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Real exchange rate, technological catching up and spillovers in a balance-of-payments constrained growth model☆

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Abstract

The main objective of this work is to investigate the theoretical interrelationships between economic growth, the National Innovation System (NIS) and the real exchange rate (RER) in an export-led growth model. Formally, this work presents new changes in the Kaldor–Dixon–Thirlwallís model by the introduction of the RER, the NIS and a function that captures the endogeneity of productivity in the industrial sector. In the short term the equilibrium growth rate depends on the real exchange rate level and of the NIS development, which responds to the size of the technological gap, the public and private investments in R&D in relation to the output growth rate ratio and the absorption capacity for technological spillovers. In the long run, assuming the constancy of all exogenous variables, the convergence of the growth process depends on the output growth elasticity in relation to exports, the price elasticity of exports and the elasticity of productivity growth relative to output growth of the economy in general and to industry, in particular.

JEL classification: E12; O11; C22

Keywords: Economic growth; Exports; Endogeneity of the international trade income elasticities and National Innovation System

Resumo

O objetivo do artigo é aprofundar a investigação das inter-relações teóricas entre crescimento econômico, Sistema Nacional de Inovação (SI) e a taxa de câmbio real em um modelo do tipo *export-led*. Em termos formais propõem-se novas alterações no modelo de Kaldor–Dixon–Thirlwall, a partir da introdução do nível da taxa real de câmbio e do desenvolvimento do SI, o qual passa a responder ao tamanho do hiato tecnológico, a taxa de crescimento dos investimentos públicos e privados em P&D (como proporção da taxa de crescimento do produto) e a capacidade de absorção de *spillover* tecnológicos. Além disso, é levada em consideração no modelo a endogeneidade da produtividade no setor industrial. No curto prazo a taxa de crescimento de equilíbrio depende da taxa de câmbio real e do desenvolvimento do SI. No longo prazo, a convergência do processo de crescimento depende do comportamento da elasticidade do crescimento do produto em relação às exportações, da elasticidade preço das exportações e

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da elasticidade do crescimento da produtividade em relação ao crescimento da produção da economia em geral e da indústria, em particular.

Palavras Chaves: Crescimento Econômico; Exportações; Endogeneidade das Elasticidades e Sistema Nacional de Inovações

1. Introduction

The core argument in the "standard" cumulative causation model is about the existence of feedback processes which reinforces the initial conditions (Veblen, 1915; Myrdal, 1957; Kaldor, 1966, 1970). Kaldor developed the idea of the cumulative growth which can be represented by the Kaldor–Verdoorn Law. His argument was that growth is demand led and, in particular, export led. This theoretical approach is represented by exported-led cumulative causation models (ELCC).

An increase in the exports growth rate has two main effects on the income growth rate. First, it increases the income growth rate through the dynamic Harrod foreign trade multiplier. Second, by relaxing the balance-of-payments constraint. Besides, it permits greater growth of other "autonomous" components of demand. That is, the growth of other supposedly autonomous expenditures is actually endogenous to export growth.

The cumulative mechanism was first formalized by Dixon and Thirlwall (1975a) and the pioneer work of Thirlwall (1979) introduced the standard balance-of-payments-constraint growth model (BPCG).[1] Based on the Kaldor–Dixon–Thirlwall framework it is introduced a new role for the Real Exchange Rate (RER) in the traditional BPCG in this paper.

In the post-Keynesian literature the relationship between the RER and economic growth has been largely neglected. In the traditional BPCG framework changes in the real exchange rate are assumed to be irrelevant for long-term growth, since some empirical evidences present either that price elasticities of exports and imports are low, meaning that the impact of a real exchange rate devaluation on the growth rate of exports and imports is small, or that terms of trade do not show a systematic trend of appreciation or depreciation in the long run (McCombie and Roberts, 2002, p. 92).[2] Notwithstanding, new evidences emphasize the important role of competitive RER in relaxing the balance of payment constraint on growth.

In general, this literature highlights the fact that a competitive and stable level of the RER can spurs investment by means of structural changes which, in turn, affects the balance of payments constraint. Therefore, the exchange rate policy can affect growth, not only due to the short run competitiveness effect, but also because it can provide incentives to investments, as well as to technological development. Indeed, as Missio and Jayme Jr. (2012) and Ferrari et al. (2013) highlighted, the level of RER can affect long run economic growth by means of their endogenous effects on trade income elasticities, besides the changes on short run price elasticities of exports and imports. Similarly, Razmi (2015) has argued that most countries (especially developing/emerging) are better described as small open economies in which exports are constrained by domestic aggregate supply rather than by foreign demand. By this way, the level of the RER does affect BOP-constrained growth, but it affects the capital accumulation and thereby the export supply rather than through effects on export demand (which is infinitely elastic for a small open country).[3]

In this context, the objective of this work is to put effort in the theoretical investigations of the interrelationships between economic growth, NIS and the real exchange rate (RER). In order to do so, it will be formally included in the analysis three new features: (i) the definition of the real exchange rate level according to the difference between the actual real exchange rate in relation to its industrial equilibrium level [as proposed by Bresser-Pereira et al. (2015)]; (ii) the endogeneity of NIS, which starts to respond to the size of the technological gap, the growth rate of public and

[1] Blecker (2013), in special, identify the key theoretical differences between the ELCC and BPCG approaches and evaluate how and to what extent they can be reconciled by representing both in a common analytical framework.

[2] Missio et al. (2014) argument that these analyses do not explore the effects that variations of the real exchange rate might have on capital accumulation and technological innovation. The mechanisms involved are characteristic of developing countries (Rapetti et al., 2012, p. 736).

[3] See also Boggio and Barbieri (2016) to see alternative ways of thinking about the role of the RER level in heterodox open economy growth models.

private investments in R&D (as a proportion of output) and the technological spillover absorption capacity and, finally, (iii) the endogeneity of productivity in the industrial sector.

The model developed in this work depart from the benchmark Kaldor-Thirlwall Dixon-modified model, including the endogeneity hypothesis of international trade income elasticities and changes in the function that captures the endogeneity productivity. Therefore it widens the explanation between productive structure and income elasticities in an effort to integrate different theoretical approaches (especially the post-Keynesian and evolutionary).

By introducing the RER is highlighted, in a theoretical way, the recent empirical findings that emphasize the role of competitive RER in relaxing the balance of payment constraint on growth (Rodrik, 2008; Razmi et al., 2009; Rapetti et al., 2012). Thus, it allows including in BPCG framework a more active role for the maintenance of a competitive and stable exchange rate.

Recently, a great number of new developments have expanded this literature, including the perspective of integration with other approaches (especially with the evolutionary and the institutionalist). Llerena and Lorentz (2004a,b), for example, contribute toward an integrated technology Schumpeterian view with demand effect via Verdoorn Law. On the other hand, Romero et al. (2011) as well as Jayme Jr. and Resende (2009) argue that the degree of development of the National Innovation System (NIS) is a qualitative determinant of a country productive potential, which plays a central role in explaining the demand export income elasticities. Therefore, there are causal relationships between the NIS, the international trade-income elasticities and export competitiveness.

In this context, it is included in the model the endogeneity of the international trade income elasticities to the NIS. An important effort to incorporate technological change into a Dixon–Thirlwall model of export-led growth is found in León-Ledesma (2002). The author made R&D expenditures endogenous in an expanded version of the model. Nevertheless, our analysis innovates by proposing to analyze the role of NIS within the BPCG framework by new associations between post-Keynesian and evolutionary approaches (which are specified in Section 4).

It is noteworthy that the impact of NIS and the RER level does not operate exclusively through the international trade elasticities, rather than other channels that could affect growth.[4] That is, it is expected these variables have influence on growth also in other heterodox approaches (e.g., models of cumulative causation, two sector "North-South" models and so on).[5] But, the main effort here is to present more clearly (with a formal model) the causal relationships between NIS and the RER level, the international trade-income elasticities and non-price competitiveness in the BPCG approach.[6] Thus, it is possible to analyze how economic policy decisions (as the investment policy in R&D or as the currency market intervention) affect the rate of growth in long run. In other words, the paper explores a new transmission mechanism which reinforces the important role that the level of the real exchange rate has on growth, in line with the current literature.

