ECONOMIC GROWTH, PRODUCTIVE STRUCTURE AND REAL EXCHANGE RATE: EMPIRICAL EVIDENCES IN PANEL DATA

Luciano F. Gabriel (CEDEPLAR/UFMG)
Frederico Gonzaga Jayme Jr. (CEDEPLAR/UFMG)

ABSTRACT

The main objective of this paper is to investigate empirically the effects of the tradable productive structure and real exchange rate (RER) on the real per capita income growth rate and economic complexity for a diversified sample of countries. It can be highlighted three contributions in the present work. Firstly, taking in account different technological gap levels in dynamic panel models (*diff* GMM) it was found that manufacturing is the prominent tradable sector to achieve greater real per capita income growth rate, independently of the magnitude of the technological gap considered and even taking in accounting the service sector. This fact supports the "engine of growth" hypothesis concerning manufacturing in the developing countries. Secondly, the farther the distance of the countries´ sample in relation to the technological frontier considered, the greater the positive effect of the lagged undervalued RER on the real per capita income growth rate. Finally, the Dumistrescu and Hurlin (2012) causality tests for heterogeneous panel data indicate that the manufacturing share to GDP in developing economies are especially important for the higher level of economic complexity in a mutual causation.

Key words: Economic growth, productive structure, technological gap and real exchange rate.

JEL: F43, O33, L16 and L60.

RESUMO

O principal objetivo do presente artigo é investigar empiricamente os efeitos da estrutura produtiva industrial (manufatureira) e da taxa de câmbio real (RER) sobre a taxa de crescimento real do produto *per capita* e o nível de complexidade econômica para uma amostra diversificada de países. Três contribuições podem ser destacadas no presente trabalho. Primeiramente, considerando-se diferentes níveis do hiato tecnológico em um painel dinâmico (*diff GMM*) constatou-se que a indústria manufatureira é o setor *tradable* fundamental para maiores níveis da taxa de crescimento real do produto *per capita*, independente da magnitude do hiato tecnológico considerado, mesmo quando se considera o setor de serviços, corroborando a hipótese de "*engine of growth*". Outra contribuição do presente trabalho é que quanto maior a distância dos países em relação à fronteira tecnológica, maior o efeito positivo da taxa real de câmbio depreciada defasada em relação à taxa de crescimento real do produto *per capita.* Por fim, vale destacar que os testes de causalidade de Granger de Dumistrescu e Hurlin (2012) para dados em painel indicam que a participação da indústria manufatureira no produto das economias em desenvolvimento é importante para o maior nível de complexidade econômica das mesmas.

Palavras chaves: crescimento econômico, estrutura produtiva, hiato tecnológico e taxa real de câmbio.
JEL: F43, O33, L16 and L60.

INTRODUCTION

The manufacturing central role to economic growth and the technological catching up process are highlighted in Szirmai (2012), Thirlwall (2005), Tregenna (2009), McCombie and Roberts (2002), among others, through stylized facts and empirical analysis. In these studies it is clear that the process of economic growth depends of the productive structure composition and, especially for the developing economies, the industry is the engine of long-term growth[1].

According to Rodrik (2016) manufacturing tends to experience relatively stronger productivity growth and technological progress over the medium to longer term. So, premature deindustrialization blocks off the main way of fast economic convergence in low and middle income countries.

In Rodrik (2009 and 2016) it can be seen that the rapid economic growth of developing economies since the 1960s is associated with the largest transfer of productive resources (labor and capital) to the most modern industries. In this sense, the structural shift toward industrial activities worked as a driver of economic growth.

Szirmai (2012) presents a series of empirical and theoretical arguments about the role of industry as the "engine of growth" in developing economies. Basically, productivity in this economic sector is higher than in agriculture because the transfer of resources from this sector to the industry provides a "structural change bonus". This "bonus" comes as a result of the transfer of work from economic activities with low productivity to high productivity activities. This automatically raises the overall productivity of the economy. However, the pattern of structural change also at some point directs resources to the services sector, given that productivity growth in this sector is usually lower than in the industrial sector, countries begin to experience some "burden" in relation to this structural change.

The manufacturing sector, in particular, offers special opportunities for economies of scale, which are less available in agriculture or in the services sector, according to Szirmai (2012). In addition, the manufacturing sector offers greater opportunities for the advancement of technologies incorporated in the goods and presents greater technological diffusion capacity to other sectors. Part of this dynamic occurs because of the so-called productive linkages and spillover effects, which are stronger within this sector[2].

Felipe Leon-Ledesma, Lanzafame and Strada (2009) used the Kaldorian theoretical framework to analyze the Asian performance from its structural change perspective[3]. According to them the economic growth verified in the panel of countries was strongly associated with the increasing industrial share in the economies studied (Kaldor´s first Law).

More specifically, in Felipe *et al.* (2009) the sector with the greatest economic growth elasticity, after controlling for other variables and exogenous shocks, was the industrial sector as a whole, followed by the services sector and then the activities of the manufacturing industry. The greater elasticity of the industrial sector in relation to the manufacturing sector was due to the forward and backwards linkages of the activities related to electricity and infrastructure economic activities. Moreover, this feature of the industry is based on the fact that the accumulation of capital and technical progress have been stronger in this sector, having important spillovers effects to the rest of the economies in the sample of countries.

---

[1] According to Rodrik (2016) it was the industrialization process that permitted catching up and convergence with the West by non-Western nations, such as Japan in the late 19th century, South Korea, Taiwan and China, among others countries.

[2] In this work industry it is considered the divisions 10-45 of the International Standard Industrial Classification (ISIC) and when referring to the manufacturing industry it is considered the divisions 15-37 of the International Standard Industrial Classification (ISIC).

[3] The authors conducted an analysis for 17 developing countries in Asia for the period 1980 to 2004.

According to this literature the process of economic growth depends on the productive structure composition and at different stages of development certain sectors are dominant in terms of its influence on per capita income growth rate. However, the role of manufacturing as a driver of this growth ("engine of growth") depends of the level of technological gap and the real exchange rate, which influence its competitiveness.

The non-price competitiveness of tradable products depends largely on the technology gap. The greater the distance of one country concerning a technological frontier, the lower tends to be the technological cumulativeness and thus lower the non-price competitiveness. Moreover, the price competitiveness of these products depends on the real exchange rate (RER) level as overvalued exchange rates leads to a progressive reduction in the share of manufacturing industry and induces an increasing transfer of production activities to other countries[4].

In view of this literature, the main objective of this paper is to investigate the effects of the tradable productive structure and the real exchange rate (RER) on the per capita income growth rate and the level of economic complexity for a sample of underdeveloped countries from 1990 to 2011. The level of economic complexity developed by Hausmann and Hidalgo *et al.* (2011) provides empirical support for the Kaldorian grounds, which understands the productive sophistication as one of the important condition for higher levels of per capita income growth rate for developing economies.[5]

As further will be discussed in the next section, despite the empirical evidences and stylized facts regarding the importance and successful development strategies based on the manufacturing sector as engine of growth, there still remains a lack of robust empirical content to present how this sector influences productive sophistication besides economic growth. In order of doing so, it will be tested how economic complexity responds to manufacturing, technological gap, undervalued exchange rate and the per capita income growth rate (besides the interrelationship among these variables in term of causality).

To fulfill the proposed objectives, this article is divided into 6 other sections besides this introduction. Section 2 presents the theoretical background concerning to the relationship between productive structure composition and economic growth. Section 3 presents the data sources and all variables to be used in the next sections. Section 4 presents an analysis through dynamic panel method (GMM) for a sample of 84 countries to analyze the relationship of per capita income growth rate and productive structure (tradable) among different levels of technological gaps and considering the effects of RER. Section 5 presents the Granger causality tests for heterogeneous panels from Dumitresco and Hurlin approach (2012) in a reduced sample (64 countries) taking into account the level of economic complexity as a proxy for productive sophistication. Through this test can be checked more adequately the robustness of the results obtained in the previous section meanwhile it tests the hypothesis of the relationship between manufacturing and the level of production sophistication. Finally, in Section 6 some conclusions are drawn.

2. Productive structure and economic growth

In the early stages of economic development the agricultural sector is dominant both in terms of employment as in the value added share. According as the per capita income growth

[4] See Palma (2005) and Bresser-Pereira (2010), for example, for this process.

[5] It must be highlighted that the tradable sectors considered in this work is the primary sector and the manufacturing industry. This occurs because the hypothesis to be tested in the econometric exercises is concerning the "engine of growth" potential in relation to manufacturing, though, it is considered the service sector in the empirical tests. Many services, such as information and communication technology (ICT) and finance, are highly productive and tradable. Nevertheless, these service industries are typically highly skill-intense and do not present the productive linkages and spillover effects over the economy (mainly in the low and middle-income countries).

the sector with the highest relative share becomes the industrial. Rowthorn and Ramaswamy (1997) highlighted two factors that explain this change: i) the effect of Engel Law, i.e., the proportion of income spent on goods from the agricultural sector declines, while the per capita income increases, causing a change in the pattern of demand for agricultural products toward industrial goods and services and ii) on the supply side, the fast growth of labor productivity in agriculture makes a reduced need for workers, moving them to the services sector, but especially for the industrial sector, in the early stages of industrialization.

