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CENTRO DE DESENVOLVIMENTO E PLANEJAMENTO REGIONAL

A MODEL OF DEVELOPMENT WITH STRUCTURAL AND TECHNOLOGICAL CHANGE*

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SUMÁRIO

ABSTRACT

The paper proposes a new model of development to describe a process of structural change of a dual economy. By introducing a novel sectoral division of the economic system into a low and a high-tech sector, the model builds on previous formulations and formalizes both a structure and a process of development which encompassing simultaneously the four main constraints to development found in the literature: structural heterogeneity, low capacity to investment and to innovate, balance of payments constraints, and income inequality. In doing so, the construction integrates different strands of the economic literature concerned with development and growth.

Keywords: Dual economies, balance-of-payments constrained growth, income distribution, structural change.

RESUMO

Esse artigo apresenta um novo modelo de desenvolvimento que descreve um processo de mudança estrutural em uma economia dual. Através da introdução de uma nova divisão setorial da economia em um setor de alta e um setor de baixa tecnologia, o modelo apresenta um avanço em relação à literatura existente ao formalizar quatro diferentes restrições ao crescimento econômico: heterogeneidade estrutural, baixa capacidade para o investimento e para inovação, restrição no balanço de pagamentos e desigualdade distributiva. Essas quatro características representam também a intregração de diferentes linhas teóricas da literatura econômica.

Palavras-chave: economias duais, restrição no balanço de pagamentos, distribuição de renda, mudança estrutural.

JEL: L16, O41, O31.

1. INTRODUCTION

Since its inception in the 1940s, development economics has dedicated a great deal of effort to shed light on the key role of capital accumulation and structural change in enabling economic development in backward economies (Rostow, 1958; Nurkse, 1958; Rosenstein-Rodan, 1958). In spite of the myriad of views and aspects stressed by the seminal theories of development, the process can be largely understood as the *structural and institutional changes that allow for continuous productivity growth, resulting in an adequate level of material wealth for most of (if not all) the country's population* (Furtado, 1964; Kuznets, 1958). In its turn, capital accumulation not only reduces employment in low-productivity backward sectors (both agrarian and urban) of peripheral economies due to structural change, but also elevates productivity within sectors, thus bringing up average productivity in the economy and reducing its structural heterogeneity (Lewis, 1958; Furtado, 1964).

Over time, due to the productive specialization that characterizes peripheral economies in face of the high necessity of imports of capital goods, higher rates of industrialization did not lead to the alleviation of balance of payments disequilibria, which in times of low international liquidity have imposed a slower pace of capital accumulation (Prebisch, 1962; 2000b; Thirlwall, 1979; McCombie & Thirlwall, 1994). The continuous dependence on imports coupled with the low rates of exports growth caused by the low diversification of periphery's production made imperative the adoption of state planed industrialization. Moreover, the low ability to invest and innovate of periphery's entrepreneurs provided a further constraint on investment, calling once again for state intervention (Hirschman, 1958).

At first, intervention focused on the so-called import substitution strategy, but soon development economists realized that this process generated a dynamic recreated the need for imports of intermediate goods and machinery in place of consumer goods. Hence, new balance of payments disequilibria would always be verified unless industrialization was coupled with exports growth and productive diversification (Tavares, 1964; Fajnzylber, 1990).

Last but not least, problems stemming from the high-income inequality associated with the process of industrialization were also addressed by ECLAC's authors such as Furtado (1964) and Fajnzylber (1990). On the other hand, although Kaleckian models of income distribution state that different accumulation regimes could theoretically lead to growth if certain conditions were met, tests of those models have not yet been conclusive (Bahduti & Marglin, 1990; Gala, 2007; Hein & Vogel, 2008). Nevertheless, peripheral economies structural and institutional characteristics indicate that those economies would be more often marked by a wage-led regime. Therefore, the negative impacts that income inequality has on market size, innovation and learning have been recently singled out as crucial elements restricting the development of peripheral countries (Albuquerque, 2007).

Hence, in the literature on development economics it is possible to identify four main constraints on the development of peripheral economies: (i) structural heterogeneity; (ii) low private capacity to investment and to innovate; (iii) balance of payments constraint; (iv) income inequality.

In this paper we argue that the fundamental way to overcome those four constraints is by developing an efficient National System of Innovation (NIS) (Nelson, 1993; Freeman, 1995;

Fagerberg, 1994; Albuquerque, 1999). In order to increase and diversify exports it is necessary to improve non-price competitiveness of locally produced goods and services. On its turn, sectors producing goods with high technological content are more prone to the acquisition of higher non-price competitiveness, and therefore present higher income elasticity of demand (Fagerberg, 1988; Gouvêa & Lima, 2010). Thus, increases in the share of the high-tech sector in the economy would contribute to reduce the structural heterogeneity and the balance of payments constraints on growth. The higher growth rates resulting from this process would increase employment, elevating wages and then progressively reducing income inequality. Parallel to this process, investment and innovation supporting institutions would be created and strengthened, continuously improving entrepreneurs' abilities to invest and to innovate. Hence, the four main constraints on development would be gradually surpassed.

