Chesnais (1981), competitiveness is related to the ability of a country to face worldwide competition through exports or via the defense of its domestic market from excessive import volumes. Fagerberg (1988) goes even further by pointing out competitiveness not only in terms of international trade, but also in terms of economic well-being and rising incomes. For him, competitiveness is related to a country's ability to achieve fundamental economic policy objectives such as raising employment. However, in seeking to measure competitiveness mathematically, he uses a less holistic and more focused on international trade proxy: The market share variable, which is in accordance with Fouquin's (1986) concept, where competitiveness is basically the share of a country's exports to the world market.

The Neo-Schumpeterian idea is that the level of technology determines the participation in external trade, the income level, and therefore affecting the possibilities for long-run growth (Dosi, Pavitt, and Soete, 1990). For the Neo-Schumpeterians, technology sets a dynamic character in relations among countries and consolidates different trajectories of long-run growth from different productive structures and degrees of innovation, differentiation and learning. Moreover, in this theoretical perspective, the mechanisms of imitation, learning by doing, and reverse engineering among others, are important sources of catch up and reduction of the technological gap between countries.

Thus, international differences in the pace of growth are explained by technological change and the innovative capacities of the countries. The technological gaps model indicates that technological development of a country depends on the level of development of its innovative activities, which can be understood by the proportion of new products in total GDP and by using new techniques in the production process.

Fagerberg (1987) uses a time series model containing three variables: Potential imitation measured by GDP per capita; efforts allocated to the exploration of this potential, used as a proxy for the participation of gross investment in GDP; and the growth of innovative activity, which is measured by the growth in the number of patents granted. In this paper, two distinct models are tested: The first is formed by the variables presented— the supply side of the economy—while the second is an expanded version, also containing a variable that captures the growth of international trade at constant prices. This version is considered by the author as a post-Keynesian model.

In the first model (supply side oriented), all variables were statistically significant as being important for economic growth. In the second model (post-Keynesian), the same results were found; however, the growth in the number of patents was less significant than in the pure supply model. The author has concluded that the technological gaps model can explain the differences in the growth rates for the sample of countries analyzed. Nevertheless, the models cannot explain the differences in the growth rate among developed countries as effectively, especially if these countries are small or medium size with close development levels, as is the case of European countries in the postwar period, which showed high GDP per capita rates with a moderate amount of innovative activities. Thus,

> (…) to explain the differences in growth between these countries in the post-war period, a much more detailed analysis of economic, social and institutional structures should be carried out. The prospects for this group of countries will partly depend on whether or not competition through innovation will be the dominant form of competition in international markets in the future (Fagerberg, 1987, p. 97).

Since new products are generally characterized by new techniques and high prices which generate high productivity, countries with high levels of innovative activities are allowed to present a high market share in external trade and high growth acceleration rates that make the countries accelerate their growth more than others, on average. It should be emphasized that, generally, the high level of technological development can be obtained by means of imitative activities, but this generates inferior results in those countries that develop innovative activities internally[2].

Fagerberg (1988) advances this approach by incorporating the supply side through international competitiveness in models of export-led growth. Based on Schumpeter's ideas, it is assumed that competitiveness does not happen only through prices but also because of the technological differentiation employed. Fagerberg (1988) finds an equation that determines the market share of exports as a function of technological factors (scope, capacity for imitation, technological innovation) of the capacity of physical production, the growth of relative prices, and external demand.

To find the growth rate, the model takes as its starting point the assumption of growth with equilibrium in the balance of payments from Thirlwall (1979), and then it inserts the international competitiveness through a measure of the market share of exports and imports. The

[2] The level of innovative activity can be measured by technological inputs or effort measures such as spending on education, research and development; employment's share of scientists and engineers. Such variables also relate to the ability of the country to imitate. Moreover, the innovative activities can be measured by means of technological products produced or output variables such as numbers of patents and innovation indices.

model was applied to data in time series, pooled cross-country, panel data and estimated from different methods (two-stage least-squares and least-square dummy variable) for a set of 15 countries over the period 1960-1983, subdivided into four sub-periods according to the peak years of the economic cycle.

For the variables of technological development and technological competitiveness growth, Fagerberg (1988) advances, compared to Fagerberg (1987), by constructing indicators that relate data on technological effort (input technology) and results (output technology) since both, when considered separately, are imperfect measures that neglect a few technology aspects. The author's main conclusion is that economic growth depends on investment and factors that influence this growth, such as the ability to imitate through the international technology diffusion and innovation and the ability to explore the benefits from newly developed technologies. Furthermore, he concluded that the competitiveness by prices, based on lower production costs, also affect growth but to a lesser extent than is indicated by much of the economic literature.

In a complementary way, the technological gaps theory indicates that the trade pattern must be considered as a process of technological convergence and divergence. Innovative processes induce greater divergence and hence technological asymmetry between countries, and the technical progress by imitation and diffusion lead to technological convergence among countries. However, to conclude on a process of technological convergence or divergence between countries, it is necessary to assess the technical change rate, the degree of lag, the technological leadership, the degree of cumulative technical knowledge and appropriateness, and the substitution rate between old and new products (Dosi, 2006).

In summary, technical change and technological competitiveness play a fundamental role concerning commercial development since technological innovation stimulates certain sectors while inhibiting others. Therefore, the comparative advantages in terms of production costs are not the only relevant factors to the trade specialization of an economy. In these terms, it is noticed that the development of technological capabilities enables better international insertion and better economic performance.