The NIS and RER affect the productive structure, which in turn, influences directly the export basket, changing the international trade elasticities. It is noteworthy that despite the precursors authors have theoretically emphasized this relationship, only recently some works have advanced in the explanation (including the construction of formal approaches and the expansion of empirical research) of which mechanisms of transmission act between productive

[4] That is, within the BOP-constrained growth model, a stronger NIS could potentially make a country's exports less price-elastic (i.e., reduce the price elasticity of exports in absolute value), if it means that the country starts to compete on quality and innovation rather than low cost. Also, in the framework of Bresser-Pereira et al. (2015), a stronger NIS could possibly influence the "industrial equilibrium" RER. For example, a country with a strong NIS could potentially be more competitive at a somewhat appreciated RER.

[5] See Razmi (2015).

[6] Clearly, there are in the mainstream approach other ways to put NIS in evidence by a variety of other channels, for example, by augmenting the Solow residual, better employing human capital or increasing the rate of endogenous innovation, etc. However, this paper follows Roberts (2007) which admits that the neoclassical approach to growth is not the only one that exists in macroeconomics. The Kaldorian approach is more appropriate because "this approach sees the growth process as involving *a complex interplay between the supply and demand sides* of an economy with demand often taking the lead. In particular, demand is often able to take the lead because, within limits, it is able to elicit a response from the supply-side of an economy in the form of induced technical progress (. . .)" (Roberts, 2007, p. 620—emphasis added). Besides, scholars such as Dani Rodrik, Ricardo Hausmann, Lant Pritchett, Jonathan Ostry, Andrew Berg (and many others) have contributed with valuable analyses of the factors that do (or do not) make developing and emerging economies converge ("conditional convergence") or which account for growth take-offs and growth sustainability. These scholars have done a great deal of empirical/econometric work, some of which identifies the key roles of (a) export structure and (b) a competitive RER for the convergence process, among other variables.

structure and imports/exports income elasticities (e.g., Araujo and Lima, 2007; Gouvêa and Lima, 2010; Missio and Jayme Jr., 2012).[7]

This paper is organized as follows: Section 2 presents Kaldor–Thirlwall–Dixon model. Section 3 presents new developments of that model by the introduction of the elasticities endogeneity hypothesis and the NIS role. In Section 4 it is presented an extension of the analysis based on new definitions for the real exchange rate and NIS role as well as a function that captures the endogeneity of productivity in the industrial sector. In Section 5 is presented the analysis of long-term stability of the model. Finally, in the last section the concluding remarks are presented.

2. The Kaldor–Dixon–Thirlwall model

Originally, Dixon and Thirlwall (1975a) present a model explaining the differences in the international or inter-regional economic growth. This model is based on the principle of cumulative causation and provides an accurate explanation for the persistence of different growth rates over time.

However, the idea of catching up is not formally introduced, being the productivity the main determinant of the output growth rate. A higher growth rate of productivity improves the competitive position of the country, positively influencing exports and therefore growth rates.

The cumulative causation model was outlined by Kaldor (1966, 1970) and first formalized by Dixon and Thirlwall (1975b). Later, the model was extended based on Thirlwall (1979), including the assumption that growth is restricted by the intertemporal equilibrium of the balance of payments (BOP). Formally, it is possible to describe it by the following equations:

$$y_t = \gamma . x_t, \tag{1}$$

where y_t is the output economic growth rate in the period t, x_t is the exports growth rate and γ is the product growth elasticity in relation to the exports growth rate. This equation describes the assumption of export led growth.

$$x_t = \eta .(p_{dt} - p_{ft} - e_t) + \varepsilon .z_t, \tag{2}$$

where p_{dt} (p_{ft}) is the domestic price growth rate (foreign); x_t is the exports growth rate; e_t represents the nominal exchange rate variation; η is the export price elasticity ($\eta < 0$); ε is the export income elasticity ($\varepsilon > 0$) and z_t is the world income growth rate. This equation represents the export demand, where z_t and p_{ft} are exogenously determined.

$$p_{dt} = w_t - r_t + \tau_t, \tag{3}$$

where w_t is the nominal wage growth rate, r_t is the average work productivity growth rate and τ_t is the mark up growth rate calculated as a margin over work costs. This equation describes domestic goods price growth rate determined by a markup rule.

$$r_t = r_a + \lambda .y_t, \tag{4}$$

where r_a is the work productivity autonomous growth rate, λ is the elasticity of the productivity growth rate in relation to economic growth rate, in other words, the Verdoorn coefficient. With this formulation the equation presents the existence of a regular association between the output growth rate and the productivity growth rate;

$$m_t = \psi .(p_{ft} + e_t - p_{dt}) + \pi . y_t, \tag{5}$$

[7] Araujo and Lima (2007) got a balance-of-payments equilibrium growth rate analogous to Thirlwall's Law from a Pasinettian multi-sectorial macrodynamic framework. The authors call it the Multi-Sectorial Thirlwall's Law, which asserts that a country's *per capita* income growth rate is directly proportional to the growth rate of its exports, with such a proportionality being inversely (directly) related to sectorial income elasticities of demand for imports (exports). Gouvêa and Lima (2010) test the original and the multisectorial version of Thirlwall's Law for a sample of Latin American and Asian countries. The authors found that while the original, aggregate Thirlwall's Law is found to hold for all sample countries but South Korea, the Multi-Sectorial Thirlwall's Law is found to hold for all of them. Following the work of Bhaduri and Marglin (1990), Missio and Jayme Jr. (2012) establish the connections between the accumulation regimes and growth. In this context, RER changes affect the companies spending decision, specially, concerning Research and Development (R&D). In Section 3.1 is presented the Razmi (2015)'s contribution to this literature due the objectives of the present work.

where m_t is the imports growth rate; y_t is the output domestic growth rate in the period t; ψ is the price import elasticity ($\psi < 0$); π is the income import elasticity ($\pi > 0$). This equation describes national demand import.

$$p_{dt} + x_t = p_{ft} + e_t + m_t, \tag{6}$$

this equation describes the trade balance equilibrium.

The Dixon and Thirlwall (1975a) model is given by Eqs. (1)–(4). The fundamental equation expresses the Verdoornís Law, which admits the cumulative and circular growth. In this context, the domestic growth raises work productivity, reducing the domestic price goods, which in turn, takes the economy to higher exports rates.[8]

The model points out Kaldor's arguments about the exports growth rate as well as the increasing return of scale in manufacture sector as the main forces of countries divergent growth rates (Britto and Romero, 2011). In this sense:

> "(...) the fact that the region with the initial advantage will obtain a competitive advantage in the production of goods with a high income elasticity of demand will mean that it will be difficult for other regions to establish the same activities. In models of cumulative causation, this is the essence of the theory of divergence between "centre" and "periphery" and between industrial and agricultural regions. This is also the essence of Kaldor's view that the openig up of trade between regions may create growth differences which are sustained or even widened by the process of trade"—Dixon and Thirlwall (1975a, p. 206).