To formalize an economic structure and a process of development which encompasses the four constraints to development, the paper builds a new model of a dual economic system. In spite of the length of the model's results, a significant simplification is achieved by the introduction of a few assumptions. Furthermore, although the main focus is placed on the dynamics of underdeveloped economies, the results could be extended to analyze developed economies.

The model is an extension of that presented by Rada (2007) and Ocampo, Rada and Taylor (2009), incorporating central issues for the development of peripheral countries which have not been addressed by the literature in a formal and integrated fashion. Chiefly amongst these issues are the balance of payments constraint, the dynamics of innovation, and the pattern of income distribution, which is incorporated as an endogenous variable.

The model´s main innovation is the proposition of an alternative specification of a dual economy. As structuralist theory has shown, in spite of many advances in terms of living standards have been observed at the periphery, industrialization and urbanization did not lead to the full development of these economies. In other words, industrialization has rendered idle traditional definitions of modern and backward sectors such as agrarian and industrialized or tradable and non-tradable producing sectors.

Alternatively, the proposed model divides the economic system into low and high-technology content producing sectors. In this fashion, the main feature of developing countries, i.e., structural heterogeneity, is still characterized by differences in productivity levels between these two sectors. Here, it is possible to assume a lower productivity in the low-tech sector given that it includes backward, low productivity and informal subsectors (i.e., subsistence and non-mechanized agriculture, mining, and, more importantly, a large array of informal, urban services).

It is important to note that classifying sectors according to the technological content of their production also allows for the incorporation of the non-price characteristics of the goods in foreign markets. Thus, the balance of payments constraint is introduced into the model to illustrate how the sectoral composition of the economy affects the rate of growth compatible with balance of payments equilibrium. Furthermore, the innovation process is included to explain the growth in the high-tech sector. The debate thus shifts from the focus on the production of tradable or non-tradable goods to the discussion of which tradable goods ought to be produced in order to foster development. Hence, this new formulation shows that the construction of an efficient National System of Innovation (NIS) is a key element in a process of structural change that allows such countries to overcome underdevelopment.

A second important improvement concerns the role of income distribution in the model. Unlike the original model, in the new version income inequality is endogenous and influences investment indirectly. Once workers and capitalists present different propensities to consume, changes in the pattern of income distribution have distinct impacts on total and sectoral demands, which will influence investment and growth. Lastly, it is important to emphasize that the model depicts the long term dynamics of an economic system, not taking into account short term fluctuations.

The paper is divided into five sections besides this introduction. In section two we describe the first part of the model, which focuses on structural change and income distribution. In section three we introduce the external constraint on the model. In section four the determinants of innovation are discussed. Finally, section five presents the conclusions of the paper.

2. A MODEL OF STRUCTURAL HETEROGENEITY WITH INCOME DISTRIBUTION

One of the most striking features of underdevelopment is the structural heterogeneity observed in those economies. This feature is represented by the division of the economy into two sectors: one sector produces low-tech goods (LT), using labor as the only input; the other sector produces high-tech goods (HT), using both capital and labor inputs. The product in each sector is given by:

$$(1)\quad P_i Y_i = P_i \varepsilon_i L_i$$

where P_i is the price level of production in each sector $i=LT, HT$, Y_i is the output of each sector, $\varepsilon_i = Y_i / L_i$ is the labor productivity, and L_i is the number of workers. Differentiating (1) and assuming the price level to be fixed[44], we have:

$$(2)\quad y_i = \xi_i + l_i$$

where y_i represents the output growth rate, ξ_i the growth rate of labor productivity, and l_i the rate of employment growth in each sector. Thus, from equation (2) we obtain the growth rate in the high-tech sector (Rada, 2007):

$$(3)\quad y_{HT} = \xi_{HT} + l_{HT}$$

[4] For ease of exposition, and given the model's focus on real variables, prices are considered constant in the same fashion as Ocampo, Rada and Taylor's (2009). Rada (2007) considers short-term price adjustments.

In the low-tech sector workers' remuneration is given according to labor productivity. However, since labor is the only input in the low-tech sector, its output is equal to its wages, i.e., $y_{LT} = w_{LT}$.

(4) $w_{LT} = \xi_{LT} + l_{LT}$

Regarding wages, in the high-tech sector, following the description of Lewis (1958) and Furtado (1964), wages depend on the wages of the low-tech sector, and therefore also on the level of productivity prevailing in that sector. This assumption is justified by the fact that an increase in employment (underemployment) in the low-tech sector promotes a downward pressure on the wage rate of the economy. Wages growth rate in the high-tech sector, therefore, depends on the rate of growth of low-tech wages:

(5) $W_{HT} = P_{HT}\chi\varepsilon_{LT}L_{HT} < \varepsilon_{HT}L_{HT}$

where $\chi > 1$ is a fixed parameter, which indicates a surplus to attract workers to the high-tech sector, coming from the low-tech one (Lewis, 1958)[5].