4. MODEL FOR GROWTH ACCELERATION: A POST-KEYNESIAN AND NEO-SCHUMPETERIAN APPROACH

The aim of this paper is to develop a model of growth acceleration that is driven by exports that tries to endogenize the income elasticity of the demand for exports and imports. The idea is to build a model that will have as its starting point the seminal papers by Thirlwall (1979) and Fagerberg (1988). Thirlwall's model assumes that relative prices are measured over time under a common currency, the equation that determines exports can be written as:

$$X_{it}^{k} = \sum\nolimits_{j \neq k}^{J} \varepsilon_{it}^{k} Z_{t}^{j} \quad [1]$$

For simplicity, set $\Sigma_{k \neq j}^{k} \varepsilon_{it}^{k} = \varepsilon_{it}^{k}$, and we can represent the sum of income elasticity of demand for exports of the sector that produces good *i* (in country *k*) for the country *j*, with $j \neq k$, which is weighted by the world income, Z_{t}^{k}, or *k*'s trading partners. Thus, we have:

$$X_{it}^{*} = \sum\nolimits_{k \neq j}^{K} \sum\nolimits_{j=1}^{J} \varepsilon_{it}^{k} Z_{t}^{j} \quad [2]$$

where X_{it}^{k} is the exports of the sector that produces good *i* in the country *k* in a given period; X_{it}^{*} is the world exports of the sector that produces good *i* in the country *j*, $j \neq k$, in a given period; ε_{it}^{k} is the income elasticity of demand for exports from the sector that produces good *i* in the country *j*, $j \neq k$, in a given period; $\Sigma_{j=1}^{j} \Sigma_{j \neq k}^{j} \varepsilon_{it}^{j} Z_{t}^{k}$ is the sum of the income elasticity of demand for exports from the sector that produces the good in other countries, which is weighted by the world income, Z_{t}^{k}, (or *j*'s trading partners) in a given period.

Exports of a given country depend on the world income and income elasticity of demand for exports, while global exports are an increasing function of world income and the sum of the income elasticity of demand of other countries. Of course, one way to measure the international competitiveness of a country is based on the indicator of market share, as expressed by Fagerberg (1988):

$$MS_{it}^{k} = \frac{X_{it}^{k}}{X_{it}^{*}} \quad [3]$$

where MS_{it}^{k} is the market-share that is the share of country *k* in total exports by sectors that produce the commodity *i* in the rest of the world in a given period. Replacing [1] in [3], we have:

$$MS_{it}^{k} = \frac{\sum_{j \neq k}^{J} \varepsilon_{it}^{k} Z_{t}^{j}}{\sum_{k \neq j}^{K} \sum_{j=1}^{J} \varepsilon_{it}^{k} Z_{t}^{j}} \qquad [4]$$

According to Fagerberg:

$$MS_{it}^{k} = A.(C_{it}^{k})^{c} \left(\frac{T_{it}^{k}}{T_{it}^{*}} \right)^{a} \left(\frac{P_{it}^{k}}{P_{it}^{*}} \right)^{-b} \qquad [5]$$

where A is a constant; C_{it}^{k} is the productive capacity of the industry that produces good *i* in the country *k* in a given period; $P_{it}^{*} = \left(1/J\right)\Sigma_{j=1}^{J} P_{it}^{j}$ is the average price in the industry that produces good *i* in the international market; $P_{it}^{*} = \left(1/J\right)\Sigma_{j=1}^{J} T_{it}^{j}$ is the world average technology used by the industries that produce good *i*; $(P_{it}^{k} / P_{it}^{*})$ is the difference between the prices of good *i* practiced in the country *k* and average prices by the rest of the world; $(T_{it}^{k} / T_{it}^{*})$ is the difference of technological competitiveness in the production of good *i* between country *k* and the world average.

Moreover, *a*, *b* and *c* are parameters (constants) that measure the sensitivity of MS_{it}^{k}regarding the variables. The negative sign in *b* is given by $P > P^{*}$, which adversely affects the country's competitiveness. The higher the domestic price (P_{it}^{k}) relative to the foreign price, the lower the international competitiveness of country *k* will be. Matching [4] and [5], we have:

$$\varepsilon_{it}^{k} Z_{t} = \sum_{k \neq j}^{K} \sum_{j=1}^{J} \varepsilon_{it}^{k} Z_{t}^{j} A.(C_{it}^{k})^{c} \left(\frac{T_{it}^{k}}{T_{it}^{*}} \right)^{a} \left(\frac{P_{it}^{k}}{P_{it}^{*}} \right)^{-b} \qquad [6]$$

where $\varepsilon_{it}^{k} Z_{t} = \Sigma_{j \neq k}^{J} \varepsilon_{it}^{k} Z_{t}^{j}$.

Equation [6] demonstrates that the income elasticity of demand for exports from the sector that produces good *i* in country *k* is an increasing function of the sum of the world income elasticity plus the production capacity and technological gap; however, it is a decreasing function of the difference in domestic prices relative to the average of international prices. Transforming equation [6] into logarithms and differentiating it with respect to time, we have:

$$g\varepsilon_{it}^{k} = \frac{\dot{\varepsilon}_{it}^{k}}{\varepsilon_{it}^{k}} = \frac{\left(\dot{\gamma}_{it}^{*J}\right)}{\left(\gamma_{it}^{*j}\right)} + c\frac{\dot{c}_{it}^{k}}{c_{it}^{k}} + a\left(\frac{\dot{T}_{it}^{k}}{T_{it}^{k}} - \frac{\dot{T}_{it}^{*}}{T_{it}^{*}}\right) - b\left(\frac{\dot{P}_{it}^{k}}{P_{it}^{k}} - \frac{\dot{P}_{it}^{*}}{P_{it}^{*}}\right) - \frac{\dot{Z}_{t}}{Z_{t}} \qquad [7]$$

with $j \neq k$, where $\gamma_{it}^{*j} = \Sigma_{k\neq j}^{K}\Sigma_{j=1}^{J}\varepsilon_{it}^{k}Z_{t}^{j}$ is the elasticity of demand for world exports weighted by their trade patterns' income.