Substituting Eqs. (2)–(4) in Eq. (1), the domestic growth rate is given by:

$$y_t = \gamma \frac{\left[\eta \left(w_t - r_a + \tau_t - p_{ft} - e_t\right) + \varepsilon.(z_t)\right]}{1 + \gamma\eta\lambda} \tag{7}$$

In Eq. (7), the domestic output growth rate varies positively in relation to the autonomous productivity growth rate, foreign prices growth rate, nominal exchange rate depreciation, world income growth rate and the demand income elasticity for exports. The output economic growth rate varies negatively in relation to nominal wages and the mark up growth rate.[9] Besides, the Verdoornís coefficient (λ) determines the cumulative and circular growth. Nevertheless, its existence is not sufficient to explain countries divergent growth rates, which are related to distinct λ levels, *ceteris paribus*.[10]

It is convenient to observe the long run growth rate (convergent or divergent) behavior in terms of the model stability. In order to do that the exports function are lagged as in Eq. (8):

$$x_t = \eta.(p_{dt-1} - p_{ft-1} - e_t) + \varepsilon.z_{t-1} \tag{8}$$

By the combinations of Eqs. (7), (3), and (4) we have the following general solution:

$$y_t = A(-\gamma\eta\lambda)^t + \gamma \frac{\left[\eta \left(w_t - r_a + \tau_t - p_{ft-1} - e_{t-1}\right) + \varepsilon.(z_{t-1})\right]}{1 + \gamma\eta\lambda} \tag{9}$$

where A is the initial condition.

Eq. (9) demonstrates that the model stability depends on the results of the multiplication between product growth rate elasticity in relation to exports growth, the price elasticity for exports and the Verdoorn's coefficient. If the result is greater than unity, so it will occur a divergent cumulative growth process. Otherwise, the growth rate differences between countries will be constant in time.

It is noteworthy that in the previous model the predicted growth rate has no upper limit. However, as originally presented in Thirlwall (1979), the intertemporal balance of payment equilibrium is this limit. In other words, to

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[8] According to Dixon and Thirlwall (1975a, p. 206) if a country gets an advantage in the production of goods with higher demand income elasticity, which causes a higher growth rate in relation to other countries, the Verdoorn mechanism increases productivity reducing domestic prices, assuming that w_t and τ_t are equal between countries. With smaller domestic prices, the export growth rate rises, as well as the domestic output, in a cumulative and circular process.

[9] It must be noted that the impact of demand price elasticity for exports on output growth is indeterminate, and its net effect will depend on the actual values of other variables and parameters.

[10] According to Dixon and Thirlwall (1975a, p. 211) "In other words, an autonomous shock which raises a region's output is not enough for its growth advantage to be maintained [...] except to the extent that the autonomous shock affects favorably the parameters of the model".

developed countries as well as developing countries, the long run growth rate can be restricted by this condition. By this way it is possible that an economy reaches its limit quite before productive utilization capacity is reached.

Formally, Thirlwall (1979)'s model is given by Eq. (3), (5) and (6). Substituting the two first equations in the last one, it is possible to show the compatible domestic growth with the balance of payment equilibrium:

$$y_t = [(1 + \eta + \psi)(p_{dt} - p_{ft} - e_t) + \varepsilon.(z_t)]/\pi \tag{10}$$

Considering the constancy of the relative prices in the long run, i.e., the terms of trade are neutral, Eq. (10) can be simplified so that Eq. (11) represents the "Thirlwall's Law":

$$y_t = \varepsilon.(z_t)/\pi \tag{11}$$

Eq. (11) presents that export-led growth is restricted by BP. In this case, the larger the income elasticity of demand for imports, the greater the constraint on growth over time. Thus, the importance of the exports growth rate to output growth rate is restated, since it has a dual function.

First, as argued by Kaldor, the operation of external trade multiplier in Harrod (1933) is reflected by the increase in aggregate demand caused by the increase in exports. Second, the increase in exports provides the foreign currency inflow needed to allow the other components of aggregate demand to grow, as the expansion of consumption and aggregate investment will certainly be associated with increasing imports. Thus, even if output growth is derived largely from the dynamics of the internal market, export growth enables the growing requirements of imports without the balance of payments is in deficit (Britto and Romero, 2011).

On the other hand, if the cumulative and circular causation idea is introduced with the impact of endogenous growth productivity in the growth rate of exports – given by Eqs. (4) and (5) – the economy growth rate in the model Kaldor–Dixon–Thirlwal (hereinafter KDT) becomes:

$$y_B = \frac{[(1 + \eta + \psi)(w_t - r_a + \tau_t - p_{ft} - e_t) + \varepsilon.(z_t)]}{\pi + \lambda(1 + \eta + \psi)} \tag{12}$$

Eq. (12) shows that the results of Eq. (10) remain valid. The difference is that the domestic inflation is represented by its components (w_t, τ_t, r_a). An increase in the growth rates of nominal wages and mark-up increases the domestic price and therefore reduces the price competitiveness of domestic products. This implies a reduction in exports (increased imports) and consequently further tightening of external constraint. On the other hand, an increase in the autonomous growth of labor productivity decreases the domestic price, stimulating exports (discouraging imports) and therefore loosening the restrictions imposed by BP.

3. The Kaldor–Dixon–Thirlwall (KDT) model revisited

According to León-Ledesma (2002, p. 202), the KDT model has been extended and tested in different works, such as Amable (1993), Atesoglu (1993), De Benedictis (1998), Targetti and Foti (1997), Thirlwall and Dixon (1979), among others.

León-Ledesma (2002) and Amable (1993) developed export-led post-Keynesian models in which the Kaldor–Verdoorn law was extended to some indicator of technological progress. In these works depending on the cumulative causation mechanisms in relation to technological knowledge it can occurs converging or diverging dynamics. In other words, the effects of innovation and catching up are explicitly considered.

These extensions point to two different improvements. The first deals with the allowance for the growth rate differences over time. The second makes explicit references to the non-price factors that determine competitiveness. The innovation and the diffusion of technologies are crucial for catching up.

Besides theses extensions pointed by León-Ledesma (2002), other major developments should be highlighted: the first is a variety of works that highlights the "composition effect", that is, the idea that the sectorial composition of the productive structure of an economy (and especially of its exports) is critical to explain their growth rates compatible with the external constraint (Araujo and Lima, 2007; among others). The main argument of these models is that changes in the composition of demand, which are not reflected in changes in elasticities, but comes from changes in the share of each sector in the aggregate exports or imports affect economic growth.

The second development is largely complementary to the first. It emphasizes the hypothesis of endogeneity of income elasticities of demand for exports and imports. In other words, it proposes to identify what are the variables that could change the magnitude of these elasticities and thus relax the external constraint.

In this context, assuming that elasticities reflect largely the diversity and sophistication of the productive structure of an economy, variables such as the level of the real exchange rate and the degree of development of the National Innovation System are considered able to induce structural changes and bring about changes in these elasticities (Missio and Jayme Jr., 2012).

The model proposed below fits within this approach and presents how the incorporation of these arguments enables a sequential logical reasoning and it complements the economic tradition inaugurated by KDT model with other theoretical approaches, such as evolutionary, for example, helping to improve the theoretical framework of the determinants of growth.

Before the formal presentation, it's emphasized, briefly, the main arguments underlying the two hypotheses to be added to the KDT model: the elasticities endogeneity hypothesis and the role of the National Innovation System.

3.1. The elasticity endogeneinety hypothesi

In the long run, as presented in Thirlwall (2005, p. 69), the only safe solution to raise the growth rate of a country, in line with the intertemporal equilibrium of BP, it is by structural changes in order to increase ε and reduce π. Thirlwall models his approach pointing the direction of causation of elasticities to economic growth. As the author points out, this is the basic premise of all the classic centre-periphery models, as Prebisch (1950), Myrdal (1957), Seers (1962) and Kaldor (1970).

The question becomes, therefore, to understand how differences in elasticities cause different growth rates and, above all, what are the factors to determine it. The hypothesis that the elasticities are endogenous captures this argument. That is, it is assumed that changes in the production structure change the external constraint and therefore policies that promote structural change have effects on growth. In this sense, recently, some researchers have incorporated in this class of models functions that try to capture this endogeneity, proposing, for example, that the income elasticity of demand for imports is a negative function of excess capacity (Palley, 2002).