Differentiating (5) and assuming that the price level is constant we get:

(6) $w_{HT} = \xi_{LT} + l_{HT}$

Hence, from (6) we are brought to examining both the growth dynamics of employment in the high-tech sector and productivity in the low-tech sector. Regarding the growth of employment in the economy as a whole, we have:

(7) $\lambda l_{HT} + (1-\lambda) l_{LT} = n$

where $\lambda = L_{HT} / L$ represents the share of workers in the high-tech sector on the total of the economy, and *n* is the exogenous growth rate of the workforce as a whole.[6] Rearranging terms of equation (7) we obtain:

(8) $l_{LT} = (n - \lambda l_{HT})/(1-\lambda)$

[5] The wage rates of each sector are determined by the productivity of the low-tech one: $\omega_{LT} = P_{LT}\varepsilon_{LT}$, $\omega_{HT} = P_{HT}\chi\varepsilon_{LT}$, where ω_i is the wage rate in each industry.

[6] It is implicitly considered that every worker is employed in one of the two sectors. Thus, in the model we introduce a *virtual* full-employment situation in order to reproduce the same characteristics of Lewis' (1958) subsistence sector. This assumption can also indicate that maintaining full employment is not enough to warrant development.

In (8) then we have the growth rate of employment in the low-tech sector depending on the employment growth rate in the high-tech sector.[77] We shall see later that the rate of employment growth in the high-tech sector depends on the investment in the sector.

In its turn, the rate of productivity growth in the low-tech sector depends positively on the introduction of technological innovations in the sector and negatively on the employment growth rate of this sector:

$$(9)\ \xi_{LT} = \bar{\xi}_{LT} + \alpha_{LT} t_{LT} - \eta l_{LT}.$$

where $\bar{\xi}_{LT}$ is the growth rate of autonomous productivity, t_{LT} is the innovation growth rate in low-tech sector, and l_{LT} is its employment growth rate.[8]

It should be noted that the negative sign in the rate of employment growth in the sector follows the assumption that the low-tech sector is characterized by decreasing returns to scale (Kaldor, 1966) related to structural underemployment, as described for the subsistence sector in Rada's (2007) model.[9]

Substituting (3) in (8), and then (9), we have:

$$(10)\ \xi_{LT} = \bar{\xi}_{LT} + \alpha_{LT} t_{LT} - \eta[\frac{n - \lambda(y_{HT} - \xi_{HT})}{(1-\lambda)}]$$

Equation (10) shows that the rate of productivity growth in the low-tech sector depends positively on the introduction of innovations in the sector, the output growth in the high-tech sector, the share of the labor in the high-tech sector in the total employment of the economy (λ), and negatively on the rate of growth of productivity in the high-tech sector. With an increase in productivity in the high-tech sector the same output can be reached with less labor. These workers are transferred to the low-tech sector, which hinders its productivity due to the diminishing returns to scale.

Nevertheless, to depict the structural heterogeneity it is still necessary to describe what determines the rate of productivity growth in the high-tech sector. Thus one can understand what drives a dynamic reduction of heterogeneity:[10]

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[7] This characteristic of the model stems from the fact that the income elasticity of demand for LT goods is lower than for HT goods. Hence, in the long term the growth of demand for the HT goods drives the growth of that sector, while reducing the LT sector. Therefore, although in reality increases in the LT sector could be promoted by short term increases in commodity prices, in the long run this short term distortions would be counteracted, and the income elasticities would perform the dominant effect.

[8] It could be assumed that the value of η varies according to the stock of employment in the sector, but for simplification we assume here that the parameter is fixed and less than one.

[9] It must be remembered that the low-tech sector includes activities such as mining, subsistence agriculture and informal sectors.

[10] It must be clear that besides the differences in the rates of productivity growth in each sector, in level we have the initial condition that $\varepsilon_{HT} > \varepsilon_{LT}$.

$$(11)\ \xi_{HT} = \bar{\xi}_{HT} + \gamma y_{HT} + \alpha_{HT} t_{HT}$$

Equation (11) represents an extended version of the Kaldorian relationship that indicates the presence of increasing returns to scale in the manufacturing industry, in which the rate of productivity growth in the high-tech sector depends on an autonomous growth ($\bar{\xi}_{HT}$, which could be attributed to organizational changes, among others), the rate of output growth in the sector (y_{HT}) and the rate of growth of technological innovations in the sector (t_{HT}). The parameter γ , therefore, indicates the so-called Verdoorn coefficient, which represents a first channel of cumulative causation within the model.