This last factor is called by Szirmai and Verspagen (2011 and 2015), Szirmai (2012) and Syrquin (1984 and 1988) of "structural change bonus". This effect is temporary, lasting only while the share of manufacturing industry is increasing. The transfer of resources from manufacturing to the services sector generates a "burden" related to structural change, known in economic literature as Baumol disease (Baumol, 1967), in which, with the growth of the services sector, the income per capita rate of growth tends to decline.

The combined effect of these two factors highlighted by Rowthorn and Ramaswamy (1997) generates a reduction both in absolute terms and in relative terms of employment and value added of the agricultural sector for the industry. After a certain level of economic development the industry declines, i.e., there is a process of deindustrialization.

Rowthorn and Ramaswamy (1997) formalized the economic growth process, in which there is an increase in the industrial sector share in the early stages of economic development and subsequently de-industrialization and transition to an economy where the services sector it is dominant in the later stages. Thus, the authors present formally that "deindustrialization" may occur as a result of successful economic development. Similarly, Rowthorn and Wells (1987) also explain that this process may be related to a higher stage of development where the standard of per capita income is, as a rule, higher.

Kaldor (1966) noticed this phenomenon occur between 1950 from 1965 in the UK economy, which grew more slowly than other advanced economies. The main reason was related to the level of "maturity" of the British economy at the time. This "maturity" was related to the high level of per capita income in the period, the lack of labor reserves in low-productivity sectors (as in agriculture) that could be transferred to the industrial sector. In this context, the economic growth rate was reduced due to the slowdown in the manufacturing industry[6].

The decreasing share of manufacturing in the developed economies was mainly in the late 1960s and throughout the 1970s, as analyzed in Rowthorn and Ramaswamy (1997) and Szirmai (2012). However, it was not linked to a change in terms of the aggregate consumption pattern of the industrial sector to the services sector or the pattern of North-South international trade, but reflected mainly the impact of differential productivity growth (and technological progress) between manufacturing and services. This productivity increased consistently faster in manufacturing. Then, the services sector absorbed a greater proportion of employment just to keep its output rising (Rowthorn and Ramaswamy, 1997, p.12 and Rodrik, 2016, p.3).

According to Szirmai and Verspagen (2011 and 2015) and Szirmai (2012), after the Second World War, industry (and manufacturing, in particular), has emerged as the main economic activity of many developing countries, shaping a new international trade structure and productive specialization. Some developing countries in the period experienced a rapid process of catching up and increasing income, which was linked to the industrialization process that began. This view is in line with the economic growth process in Kaldorian tradition where is in the manufacturing industry that there are more opportunities for capital

[6] So, it is more evident that not only the intrasectoral productivity of the primary sector and services matters for economic growth, but the intersectoral productivity, mainly from manufacturing, which affects the average productivity of the economy.

accumulation, static and dynamic economies of scale, more intense technological progress and spillover effects (Kaldor, 1966 and 1967).

In general, in the case of several Latin American countries, this process of increasing industry share in the economy occurred via of import substitution industrialization (ISI) as a necessary first step to build a local production base, essential for the countries insertion in the international markets. In some Asian countries, such as South Korea, a growth strategy led by exports was persecuted (i.e. export-led strategies). Also, undervalued RER, according to Woo (2004) and Gala (2008), were critical to the highest rates of economic growth observed in Asian countries. Over the past 30 years, while Latin American countries, in general, were focused on an inward industrialization, Asian countries (such as South Korea and Taiwan) pursued a growth strategy led by exports, with heavy incentives for exporters and industry and competitive real exchange rates (Gala, 2008, p.286 and Rodrik, 2006, p.20).

In Latin American countries the decline of industry share in the economy occurred at a level of per capita income much lower. Moreover, over the past decades this process of reduction in the share of manufacturing and industry as a whole in these economies was due to a number of causes such as persistent exchange rate misalignment (overvalued), technological asymmetries (i.e. high technological gap), financial openness and terms of trade appreciation (Palma, 2005 and Bresser-Pereira and Marconi, 2008).[7]

Rodrik (2016, p. 4) points that as these economies opened to trade without a strong comparative advantage in manufacturing, they became net importers, reversing a long process of import substitution industrialization. Besides, most developing countries "imported" deindustrialization from advanced countries as they became exposed to the relative price trends produced in the latter. This decline in the relative prices in the advanced economies put a squeeze on manufacturing in the developing economies, mainly in the countries where the technological gap were greater. The consequences of these processes are the strong reduction in employment and value added share in developing countries.

This reduction in the manufacturing share to GDP in lower levels of economic development in Latin America and others developing economies has long-term consequences in terms of its economic growth potential and reducing technological asymmetries, that is, the chances of technological catching up and income convergence are diminished or unsustainable (falling behind situation). This is because the transfer of resources and labor from manufacturing sectors to lower productivity activities (such as in agriculture and mining) can produce a smaller growth per capita income, as well as a lower level of productive sophistication.

Despite of the empirical evidences and stylized facts above mentioned regarding the importance and successful development strategies based on the manufacturing sector as engine of growth and the negative effects of the premature decrease of its GDP share, there still remains a lack of robust empirical content to present how this sector influences productive sophistication.

Through the economic complexity indicator of Hausmann and Hildalgo *et al.* (2011) it will be possible to test whether the level productive sophistication captured by this indicator is affected by the relative share of manufacturing industry in a diverse sample of developed and developing countries.

The level of complexity of economies is measured in terms of the product composition of their productive structures taking into account the diversity and ubiquity of tradable

[7] For a thorough analysis of the causes of deindustrialisation processes at the international level, see Rowthorn and Coutts (2004) and Palma (2005). Although it is discussed briefly here the "early" deindustrialization, the main focus is on industry (especially the manufacturing) as a dynamic sector (s) and driver (s) of economic growth, as we highlighted in the literature on this subject in this section.

products.[8] The greater the diversity of products that require know-how, technologies and knowledge and lower the ubiquity of these products, the more it tends to be. This variable measures indirectly the level of sophistication of the productive structure of the countries because it considers the ubiquity and diversity of tradable production as dependent on the specialization level and the stock of knowledge.

In the context of this discussion, in section 4 will be empirically investigated the relationship between the per capita income growth rate and the production structure (tradable) considering different levels of technological gap and the effect of the real exchange rate (RER), taking into account a set of control variables through dynamic panels. In section 5 it will be tested the interrelationship between the per capita income growth rate, technological gap, manufacturing, real exchange rate (RER) and economic complexity (used as a proxy for productive sophistication) through Granger causality tests for panel data. Before the empirical estimates in Section 4 and 5, in section 3 are presented the data, sources and the control variables.

3. VARIABLES, SOURCES AND CONTROLS

Given the empirical models to be tested in Sections 4 and 5, where will be taken into account the influence of tradable productive structure on per capita income growth rate, this section will present the variables, sources and control variables for the panel data estimations (broad sample) and Granger causality tests (reduced sample). For the broad sample, the panel estimation is unbalanced, with random missings covering 84 countries (n=84) to 22 years of analysis (t = 22), where 18 are developed countries and 66 are developing countries. For the reduced sample, which includes the economic complexity indicator was used an unbalanced panel with 64 countries, where 47 are developing or emerging countries and 17 developed countries. Appendixs 1 and 2 are presented the countries by name. This reduced sample covers the period 1990-2011.[9] Table 1 (below) presents the abbreviation, a brief description of the variables used in the econometric models and their sources.

Table 1 – Description of the variables used in the models, its measures and sources

Abbreviations	Brief variable description	Source
pibpc	*per capita* GDP in real terms (US$ dollars - 2005)	IMF
tcpibpc	Real per capita GDP growth rate	IMF
vamanu	Manufacturing sector share to GDP (value added , in %) - 15-37 divisions from the *International Standard Industrial Classification* (ISIC)*	WDI- GGDC
vaprim	Primary sector share to GDP (value added , in %) - 1-5 division from *International Standard Industrial Classification* (ISIC)*	WDI- GGDC
vaserv	Services sector share to GDP (value added , in %) - 50-99 divisions from *International Standard Industrial Classification* (ISIC)*	WDI- GGDC
gaptec	Technological gap between countries from Verspargen (1993) methodology	Author´s own elaboration based on PWT 8.0
misxrate	RER adjusted by the Balassa-Samuelson effect according to Rodrik (2008) – undervaluation measure.	Author´s own elaboration based on PWT 8.0

[8] The construction of this indicator is based on international trade data. The justification of Hausmann and Hidalgo *et al.* (2011) for this is that these datas have a standardized classification linking countries to their products. In principle, if countries produce goods that do not export, they are not so specialized in terms of quality and/or lack international competitiveness. Finally, Hausmann and Hidalgo *et al.* (2011) emphasize that this indicator does not take into account non-tradable data due to a limitation of the majority of countries regarding the quantity and quality of the data available.