The rationale for this procedure is the fact that imports are related to “bottlenecks” in the economy. As excess capacity and unemployment decrease, these “bottlenecks” become more relevant and the share of imports as the income increases, reaches new limits. Moreover, McCombie and Roberts (2002) incorporate structural change to the Thirlwall Law by introducing hysteresis in the parameters that determine the long-term rate of growth. In this case, the demand income elasticity is specified as a nonlinear function of the past growth rates.

Botta (2009) admits that the income elasticities of demand for exports (imports) in developing countries are a positive function (negative) of the manufacture share in the domestic economy. In other words, the income elasticity of demand for imports–exports is endogenous, and its evolution depends on the effects of industrialization in developing countries over the pattern of income elasticities of import/exports.

It is assumed also the endogeneity of income elasticities of demand for imports and exports in relation to the level of the real exchange rate (Barbosa-Filho, 2006; Ferrari et al., 2013; Oreiro et al., 2015; Gabriel et al., 2016). According to Missio and Jayme Jr. (2012) this is because maintaining an undervalued real exchange generates incentives for research and innovation via effects on the conditions of self-financing and access to credit, allowing the modernization and diversification of productive capacity. This implies the expansion (decrease) of export capacity (import) in the long term.

Specifically, the authors argue that the income elasticity of demand for exports is a direct function of, among other factors, the number of goods produced by a country and the degree of embedded technology in these goods. Regarding the number of products, changes in the real exchange rate modifies real wages, leading to diversification or specialization of production. This is because when there is an increase in real wages, for example, the sectors that already compete with disadvantages in the international market, given the low technological content embedded in their products, lose market or cease to exist, forcing the economy to specialize in sectors where there are just natural comparative advantages. For developing countries, this means specialization in the production of primary natural products. It turns out that the income elasticity of demand for exports of these products is low, which shows that specialization in these sectors imposes a major constraint to growth with external balance. On the other hand, a reduction in real wages (devaluation) leads to a productive diversification, which in the long term grants a higher capacity to export and less dependence of imports.

Regarding the degree of sophistication of products, Missio and Jayme Jr. (2012) note that the devaluation of the real exchange rate can increase corporate profits and its cash flows and, therefore, changing the availability of funds that they have to investment projects related to research and innovation (R&D).

Although our main focus in this paper is how RER and NIS can modify the income elasticity in a KDT modelís extension, another way to treat the endogeneinety hypothesy can be found in Razmi (2015). To the extent that both supply and demand-side variables determine exports, ignoring one set of factors creates logical and econometric problems such as those involving the treatment of relative prices. According to Razmi (2015) it is better to incorporate both sets of factors in a broader framework and then explore mechanisms that drive external account adjustment.

The author uses an alternative mechanism through which economic growth is achieved where the adjusting role of output is highlighted, while the balance-of-payments constraint is retained. In addition to world demand, Razmi (2015) emphasizes the role of investment in the tradable sector, which determines the growth of exports and hence constrains the rate at which output, relative prices and imports can change.

Generally, the literature indicates that there are three mains ways, not mutually exclusive, to promote a change in trade elasticities: (i) a progressive structural change in the composition of an export profile (*composition effect*); (ii) given an export composition, a technological upgrading in the exports sectors (*sophistication effect*) and, (iii) structural change that involves the creation of new products (*diversification effect*).

Concerning the first factor, considering the aggregated trade elasticities are a weighted average of the different sector elasticities, a change in the share of each sector in an export or import profile could promote a change in the aggregated trade elasticities (Thirlwall, 1997; McCombie and Roberts, 2002; Araujo and Lima, 2007; Gouvêa and Lima, 2010).

The second factor indicates that trade elasticities can change because the economy is benefited by a process of technological upgrading (in a broad sense), as a consequence of the effects of technological diffusion [assimilation and adaptation of new technologies, such as in Garcimartín et al. (2012, p. 199)].

Finally, in relation to the last factor, changes in economic policy affect the range of products that a country produces and exports. That is, according to certain policies (competitive level of the RER, for example), it can be expected of firms to undertake innovative activities that result in greater structural diversification (variety of products).

From these discussion important questions follows: does the more competitive RER really change the elasticities of individual products? Or does it rather lead to structural change, for example, in the form of higher weights on the industries or goods that have higher income elasticities of export demand? In other words, RER really change the elasticities at the industry level, or the weights on the different industries, or both?

The answer to these questions involves recognizing that the real exchange rate level can promote a change in trade elasticities through the three above mentioned ways. Whereas the aggregate elasticities can be considered as a weighted average by sectorial elasticities, then the exchange rate affects the aggregate elasticities because: (i) RER can be an important variable to promote growth through temporary changes, but long enough in the relative prices between tradable and non-tradable goods. That is, the real exchange rate effect on aggregate demand in the short term persists in the long run when it is kept at a stable and competitive level to promote a change in production structure in favor of high tech tradable goods, which have higher income elasticity of demand (composition effect); (ii) the real exchange rate can influence technological progress and thus change the degree of built-in technology products. In this case, the income elasticity associated with each product changes (sophistication effect); and, (iii) changes in the level of real long-term exchange rate modify the amount of goods (sectors) that are presented in the exports and imports baskets because the competitive exchange rate stimulates investments for export as it facilitates access to the foreign market by national companies (diversification effect).

Finally, the time required to carry out this process (change the elasticities) is an empirical question (Eichengreen, 2007). It is likely that these effects vary between countries, given the differences between their production structures.[11] There are also empirical reasons to assume that this effect starts in the short/medium term. A specific way to justify this is to note that, according to some works of the literature about the determinants of technological progress, the variable cash flow and sales, lagged in one period, are the main determinants of investment in R&D (Hall, 1992;

[11] Since the inter and intra sectors are different in each country, as well as the technological development (besides the financial institutional arrangements) the trade income elasticity in every sector respond distinctly to changes in the level of the real exchange rate (Araujo et al., 2013).

Himmelberg and Petersen, 1994; Harhoff, 1998). These variables are directly affected by the RER. Additionally, it must be considered that these investments have a number of features (path dependence, cumulativeness, etc.) that characterize the evolution of technology. This means that in the short/medium term, changes in the real exchange rate level stimulate investment and cause changes in trade income elasticities.

3.2. The National Innovation System (NIS) role

The explanation about the productive structure differences based on evolutionary theory can present others insights on the income elasticities differences (and its evolution), especially in the analysis of the NIS's role. The BOP growth models state that the differences in elasticities come from structural differences. The existence of these differences can be explained, largely, with the aid of evolutionary theory, mainly by analyzing the technological trajectories followed or developed by different countries.

The starting point of this interaction is to understand the concept of NIS. According to Albuquerque (1996, p. 228), the NIS concept refers to "an institutional structure which drives technological development [. . .] creating a *National Innovation System*, enabling the flow of scientific and technological information and knowledge required for the innovation process to take place".

In the evolutionary tradition, National Innovation Systems are needed for the new knowledge and innovation to spread throughout the economy; and innovation systems require the presence of dynamic links between different actors (companies, financial institutions, research/education, public sector resources, intermediary institutions), as well as horizontal links within organizations and institutions (Lundvall, 1992; Freeman, 1995).

In addition, Lundvall (1992) and Freeman (1995) explain that there is a link between the production structure and income elasticities of international trade which can be explained by the complexity of the production chain in the country.[12] Thus, even countries that have made the process of industrialization, continue to suffer from the external constraint on growth. The inspiration for this argument is in the evolutionary literature:

> Country-specific factors are, through various channels, assumed to influence the process of technological change, and thus give the technologies-and the process of technological change-of different countries a distinct "national" flavor ("national technology"; Nelson and Wright, 1992, p. 1935). Thus, as an analytical device, many writers in this area-explicitly or implicitly-view countries as separate (technological) systems, each with its own specific dynamics. Lundvall (1992) and Nelson (1993) both use the concept "national system of innovation" for this purpose (Fagerberg, 1994, p. 1156).