Regarding income distribution, the rate of growth of the wages in the economy as a whole is given by:

$$(12)\ w = \varphi_{LT} w_{LT} + (1 - \varphi_{LT}) w_{HT}$$

where $\varphi_{LT} = W_{LT} / W$. Substituting (4) and (6) in (12), we obtain:

$$(13)\ w = \varphi_{LT}(\xi_{LT} + l_{LT}) + (1 - \varphi_{LT})[\xi_{LT} + l_{HT}].$$

Substituting the rate of employment growth in the high-tech sector (3) in (13), we have:

$$(14)\ w = \varphi_{LT}(\xi_{LT} + l_{LT}) + (1 - \varphi_{LT})[\xi_{LT} + y_{HT} - \xi_{HT}].$$

Equation (14) shows that the rate of growth of wages in the economy depends positively on the rate of growth of output in the high-tech sector and on the rate of productivity growth in the low-tech sector; and negatively on the rate of productivity growth in the high-tech sector (i.e., it is positively related to the employment level of the high-tech sector).

For the distribution to change, however, it is required that *w* grows faster than *r,* which denotes the rate of growth of profits. Assuming that income is distributed between workers (wages) and capitalists (profits), we have:

$$(15)\ P_{HT} Y_{HT} = P_{HT} R_{HT} + P_{HT} W_{HT}$$

Substituting (5) in (15) we have:

$$(16)\ P_{HT} Y_{HT} = P_{HT} R_{HT} + P_{HT} \chi \varepsilon_{LT} L_{HT}.$$

Differentiating equation (16), assuming that prices are fixed, and rearranging its terms, the rate of growth of profits is given by:

$$(17)\ r_{HT} = \frac{y_{HT} - \psi_{HT}(\xi_{LT} + l_{HT})}{1 - \psi_{HT}}$$

where $\psi_{HT} = W_{HT} / Y_{HT}$. Substituting equation (3) in equation (17) we have:

$$(18)\ r_{HT} = \frac{l_{HT} + \xi_{HT} - \psi_{HT}(\xi_{LT} + l_{HT})}{1 - \psi_{HT}}$$

Equation (18) shows that the rate of growth of profits depends positively on the productivity growth rate and the employment growth rate in the high-tech sector, and negatively on the productivity growth rate in the low-tech sector. Increasing productivity in the later increases the wage rate in both sectors, reducing profits. Employment growth in the high-tech sector also has a negative impact on profit growth, since it raises production costs.

Equation (5) shows that if the output growth rate in the high-tech sector results from increased employment, and not from productivity, then wages will increase. Moreover, the impact of employment growth in the high-tech sector on the productivity in the low-tech sector will be positive if $\xi_{HT} < l_{HT} \geq n / \lambda$, which implies wages growth in both sectors, resulting in further increase of wages.[11] However, to determine if $w > r_{HT}$ one must determine the values of the other parameters of the equations (14) and (18).

Finally, from equation (2) we have that the rate of output growth of the high-tech sector, is determined by its productivity growth rate, i.e., equation (11), and its employment growth rate. Regarding the rate of growth of employment, since the production of the high-tech sector uses both capital and labor as inputs, the number of workers in this sector is associated with the stock of capital:

$$(19)\ K_{HT}{*} = (K_{HT}{*} / K_{HT})(K_{HT} / L_{HT})L_{HT}$$

where K_{HT}* denotes the stock of capital in the economy and K_{HT} is the amount of capital actually used in current production. Thus, differentiating (19) and rearranging its terms we have:

$$(20)\ l_{HT} = i_{HT} - \hat{k}_{HT} - g_{HT}$$

where $\hat{k}$ indicates the rate of growth of the amount of capital per worker, i_{HT} is the investment growth rate, and g_{HT} the growth rate of idle capacity.[12]

Equation (20) highlights, on the one hand, that an increase in the employment growth rate in the high-tech sector can result from higher investment, or lower (negative growth rate) idle capacity or

[11] From equations (10) and (7).

[12] Such a structure carries the assumption that each level of technological development (or machines) implies a fixed capital-labor ratio, i.e., there is no perfect substitution of factors. An alternative is to assume a constant capital-labor ratio and total capacity utilization, so that employment growth in the high-tech sector depends only on increasing investment, which determines the growth rate of capital stock, i.e., : $i_{HT} = l_{HT}$.

capital-labor ratio. On the other hand, higher rates of growth of investment can either result in higher employment, higher capital-labor ratio, or even in higher idle capacity. Thus, by substituting equation (20) in equation (3) we have that $y_{HT} = \xi_{HT} + i_{HT} - \hat{k}_{HT} - g_{HT}$, which shows that investment and capacity utilization ultimately determine the rate of output growth in the high-tech sector.

Considering that the growth rate of idle capacity is inversely related to the growth rates of demand and profit share in income ($r_{HT} - y$), we have: [13]

$$(21)\quad g_{HT} = -\upsilon_1 \mu_{HT} y - \upsilon_2 \mu_{HT} z - \upsilon_3 (r_{HT} - y)$$

where υ_i are proportionality parameters that indicates the magnitude of the response of the idle utilization to changes in demand and profits.