[9] The random missings were less than 1% in the two samples.

ppp	Purchasing Power Parity (PPP) in relation to GDP of each country measured in US$ units of 2005.	PWT 8.0
xrat	Nominal exchange rate for each country in terms of USA dollars	PWT 8.0
rer	RER adjusted by the Purchasing Power Parity (PPP)	Author´s own elaboration based on PWT 8.0
txinfla	Annual inflation rate (from the *Consumer Price Index* – CPI, for each country)	WDI
fbkf	Gross fixed capital formation as a proportion of annual GDP	WDI
govexp	Government consumption in terms of goods and services in relation to GDP in real terms.	*World Bank*
humank	Percentage of the population of each country in higher education regardless of age.	WDI
ttrade	Terms of trade: index calculated as the percentage ratio of the unit export value index in relation to the unit import value index - base year 2000.	WDI
eci	Hausmann e Hidalgo *et al.* (2011) complexity indicator	MIT

Fonte: Elaboração própria.
Nota: * Revision 3.0 of the *International Standard Industrial Classification* for economic activities of the United Nations Statistics Division (UNSD); Value added is the net product of the economic sector after adding the gross value of the entire product and subtracting the intermediate goods involved in the production process. It was calculated without taking into account deductions for depreciation, depletion and degradation of natural resources. Relative participation (%) calculated at constant prices in terms of 2005 dollars. IMF - *International Monetary Fund*; WDI - *World Development Indicators*; PWT - *Penn World Tables* 8.0 (see Feenstra *et al*., 2015) and MIT - *Massachusetts Institute of Technology*. GGDC - *Groningen Growth and Development Center*.

The use of value added for the tradable and non-tradable sectors is particularly important when working with the industry assumption of “engine of growth”, since the main implications of this sector on growth is captured by its relative share by this measure. According to Tregenna (2009, p.439-441):

i) the effects of the industry on growth through forward and backward linkages are more strongly linked to its economic effect in terms of value added : even if this economic sector lowers its employment share, it can increase the value added share and rise the demand for capital goods and the amount of raw materials in the upstream sector besides promoting incentives to reduce costs in downstream sectors;
ii) the effects of the economies of scale and learning-by-doing (stronger in this sector) on the industry growth in terms of value added and increased production are compatible with lowers employment levels, so the sector can increase its share in terms of value added , without necessarily having a constant or increasing share of workers and as technical progress and innovation are particularly important in this sector it follows that it is also compatible with the expansion of the manufacturing industry in terms of production and value added while reducing the share of workers employed.

The technological gap (*gaptec* or G) is defined following the methodology used by Verspagen (1991), Verspagen (1993), Fagerberg (1994), Fagerberg and Verspagen (2002) and Fagerberg, Srholec and Knell (2007), among others. In this case the technological leader is the United States and its per capita GDP is a proxy for productivity. Thus, the technological gap is measured by the ratio of US per capita GDP compared to other country per capita GDPs, such that $G = (GDPpc_{EUA}/GDPpc_{it})$.

The assumption behind this measure is related to the way the evolutionary approach works with the idea of technological gap. They relate the technological level of each productive system with its innovative activities: a high level of innovative activity means a greater share of “new” products in relation to GDP and a further extension of the use of “new” techniques in the production process. Since these new goods and techniques involve a higher level of prices and productivity, respectively, it follows that countries with higher levels of innovative activities tend to display higher value added per worker or per capita income than others.

From the foregoing context, the technological catching up occurs when the technological gap decreases and can positively influence the per capita income growth rate over the process of income convergence.

The real exchange rate (*misxrate*) was constructed following the methodology proposed by Rodrik (2008). Applying this methodology is possible several comparisons in the relevant literature between panels of countries over time. This variable is essentially the real exchange rate adjusted by the Balassa-Samuelson effect, that is, a real exchange rate adjusted by the relative prices for the tradables sectors in relation to non tradables[10]. So, the *misxrate* variable represents an indicator of undervaluation (*misxrate*).

The variable *misxrate* is calculated from 3 steps. First it is used the nominal exchange rates from the countries ($XRAT_{it}$) and the conversion factor of purchasing power parity (PPP_{it}) to calculate the real exchange rate (RER_{it}):

$$lnRER_{it} = ln(XRAT_{it}/PPP_{it}) \tag{4.1}$$

where the index *i* are the 84 countries in the sample and *t* the time index, which in this work are 22 years (1990-2011). The variables $XRAT_{it}$ and PPP_{it} are expressed in terms of dollars. RER values above one indicate that the value of the national currency is more undervalued than indicated by the purchasing power parity (PPP_{it}). However, the non-tradable sector is also cheaper in poorer countries (through the Balassa-Samuelson effect), which requires an adjustment. Thus, in the second step it takes into account this effect regressing RER_{it} in relation to per capita GDP:

$$lnRER_{it} = \alpha + \beta ln\ (PIBpc_{it}) + f_t + u_{it} \tag{4.2}$$

where f_t is the fixed effect for the period of time and u_{it} is the error term. The panel estimation for fixed effects resulted in a $\hat{\beta}$ of -0.71 (with *t* value of -30.67 and *p* value of 0.00) suggesting that there is a strong and significant influence of the Balassa Samuelson effect (when the income increases by 10% the real exchange rate falls around 7.1%). Using robust estimation of (4.2) and correcting for the problems of the heteroskedastic structure between the panels and “within” autocorrelation $\hat{\beta}$ is -0.21 (*t*=-21.55), with a *p* value of 0.00,

[10] Béla Balassa (1964) and Paul Samuelson (1964), in independent works, presented methods of calculating the exchange misalignment taking into account the tradable and non-tradable sectors of the economies. These authors explain that in richer countries the productivity rate of growth in the industrial sector is higher than in the services sector. With the labor market defining the average level of wage equilibrium among sectors, the price of services tends to be higher (and thus mean wages). Thus, the aggregate price level taking into account these two sectors tends to be higher in the more developed countries, which causes the real exchange rate tend to be overvalued in PPP terms (the reverse is true in developing countries , i.e. lower levels of productivity lead exchange rates to be more depreciated, since relative prices are lower). Thus, the real exchange rate (RER) not adjusted for these differences between the sectors, do not present themselves as valid to measure appreciation/depreciation of real exchange rates. However, when RER is adjusted for the differences between the average level of productivity between sectors, Balassa (1964) and Samuelson (1964) explain that it is possible to make appropriate comparisons. In this context, it is assumed here that the calculation of the real exchange rate of Rodrik (2008) is a good proxy for the behavior of this variable.

i.e. statistically significant and very close to the Balassa Samuelson effect calculated by Rodrik (2008) [11].

Finally, in order to calculate Rodrik (2008)´s $misxrate_{it}$ indicator, it is estimated the following equation:

$$ln(misxrate_{it}) = lnRER_{it} - ln\widehat{RER}_{it} \quad (4.3)$$

Defined this way, the variable $misxrate_{it}$ is comparable between the panels of countries over time. When $misxrate_{it}$ it is above the unit, we have the real exchange rate is set so that the domestically produced goods are relatively cheaper in terms of dollar, that is, the exchange rate is undervalued. Conversely, when $misxrate_{it}$ is below the unit, the real exchange rate is overvalued. This variable is centered at zero, with the overall standard deviation of 0.398664, between standard deviation of 0.3180682 and within standard deviation of 0.2432237 (Chart 1).

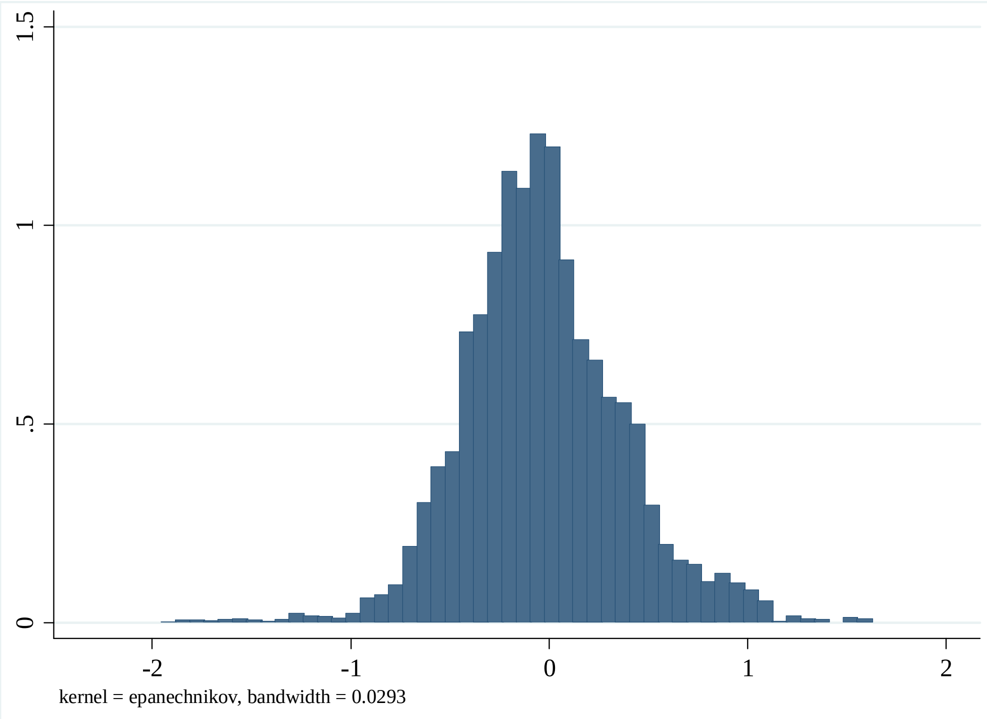
To ensure the robustness of the empirical estimations in section 4, a set of different control variables is used[12]. They are divided between structural and macroeconomic variables. In the latter case it is taken into consideration the inflation rate (*txinfla*), which is a proxy for economic stability, and monetary policy, gross fixed capital formation (*fbkf*), a proxy for the aggregate investment in the economy, and the government consumption share (*govexp*). It is expected a negative sign for *txinfla* and a positive sign for the variable *fbkf*. Regarding the *govexp* is expected a negative sign suggesting that countries with a higher share of government in the final consumption have lower per capita growth rates.