If we consider the income elasticity of demand for imports of the sector that produces good i in country k as π_{i}^{k} and the income elasticity of demand for world imports as π_{i}^{*}, we have that the inverse of the above relationship is also valid:

$$g\pi_{it}^{k} = \frac{\dot{\pi}_{i}^{k}}{\pi_{i}^{k}} = \frac{\left(\dot{\gamma}_{it}^{k}\right)}{\left(\gamma_{it}^{k}\right)} + c\frac{\dot{c}_{it}^{k}}{c_{it}^{k}} + a\left(\frac{\dot{T}_{it}^{k}}{T_{it}^{k}} - \frac{\dot{T}_{it}^{*}}{T_{it}^{*}}\right) - b\left(\frac{\dot{P}_{it}^{k}}{P_{it}^{k}} - \frac{\dot{P}_{it}^{*}}{P_{it}^{*}}\right) - \frac{\dot{Y}_{t}^{k}}{Y_{t}^{k}} \qquad [8]$$

with $j \neq k$, where $\gamma_{it}^{k} = \Sigma_{i=1}^{I}\pi_{it}^{k}Y_{t}^{k}$ is the elasticity of demand for imports from country j weighted by its own income. However, the ability to offer good i of country k in period t, C_{it}^{k}, is determined by three other factors[3]:

$$\frac{\dot{c}_{it}^{k}}{c_{it}^{k}} = v^{k}\frac{\dot{Q}_{it}^{k}}{Q_{it}^{k}} + r^{k}\frac{\dot{K}_{it}^{k}}{K_{it}^{k}} - l^{k}\frac{\dot{Z}_{t}}{Z_{t}} \qquad [9]$$

where $\dot{c}_{it}^{k}/c_{it}^{k}$ is the capacity growth rate of country k offering good i in period t; $\dot{Q}_{it}^{k}/Q_{it}^{k}$ is the technological capacity growth rate from country k to offer good i in period t, which is possible through technology diffusion of the country on the technological boundary (learning by doing); $\dot{K}_{it}^{k}/K_{it}^{k}$ is physical production growth, infrastructure, equipment and buildings; $g_{zt} = \dot{Z}_{t}/Z_{t}$ is the growth rate of world income that adversely affects the productive capacity since it reduces the possibility of answering to the external demand only through domestic production.

Furthermore, the literature on technological gaps considers that the dissemination of knowledge follows a logistic curve. That is, technological diffusion and its contribution to economic growth is an increasing

[3] As shown by Fagerberg (1988).

function of the distance between the total level of appropriation of knowledge in the k^{th} country in relation to the country that is at the technological frontier. This implies

$$\frac{\dot{Q}_{it}^{k}}{Q_{it}^{k}} = f - f\frac{Q_{it}^{k}}{Q_{it}^{*}} \qquad [10]$$

where f is a positive constant and Q_{it}^{k}/Q_{it}^{*} is the ratio between the level of technological development of country k that offers good i relative to countries in the technological boundary (exogenous variable). The smaller the technological level of the country k, Q_{it}^{k}, in relation to the technological level of border countries, the greater the distance in terms of technological standard of this country in relation to the partner and, therefore, the greater the impact of the spread of certain knowledge about the rate of growth of the technological capacity and, consequently, of productive capacity, [10] in [9], we have:

$$\frac{\dot{c}_{it}^{k}}{c_{it}^{k}} = v^{k} f - f\frac{Q_{it}^{k}}{Q_{it}^{*}} + r^{k}\frac{\dot{K}_{it}^{k}}{K_{it}^{k}} - l^{k}\frac{\dot{Z}_{t}}{Z_{t}} \qquad [11]$$

Matching the [11] with the income elasticity of demand for exports and imports (equations [7] and [8]), we have:

$$\begin{aligned}\frac{\dot{\varepsilon}_{it}^{k}}{\varepsilon_{it}^{k}} &= \frac{\left(\dot{\gamma}_{it}^{*J}\right)}{\left(\gamma_{it}^{*j}\right)} + cv^{k} f_{X} - cv^{k} f_{X}\frac{Q_{it}^{k}}{Q_{it}^{*}} + cr_{X}^{k}\frac{\dot{K}_{it}^{k}}{K_{it}^{k}} - cl_{X}^{k}\frac{\dot{Z}_{t}}{Z_{t}} \\ &\quad + a_{X}^{k}\left(\frac{\dot{T}_{it}^{k}}{T_{it}^{k}} - \frac{\dot{T}_{it}^{*}}{T_{it}^{*}}\right) - b_{X}^{k}\left(\frac{\dot{P}_{it}^{k}}{P_{it}^{k}} - \frac{\dot{P}_{it}^{*}}{P_{it}^{*}}\right) - \frac{\dot{Z}_{t}}{Z_{t}}\end{aligned} \qquad [12]$$

and

$$\begin{aligned}\frac{\dot{\pi}_{i}^{k}}{\pi_{i}^{k}} &= \frac{\left(\dot{\gamma}_{it}^{k}\right)}{\left(\gamma_{it}^{k}\right)} - cv^{k} f_{M} + cv^{k} f_{M}\frac{Q_{it}^{k}}{Q_{it}^{*}} + cr_{M}^{k}\frac{\dot{K}_{it}^{k}}{K_{it}^{k}} - cl_{M}^{k}\frac{\dot{Z}_{t}}{Z_{t}} \\ &\quad + a_{M}^{k}\left(\frac{\dot{T}_{it}^{k}}{T_{it}^{k}} - \frac{\dot{T}_{it}^{*}}{T_{it}^{*}}\right) - b_{M}^{k}\left(\frac{\dot{P}_{it}^{k}}{P_{it}^{k}} - \frac{\dot{P}_{it}^{*}}{P_{it}^{*}}\right) - \frac{\dot{Y}_{t}^{k}}{Y_{t}^{k}}\end{aligned} \qquad [13]$$

with $j \neq k$. Moreover, the subscripts M and X are sensitivity parameters of the above equations, which refer to the exports and imports. Thus, we denote the distinction between the parameters of each income elasticity of demand.

Equations [12] and [13] show that the growth of the income elasticity of demand for exports and imports of countries depends on technological factors relating to the other countries: Technological innovation and capacity for imitation; infrastructure or capacity for physical production; growth of external demand (in the case of $\dot{\varepsilon}_{it}^{k}$; and domestic demand (in the case of $\dot{\pi}_{i}^{k}$), and the difference in relative prices.