Investment, in its turn, is determined by an autonomous component (i_{HT0}), a component driven by technological innovation that opens up profit opportunities in new markets (t_{HT}), and another two components induced by increases in domestic demand (y) and external demand (z). It is also assumed that both industrial policy (q) and the availability of credit (f) have positive impacts on investment. On the other hand, the existence of idle capacity (g_{HT}) provides a disincentive to investment.[14] Lastly, increases of the share of profits in the income increases the rate of growth of investment
($r_{HT} - y$):[15]

$$(22)\quad i_{HT} = i_{HT0} + \phi_1 \mu_{HT} y + \phi_2 (r_{HT} - y) + \phi_3 \mu_{HT} z + \beta_1 q + \beta_2 t_{HT} + \beta_3 f - \beta_4 g_{HT}$$

where μ_{HT} represents the income elasticity of consumption of high-tech sector's goods for foreign and local markets.[16]

It is important to remark that the introduction of the rate of output growth as a determinant of investment indicates a second channel of cumulative causation (Fagerberg, 1988). The introduction of innovations on the right hand side of equation (22), on its turn, represents its influence on the non-price competitiveness of high-tech goods.

To understand the role played by income distribution, demand is divided to consider impulses coming from profits and wages separately:

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[13] Bhaduri & Marglin (1990) demonstrate that using the rate of profit is equivalent to using the share of profits in the income, once the profit rate derives from the profit share: *r=R/K=(R/Y)(Y/Y*)(Y*/K)*.

[14] One can consider that investment will only be encouraged by demand pushes if idle capacity is near to zero.

[15] The inclusion of this component reflects some short-sightedness of businessmen, who for his investment decision can evaluate both demand and/or profits.

[16] Hein and Vogel (2008) estimate an investment function where *I = f (y, r, i)*, where *i* represents the interest rate, trying to measure the opportunity cost of investment. However, this variable shows no significance. An alternative to capture effects of the money market on investment we include the credit *(f)* in our equation. In the authors' model, *y* represents a proxy for the level of capacity utilization. Regarding the impact of expectations on investment, stressed by post-Keynesian theorists, it is assumed that changes in expectations impact the magnitude of parameters. In estimations with time series changes in expectations can be analyzed by testing for structural breaks.

(23) $y = \psi w + (1-\psi) r_{HT}$

where $\psi = (W_{LT} + W_{HT})/Y$. Substituting (23) and (21) into (22) we have:

(24) $i_{HT} = i_{HT0} + \vartheta_1 w + \vartheta_2 r_{HT} + \vartheta_3 z + \beta_1 q + \beta_2 t_{AT} + \beta_3 f$

where for simplicity, we have $\vartheta_1 = \{[\phi_1 + (\upsilon_1 - \upsilon_3)\beta_4]\mu_{wHT} - \phi_2\}\psi$, $\vartheta_2 = \{[\phi_1 + (\upsilon_1 - \upsilon_3)\beta_4]\mu_{rHT} - \phi_2\}(1-\psi) + \phi_2 + \upsilon_3\beta_4$ and $\vartheta_3 = (\phi_3 + \upsilon_2\beta_4)\mu_{HT}$.

The income elasticities of consumption are different for workers' consumption and capitalists' consumption, i.e., $\mu_{wHT} > \mu_{rHT}$ (Hein and Vogel, 2008). This assumption has some implications. First, growth coupled with better income distribution has greater impact on demand. Secondly, the different income elasticities influence the determination of the pattern of demand in the economy. One can expect that higher workers' demand will lead to a more than proportional increase in demand for less sophisticated goods. This would be a pattern of consumption closer to the profile of domestic production structure of an underdeveloped country. The opposite occurs with increased capitalists' consumption, which consume proportionally more sophisticated goods. Given that not all high-tech goods are locally produced, an increase in imports may occur. A pattern of growth based on increasing income inequality, therefore, worsens balance-of-payments imbalances.

Substituting then (24) in (20):

(25) $l_{HT} = (i_{HT0} + \vartheta_1 w + \vartheta_2 r_{HT} + \vartheta_3 z + \beta_1 t_{HT} + \beta_2 q + \beta_3 f) - \hat{k}_{HT} - g_{HT}$

Equation (25) shows that innovations have an ambiguous impact on the rate of employment growth in the high-tech sector. If the incentive for investment via potential profits is greater than the disincentive on employment by increasing the productive capacity of the machinery (with increased capital-labor ratio), then its impact will be positive. If the opposite is verified, however, the impact of innovations on the employment growth rate in the high-tech sector will be negative.[17]

Moreover, from (25) we note that w_{HT} has a positive effect on investment through its impact on demand (through w) and a negative effect through its impact on the rate of profit.[18] The outcome will depend on the initial distribution of income, the income elasticities of demand of workers and capitalists, and the profit elasticity of investment (ϕ_2).