Regarding the structural variables are taking into consideration the human capital through the *humank* variable. This variable must be observed of an evolutionary perspective, i.e., as a proxy for learning ability in a broad sense, including technology. In other words, it is a proxy for human capital at the macroeconomic level. It is expected a positive sign, indicating that the higher learning ability, the greater the impact on the explained variable (income per capita growth rate). The variable *tcpop* captures the effects of the population growth rate on the explanatory variable. In this case, it is expected a negative sign. Finally the *ttrade* variable, which represents the international terms of trade for the sample of countries. It is expected a positive sign for this variable.

[11] Rodrik (2008) found a $\hat{\beta}$ of -0.24 (t = -20), with a p-value of 0.00 for a panel of 188 countries within 1950-2004. However, he used averages of 5 years for its data, conforming subperiods of 11 years. The small difference between these statistics suggests some constancy of the Balassa Samuelson effect over time. Correction for heteroskedasticity and autocorrelation was performed using the generalized least squares method (GLS).

[12] In this case we are following Gala (2006). A comprehensive analysis for potential control variables for the economic growth literature can be seen in Bhalla (2012).

Chart 1 – Density distribution from Epanechnikov Kernel of the $\boldsymbol{misxrate_{it}}$ to the panel of countries



Source: Author´s own elaboration.

4. ECONOMIC GROWTH AND PRODUCTIVE STRUCTURE: A DYNAMIC PANEL ANALYSIS (GMM)

In order to investigate the relationship between per capita income growth rate and the production structure (tradable) it will be used the methodology of dynamic panel which allows to control for individual unobserved characteristics of the sample that affect the dependent variable and the possible endogeneity of independent variables[13].

The estimators for dynamic panels of Arellano and Bond (1991) and Arellano-Bover/ Blundell-Bond (Arellano and Bover 1995; Blundell and Bond, 1998) are efficient estimators called Generalized Method of Moment (GMM) widely used in empirical researches in cases where it is observed, according to Roodman (2009): i) periods (T) smaller than the number of individual units (*n*); ii) linear functions; iii) lagged dynamic variable, i.e., influenced by their own past values; iv) independent variables that are not strictly exogenous and can be correlated with its past values and possibly current realizations of the error term; v) individuals fixed effects; vi) heteroskedasticity and within autocorrelation; vi) some variables can be predetermined, but not strictly exogenous, so that may be influenced by its past values;

[13] According to Greene (2012) endogeneity implies the correlation between the covariates and the error term, that is, $E(X_{it}u_{it}) \neq 0$. As in the dynamic model it will be taking into account the income per capita growth rate lagged effects on the present, the conventional method (OLS) to panel data leads to inconsistent estimates, since this variable is correlated with the error term c_i. The traditional sources of endogeneity are due to dynamic effects such as the cited, simultaneity between variables, omitted variables or measurement errors of variables.

vii) possibility of “internal” instruments, i.e. based on their own lagged variables or “external” instruments. [14]

Given these estimator´s features and the objectives of this Section, it is used the standard Arellano and Bond (1991) procedure for the dynamic panel data estimation (see Equation 1):

$$tcpibpc_{it} = \beta_0 + \xi tcpibpc_{it-1} + \beta_1 misxrate_{it} + \beta_2 misxrate_{it-1} + \beta_3 gaptec_{it} + \beta_4 vamanu_{it} + \beta_5 vaprim_{it} + \sum_{J=6}^{K} \beta_j Z_{i,tj} + c_i + u_{it} \quad (1)$$

where i=1...,*N*, t=1...,*T*, j=6,...,*K*.. Through this specification it will be tested the relationship of per capita income growth rate in relation to the influence of the productive structure (tradable) at different technological gap levels while it takes into account other relevant variables in the empirical literature on growth that affect the dependent variable, as the RER such as in Rodrik (2008 and 2009, among others), the own technological gap, as it is seen in Verspagen (1993), among others, controlling for other variables.[15] The β_j´s and ξ are the parameters to be estimated, u_{it} is the random disturbance, which captures the unobserved factors on the independent variable and c_i is a random variable that captures the unobserved characteristics or heterogeneity of each country that affects the per capita income growth rate. $Z_{i,tj}$ represents the set of control variables, which for all specification were 6. [16] All variables were considered potentially endogenous and were used until one lag as instrument for each. [17] In addition, we used a robust estimation process for heterocedasticity by the Arellano and Bond robust covariance matrix (robust vce) and Windmeijer (2005) standard errors.

As reported, the estimates of (1) were performed considering different technological gap levels (*gaptec*). For the sample used in this estimates the *gaptec* has an average of 40.28 and a standard deviation of 1.42[18]. It was considered in this econometric exercise that countries at the technological frontier have technological gap less than 1.5 (In Appendix 1 is presented the sample of countries within this criteria). The between standard deviation, i.e., between countries was 57.72, with a minimum of 0.68 and a maximum of 311.78.

Based on the classification criteria of the sample that are not on the technological frontier in relation to the magnitude of the technological gap standard deviations (*between*), it is reported in Table 2 the estimates for the dynamic panel specified in (1) for the sample of 84 countries for until one between standard deviation (“intermediate” technological gap), in the range of two to one between standard deviations (“high” technology gap) and above two between standard deviations (“very high” technology gap). Furthermore, it was estimated in the second column a dynamic panel for the broad sample (see Appendix 1 for the country samples by technological gap).

It can be observed in the Table 2 that the effect of real undervalued RER is positive and significant with a lag for all the technological gap levels considered, increasing their effect on the per capita income growth rate when the technological gap measure is higher (for each group of countries). In other words, the greater effect of undervalued RER on the per capita

---

[14] A potential disadvantage for this class of estimators is that they can easily generate invalid estimates depending on model specifications, as Roodman (2009) explains.

[15] In the Section 2 the reasons for the importance of these variables on economic growth was presented and justified.

[16] The control varibles are *txinfla, humank, govexp, ttrade, fbkf* e *govexp*.

[17] According to Roodman (2009), there is no specific test in the literature for choosing the “optimal” number of instruments, so it is necessary to test the validity of instruments used with tests such as by Sargan (1958) or Hansen (1982).

[18] It must be emphasized that these values are related to the mean and the global standard deviation of the broad sample, that is, without taking into account variations “within”, “between” or “weighted” order.

growth rate is conditional on the technological gap level considered: the farther the sample of countries is related to the technological frontier, the greater the effect of the undervalued RER on per capita income growth rate.

The variable *misxrate* was insignificant statistically without lag in the panel of countries with "high" and "very high" technological gap while was found negative and significant for the broad sample and to "intermediate" technological gap sample. This result suggests that the effect of *misxrate* variable affects only the per capita income growth rate in a non-contemporary way.

The variable related to the manufacturing share to GDP was positive and significant for all levels of technological gap considered as well as in the broad sample. Furthermore, it did not present significant differences in magnitude to the different levels of technological gap. This result suggests that regardless of the technological gap distance of each sample of countries, manufacturing has a positive and significant effect on the per capita income growth rate.

The primary sector share to GDP influences negatively the per capita income growth rate in all technological gap levels considered, but with statistical significance only in the case of "high" and "very high" technological gap. This result implies that even for the sample of countries considered less developed and with higher technological gap the primary sector to GDP does not influence positively the per capita income growth rate.