To Fajnzylber (1983) *apud* Jayme Jr. and Resende (2009), the fact of the external constraint to be more effective in developing countries is due to their technological weakness, largely originated in the low level of progress and diffusion of its technological dynamic core, understood as a scientific and technological infrastructure inserted and closely linked to the productive apparatus. The underlying idea is that innovations arising from the technological dynamic core increase the international competitiveness of the productive structure causing the export sector to be benefited from the development of products with higher income elasticity.

In other words, there is a competitive differential (and, therefore, also of income elasticities) among economies specializing in high technology intensive goods and economies specializing in goods with low technological intensity. So:

> "The success of a country in world markets is due to product innovation, namely, developing products for which world demand will rapidly grow. It is unlikely that merely reducing the prices of existing products by squeezing costs and real wages will be a successful long term strategy" and the exogenous paremeters of the standard cumulative causation model are "deeply endogenous" (Setterfield, 1997; McCombie and Roberts, 2002).

To Jayme Jr. and Resende (2009, p. 18) and Resende and Torres (2008), the export value of an economy depends on four characteristics of the markets for exported products. The first concerns the market structure, the second refers to

[12] About the link between the productive structure and trade elasticities: "*Moreover, different commodities and sectors are likely to be associated with different levels of opportunities for innovation and different income elasticities of demand. Hence, the national patterns of technological and production specialization may feedback on the long term dynamism of each economy*" (Dosi et al., 1994, p. 16).

the dynamism of the exported product market and the third to the degree of protection.[13] Finally, the fourth and final factor is that related to the diversification of the productive base of the economy.

In this fourth and last factor its explanation is related to the development of NIS since this system affects the degree of technological sophistication of national production, with effects on its exports through the process of catching up, fundamental to developing economies to be able to achieve technological standards as seen in developed economies.

Thus, the more developed the NIS, the greater the possibility of progress toward the technological frontier of different production sectors of the economy. In this sense, greater tends to be the degree of diversification of the productive system of the economy. This diversification linked to higher technological content mean higher (less) income elasticity of exports (imports).

It is evident, therefore, that the development of the NIS allows for greater technological sophistication in the productive structure, which is reflected in changes on trade income elasticities (higher income elasticity of demand for exports and lower income elasticity of demand for imports), and therefore, the loosening of the external constraint and greater long-term economic growth. That is, the technological intensity of products exported that sustains the positive trade balance over time. So it is established the connection between the evolutionary theory and BOP constraint growth models.

It is noteworthy that although the greater degree of development of the NIS could also affect its growth though making a country's exports less price-elastic (i.e., reducing the price elasticity of exports in absolute value), our main focus in this KDT extension is through its influence on productive structure. The NIS development induces structural changes which will be reflected by a greater diversity and added value in the goods produced in an economy. For this channel, the export income elasticity tends to be greater in relation to the import income elasticity.

4. The Kaldor–Dixon–Thirlwall model modified

Based on the above discussion two modifications are proposed to the KDT model:

i) The first incorporates the hypothesis of endogeneity of income elasticities with respect to the level of the real exchange rate (θ_t) and the degree of the NIS development. Formally, the endogeneity of elasticity is given by:

$$\varepsilon = f(\theta_t, SNI_t)$$

$$\pi = f(\theta_t, SNI_t)$$

in which, for convenience, it is assumed the following functional formula[14]:

$$\varepsilon = \delta_0 + \delta_1\theta_t + \delta_2 SNI_t \quad (13)$$

$$\pi = \alpha_0 + \alpha_1\theta_t + \alpha_2 SNI_t \quad (14)$$

where δ_0 (α_0) is a positive constant and $\delta_2 >, \alpha_2 < 0$. Furthermore, it is assumed that;

$$\partial\varepsilon/\partial\theta_t = \delta_1 > 0 \quad \text{if} \quad \theta_t > \theta_i \quad (15a)$$

$$\partial\varepsilon/\partial\theta_t = \delta_1 < 0 \quad \text{if} \quad \theta_t < \theta_i \quad (15b)$$

$$\partial\pi/\partial\theta_t = \alpha_1 > 0 \quad \text{if} \quad \theta_t < \theta_i \quad (15c)$$

$$\partial\pi/\partial\theta_t = \alpha_1 < 0 \quad \text{if} \quad \theta_t > \theta_i \quad (15d)$$

[13] Regarding market structure Jayme Jr. and Resende (2009) explain that when closer the oligopolistic structure or monopoly is the exports market structure, greater the capacity of the exporting company to fix the prices of their products and, therefore, most likely to be the profitability and revenue of its exports. Regarding the dynamism of the market, the greater the demand growth rate in a market, the greater will be the revenue of exports to this market. With regard to market protection, the less likely the market is subject to protectionist practices, the greater will be the reveneu of exports to this market.

[14] The assumption of linearity in those functions is consistent with existing empirical evidence on the subject Missio et al. (2014).

where θ_t is the currently level of the real exchange rate of the economy and θ_i is industrial equilibrium level, defined as the exchange rate level that would enable efficient producers of manufactured goods to export and preserve their profitability (Bresser-Pereira et al., 2015).[15]

Our case of interest is when $\theta_t > \theta_i$. If θ_t is set in its industrial equilibrium level it means that it is at the level that allows domestic industrial enterprises to operate competitively in the international market with technologies that are at the cutting edge of their economic activity.[16]

Considering the results of Eqs. (15a) and (15d) in Eqs. (13) and (14), it is possible to present more specifically the behavior of interest in this analysis. As can be seen, only when the exchange rate reaches its industrial equilibrium level is that the positive effects on the exports income elasticities, for example, begin to appear. The intuition is that from that level corporate profitability is sufficient to implement their investment projects including those related to research and innovation. Then, this allows for greater complexity of the production structure that, in turn, translates into more productive diversification by country and a greater degree of technology embedded in these products (i.e., high/low income elasticity of exports/imports). Before θ_t reaches the industrial equilibrium level, devaluations are negatively (positively) correlated with the income elasticity of exports (imports) (Eqs. (15b) and (15c)).

In short, the argument is that the level of exchange rate is critical to the profitability of industrial enterprises. However, this is not a sufficient condition for the occurrence of technologies adoption that are at the frontier of knowledge if the economy does not have enough learning ability (or learning capability) to implement.

The ability to learn, first of all, depends directly on the technological distance from the country in relation to the technological frontier (the so-called technological gap). For a given technology gap, this capacity varies depending on the combination of a number of factors, such as education of the workforce, the level of industrialization of the economy and the sectorial composition of the productive structure.

Following the work of Fagerberg (1988) and Verspagen (1993), there is a close relationship between the level of technological development and the level of economic development between different countries and the economic growth rate of a country is positively influenced by the growth rate of investment to reduce the technological gap. Still, the rate at which a country explores the existing possibilities for the technological gap depends on which resources are mobilized for the transformation of its social structure, institutional and economic.

To Abramovitz (1986) the combination of technological gap and social empowerment defines the potential of a country to increase their productivity through the catching up long-term process. According to the author:

> "The pace at which potential for catch-up is actually realized in a particular period depends on factors limiting the diffusion of knowledge, the rate of structural change, the accumulation of capital, and the expansion of demand. The process of catching up tends to be self-limiting, but the strength of the tendency may be weakened or overcome, at least for limited periods, by advantages connected with the convergence of production patterns as followers advance towards leaders or by an endogenous enlargement of social capabilities." (Abramovitz, 1986, p. 390).

In this work the learning capacity of the economy is directly related to the arrangement of the National Innovation System (NIS), which involves investments (public and private) in R&D by companies, universities and research institutes as well as the ability to absorb spillovers. This system reflects in the learning capacity of the economy as in the generation of knowledge itself. Furthermore, it admits the possibility of technological catching up by developing economies.