Supposing an increase in productivity due to an innovation in the low-tech sector, an increase in the wage rate of both sectors would occur, which in turn would lead to a reduction in profits (negative growth). If $\vartheta_1 > \vartheta_2$, wage growth will incentive higher investment. Such a framework

[17] Which is akin the impact of the adoption of labour-saving technologies, as discussed by the structuralist literature

[18] Equation (15).

characterizes what Bhaduri and Marglin (1990) called the *wage-led* growth regime (which may or may not be based on cooperative capitalism: when both wages and profits are growing).[19]

On the other hand, if $\vartheta_1 < \vartheta_2$, then the negative impact of the increased wages on profits will prevail, so that profits growth will be the most important factor in determining investment, which characterizes the *profit-led* regime. Similarly, this scheme may also be cooperative or not, since productivity growth in high-tech sector may or may not be associated with the growth of wages.

Since the rate of growth of wages in the high-tech sector is related to productivity growth in the low-tech sector, the productivity growth in the high-tech sector can be transferred completely to profits (uncooperative *profit-led* regime) unless this increase in productivity is more than offset by an employment increase in the sector, which causes an increase in productivity in the low-tech sector, raising wages in both sectors (cooperative *profit-led* regime).

Substituting (12) in (24) so that w is replaced by the sum of the wage growth in each sector (w_i), then we have a system composed of ten equations - (3), (4), (6), (8), (9), (11), (17), (20) and (21) and (24) - determining ten endogenous variables. For the high-tech sector we have its (i) output growth rate (y_{HT}); (ii) employment growth rate (l_{HT}); (iii) productivity growth rate (ξ_{HT}); (iv) wages growth rate (w_{HT}); (v) profits growth rate (r_{HT}); (vi) investment growth rate (i_{HT}); and (vii) idle capacity growth rate (g_{HT}). For the low-tech sector we have its (viii) wages growth rate ($w_{LT} = y_{LT}$); (ix) employment growth rate (l_{LT}); (x) productivity growth rate (ξ_{LT}).

2.1. Productivity growth in the high-tech sector

In order to analyze the general implications of the model we start from the analysis of the impact of productivity growth on the output growth rate. As will be seen, although the model presents several changes, the theoretical relationships between the variables are maintained following Ocampo, Rada and Taylor (2009).

First, if the income elasticity of investment ($\vartheta_1 < \vartheta_2$) is high, then productivity growth that creates higher profits increase the rate of growth of output – equation (24). This framework characterizes the *profit-led* regime, depicted in Figure 1. This regime is illustrated by the positive slope of the curve l_{HT} in quadrant I, showing a positive relationship between the productivity and the employment growth rates in the high-tech sector. Thus, increases in productivity lead to raises in investment and in utilization of idle capacity, which improves employment in the sector.

The starting point is given by the equilibrium between the rates of productivity growth and employment growth in the high-tech sector (quadrant I - determining the rate of employment growth

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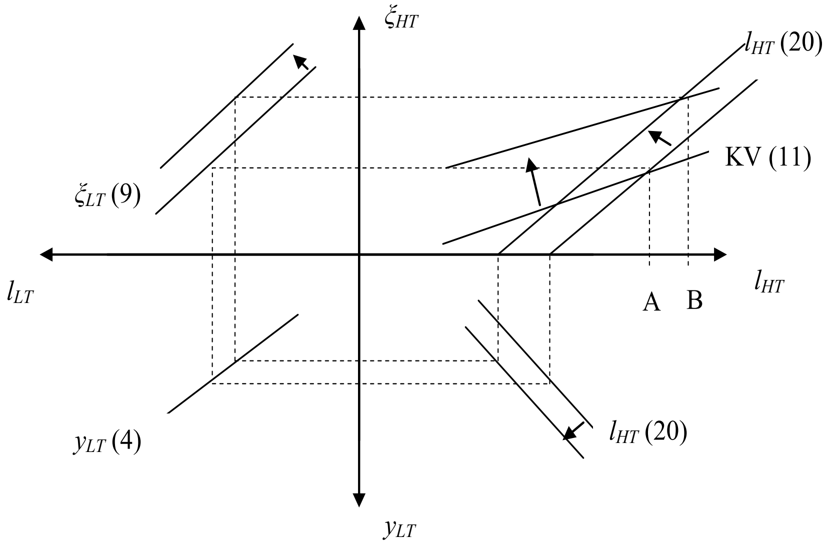
[19] One must remember that to have wage growth in the high-tech sector productivity of the low-tech sector needs to grow, and for that we need to raise the work in the high-tech sector (excluding the possibility of innovations in the low-tech sector). That is, the rate of growth in the high-tech sector must necessarily increase, and therefore also the profits. It is also important to note that this model only considers changes in the distribution of income as a result of a better distribution of the income obtained through the production process. Another possibility, which involves no increase in the amount of profits, is an increase in the rate of growth of productivity in the low-tech sector.