Therefore, from equations [12] and [13], we can endogenize the income elasticities of demand for exports and imports as a function of the technological dynamism, infrastructure, and other product terms. Thus, in a growth model with the balance of payments constrained, the performance of technological factors would be able to provide a change in the productive structure of the economy that may be strategic for a given economy since it reduces the degree of exposure to external imbalances. Thus, it also explains the differences in the ratios of income elasticities of exports and imports of the country in relation to its trading partners.

As demonstrated in the previous section, Thirlwall's model assumes that the growth rate of output of economies in the long run (g_{yt}^{k}) is a function of the ratio of the income elasticity of demand for exports and total imports of the country multiplied by the growth rate of world income (g_{zt}):

$$g_{yt}^{k} = \frac{\varepsilon_{it}^{k}}{\pi_{it}^{j}} g_{zt} \qquad [14]$$

Transforming equation [14] in logarithms and differentiating it according to time, we have:

$$\dot{g}_{yt}^{k} = g\dot{\varepsilon}_{it}^{k} - g\dot{\pi}_{it}^{k} + \dot{g}_{zt} \qquad [15]$$

Equation [15] is a second-degree ordinary differential equation, also called the speed up of economic growth. Note that it is a function whose dependent variable is the acceleration of the growth of the national product ($\dot{g}_{yt}^{k}$) and its determinants, namely, the growth acceleration of world output ($\dot{g}_{zt}$) and growth rates of income elasticities of demand for exports and imports.

Matching [12] and [13] in [15] and considering that $\dot{g}_{zt} = \frac{\dot{Z}_t}{Z_t} - \frac{\dot{Z}_{t-1}}{Z_{t-1}}$, we have:

$$\dot{g}^k_{yt} = \frac{\left(\dot{\gamma}^{*J}_{it}\right)}{\left(\gamma^{*j}_{it}\right)} - \frac{\left(\dot{\gamma}^k_{it}\right)}{\left(\gamma^k_{it}\right)} + (cv^k f_X + cv^k f_M)\left(1 - \frac{Q^k_{it}}{Q^*_{it}}\right)$$
$$+ (cr^k_X + cr^k_M)\left(\frac{\dot{\mu}^k_{it}}{\mu^k_{it}}\right) + [1 + (cr^k_X + cr^k_M)]\left(\frac{\dot{Y}^k_t}{Y^k_t}\right)$$
$$- [1 + (cl^k_X + cl^k_M)]\left(\frac{\dot{Z}_t}{Z_t}\right) - (a^k_X + a^k_M)\left(\frac{\dot{T}^*_{it}}{T^*_{it}} - \frac{\dot{T}^k_{it}}{T^k_{it}}\right) \quad [16]$$
$$+ (b^k_X + b^k_M)\left(\frac{\dot{u}^*_{it}}{u^*_{it}} - \frac{\dot{u}^k_{it}}{u^k_{it}}\right) + \left(\frac{\dot{Z}_t}{Z_t} - \frac{\dot{Z}_{t-1}}{Z_{t-1}}\right)$$

We also consider that the price charged in country *k* by *i* is a function of the unit cost of domestic production with production factors. Adopting the idea that price is a function of the markup, we have that:

$$P^k_{it} = b' u^k_{it} \quad [17]$$

where P_i is the unit price in the country *k*; u_{it} is the unit cost practiced in country *k*; and $b' = m/(1-n)$ is a constant that expresses the parameters *m* and *n*, which measure the power to establish the price of the firm in relation to others and its cost of production. In terms of the growth rate, we have:

$$\frac{\dot{P}^k_{it}}{P^k_{it}} = \frac{\dot{u}^k_{it}}{u^k_{it}} \quad [18]$$

Additionally, considering that the physical production is equal with the capacity utilization degree multiplied by the real production, we have:

$$K^k_{it} = \mu^k_{it} Y^k_t \quad [19]$$

where μ is the utilization of the installed capacity, the limit of production or maximum production capacity of an economy *k*; *i.e.*, a parameter that measures the quantity of units of product that the installed infrastructure and equipment in a country can produce. In terms of the growth rate, we have:

$$\frac{\dot{K}_{it}^{k}}{K_{it}^{k}}=\frac{\dot{\mu}_{it}^{k}}{\mu_{it}^{k}}+\frac{\dot{Y}_{t}^{k}}{Y_{t}^{k}} \qquad [20]$$

This means that physical production growth is a positive function of the growth of installed capacity. If so, when an economy is operating with full employment of factors or at the maximum of its installed capacity, $(\dot{\mu}_{it}^{k}/\mu_{it}^{k})$ will be zero. Likewise, the physical production growth $(\dot{Y}_{t}^{k}/Y_{t}^{k})$ also depends on the economic growth, which is a function of all production factors that restrict it, such as physical capital, human capital, infrastructure, and so on.

Matching [18] in [16] yields the growth acceleration function:

$$\begin{aligned}\dot{g}_{yt}^{k}=&\frac{\left(\dot{\gamma}_{it}^{*J}\right)}{\left(\gamma_{it}^{*j}\right)}-\frac{\left(\dot{\gamma}_{it}^{k}\right)}{\left(\gamma_{it}^{k}\right)}+(cv^{k}f_{X}+cv^{k}f_{M})\left(1-\frac{Q_{it}^{k}}{Q_{it}^{*}}\right)\\&+(cr_{X}^{k}+cr_{M}^{k})\left(\frac{\dot{\mu}_{it}^{k}}{\mu_{it}^{k}}\right)+[1+(cr_{X}^{k}+cr_{M}^{k})]\left(\frac{\dot{Y}_{t}^{k}}{Y_{t}^{k}}\right)\\&-[1+(cl_{X}^{k}+cl_{M}^{k})]\left(\frac{\dot{Z}_{t}}{Z_{t}}\right)-(a_{X}^{k}+a_{M}^{k})\left(\frac{\dot{T}_{it}^{*}}{T_{it}^{*}}-\frac{\dot{T}_{it}^{k}}{T_{it}^{k}}\right)\\&+(b_{X}^{k}+b_{M}^{k})\left(\frac{\dot{u}_{it}^{*}}{u_{it}^{*}}-\frac{\dot{u}_{it}^{k}}{u_{it}^{k}}\right)+\left(\frac{\dot{Z}_{t}}{Z_{t}}-\frac{\dot{Z}_{t-1}}{Z_{t-1}}\right)\end{aligned} \qquad [21]$$

with $j\neq k$. Equation [21] summarizes our growth acceleration model of country *k*, which depends:

- Positively on the difference between the sum of world income elasticity of exports and the sum of world income elasticity of imports.
- Positively on technological diffusion, *i.e.*, when country *k* in analysis is one of the boundary countries, the second term of the equation is equal to zero, since $Q_{it}^{k}/Q_{it}^{*}=1$ (the closer the technological level of the country *k*, Q_{it}^{k}, in relation to Q_{it}^{*}, the smaller the positive effect of a technological improvement on the country's productive capacity and, hence, in the growth acceleration of *k*).

- Positively on the growth of utilization capacity of the economy, which allows an increase of the capital accumulation growth rate (physical production capacity), infrastructure, equipment, and buildings in country *k*.
- Negatively on the technological gap, in the sense that the greater the difference in the growth of technological competitiveness of country *k* relative to the growth of technological competitiveness of the rest of the world, the lesser the growth acceleration will be.
- Positively on the income growth rate and, therefore, depends on the growth rate of all production factors, since it stimulates the investment due to the principle of acceleration.
- Positively on the difference in the unit costs of production practiced internally and externally, and international competitiveness and the growth rate of the product, as the lower the cost of domestic production relative to other markets, the greater the growth acceleration will be.
- Negatively on the current growth of world income in period t, expressing increasing demand for global exports triggered by rising global income that captures the effect of increased international competition on exports of country *k*.
- Positively on growth acceleration of world income, demonstrating that there is an interdependence between countries.

5. METHODOLOGY, DATABASE AND EMPIRICAL RESULTS

The conventional econometric models have, as their main problem, a common occurrence of inconsistent estimates due to the existence of omitted variables when these are correlated with the regressors contained in the equations. These variables would mostly be those that often cannot be measured and are not available in the databases but, at the same time, are relevant variables and help explain the behavior of the dependent variable.

Indeed, the use of panel data models is a suitable alternative to this problem. The availability of data for the same unit of observation over a given period can correct the inconsistency of the estimated parameters of the models somewhat. Thus, this section presents a brief description of the method used for the estimation of causal effects.

5.1. Methodology

One of the advantages of the panel data methodology is that it allows the researcher to better understand the dynamic relationships that are characterized by the presence of the lagged dependent variable among the regressors, demonstrated in the following expression from Baltagi (2001):

$$y_{it} = \alpha_i + \delta y_{i,t-1} + x'_{it}\beta + u_{it} \quad [22]$$

where δ is a scalar, x'_{it} is a $1\times K$ matrix of explanatory variables, and β is a $K\times 1$ vector of parameters. It is assumed that u_{it} follows this model error component:

$$u_{it} = \mu_i + v_{it} \quad [23]$$

where $\mu_i \sim \text{IID}(0, \sigma_u^2)$ and $v_{it} \sim \text{IID}(0, \sigma_v^2)$ are serially independent in time and to each other.

To get a consistent estimator δ when $N\rightarrow\infty$ and T is fixed, we simply take the first difference of equation [23] to eliminate the individual effects and thereby remove the source of inconsistency in the model:

$$y_{i,t} - y_{i,t-1} = \delta(y_{i,t-1} - y_{i,t-2}) + \beta(x_{i,t} - x_{i,t-1}) + v_{i,t} - v_{i,t-1} \quad [24]$$

By construction, $y_{i,t-1}$ in [24] is correlated with the effect of individual but not observed μ_i. Although we have eliminated the fixed effect term μ_i in [24], a new problem arises: The term y_{t-1} contained in $\Delta y_{t-1} = y_{t-1} - y_{t-2}$ is a function of v_{t-1} that is contained in $\Delta v_{it} = v_{it} - v_{it-1}$. Therefore, Δy_{t-1} is correlated with Δv_{it} in [24] by construction and cannot estimate δ consistently by ordinary least squares (OLS) even if the errors v_{it} are serially uncorrelated. Anderson and Hsiao's (1981) suggestion is to use a two-stage least squares estimator (2SLS), using as instruments for Δy_{t-1}, as variables $\Delta y_{i,t-2}$ and other previous lags or simply y_{t-2} (and its other previous lags). These instruments will not be correlated with $\Delta v_{it} = v_{it} - v_{it-1}$ since the process v_{it} are not serially correlated.

The estimator that uses instruments in levels, *i.e.*, y_{t-2}, has no singularities, presents lower values of variances, and is, therefore, recommended.

Arellano and Bond (1991) showed how to construct moment conditions from the lagged levels y_{it} (as from y_{it-2}) and the first difference of the idiosyncratic errors[4]. The Arellano-Bover/Blundell-Bond estimator (also known as the GMM System estimator) increases the Arellano-Bond estimator (known as the GMM Difference estimator) with an additional assumption that the first differences of the instrumental variables are uncorrelated with the fixed effects. This allows the use of more tools, which can greatly increase efficiency. In the latter estimator, a system of two equations is constructed, the original differential equation and a transformed equation.