In the literature of catching up processes countries with low levels of per capita income tend to grow at higher rate, which may eventually lead to convergence over time in relation to developed countries in terms of per capita income and economic growth rates. According to Verspagen:

[15] Empirically the θ_i level can be defined as the ratio of unit labor costs between different economies (Marconi, 2012).

[16] Marconi et al. (2015) conduct an empirical study for 64 countries and 18 years. These authors found evidence that the real exchange rate at its industrial equilibrium level allows countries to expand their exports of manufactured goods, changing its production structure and the composition of its exports, thus relaxing the external constraint on growth, because the elasticity export income tends to increase in relation to the income elasticity of imports. Besides, as we could see in the last section, the development of the NIS allows for greater technological sophistication in the productive structure, which is reflected in changes on trade income elasticities. In other words, the NIS development reinforces the structural change in the economy.

> "In a broader (theoretical) concept, catching up refers to the principle that countries with relatively low technological levels are able to exploit a backlog of existing knowledge and therefore attain high productivity growth rates, while countries that operate at (or near to) the technological frontier have fewer opportunities for high productivity growth. Therefore, countries with lower levels of technological knowledge will tend to achieve higher growth rates (. . .) Implicitly, this interpretation of the catching-up hypothesis is based on the intuition that technological change is to some extent a 'public' good, i.e., it can be used 'freely' by countries other than the initial innovator. International knowledge spillovers enable countries with lower technological levels to achieve faster productivity growth." Verspagen (1993, p. 52)—emphasis added.

It is assumed that the learning capacity of the economy depends on the initial stock of knowledge, spending on Research and Development (R&D) and the capacity of spillovers assimilation. Thus, it is assumed that the National Innovation System (NIS) takes the following functional form[17]:

$$NIS_t = \beta_t + e^{\text{R\& D}+\Omega} + e^{\frac{1}{(\text{R\& D}+\Omega-G)}} \tag{16}$$

with $\text{R\& D}+\Omega < G$ e $0 < G < 1$.

Eq. (16) shows that the NIS_t growth is a function of knowledge stock growth such as in Verspagen (1993), which in turn is given by the dynamic learning effects and technological spillover. In other words, the development of NIS depends on exogenous growth rate of the stock of knowledge (β_t) and spillovers assimilation capacity given by the term ($e^{\text{R\& D}+\Omega}$), and the possibility of performing the process of technological catching up ($e^{\frac{1}{(\text{R\& D}+\Omega-G)}}$). G represents the technological frontier and $\text{R\& D}+\Omega-G$ represents the technological gap.

The spillovers assimilation capacity is positively related to the spending on research and development (R&D) and the intrinsic capacity of assimilation of these spillovers (Ω). The parameter (Ω) is the government's policies on education (in a broad sense), infrastructure investment, among others, so that this intrinsic capacity can be increased (or reduced) through State action.[18] When $\Omega = 0$, it is assumed that there is no direct influence of the State in terms of government policies to create the necessary conditions for the occurrence of an increase in the stock of knowledge through spillover effects. That is, it is assumed that the State's role is not limited to the creation of knowledge through universities and national laboratories, but also involves the mobilization of resources to the dissemination of knowledge and innovation across all sectors of the economy (Mazzucato, 2014).

It can be observed that the increase in investment in Research and Innovation has a positive effect on the development of NIS, assuming that the direct effect on learning is greater than the negative effect arising from the reduction of the technological gap (Eq. (16a)).

On the other hand, Eq. (16) explicitly incorporates the possibility of catching up, since the increased technological gap (given by an expansion of technological frontier), has a positive effect on the NIS. In other words, it is being implicitly assumed that countries that are not at the technological frontier can benefit through the spillovers absorption and imitation processes, the so-called advantage of "late comer" (Eq. (16b)). Thus, these economies tend to increase their growth rate counting on the possibility of using technologies already employed by technological leaders (Abramovitz, 1986). Of course, it is considered that the initial stock of knowledge is sufficient to allow these economies to perform such process. So:

$$\frac{\partial SNI_t}{\partial \text{R\&D}} = e^{\text{R\&D}+\Omega} - \frac{1}{(\text{R\&D}+\Omega-G)^2} e^{\frac{1}{(\text{R\&D}+\Omega-G)}} > 0 \tag{16a}$$

$$\frac{\partial SNI_t}{\partial G} = \frac{1}{(\text{R\&D}+\Omega-G)^2} e^{\frac{1}{(\text{R\&D}+\Omega-G)}} > 0 \tag{16b}$$

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[17] Despite its unusual format this function has interesting properties that allow capturing the arguments in mathematical terms without further complications. Their behavior can be observed in Appendix A.

[18] Clearly, it is possible that private operations also improve this intrinsic capacity through investments in infrastructure, for example. However, for developing countries, it is assumed that the State works as the main actor. Furthermore, this NIS functional form tries to capture the idea that it is not only the isolated amount of spending on R&D that matters, but rather the social training and assimilation capacity of its distribution throughout the economy, generally reflecting the crucial role of the State to influence the distribution (Freeman, 1995; Lundvall, 1992).

Furthermore, the specification of Eq. (16) (and its relationship to the Eqs. (13) and (14)) explicitly incorporates into the model how technological factors increase the non-price competitiveness of products. The endogeneity of income elasticities of foreign trade presents this argument.[19] Here is the association between of the post-Keynesian and evolutionary approaches.

For simplicity, we rewrite the Eq. (16) like;

$$NIS_t = \beta_t + e^A + e^{1/H} \tag{16c}$$

where $A = \text{R\&D} + \Omega$ and $H = \text{R\&D} + \Omega - G$. Substituting Eq. (16c) into equations for the elasticities:

$$\varepsilon = \delta_0 + \delta_1\theta_t + \delta_2\left[\beta_t + e^A + e^{1/H}\right] \tag{17}$$

$$\pi = \alpha_0 + \alpha_1\theta_t + \alpha_2\left[\beta_t + e^A + e^{1/H}\right] \tag{18}$$

with $\partial\varepsilon/\partial\text{R\&D}, \partial\varepsilon/\partial\Omega, \partial\varepsilon/\partial G > 0$ and $\partial\pi/\partial\text{R\&D}, \partial\pi/\partial\Omega, \partial\pi/\partial G < 0$.

ii) The second modification admits that productivity is a function also of the industry's share in the economy through the mechanism associated with learning capacity in this sector (Verspagen, 1993). This argument is in line with the Kaldorian and evolutionary literature, which emphasize the fundamental role of industry as an increasing return to scale activity. The latter refers to increasing returns posed by technological progress induced by learning (learning by doing, specifically). According to Verspagen (1993) and Setterfield and Cornwall (2002) in a model where growth is led by demand the development of productive resources can be affected through its influence on the learning by doing process, meanwhile it affects productivity linked to industrial activity. From this, the productivity equation is:

$$r_t = r_a + \lambda y_t + \nu gdp_I \tag{19}$$

where gdp_I represents the industrial share rate of growth (in term of added value).

Eq. (19) also captures the idea that the increases in productivity just come from the structural change associated with the migration process from low-quality activities for high-quality activities, toward the technological sophistication of the economy. For this the construction of a complex and diverse industrial system is fundamental, subject to increasing returns to scale, high synergies and linkages between activities (Reinert, 2010, p. 3). It is also explicit that the productivity dynamics of an economy depend largely on its industry setting. That is, the pattern of productive specialization of an economy is important to understand the productivity-enhancing process. So the productivity increase of an economy depends on its sectorial composition and the type of product that a country is capable of producing.