A). This equilibrium determines the rate of employment growth in the low-tech sector (quadrant II), which gives us the output growth rate in this sector (quadrant III), finally determining the magnitude of the impact of the demand growth rate of the low-tech sector on the employment growth rate of the high-tech sector (quadrant IV).

An increase in the productivity growth rate in the high-tech sector shifts the Kaldor-Verdoorn curve (KV) upwards, increasing profitability, boosting the growth of investment and reducing idle capacity, which increases the employment growth rate (from A to B in quadrant I). This new equilibrium implies reducing the employment growth rate in the low-tech sector (quadrant II), which reduces its rate of growth.[20]

FIGURE 1

The model of structural heterogeneity with a *profit-led* regime



Source: Authors' elaboration based on Ocampo, Rada and Taylor (2009, chapter 8, p.126).

If on the one hand a reduction in the rate of growth of employment in the low-tech sector has a negative impact on the output of the sector (quadrant III), on the other hand it generates an increase in its productivity growth rate which, in its turn, has a positive impact on output growth. Hence, for a reduction in employment in the low-tech sector to cause a decrease in this sector's output it is necessary that this negative effect predominates, i.e, the elasticity of productivity with regard to employment in this sector must be low. In other words, it should present only slightly decreasing returns in the sector ($\eta < 1$ in equation (9)) which is a realistic assumption adopted by Rada (2007).[21]

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[20] The shift in curve (9) results from the upward shift in KV curve. Now, for the same rate of growth of employment in the low-tech sector, a higher rate of growth of productivity in the high-tech sector is achieved.

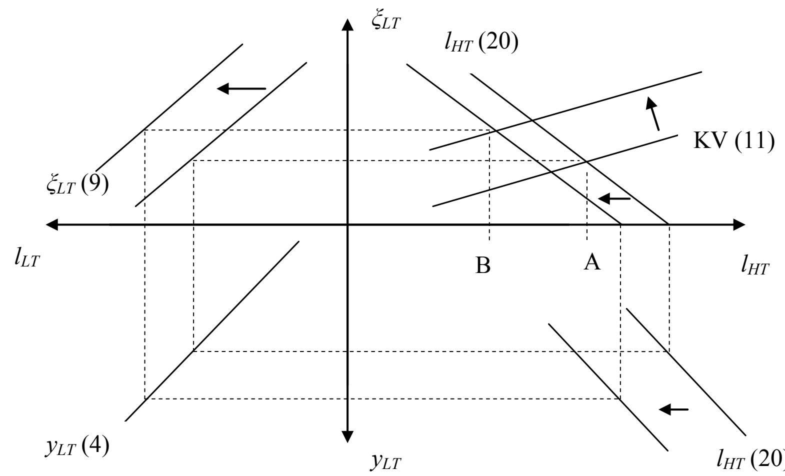
[21] For a deeper discussion on the slopes of the curves of the northeast and southwest quadrants, see Rada (2007) and Ocampo, Rada and Taylor (2009). It is also interesting to highlight that innovations in the low-tech sector – equation (9) – would induce a downward shift of the curve y_{LT} in the southwest quadrant.

Finally, a fall in the growth rate in the low-tech sector reduces the demand growth rate stemming from this sector to the high-tech one, thus slightly reducing the growth rate in the later.[22] Furthermore, the reduction in the employment growth rate in the low-tech sector raises its productivity growth rate, resulting in higher wage rate in both sectors - equation (4). On the one hand, this increase raises demand and generates a positive impact on investment. On the other hand, higher wages reduce profits in the high-tech sector - equation (18) - which has a negative impact on investment. Thus, since we are considering a *profit-led* accumulation regime, then the dominant effect would be that on profits, which results in a leftward shift of the l_{HT} curve in the quadrant IV. This shift indicates that for a given output growth rate in the low-tech sector, employment in the high-tech sector will be lower due to lower investment and capacity utilization resulting from the compression of profits in face of rising wages. The same effect would be observed for the l_{HT} curve in the quadrant I.[23]

Regarding the repercussions of an increase in productivity growth rate in a *wage-led* regime, we observe that the characterization of the situation in Figure 2 is given by the negative slope of the curve l_{HT} in quadrant I. In Figure 2 an increase in the productivity growth rate in the high-tech sector shifts the KV curve upwards, increasing profitability.

FIGURE 2

The model of structural heterogeneity with *wage-led* regime



Source: Authors' elaboration based on Ocampo, Rada and Taylor (2009, chapter 8, p.129).

Nevertheless, the weak response of investments and capacity utilization to increases in the profits growth rate ($\vartheta_1 > \vartheta_2$) causes a reduction in the employment growth rate (from A to B in quadrant I). This new equilibrium implies higher employment growth rate in the low-tech sector (quadrant II), which leads to a higher growth rate in the sector (quadrant III). On the one hand, it

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[22] The effect becomes clear through the intercepts of the curve l_{AT} in quadrant I. These intercepts are determined by the rate of growth of the low-tech sector (Ocampo, Rada and Taylor, 2009).