A crucial assumption for the validity of these two estimation methods is that the instruments are exogenous. If the model is over-identified, a statistical test to verify the joint validity of the moment conditions is obtained directly from the structure of the GMM estimation. Under the null hypothesis of joint validity, the vector of empirical moments $\frac{1}{N}Z'E$ is distributed randomly around zero, and a Wald test can verify this hypothesis using the χ^2 distribution. This is the Hansen J statistical test for over-identifying constraints. The test statistic is precisely the minimized value of the criterion function of the efficient and feasible GMM estimator. This procedure can also be used to test the validity of subsets of specific instruments through the difference in Sargan test, also known as the C statistic.

However, caution must be taken with respect to two issues that arise when excessively increasing the number of instruments (or moment conditions). The over-identifying restrictions test becomes weaker because you have to simultaneously satisfy a very large number of moment conditions, and it is very difficult to get since the vector of all empirical moments $\frac{1}{N}Z'E$ becomes zero in their entirety.

Other problems can arise when excessively increasing the number of instruments when working with finite samples. According to Roodman (2006), it does not compromise the consistency, but it can cause problems with the estimation. For the feasible, efficient GMM estimator (FEGMM), you need to use a lot of sample information for the estimation of large arrays (when working with a large number of instruments). In addition,

4 For details, see Baltagi (2001).

a large number of instruments can weaken the Hansen test to the point of generating implausible *p*-values equal to 1. The difference is that the Hansen test lets one choose between the System GMM and Difference GMM methods, which is the most suitable estimator. If the *p*-value of the test statistic is high, it is concluded that the instruments in level are valid; hence, the System GMM method will be the most suitable.

For the present application of dynamic models, the xtabond2 Stata command is used with the options small, orthog, two-step, and robust. The first of these options allows the use of more appropriate statistics for small samples. The orthog option defines that the operation of differentiation of the equation in level is made with the orthogonal differentiation, *i.e.*, subtracting the mean values of future observations from the values of the observations, further leveraging the sample information. The robust option points to estimate standard errors with corrections for heteroscedasticity bias. For the tests of over-identifying restrictions (validity tests of instruments), two alternatives may be used: The Sargan test and Hansen test. The first is not robust but it is not weakened by many instruments. The second is strong but is weakened by many instruments. If the equation has few instruments, we can be more confident about the results of the second test.

5.2. Database

To estimate the proposed mathematical model of growth acceleration, we used an empirical model with variables *extracted* from the World Development Indicators (WDI) of the World Bank. However, many data for the most recent periods of the database were not available for a first exercise of estimation. This is the case, for example, of patent data and expenditure on research and development (R&D), so we opted for a small sample of the WDI, contemplating the countries and years for which there were available data of the selected variables for the model. Thus, initially, the tested model covers the period 1997-2011 and a group of 63 countries[5]. From Table A in the Appendix Tables, it is possible to

[5] List of countries: High Income (Organisation for Economic Co-operation and Development, OECD): Austria, Greece, Norway, Belgium, Iceland, Poland, Canada, Ireland, Portugal, Czech,

verify the description of the dependent variable, the explanatory variables, and the expected sign. Furthermore, the names of the variables in the WDI database are given for the calculation of each index proposed by the mathematical model[6].

There is a range of advantages and disadvantages related to the use of certain variables expressing technological activities. According to Fagerberg (1987, 1988), both effort indicators such as spending on R&D and outcome indicators such as patents are imperfect measures of the technological level of the country. For example, many sectors of the economy present high levels of spending on R&D without presenting a significant number of patents and vice versa. However, the author's empirical studies demonstrate a high level of correlation between R&D and patent activities, which would lead to a high degree of multicollinearity if they were put in the same model.

Fagerberg (1988) constructed indicators that expressed technological parameters from the weighted average of both indices: Spending on R&D and number of patents. Additionally, as it was found that the variance of indices differed substantially, the author used weights to adjust such differences. This paper, therefore, follows such considerations made by the author and calculates the same indicators for the selected sample.

As a proxy for technology diffusion, we used the tl_k indicator, defined as the weighted average of the index of patents (P_k) and the index of R&D (R_k), using the standard deviation as weights:

$$tl_k = \left\{ \frac{std(R)}{[std(P) + std(R)]} \right\} P_k + \left\{ \frac{std(P)}{[std(P) + std(R)]} \right\} R_k \qquad [25]$$

Israel, Slovak, Denmark, Japan, Slovenia, Estonia, Korea, Spain, Finland, Luxembourg, Sweden, France, Netherlands, the United Kingdom, Germany, New Zealand and the United States of America; High income (non OECD): Croatia, Hong Kong, Latvia, Lithuania, Malta, Russia, and Singapore; Upper middle income: Argentine, Azerbaijan, Belarus, Brazil, Bulgaria, China, Colombia, Ecuador, Hungary, Kazakhstan, Macedonia, Malaysia, Mexico, Romania, South Africa, Thailand, Tunisia, and Turkey; Lower middle income: Armenia, Egypt, Georgia, India, Moldova, Mongolia, Pakistan, and Ukraine; Low income: Kyrgyz Republic, Madagascar, and Tajukistan.

6 For simplicity, we assume that the utilization capacity growth of most economies is constant; thus, we have not used a proxy for that variable in our econometric model.

The patent index (P) is defined as the number of foreign patent applications (PAT), divided by the number of inhabitants in the country (POP), and the degree of openness of the economy, measured by exports as a percentage of GDP (XSH), $P_k = {PAT_k}/{(POP_K * XSH_K)}$.

The rate of R&D (R) is defined as public spending on research and development as a percentage of GDP. As proposed by Fagerberg (1988), each index was normalized to 0, dividing all observations in year t with the maximum value for that year.

As a proxy for the technology gap, we used the indicator of technological competitiveness of a country relative to the others, tg_k, developed by Fagerberg (1988), which is also constructed from the variables of patents and spending on R&D from the WDI database. However, in order to adjust the mathematical model that expresses such variables in terms of growth rates, the growth rate of tg_k, an indicator identified in the model as ltg_k, was calculated:

$$tg_k = \left\{ \frac{std(RG)}{[std(PG) + std(RG)]} \right\} PG_k + \left\{ \frac{std(PG)}{[std(PG) + std(RG)]} \right\} RG_k \quad [26]$$

where the index of patents (PG) is defined as the growth in foreign patent applications of country k minus the average growth rate of all countries. The rate of R&D (RG) is defined as the ratio of public spending such as R&D as a percentage of GDP (RD) and GDP per capita (T) of country k, minus the average ratio for all countries in each period:

$$RG_k = \frac{RD_k}{T_k} - \frac{\overline{RD_i}}{T_i} \quad [27]$$

where $\overline{RD_i}$ denotes the average RD within the period.