Table 2 – Dynamic Panel Estimations (*GMM*) – Arellano e Bond (*Diff* GMM – *two step Robust*) with Windmeijer (2005) standard errors - 1990 - 2011

	Tradable				Tradable+non Tradable
tcpibpc	Broad sample	Intermediate Technological Gap	High Technological Gap	Very High Technological Gap	Underdeveloped Countries
l.tcpibpc	-0.0730	-0.105	-0.216	-0.415***	-0.0803
	(-1.24)	(-1.67)	(-1.93)	(-4.65)	(-1.41)
l.misxrate	7.783***	6.307*	7.473**	10.71***	5.742*
	(4.36)	(2.34)	(2.79)	(3.65)	(2.30)
misxrate	-5.142*	-5.419*	-5.301	-3.083	-3.490
	(-2.41)	(-2.25)	(-1.82)	(-1.08)	(1.50)
gaptec	-0.205*	0.0529	-0.269*	-0.191***	-0.145**
	(-2.32)	(0.45)	(-2.49)	(-4.00)	(-2.82)
vaserv					-0.225*
					(-2.37)
vamanu	0.464**	0.559***	0.510**	0.531**	0.275*
	(2.64)	(4.02)	(2.74)	(2.59)	(2.37)
vaprim	-0.0744	-0.121	-0.281***	-0.312***	-0.234*
	(-0.53)	(-0.88)	(-5.87)	(-3.65)	(-2.32)
humank	-0.0516	-0.0485	-0.591	0.0615	-0.0710
	(-0.57)	(-1.46)	(-1.46)	(0.15)	(-1.56)
txinfla	0.00269	0.00139	-0.0610	-0.0958**	0.00143
	(1.07)	(1.03)	(-0.64)	(-3.09)	(0.83)
fbkf	0.304**	0.486***	0.0216	0.206	0.246**
	(2.80)	(6.27)	(0.52)	(1.86)	(2.85)

govexp	-0.344** (-3.05)	-0.319* (-2.09)	0.299*** (3.98)	-0.510** (-2.78)	-0.290 (-1.95)
ttrade	-0.00662 (-0.36)	-0.00443 (-0.34)	0.0469*** (4.04)	-0.0358 (-0.93)	-0.0289* (-2.49)
tcpop	-1.552* (-1.95)	-1.297*** (-3.76)	2.118 (1.01)	-0.520 (-0.35)	-0.987* (-2.41)
_cons	6.585 (0.85)	-10.01 (-1.50)	17.97* (2.22)	49.78** (2.98)	27.15** (2.93)
Arellano and Bond´s test for AR(1) – *A*	z=-3.2730 prob>z 0.0011	z=-2.2968 prob>z 0.0216	z=-1.5004 prob>z 0.1335	z=-1.5756 prob>z 0.1151	z=-4.3226 prob>z 0.0000
Arellano and Bond´s test for AR(2) – *A*	z=-1,1617 prob>z 0.2454	z=-1.5921 prob>z 0.1114	z=-1.0926 prob>z 0.2746	z=-0.46553 prob>z 0.6416	z=-0.63057 prob>z 0.52
Sargan´s test for overidentified restrictions – *B*	chi2(398)=63,5433 Prob>Chi2=1.0000	chi2(64)=48.34217 Prob>Chi2=1.0000	chi2(64)=61.10753 Prob>Chi2=0.5794	chi2(70)=86,67309 Prob>chi2=0.0860	chi2(64)=60.10753 Prob>Chi2=0.5693

Note: The *t* (s) statistics are in brackets; * p<0.05, ** p<0.01, *** p<0.001. In *A* – The null hypothesis: there is no "n" order correlation in the residues. In *B* – The null hypothesis: the model is correctly specified and all overidentifications are correct.
Source: Author´s own elaboration.

Except for the "intermediate" technological gap sample of countries, for all other estimates the technological gap variable has a negative and statistically significantly effect on the per capita income growth rate. Thus, the greater the distance of the relative technological frontier, the lower tends to be the per capita income growth rate.

The *humank* control variable only got the expected sign to the sample of countries with "very high" technological gap, but it was not statistically significant. Likewise, the *txinfla* control variable was negative only in this technological gap level. However, it was significant just in the sample of countries with "very high" technological gap. In relation to *fbkf* control variable, it can be seen that it has the expected sign for all samples, but it was just statistically significant only in the broad sample and in the "intermediate" technological gap sample.

The *govexp* control variable obtained the expected sign and was statistically significant in the broad sample estimations, in the "intermediate" and "high" technological gap sample. However, it did not get the expected sign in the group of countries with "high" technological gap.

For *ttrade* variable, it can be seen that it has a positive sign and is statistically significant only in the case of "high" technological gap. The *tcpop* variable was negative and statistically significant for the countries of "intermediate" technological gap sample of countries, but it was not significant statistically for the broad sample of countries and with "very high" technological gap and had a positive sign in the case of the "high" technological gap sample of countries.

For the dynamic panel data estimation expressed in (1) it was also estimated the productive structure effect on per capita income growth rate taking in account the non-tradable sector (in terms of its value added) for the underdeveloped countries (see Appendix 1 for the countries' groups). As it can be seen the estimates presents manufacturing positively affecting the per capita income. This result was statistically significant. The primary sector and the service sector, both in terms of its value added share to GDP, negatively affect the per capita income growth rate. Similarly to the last estimates in Table 2, the undervalued real exchange rate just affect positively the per capita growth rate in a lagged form. Besides, this effect was statistically significant.

The main hypothesis concerning the negative result about the primary and service sectors in this econometric exercise is because for these sample of countries (underdeveloped) the majority of the activities within these sectors presents lower productivity, value added per worker and lower skilled labor.[19]

The technological gap variable negatively affects the per capita income growth rate (*gaptec* was negative and statistically significant). The control variables *tcpop, fbkf* and *ttrade* were statistically significant. Although, the latter had a different sign than the expected. The variables *govexp*, *txinfla* and *humank* were not statistically significant. Just the former variable presented the expected sign.

The above results support the "engine of growth" hypothesis presented in section 2 for the country sample studied. Besides, it was expected a positive sign for the primary sector parameter at least for the "very high" technological gap sample of countries. However, this was not verified.

In all estimations reported in Table 2 it is not rejected the null hypothesis that overidentified restrictions are valid at the 1% level of significance[20]. Similarly, it does not reject the null hypothesis that there is no autocorrelation for higher order than AR (2).[21] Furthermore, with the two step estimation it was obtained efficient and robust parameters for any standard of heterocedasticity, whereas for the Windmeijer (2005)´s standard errors it was avoided the downward bias for the standard errors in the estimators.

5. Testing for Granger non-causality in heterogeneous panels

In this section it will be applied the Granger non-causality test for heterogeneous panels with fixed coefficients recently proposed by Dumitrescu and Hurlin (2012).[22] By doing it, it will be to tested the interrelationships between the per capita income growth rate, technological gap, manufacturing and economic complexity. As we have seen in the previous section, the manufacturing industry is more important than the primary sector to the per capita income growth rate, even when taking into account different levels of technological gap or the service sector. Now, it will be further investigated the influences/interrelationships (causalities) between these variables. In addition, a relevant question to these tests is whether the productive sophistication and smaller technological gap are the (sole) causes of higher per capita income growth rate or if they are first the results of the positive effects of manufacturing on the sample of economies.

According to Granger (1969) the concept of causality is the capacity of a variable to assist in predicting the behavior of another variable of interest. Therefore, it is the existence of an intertemporal precedence in the explanation of a given variable.

[19] For further analyses of these features in underdeveloped countries within these sectors see Su and Yao (2016), Rodrik (2008, 2009 and 2016) and Marconi (2015).

[20] Whenever there is heteroskedasticity the Sargan (1958) test of overidentifying constraints usually rejects the null hypothesis (which is that they are valid). This means that there may be the presence of heteroscedasticity, poor model specification or even inadequate use of the number of instruments, cf. Roodman (2009). In addition to the Sargan test (1958) there is the Hansen test (1982). The two tests have good asymptotic properties in the absence of heteroscedasticity and autocorrelation, as in the case of the panels estimated in Table 2. However, if the residues present any of these uncorrected problems, the Hansen test (1982) presents superior statistical properties, having only the problem of loss of power when the number of instruments used is high.

[21] According to Cameron and Trivedi (2010), if the residuals of the estimated models are not autocorrelated, they are expected to be in AR (1) but not in higher order, i.e., AR (n>1). If this condition is verified, as in the case of the estimates in Table 2, the null hypothesis of no serial autocorrelation of the residuals is not rejected.

[22] The idea of this test was first exposed by Hurlin (2005) at the LIIIe Annual Congress of the French Economic Association. However, in Hurlin (2005) it can only be observed a general outline of the Dumitrescu and Hurlin (2012) test, where cross-dependency issues are not worked out, as is the case for unbalanced panels. In Hurlin (2005) the asymptotic and semi-asymptotic theory of the test is not formally developed, which is done in Dumistresco and Hurlin (2012) from Monte Carlo simulations.

The Granger causality test (1969) extension to panel data is a fairly recent methodological approach. The Holtz-Eakin, Newey and Rose (1988) and Kónya (2006) methodologies are examples of other possible approaches.