The gdp_I rate of growth, in turn, is given by:

$$gdp_I = \rho_0 + \rho_1\theta_t + \rho_2 NIS \tag{20}$$

with

$$\partial gdp_I/\partial\theta_t = \rho_1 > 0 \quad \text{if} \quad \theta_t > \theta_i \tag{20a}$$

$$\partial gdp_I/\partial\theta_t = \rho_1 < 0 \quad \text{if} \quad \theta_t < \theta_i \tag{20b}$$

Eq. (20) is a modified version of a similar function proposed by Araujo et al. (2013). Now, is the industrial share rate of growth that is endogenous at RER and additionally it becomes endogenous also to NIS. Following the literature on the Dutch Disease, the appreciation of the real exchange rate affects negatively the competitiveness (and the size) of manufacturing tradable sector (Bresser-Pereira, 2008; Magud and Sosa, 2013). In other words, we

[19] Companies and countries have engaged increasingly in non-price competitiveness. Even if some of them have similar export products or baskets, but use different levels of technology, production techniques or any other factor that produces some sort of product differentiation, the income elasticities of its exported products will not necessarily be the same, because although producing the same goods, consumer markets are not identical, as the dynamic consumption associated with each. In the case of manufacturing enterprises it can be noted that for the most part they are characterized by an oligopolistic market structure in which competition rule is through non-price factors (McCombie and Thirlwall, 1994, pp. 262–300).

are incorporating the idea that the exchange rate level and fluctuations influence the competitiveness of a country in foreign markets, the profitability of various sectors, the composition of aggregate demand and of investments. Therefore, currency appreciation ($\theta_t < \theta_i$) for prolonged periods can increase the relative share of primary goods in exports and of manufactured goods in imports (mainly intermediate goods), possibly leading to regressive specialization in the productive structure and deindustrialization (Marconi, 2012). Besides, the inclusion of the NIS as a determinant of industry participation in the product takes into account the arguments of evolutionary theory and, more specifically, the idea that a country must have an endogenous core of technological dynamism capable of promoting industrialization toward intensive sectors in technology. This is because the industrial sector is important for its learning curves, rapid technical progress, high content of R&D, high barriers to entry, increasing returns to scale, among others, which are fundamental to growth and development.

Replacing Eq. (16c) in to Eq. (20) and the result in Eq. (19):

$$r_t = r_a + \lambda y_t + v\left\{\rho_0 + \rho_1\theta_t + \rho_2\left[\beta_t + e^A + e^{1/H}\right]\right\} \tag{21}$$

In Eq. (21), we have that the productivity of the economy depends on the Verdoorn coefficient and the effects that the dynamics of the real exchange rate have on the industrial share evolution. In addition, when greater the governmental policies on NIS (via R&D and Ω) and higher technological gap – given the economy capacity of catching up − the greater will be the growth rate of productivity.

Thus, the equilibrium rate of economic growth in extended KDT model becomes:

$$y_B = \frac{\varphi\left\{w_t - r_a - v\left[\rho_0 + \rho_1\theta_t + \rho_2\left(\beta_t + e^A + e^{1/H}\right)\right] + \tau_t - p_{ft} - e\right\} + \left\{(\delta_0 + \delta_1\theta_t + \delta_2\left(\beta_t + e^A + e^{1/H}\right)\right\}.(z_t)^{+\alpha_1\theta_t + \alpha_2\left(\beta_t + e^A + e^{1/H}\right)}}{\overbrace{\varpi + \alpha_1\theta_t + \alpha_2\left(\beta_t + e^A + e^{1/H}\right)}} \tag{22}$$

with $\varphi = (1 + \eta + \psi)$ and $\varpi = \lambda\varphi + \alpha_0$.

From Eq. (22), it can be performed comparative static exercises to check the effects of the real exchange rate, in research and development investment, government policies and technological gap in relation to economic growth rate.[20]

a) The real exchange rate effect over economic growth ($\theta_t > \theta_i$)

$$\frac{\partial y_B}{\partial \theta} = \frac{\overbrace{[-\varphi v\rho_1 + \delta_1.z_t]}^{+}\left\{\overbrace{\varpi + \alpha_1\theta_t + \alpha_2 NIS}^{+}\right\}\overbrace{-\alpha_1}^{+}\left\{-\varphi v\left[\overbrace{\rho_0 + \rho_1\theta_t + \rho_2 NIS}^{+}\right]\right\}\overbrace{-\alpha_1}^{+}\left\{\left[\overbrace{\delta_0 + \delta_1\theta_t + \delta_2 NIS}^{+}\right].(z_t)]\right\}}{\{\varpi + \alpha_1\theta_t + \alpha_2 NIS)\}^2} > 0 \tag{23}$$

Eq. (23) shows that a depreciation in the real exchange rate level has positive effects on growth (considering $\theta > \theta_i$ and the existence of the Marshall–Lerner condition). The effect of the real exchange operates on price competitiveness and non-price competitiveness. In the first case, by increasing the growth rate of industrial share and thus productivity, the depreciation of the real exchange rate reduces the price of domestically produced goods. Exports become cheaper and improve the BOP. In the second case, to improve the profitability of companies and promote structural changes toward more intensive sectors in technology (increased spending on investment in research and innovation, which improves the ability to incorporate technological content and diversify exports), the real exchange also improves non-price competitiveness relaxing the external constraint (increase ε and reduction π).

[20] It is considered that the growth rate of wages, mark up, work productivity autonomous growth rate, foreign prices and the nominal exchange rate are zero.

b) The R&D e Ω effect over economic growth

Eq. (24) presents the effects of the spending in R&D and the intrinsic capacity of assimilation of spillovers. In terms of price competitiveness, it is observed that elevations in R&D and Ω improve the learning capacity of the economy, which is reflected in higher productivity and thus higher benefits in terms of international trade. In other words, increasing capacity to assimilate and incorporate technological factors reduces the price of domestic products. It must be noted that an improvement in NIS allows a greater growth rate in the industrial share, which implies better use of dynamic effects from this sector (especially those related to increasing returns to scale and greater dissemination of technical progress).

In terms of non-price competitiveness, the endogeneity of elasticities with respect to the degree of development of NIS captures this effect. Since an increase in R&D and Ω improves NIS and stimulates the increase in the industrial share, there is greater diversity and technology intensity of national production, which implies a reduction (increase) in imports (exports). Moreover, this effect also captures the result of the expected structural change toward productive diversification and greater industry standardization as a result of higher learning capacity of the economy.

$$\frac{\partial y_B}{\partial \mathrm{R\&D}}, \frac{\partial y_B}{\partial \Omega} = \frac{\left\{ \overbrace{[-\varphi\upsilon\rho_2]}^{+} \overbrace{\left(e^A - \frac{1}{(H)^2} e^{1/H}\right)}^{+} + \overbrace{\delta_2}^{+} \overbrace{\left(e^A - \frac{1}{(H)^2} e^{1/H}\right)}^{+} \right\} \left\{ \overbrace{\varpi + \alpha_1\theta_t + \alpha_2\left(\beta_t + e^A + e^{1/H}\right)}^{+} \right\} \overbrace{-\alpha_2}^{+} \left\{ \overbrace{-\varphi\upsilon}^{+} \left\{ \overbrace{\rho_0 + \rho_1\theta_t + \rho_2\left(\beta_t + e^A + e^{1/H}\right)}^{+} \right\} \right\} \overbrace{-\alpha_2}^{+} \left\{ \left[\overbrace{(\delta_0 + \delta_1\theta_t + \delta_2\left(\beta_t + e^A + e^{1/H}\right)}^{+} \right] .(z_t)] \right\}}{\left\{ \varpi + \alpha_1\theta_t + \alpha_2\left(\beta_t + e^A + e^{1/H}\right) \right\}^2} > 0 \quad (24)$$

c) Technology gap effect on economic growth

The result of Eq. (25) presents that an increase in the technological gap, *ceteris paribus*, increases the growth rate of y_b. The higher the technology gap of developing countries in relation to the knowledge frontier, the greater will be the so-called advantage of the "late comers". Obviously, this result should only be kept for countries that have sufficient initial social capacity to undertake catching up. Therefore, countries that manage to get this advantage improve their price competitiveness and non-price competitiveness, allowing them to improve their insertion in international trade and thus loosening the external constraint.