5.3. Empirical results

The period selected for estimation is marked by the 2008 economic crisis, which affected the growth rates of countries in subsequent years. As a result, we chose to use a dummy variable that takes the value 1 in the year of the crisis and in years 2009 and 2010 in order to capture the effect of the crisis on the accelerating economic growth of countries. The following equation was estimated:

$$\dot{g}_{yt}^{k} = \beta_0 + \beta_1 tl_{kt} + \beta_2 ltg_{kt} + \beta_3 \dot{k}_t^k + \beta_4 \dot{z}_t + \beta_5 \dot{g}_{zt} + \beta_6 g\inf_{kt} + u_{kt} \quad [28]$$

As a function of the existence of endogeneity between the variables, both methods, Difference GMM and System GMM, were used. Table 1 presents the results of the model of acceleration growth estimated for the period 1997-2011 (GMM Difference and System 1)[7].

The Arellano-Bond AR(1) and AR(2) tests showed the expected results in both estimations, a high correlation between the explanatory variables and the residuals in the AR(1) test and a low correlation in the AR(2) test. Both tests of instrument validity, the Sargan test and Hansen test, showed a high *p*-value in the two estimates, *i.e.*, testing of the null hypothesis cannot be rejected: The instruments are valid and uncorrelated with the error term of the equation, and the endogeneity bias was eliminated. It is worth noting that, although the Hansen test, which is robust, has been weakened in the System GMM estimation given the large number of instruments, it presented a plausible *p*-value less than 1; therefore, the validity of the instruments was not affected.

The most appropriate results refer to the System GMM method. This is because the Hansen difference test *p*-value was greater than 0.05 and thus we conclude that the instruments in level are also valid, and the System GMM estimator method is the most appropriate one.

The signs of all variables are in line with expectations in both estimation methods, except the inflation variable that was shown to have a positive effect, although not significant, on the acceleration of growth in the Difference GMM method. The technological diffusion variable, which expresses the technological level of country *i* relative to the sample, was significant at 10% in the System GMM method and positively related to the dependent variable. Thus, as demonstrated in the mathematical model, the technological diffusion shows that the further away from the technological frontier a country is, the more it will benefit from the

[7] The previous results from the random and fixed effects estimations were also included in the appendix tables.

Table 1. Results of estimations with panel data using GMM system
Dependent variable: GDP growth rate acceleration, 1997-2011

Variables	1997-2011	
	GMM Difference	GMM System
Technological diffusion	0.0175633	0.0179749*
	(0.046812)	(0.104248)
Technological gap	−0.00000361	−0.0000171***
	(0.0000123)	(0.00000543)
Capital accumulation	0.1045382*	0.0877272***
	(0.0563778)	(0.0287126)
Growth rate of world income	−0.0794321	−0.02680883**
	(0.0185114)	(0.1257745)
Growth acceleration of world	0.8872909***	0.9870167***
	(0.2067434)	(0.1582627)
Inflation differential	0.01634	−0.0005717
	(0.0193242)	(0.010518)
Dummy Year 2008	−1.826937	−2.502266*
	(2.152114)	(1.4022)
Dummy Year 2009	2.354746*	1.959259*
	(1.359933)	(1.121574)
Dummy Year 2010	2.30195***	1.305441***
	(0.6459362)	(0.4369957)
Observations	694	790
Number of id	60	61
Arellano-Bond test for AR(1) in 1st difference: *z*	–2.380	–2.370
AR(1): *Pr* > *z*	0.017	0.018
Arellano-Bond test for AR(2) in 1st difference: *z*	0.980	1.050
AR(2): *Pr* > z	0.327	0.296
Sargan test: chi^2	27.750	71.140
Sargan test: *P* > chi^2	0.726	0.605
Hansen test: chi^2	32.550	56.870
Hansen test: *P* > chi^2	0.489	0.941
Diff Hansen test: chi^2	-	33.770
Diff Hansen test: *P* > chi^2	-	0.430
Type of estimation	Difference	System
Number of instruments	42	84

Notes: 1/ Standard errors in parentheses. 2/ Statistical significant is denoted as *** 10%, ** 5%, and * 1%.
Source: Own elaboration·

effect of diffusion of an innovation on the rate of growth of technological capacity and, therefore, the greater the growth acceleration will be.

On the other hand, the proximity of the level of technological development of a country in relation to the technological frontier implies smaller effects of technological diffusion for the country, reducing the acceleration of output growth. Thus, this result may indicate that the acceleration of growth in developed countries will be relatively smaller compared to the least developed.

The technological gap was statistically significant in the System GMM method, but the parameter is practically zero in both estimates. However, this result shows that the gap is an important variable in explaining output growth acceleration. The growth rate of capital accumulation variable, which is capturing the expansion capacity of physical output of the economy, had a positive and significant sign in both the estimations, as expected, meaning that investments are fundamental to the country's growth acceleration strategy. Thus, investment works as a simple accelerator mechanism of productive capacity and hence of income growth acceleration. Still, as pointed out by Fagerberg (1988), investment in physical productive capacity should also be a complement to the expansion of international competitiveness through growth in the number of R&D facilities, increasing the number of scientists, engineers, and advanced electronics.

The growth of world income in the previous year showed a negative signal in the Difference GMM and System GMM methods, but was statistically significant only in the latter. As expected by the mathematical model, we can see that it represents the negative effect of global competition on growth acceleration. The acceleration of world income had a positive impact, as expected, and is significant at 1% in both estimations. Moreover, the parameters found were relatively high in estimations, 0.888 and 0.988, demonstrating that the output growth acceleration in the country closely follows the acceleration of global growth and therefore, there is a strong interdependence between the economies.