More recently two other approaches have been used for the analysis of causal analysis in panel data and have gained prominence in the empirical literature. In the Kar Nazlioglu and Agir (2011)´s approach is estimated an error correction vector by GMM . However, this method does not control for the potential cross section dependence between the panels, which is made in Dumitrescu and Hurlin (2012). [23]

The Dumitrescu and Hurlin (2012)´s approach generates more efficient estimators even in small samples multivariate models. It can be applied to unbalanced panels allowing different lags order for different cross section units, and thus this approach is more robust than others. Considering two stationary variables *x* and *y* the null and alternative are the following:

$$H_{0:}\ \beta_i = 0\ \ \forall\ i = 1, \dots N \text{ com } \beta_i = \left(\beta_i^{(1)}, \dots, \beta_i^{(K)}\right)' \qquad (2)$$
$$H_{1:}\ \beta_i = 0\ \ \forall i = 1, \dots N_1 \text{ e } \beta_i \neq 0\ \ \forall i = N_1 + 1, N_1 + 2, \dots, N$$

The null hypothesis states that the analyzed causal relationship does not exist for any individual unit panel (N_1) and the alternative hypothesis indicates that for at least one subgroup of countries there is a causal relationship (i.e. $N_1 + 1, N_1 + 2, \dots, N$). Given this methodological construction of Dumistrescu and Hurlin and test (2012), the test is formally called Granger *non*-causality test for heterogeneous panels.

In the context of the application of the Dumistrescu and Hurlin (2012)´s Granger causality test, the following causal interrelationships are presented in the format of linear equations in order to be tested:

$$tcpibpc_{i,t} = \alpha_i + \sum_{k=1}^{K} \gamma_i^{(K)} vamanu_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(K)} eci_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(K)} gaptec_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(K)} misxrate_{i,t-k} + \varepsilon_{i,t} \qquad (3)$$

$$vamanu_{i,t} = \alpha_i + \sum_{k=1}^{K} \gamma_i^{(K)} tcpibpc_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(K)} eci_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(K)} gaptec_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(K)} misxrate_{i,t-k} + \varepsilon_{i,t} \qquad (4)$$

$$eci_{i,t} = \alpha_i + \sum_{k=1}^{K} \gamma_i^{(K)} tcpibpc_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(K)} vamanu_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(K)} gaptec_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(K)} misxrate_{i,t-k} + \varepsilon_{i,t} \qquad (5)$$

$$gaptec_{i,t} = \alpha_i + \sum_{k=1}^{K} \gamma_i^{(K)} tcpibpc_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(K)} vamanu_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(K)} eci_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(K)} misxrate_{i,t-k} + \varepsilon_{i,t} \qquad (6)$$

$$misxrate_{i,t} = \alpha_i + \sum_{k=1}^{K} \gamma_i^{(K)} tcpibpc_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(K)} vamanu_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(K)} eci_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(K)} gaptec_{i,t-k} + \varepsilon_{i,t} \qquad (7)$$

Similarly to what is observed in the research on time series econometric, the presence of unit roots in panel data can lead to spurious econometric relations in the Granger causality tests. In this work it is used the Im Pesaran and Shin (1997) test and the ADF Fisher and PP

[23] In Dumitrescu and Hurlin (2012) the Monte Carlo simulations present that even in conditions of existence of cross section dependence in panel, the results of the test are robust.

Fisher tests versions proposed by Maddala and Wu (1999) and Choi (2001), given the fact that the panel is unbalanced.

As can be seen in Table 3 only g*aptec* is not stationary at 1% significance level. This variable is I (1) integrated, so that it was verified as stationary after the transformation process of the series (at 1% significance) in the three methods employed in order to be used in the Granger causality tests as *dgaptec*.

Table 3 – Panel Data Unit Root Tests – 1990 – 2011

Variable	Method (*)	Statistic	p-value (**)	Result	I order
tcpibpc	Im-Pesaran-Shin – W – stat	-20,1313	0,00	ST	I(0)
	ADF – Fisher χ^2	898,844	0,00	ST	
	PP – Fisher χ^2	1432,72	0,00	ST	
vamanu	Im-Pesaran-Shin – W – stat	-3.98919	0,00	ST	I(0)
	ADF – Fisher χ^2	363,773	0,00	ST	
	PP – Fisher χ^2	293,872	0,00	ST	
misxrate	Im-Pesaran-Shin – W – stat	-1,94446	0,02	ST	I(0)
	ADF – Fisher χ^2	330,332	0,00	ST	
	PP – Fisher χ^2	329,944	0,00	ST	
gaptec	Im-Pesaran-Shin – W – stat	-0,87192	0,20	NST	I(1)
	ADF – Fisher χ^2	361,165	0,00	ST	
	PP – Fisher χ^2	608,03	0,00	ST	
eci	Im-Pesaran-Shin – W – stat	-5,71239	0,00	ST	I(0)
	ADF – Fisher χ^2	298,961	0,00	ST	
	PP – Fisher χ^2	360,412	0,00	ST	

Note: (*) Tests considering trend and intercept. The lag selection was chosen according to *Akaike Information Criterion* (AIC). (**) In several cases the *p* value had different numbers than zero only from the third decimal place However, for convenience, we chose to report in the table only two decimal places, which does not detract from the analysis of the existence of a unit root of the series.
Source: Author´s own elaboration.

The optimal number of lags (*K*) for each estimation in the equation system in (3-7) was defined as 2 by the Hanna Quinn criteria information.

In the Tables 6 and 7 are reported the calculations of the Wald statistics, the Zbar[24] statistics and the associated p-value for the samples, 47 countries (Table 4 - sample of developing or emerging countries) and 17 countries (Table 5 – Sample of developed countries) – See Appendix 2 for the sample of countries.

In Table 4 it can be seen that there is a unidirectional causal relationship of the technological gap in relation to the level of economic complexity, per capita income growth rate and the manufacturing share to GDP. Similarly, there is a significant and unidirectional relationship of the economic complexity level towards *misxrate* and a bidirectional relationship between the manufacturing share to GDP and the economic complexity level.

As Table 4 presents there is a bidirectional or simultaneity of the real exchange rate (*misxrate*) and the manufacturing share to GDP and a unidirectional relation between *misxrate* to the per capita growth rate.

It can be observed a statistically significant bidirectional relationship or simultaneity between the manufacturing share to GDP and per capita income growth rates. Similarly, there is a bidirectional relationship or simultaneity between the manufacturing share to GDP and the economic complexity level.

These results imply that the premature decrease of the manufacturing share to GDP in the developing economies can reduce the level of productive sophistication, hindering the catching up process and the achievement of higher per capita income levels (falling behind situation). Moreover, the productive sophistication and smaller technological gap affect in a

[24] The Zbar statistic corresponds to the normalized statistic considering T fixed, in this case T=22.

bidirectional way the manufacturing share to GDP and in turn, this sector share affects also in a bidirectional way the per capita income growth rate. Therefore, these results suggest that the productive sophistication captured by Hausman and Hidalgo *et al*. (2011), affect the per capita income growth rate through manufacturing.

So, the greater productive sophistication and smaller technological gap are the causes of higher per capita income growth rate but there is a mutual interrelationship between manufacturing and the productive sophistication, as discussed in Section 2 and verified in this section.

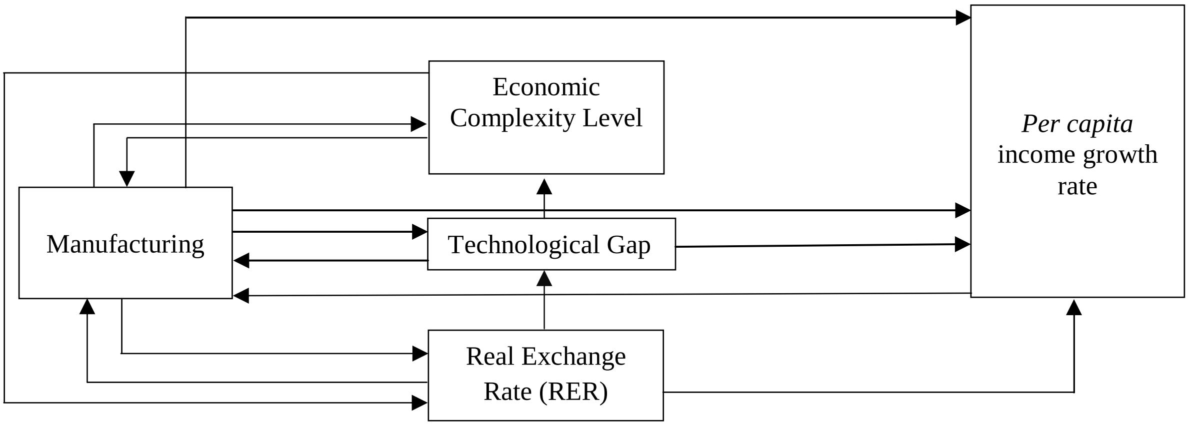
Table 4 - Dumitrescu-Hurlin (2012) Granger Non-Causality Test´s Results for K=2 - Emerging or Developing Countries