$$\frac{\partial y_B}{\partial G} = \frac{\left\{ \overbrace{[-\varphi\upsilon\rho_2]}^{+}. \overbrace{\left(\frac{1}{(H)^2} e^{1/H}\right)}^{+} + \overbrace{\delta_2}^{+} \overbrace{\left(\frac{1}{(H)^2} e^{1/H}\right)}^{+} \right\} \left\{ \overbrace{\varpi + \alpha_1\theta_t + \alpha_2\left(\beta_t + e^A + e^{1/H}\right)}^{+} \right\} \overbrace{-\alpha_2}^{+} \overbrace{\left(\frac{1}{(H)^2} e^{1/H}\right)}^{+} \left\{ \overbrace{-\varphi\upsilon}^{+} \left\{ \overbrace{\rho_0 + \rho_1\theta_t + \rho_2\left(\beta_t + e^A + e^{1/H}\right)}^{+} \right\} \right\} \overbrace{-\alpha_2}^{+} \overbrace{\left(\frac{1}{(H)^2} e^{1/H}\right)}^{+} \left\{ \left[\overbrace{(\delta_0 + \delta_1\theta_t + \delta_2\left(\beta_t + e^A + e^{1/H}\right)}^{+} \right] .(z_t)] \right\}}{\left\{ \varpi + \alpha_1\theta_t + \alpha_2\left(\beta_t + e^A + e^{1/H}\right) \right\}^2} > 0 \quad (25)$$

Finally, taking into account the modifications developed in the original KDT model, it is convenient to exam the model behavior in terms of its stability in the long run, i.e., the convergence or divergence conditions of the economic growth rate. Using the lagged function of exports and Eqs. (7), (3) and (4) modified by the endogenization of the real exchange rate and the NIS:

$$y_t = A(-\gamma\eta\lambda)^t + \gamma\frac{\{\eta\left[w_t - r_a - vgdp_I + \tau_t - p_{ft-1} - e_{t-1}\right]\}}{1+\gamma\eta\lambda} \tag{26}$$

where:

$$gdp_I = \rho_0 + \rho_1(\theta - \theta_i) + \rho_2\left(\beta_t + e^{\mathrm{R\&D}+\Omega} + ae^{\frac{1}{(\mathrm{R\&D}+\Omega-G)}}\right) \tag{26a}$$

The long term behavior model is similar to the original model Dixon and Thirlwall (1975a), that is, assuming the constancy of all exogenous variables, y_t behavior depends on $\gamma\eta\lambda$ values. As $\eta < 0$, $(-\gamma\eta\lambda)^t > 0$. Thus, the condition for cumulative divergence is that $(-\gamma\eta\lambda)^t > 1$. If $(-\gamma\eta\lambda)^t < 1$, it will occur constant differences in growth rates of y_t.

However, unlike the original model, in this extended version shocks in terms of economic policy (specifically, the exchange rate policy and investment policy in R&D or those related to the intrinsic ability of assimilation of technological spillovers) affect the productivity and therefore the growth rate. In the original Dixon and Thirlwall (1975b) model it is assumed that an exogenous event in a particular country generates stimulus to other countries growth. Given the Verdoorn's law, this higher income growth increases productivity and thus generates new impulses for growth. As not all countries (or regions) experienced the same exogenous shock, economic growth rates diverge over time. In the extended version of the model, in addition to this possibility of exogenous shocks, it is explicitly incorporated the possibility of technological catching up and the effects of increased generation and absorption capacity of technological spillovers, and the role of the level of the real exchange rate. So to occur a change in the level in economic growth rates is necessary that the determinants of gdp_I are such that accelerate productivity gains and structural change, that is, the economy must maintain a real exchange rate depreciated in relation to its industrial equilibrium level and increase the degree of development of the National Innovation System (NIS).

5. Concluding remarks

The objective of this work was to advance in the theoretical investigations of the interrelationships between economic growth, National Innovation System and the real exchange rate. The real exchange rate had positive effects on trade elasticities when its level was higher than the industrial equilibrium exchange rate. Besides, it was specified a function that captures the evolution of the National Innovation System from the technological gap and the rate of change of public and private investment.

It was explicitly incorporated the possibility of technology catching up. In addition, it was demonstrated that the productive structure directly influences the productivity and export pattern, affecting the elasticity of exported and imported goods. In this context, the degree of development of the National Innovation System is a qualitative determinant of the productive potential of a country.

Thus, the economic growth rate is positively related to the real exchange rate (when depreciated), the growth rate of investment in R&D and government policies on education, infrastructure investment, among others, that is, the ability to assimilate spillovers can be increased by the State action. Furthermore, considering that developing countries have an initial capacity to assimilate technological progress and spillovers, higher technological gap can mean greater economic equilibrium growth rate taking into account the external constraint.

In the long run, assuming the constancy of all exogenous variables, the convergence of the growth process depends on the output growth elasticity in relation to exports, the price elasticity of exports and the elasticity of productivity growth over the production growth of the economy in general and to the industry in particular. In other words, to the occurrence of a level change in economic growth rates is required to undertake structural changes to accelerate productivity gains.

Appendix A.

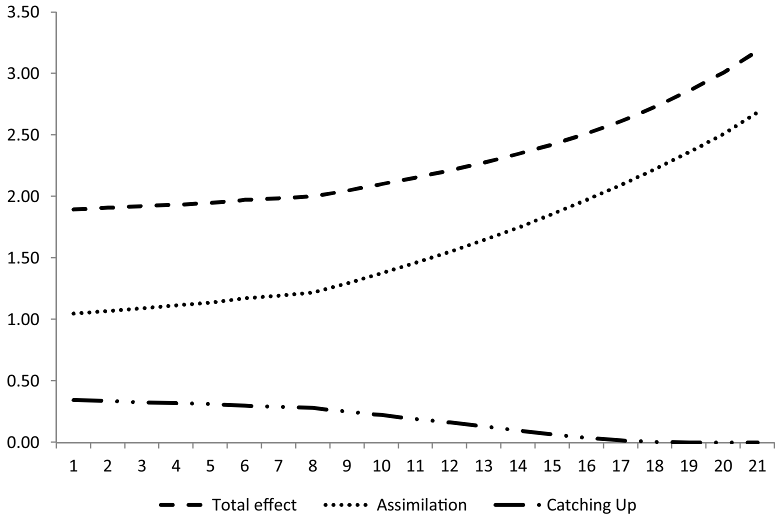

Fig. A1. NIS equation format.

Source: Author's own elaboration.

Table A1
Simulation of Eq. (16) ($G = 0, 99$).

R & D	Ω	Gap	Total effect	Assimilation	Catching up
0,02	0,03	0,94	1,90	1,05	0,35
0,03	0,04	0,92	1,91	1,07	0,34
0,04	0,05	0,9	1,92	1,09	0,33
0,05	0,06	0,88	1,94	1,12	0,32
0,06	0,07	0,86	1,95	1,14	0,31
0,08	0,08	0,83	1,97	1,17	0,30
0,09	0,09	0,81	1,99	1,20	0,29
0,1	0,1	0,79	2,00	1,22	0,28
0,15	0,11	0,73	2,05	1,30	0,25
0,2	0,12	0,67	2,10	1,38	0,22
0,25	0,13	0,61	2,16	1,46	0,19
0,3	0,14	0,55	2,22	1,55	0,16
0,35	0,15	0,49	2,28	1,65	0,13
0,4	0,16	0,43	2,35	1,75	0,10
0,45	0,17	0,37	2,43	1,86	0,07
0,5	0,18	0,31	2,51	1,97	0,04
0,55	0,19	0,25	2,61	2,10	0,02
0,6	0,2	0,19	2,73	2,23	0,01
0,65	0,21	0,13	2,86	2,36	0,00
0,7	0,22	0,07	3,01	2,51	0,00
0,75	0,239	0,001	3,19	2,69	0,00

Source: Author's own elaboration.

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