The differential in inflation rates was not significant in any of the estimation methods, demonstrating that competitiveness via prices is not relevant in the period for growth rate acceleration. It is worth noting that such a price index is quite volatile and affected by several other variables not explicit in the model such as the exchange rate differential. Fagerberg

(1988), in his model of competitiveness, relates growth in market share with the growth of unit labor costs in common currency —this variable is not available for the selected sample in this study. However, the author finds a similar result to that found here— the net effect of the growth of unit labor costs on the growing market share of exports, in terms of value, was negligible as compared to the effect of the technological diffusion, technological gap, and investment in productive capacity.

6. CONCLUDING REMARKS

Based on the Kaldorian literature on the balance of payments constrained growth and contributions from the Neo-Schumpeterian approach, it is argued in this paper that growth can overcome the external constraint through long-run structural change and reduction of the technological gap, through catching-up processes.

The main equation of our mathematical model shows that growth acceleration depends positively on: Technological diffusion; utilization capacity growth of the economy; the difference between the sum of the world income elasticity of exports and the sum of world income elasticity of imports; the growth income rate; the difference in the unit costs of production practiced internally and externally; and the growth acceleration of world income. Similarly, it depends negatively on the technological gap and on the current growth of world income. In this sense, structural change would occur by increasing the ratio of the income elasticity of exports and the income elasticity of imports; in other words, by increasing the relative share of manufactured goods in total exports relative to imports. Nevertheless, technological capacity, infrastructure and the difference in cost of production of a country relative to the rest of the world would be decisive for these acceleration elements and, therefore, should be a fundamental aspect within a program of economic growth acceleration.

The econometric application suggests the main determinants of economic growth acceleration are the differences of technological competitiveness, related to the ability to explore the technology disseminated by the border countries, the national technological competitiveness, and the productive capacity, closely related to investments. The growth acceleration is also determined by the acceleration of world income and is negatively influenced by positive shocks of world income in the previous period that increases the international competition and, thus, tends to slow down the growth of individual countries. Furthermore, the results suggest that price competitiveness (production costs) is not significant to determine the growth acceleration of countries regarding the technological variables and capital accumulation.

The model proposes an alternative to the problems currently discussed by the post-Keynesian approach of endogenization of the income elasticities of demand models with external constraints. It introduces new elements in the post-Keynesian literature, as the technological gap, diffusion —absorption capacity— of technology and physical capacity. Moreover, it proposes a model of growth acceleration that does not exist in the literature, associating a Keynesian external constrained growth model with Neo-Schumpeterian elements of international competitiveness. Our results are not comparable to other papers on growth acceleration, since they do not present mathematical models that support their empirical applications. However, the model of growth acceleration developed in this work is providential —since it deals with this issue shortly after the global crisis of 2008— as well as pioneering and innovative, for it prezents an alternative suggestion to that proposed by Hausmann, Pritchett, and Rodrik (2005). The theoretical model and results presented are an invitation for future works, which aim to improve the model in several aspects, among them, the importance of human capital and the exchange rate, as well as the role of government in accelerating economic growth. Moreover, it is an invitation for others to conduct further empirical analysis with other periods and countries that can express new stylized facts or specificities. ◂

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APPENDIX TABLES

Table A1. Description of variables

	Description	Expected sign	Source	Name of variables in the source
$\dot{g}^{k}_{yt}$	Gross Domestic Product Growth Rate Acceleration (GDP per capita). Difference in the rate of annual growth of GDP per capita of country *k* relative to its growth rate in the previous period.			GDP per capita growth (Annual %)
$\dot{k}_{kt}$	Capital Accumulation. Growth rate of Gross Fixed Capital Formation, a proxy for the growth rate of the country's productive capacity *k*.	+		Gross Capital Formation (Annual % growth)
g_{zt}	World GDP Growth Rate in the period t–1.	–		World GDP per capita growth (Current US$)
$\dot{g}_{zt}$	World GDP Growth Acceleration. Difference in the rate of annual GDP growth per capita in the world in period *t* relative to its growth rate in the previous period.	+	World Development Indicators (2013)	
tl_{kt}	Technological diffusion which expresses the difference between the technological levels of the country *k* relative to other countries in the sample, based on the Fagerberg's (1988) index (TL_k).	+		Calculation methodology indexes to follow
ltg_{kt}	Technological gap that expresses the growth of the technological competitiveness of a country relative to other countries in the sample, based on Fagerberg's (1988) index (TG_k).	–		
inf_{kt}	Prices Index Growth Rate of countries in dollars. Index that reflects the difference in production costs between countries.	–		Inflation, consumer prices (Annual %)

Source: Own elaboration.

Table A2. Results of estimations with panel data using fixed-effects and random-effects

Dependent variable: Gross Domestic Product growth rate acceleration

Variables	Fixed-effects	Random-effects
Technological diffusion	0.0076053	0.12945
	(0.0214702)	(0.0199713)
Technological gap	–0.00000103	–0.0000134
	(0.0000671)	(0.0000630)
Capital accumulation	0.1245635***	0.1146879***
	(0.1074780)	(0.0099792)
Growth rate of world income	–0.1161864	–0.0749299
	(0.1331810)	(0.1281799)
Growth acceleration of world	1.118501***	1.11348***
	0.0915269	(0.8862120)
Inflation differential	0.0002173	–0.0000636
	(0.0036558)	(0.0033491)
Constant	–0.4471892*	–0.4526556**
	(0.2375898)	(0.2302540)
Adjusted R2	0.43	0.43
Hausman test	-	6.38
		(0.3824)
Observations	790	790

Notes: 1/ Standard errors in parentheses. 2/ Statistical significant is denoted as *** 10%, ** 5%, and * 1%.

Source: Own elaboration.