Hipótese nula (HNC)* :	W-Stat.	Zbar-Stat.	Prob.
eci → dgaptec	3.03212	1.69364	0.0903
dgaptec → eci	4.06259	4.20979	3.E-05***
misxrate → dgaptec	3.14691	1.97393	0.0484**
dgaptec → misxrate	3.09262	1.84136	0.0656
tcpibpc → dgaptec	2.43346	0.23184	0.8167
dgaptec → tcpibpc	21.5187	46.8334	0.0000***
vamanu → dgaptec	3.40307	2.59942	0.0093***
dgaptec → vamanu	3.85992	3.71492	0.0002***
misxrate → eci	2.78905	1.19534	0.2320
eci → misxrate	3.26031	2.37585	0.0175**
tcpibpc → eci	2.94626	1.58916	0.1120
eci → tcpibpc	2.71862	1.01890	0.3082
vamanu → eci	4.55575	5.65794	2.E-08***
eci → vamanu	3.27737	2.44049	0.0147**
tcpibpc → misxrate	2.82625	1.28851	0.1976
misxrate → tcpibpc	3.54271	3.08326	0.0020***
vamanu → misxrate	4.22611	4.79519	2.E-06***
misxrate →vamanu	5.00871	6.75562	1.E-11***
vamanu → tcpibpc	3.60422	3.23736	0.0012**
tcpibpc → vamanu	3.31266	2.50700	0.0122**

Note: ***, ** Determines the level of significance at 1% and 5%, respectively. * The null hyphotesis: "*does not homogeneously cause*" (HNC).
Source: Author´s own elaboration.

In the diagram 1 it is schematically presented the Granger causality relations results for developing countries (Table 4). It can be seen that the relationship between per capita income growth rate and productive structure has in the manufacturing an important mechanism for catching up (i.e. reducing the technological gap) as well as for income convergence.

Diagram 1 – Interelationship between economic growth, manufacturing industry, technological gap and real exchange rate for emerging or developing countries.



Source: Author´s own elaboration.

Table 5 presents the Granger causality tests results for the developed countries sample. Differently from the developing countries results, it can be seen that the technological gap does not precede unidirectionally the level of economic complexity, but it precedes the per capita income growth rate and manufacturing share to GDP.

Table 5 – Dumitrescu-Hurlin (2012) Granger Non-Causality Test´s Results for K=2 - Developed Countries

Hipótese nula (HNC)* :	W-Stat.	Zbar-Stat.	Prob.
eci →dgaptec	2.77802	0.64429	0.5194
dgaptec →eci	2.47591	0.20657	0.8363
misxrate →dgaptec	2.39153	0.08431	0.9328
dgaptec →misxrate	2.77793	0.64415	0.5195
tcpibpc →dgaptec	1.97024	-0.52606	0.5988
dgaptec →tcpibpc	9.97576	11.0726	0.0000***
vamanu →dgaptec	2.50033	0.24195	0.8088
dgaptec →vamanu	6.24219	5.66329	1.E-08***
misxrate → eci	2.04546	-0.38924	0.6971
eci → misxrate	4.18267	2.78310	0.0054**
tcpibpc → eci	2.55254	0.36344	0.7163
eci → tcpibpc	2.44952	0.21052	0.8333
vamanu → eci	2.24962	-0.08620	0.9313
eci → vamanu	3.23175	1.37162	0.1702
tcpibpc → misxrate	3.03894	1.08542	0.2777
misxrate → tcpibpc	3.78911	2.19893	0.0279**
vamanu → misxrate	5.74843	5.10723	3.E-07***
misxrate → vamanu	2.34815	0.06005	0.9521
vamanu →tcpibpc	11.1282	13.0925	0.0000***
tcpibpc → vamanu	5.58742	4.86822	1.E-06***

Note: ***, ** Determines the level of significance at 1% and 5%, respectively. * The null hypothesis: "*does not homogeneously cause*" (HNC).
Source: Author´s own elaboration.

The main similar statistical relationship to that found in developing countries is related to bidirectional or simultaneity concerning the manufacturing share to GDP in relation to per capita income growth rates and the fact that the manufacturing share to GDP temporally precedes the real exchange rate level. This result suggests that even in developed countries the manufacturing industry plays an important role in terms of per capita income growth rate.

It was not verified any causal relationship between manufacturing share to GDP and the economic complexity. Otherwise, the assumption behind this result is that the level of economic complexity in the developed countries sample has come, at least for the most part, from the services sector.

Finally, it can be seen a statistically significant precedence in relation to economic complexity towards the real exchange rate indicator, but not vice versa.

6. CONCLUSIONS

The main objective of this paper was to investigate empirically the effects of the tradable productive structure and real exchange rate (RER) on the real per capita income growth rate and economic complexity for a diversified sample of countries.

According to the Kaldorian approach it can be seen that the increasing returns of scale in the manufacturing industry and its technological spillovers to the rest of the economy are the driving forces behind the positive effects of this sector on the labor productivity dynamics and economic growth. In this sense, the empirical analyzes carried out in this article provided robust results that place the manufacturing industry positively influencing the level of economic complexity (proxy for productive sophistication), the income per capita growth rate and negatively the level of technological gap. In other words, we have found results that corroborate the role of “engine of growth” in this sector and its important role for the process of catching up in the developing countries sample.

Even when considered the non-tradable sector in terms of its value added to GDP, the estimates presented that manufacturing still plays a positive and statistically significant role concerning the per capita income growth rate.

The premature decrease of the manufacturing share to GDP in the developing economies can reduce the level of productive sophistication, hindering the catching up process and the achievement of higher per capita income levels (falling behind situation).

Another important empirical evidence concerns the effect of the undervalued real exchange rate on the income per capita rate of growth. The positive effect of the former to the latter was conditional on the technological gap level considered and it was lagged. The farther the sample of countries considered was in relation to the technological frontier, the greater the effect of the undervalued RER in relation to the income per capita growth rate.

With the reallocation of resources to non-industrial sectors, such as activities linked to commodity production (in the primary sector), where there are decreasing returns to scale, the real appreciation of the RER reduces the total productivity of the economy and the structural change is towards to lower value added goods. Therefore, a structural change that negatively affects manufacturing in developing economies, in particular, reduces the level of technological development and diversity of tradable goods production, negatively affecting the level of productive sophistication (i.e. the level of economic complexity).

Finally, the found results indicates that the real exchange rate is an important economic policy variable to income per capita growth rate and the higher level of economic complexity as well as to the decrease of the technological gap, since it affects manufacturing.

REFERENCES

ARELLANO, M. e BOVER, O. Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics* 68: 29–51. 1995.

ARELLANO, M., e BOND S. Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Review of Economic Studies* 58: 277–297. 1991.
BALASSA, Béla. The Purchasing Power Parity Doctrine: A Reappraisal. *Journal of Political Economy* 72, no. 6: 584-96.
BHALLA, Surjit S. *Devaluing to prosperity: misaligned currencies and their growth consequences.* Peterson Institute for International Economics. *Washington*, DC, August 2012.
BLUNDELL, R., e S. BOND. Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics* 87: 115–143. 1998.
BOND, S. Dynamic panel data models: A guide to micro data methods and practice. *Working Paper CWP09/02,* Cemmap, Institute for Fiscal Studies. Available at http://cemmap.ifs.org.uk/wps/cwp0209.pdf. 2002.
BRESSER-PEREIRA, L.C e MARCONI, N. Existe doença holandesa no Brasil? *Anais do IV Fórum de Economia de São Paulo*, Fundação Getúlio Vargas: São Paulo. 2008.
CAMERON, A. e TRIVEDI P. *Microeconometrics: methods and applications*. Cambridge University Press, 2005.
CHEN, Mei-Yuan Panel. *Unit Root and Cointegration Tests*. Department of Finance National Chung Hsing University. 2013.
CHOI, I. Unit Root Tests for Panel Data. *Journal of International Money and Finance*, 20, p.249-272, 2001.
DUMITRESCU, E.-I. e HURLIN, C. Testing for Granger non-causality in heterogeneous panels. *Economic Modelling* 29 1450–1460. 2012.
FAGERBERG, J. A technology gap approach to why growth rates differ. *Research Policy* 16 87-99. 1987.
FAGERBERG, J. Technology and International Differences in Growth Rates**.** *Journal of Economic Literature*, Vol. 32, No.3., pp. 1147-1175. Sep., 1994.
FAGERBERG, J. e VERSPAGEN, B. Technology-gaps, innovation-diffusion and transformation: an evolutionary interpretation. *Research Policy* 31 **-** 1291–1304. 2002.
FAGERBERG, JAN, SRHOLEC, MARTIN e KNELL, MARK. The Competitiveness of Nations: Why Some Countries Prosper While Others Fall Behind. *World Development* Vol. 35, No. 10, pp. 1595–1620, 2007.
FEENSTRA, Robert C., INKLAAR, Robert e TIMMER, Marcel P. The Next Generation of the Penn World Table. *American Economic Review*, 105(10), 3150-3182. 2015.
GALA, P. *Política cambial e macroeconomia do desenvolvimento.* Tese de Doutorado, São Paulo: FGV-SP, 2006. Disponível em: http://eumed.net/tesis/2007/psosg/> Acesso em 01/02/2015.
GALA, P. Real Exchange rate levels and economic development: theoretical analysis and econometric evidence. *Cambridge Journal Economics*, 32, 273-288. 2008.
GRANGER, C.W.J. Investigating causal relations by econometric models and cross spectral methods, *Econometrica* 37(3); 424-438. 1969.
HANSEN, L. P. Large sample properties of generalized method of moments estimators. *Econometrica.* 50: 1029–1054. 1982.
HAUSMANN, Ricardo, HIDALGO, César A., BUSTOS, Sebastián, COSCIA, Michele, CHUNG, Sarah, JIMENEZ, Juan, SIMOES, Alexander, YILDIRIM, Muhammed A. *The atlas of Economic Complexity – Mapping paths to prosperity.* Puritan Press. 2011
HIDALGO, C., e R. HAUSMANN. The building blocks of economic complexity. *Proceedings of the National Academy of Sciences* 106(26): 10570–10575. 2009.
HOLTZ-EAKIN, D., NEWEY, W. and ROSEN H.S. Estimating vector autoregressions with panel data. *Econometrica* 56, 1371-1396. 1988.
HURLIN, C. Un Test Simple de l'Hypoth_ese de Non Causalit_e dans un Modele de Panel Heterogene, LIIIe annual congress of the French Economic Association 2004, *Revue Economique*, 56(3), 799-809. 2005.
IM, K.S., PESARAN, M.H., e SHIN, Y. *Testing for Unit Roots in Heterogeneous Panels*, manuscript, Department of Applied Economics, University of Cambridge, UK. 1997.
KALDOR, N. *Causes of the slow rate of economic growth of the United Kingdom*, Cambridge: Cambridge University Press, 1966.

KALDOR, N. *Strategic factor in economic development*. Ithaca, NY: New York State School of Industrial and Labour Relations, Cornell University, 1967.
KÓNYA, L. Exports and growth: Granger causality analysis on OECD countries. *Economic Modelling*, 23(6):978–992. 2006.
MCCOMBIE, J. e ROBERTS, M. The role of the balance of payments in economic growth. In: Setterfield, M. (org.). *The Economics of Demand Led-Growth: challenging the supply side vision of the long run*. Edward Elgar: Aldershot, pp. 87-114, 2002.
MADDALA, G. S.; WU, S. Comparative Study of Unit Root Tests with Panel Data and a New Simple Test. *Oxford Bulletin of Economics and Statistics*, 61 (1), p.631-652, 1999.
MARCONI, N. Estrutura Produtiva e desenvolvimento econômico. In: Barbosa, N., Marconi, N. Pinheiro, M.C. and Carvalho, Laura (org). Indústria e Desenvolvimento Produtivo no Brasil. 1ª. Ed. Rio de Janeiro: Elsevier: FGV, 2015.
PALMA, G. Quatro fontes de desindustrialização e um novo conceito de doença holandesa. *Conferência de Industrialização, Desindustrialização e Desenvolvimento*, Federação das Indústrias do Estado de São Paulo, Agosto. 2005.
RODRIK, D. Real Exchange Rate and Economic Growth, *Brookings Papers on Economic Activity*, Fall 2008.
RODRIK, D., *Growth after the Crisis*. Harvard Kennedy School, Cambridge, MA. 2009.
RODRIK, D. Premature Deindustrialization. Journal of Economic Growth. March 2016, Volume 21, Issue 1, pp 1–33.
ROODMAN, D. A Short Note on the Theme of Too Many Instruments, Center for Global Development. *Working Paper* - Number 125, 2007.
ROODMAN, D. How to do xtabond2: An introduction to difference and system GMM in Stata, Number 1, pp. 86–136, Center for Global Development *Working Paper* Number 103, *2006. The Stata Journal*. 2009.
ROWTHORN, Robert e COUTTS, Ken. De-industrialization and the balance of payments in advanced economies. *United Nations Conference on Trade and Development*.no. 170. 2004.
ROWTHORN, Robert e RAMASWAMY, Ramana. Deindustrialization: Causes and Implications. IMF Working Paper.1997.
SARGAN, J. D. The estimation of economic relationships using instrumental variables. *Econometrica* 26: 393–415. 1958.
SU, Dan and YAO, Yang. Manufacturing as the key engine of economic growth for middle-income economies. ADBI Working Paper Series. No. 573, May 2016.
SYRQUIN, M. Patterns of Structural Change. In: H.B. Chenery and T.N. Srinivasan (eds), *Handbook of Development Economics*, Amsterdam: North-Holland, pp. 203-273. 1988.
SYRQUIN, M. Resource Allocation and Productivity Growth, in M. Syrquin, L. Taylor and L.E. Westphal (eds), *Economic Structure and Performance - Essays in Honor of Hollis B. Chenery*, Orlando: Academic Press Inc, pp. 75-101. 1984.
SAMUELSON, P.A. Theoretical Notes on Trade Problems. *Review of Economics and Statistics* 46, no. 2: 145 – 54.
SZIRMAI, A. Industrialisation as an engine of growth in developing countries, 1950-2005. *Structural Change and Economic Dynamics*. 23, 406– 420, 2012.
SZIRMAI, Adam and VERSPAGEN, Bart. Manufacturing and Economic Growth in Developing Countries, 1950-2005. UNU-MERIT. 2011.
SZIRMAI, Adam and VERSPAGEN, Bart Manufacturing and economic growth in developing countries, 1950–2005. Structural Change and Economic Dynamics 34 (2015) 46–59.
THIRLWALL, A, P. A *natureza do crescimento econômico: um referencial alternativo para compreender o desempenho das nações*. Brasília: IPEA, 2005. 112p.
TREGENNA, F. Characterising deindustrialisation: An analysis of changes in manufacturing employment and output internationally. Cambridge Journal of Economics, 33, 433–466. 2009
VERSPAGEN, B., (1991), A New Empirical Approach to Catching Up or Falling Behind, *Structural Change and Economic Dynamics*, vol. 2, pp. 359-380.
VERSPAGEN, B. *Uneven growth between interdependent economies*. London: Averbury. 1993.
WINDMEIJER, F. A finite sample correction for the variance of linear efficient two-step GMM estimators. *Journal of Econometrics* 126: 25–51. 2005.

Appendix 1 – Dynamic panel – countries samples by technological gap

Emerging or underdeveloped countries			Developed Countries
(1) "Intermediate" *G* (i.e. within a standard deviation between)	**(2) "High" *G* (i.e. within one and two standard deviation between)**	**(3) "Very high" *G* (i.e. within two standard deviation *between*)**	**(4) Technological frontier (N=18)**
Argentina, Bolivia, Botswana, Brazil, Bulgaria, Cameroon, Chile, China, Colombia, Costa Rica, Dominican Republic, Ecuador, Egypt Arab Rep., El Salvador, Estonia, Gabon, Georgia, Indonesia, Iran. Islamic Rep., Jordan, Korea. Rep., Latvia, Lithuania, Malaysia, Mauritius, Mexico, Moldova, Mongolia, Morocco, Namibia, Nigeria, Oman, Panama, Paraguay, Philippines, Russian Federation, Senegal, South Africa, Thailand, Trinidad and Tobago, Tunisia ,Turkey, Turkmenistan, Ukraine, Uruguay	Bangladesh, Ghana, India, Kenya, Mali, Mauritania, Pakistan, Sudan, Uzbekistan, Vietnam, Zambia, Zimbabwe	Ethiopia, Guinea, Liberia, Madagascar, Malawi, Mozambique, Tajikistan, Tanzania, e Uganda.	Australia, Austria, Denmark, Finland, France, Germany, Greece, Italy, Japan, Netherlands, New Zealand, Norway, Singapore, Spain, Sweden, Switzerland, United Kingdom, United States.
(N=45 and T=22)	(N=12 and T=22)	(N=9 and T=22).	(N=18 e T=22)
Broad sample (1)+(2)+(3)+(4)			(N=84 and T=22)

Source: Author´s own elaboration.

Appendix 2 –Dumitrescu and Hurlin (2012)´s Causality test samples

Developed Countries	Underdeveloped Countries
United States, Australia, Austria, Denmark, Finland, France, Germany, Italy, Japan, Korea. Rep., Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom, Greece.	Argentina, Bangladesh, Bolivia, Brazil, Cameroon, Chile, China, Colombia, Costa Rica, Dominican Republic, Ecuador, Egypt. Arab Rep., El Salvador, Ethiopia, Ghana, Guinea, India, Indonesia, Jordan, Kenya, Madagascar, Malawi, Malaysia, Mauritania, Mauritius, Mexico, Mongolia, Morocco, Mozambique, Singapore, South Africa, Sudan, Oman, Pakistan, Panama, Philippines, Senegal, Tanzania, Thailand, Trinidad and Tobago, Tunisia, Turkey, Uruguay, Vietnam, Zambia, Zimbabwe.
(N=17 and T=22)	(N=47 and T=22)

Source: Author´s own elaboration based on the WDI (2015)´s classification.