[23] For a given level of productivity growth rate, employment growth rate in the high-tech sector would now be smaller due to the reduction in investment/capacity utilization resulting from profit squeeze.

increases the demand growth rate stemming from this sector to the high-tech one. On the other hand, a higher employment in the low-tech sector reduces its productivity, reducing wage rates in both sectors - equation (4). This reduction raises profits, but once we are considering a *wage-led* regime, the predominant effect on investment is the negative impact of reduced wages growth rate. Considering that this effect outweighs the demand push stemming from the low-tech sector growth, once wages are reduced in both sectors, it will generate a leftward shift in the l_{HT}, thus deepening the employment reduction in the high-tech sector.[24]

Therefore, in a country characterized by a *wage-led* regime (low profit elasticity of investment, $\vartheta_1 > \vartheta_2$), increases in the productivity growth rate in the high-tech sector lead to a structural change which is inverse to the one required to achieve higher average productivity, increasing the share of the low-tech sector in the economy at the expense of the high-tech sector. Such a framework would undermine not only the average productivity of the economy, but also the distribution of income, since it reduces productivity in the low-tech sector, thus lowering wages in both sectors.

This case of sectoral productivity growth associated with a structural change toward low-tech sectors represents the same picture described by McMillan and Rodrik (2011) and Cimoli, Porcile and Rovira (2010) for the Latin American economies in the recent years, which corroborates the implications of the model described here. McMillan and Rodrik (2011) find that the opposite is verified for the Asian countries.

3. INTRODUCING EXTERNAL CONSTRAINT IN THE MODEL

So far the model has addressed underdevelopment's low capacity of capital accumulation, structural heterogeneity, and unequal income distribution. For completeness, the effects of external constraints on growth and of low innovation capacity, key characteristic of peripheral economies, must be included in the analysis. The starting point is a sectoral division of the domestic economy:[25]

$$(26)\quad y = \delta_{LT} y_{LT} + (1-\delta_{LT}) y_{HT}$$

where $\delta_{LT} = Y_{LT} / Y$.[26] The growth rates of demand for imports and exports, divided among low and high technology goods, are given by:

$$(27)\quad m = [\sigma_{mLT}\mu_{mLT} + (1-\sigma_{mLT})\mu_{mHT}]y + [\sigma_{mLT}\theta_{mLT} + (1-\sigma_{mLT})\theta_{mHT}]e_r$$

$$(28)\quad x = [\sigma_{xLT}\mu_{xLT} + (1-\sigma_{xLT})\mu_{xHT}]z + [\sigma_{xLT}\theta_{xLT} + (1-\sigma_{xLT})\theta_{xHT}]e_r$$

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[24] Again the effect becomes apparent when considering the intercepts of curve l_{HT} in quadrant I.

[25] For simplification we do not include the subdivision of the international economy.

[26] Extensions of this model may also include differences in income elasticities of demand of different social strata (workers and capitalists), which is beyond the scope of this paper. However, it should be noted that by disaggregating y in equation (26) it is possible to analyze the interaction between sectoral composition and income distribution.

where *m* denotes total imports, *x* total exports, e_r the real exchange rate, μ_{mLT} and μ_{mHT} the income elasticities of demand for imported goods from the low-tech and high-tech sectors respectively; μ_{xLT} and μ_{xLT} the income elasticities of demand for exported goods from the low-tech and high-tech sectors respectively; and $\theta_{xLT}, \theta_{xHT}, \theta_{mLT}, \theta_{mHT}$ are the price elasticities of demand for exports and imports of goods from each sector. Still, $\sigma_{mLT} = M_{LT} / M$ and $\sigma_{xLT} = X_{LT} / X$.[27]

Following Thirlwall (1979), balance of payments equilibrium is given by:

$$(29)\ m + e_r = x$$

Substituting equations (27) and (28) in equation (29) we find the rate of output growth compatible with balance of payments equilibrium:

$$(30)\ \ y = \frac{[\sigma_{xLT}\mu_{xLT} + (1-\sigma_{xLT})\mu_{xHT}]z + [\sigma_{xLT}\theta_{xLT} - \sigma_{mLT}\theta_{mLT} + (1-\sigma_{xLT})\theta_{xHT} - (1-\sigma_{mLT})\theta_{mHT}]e_r - e_r}{[\sigma_{mLT}\mu_{mLT} + (1-\sigma_{mLT})\mu_{mHT}]}$$

If we assume that changes in the terms of trade do not affect the long-term output growth rate, then we have the so-called Multi-Sectoral Thirlwall's Law (MSTL):[28]

$$(31)\ \ y = \frac{[\sigma_{xLT}\mu_{\mathrm{xLT}} + (1-\sigma_{xLT})\mu_{\mathrm{xHT}}]\mathrm{z}}{[\sigma_{mLT}\mu_{\mathrm{mLT}} + (1-\sigma_{mLT})\mu_{\mathrm{mHT}}]}$$

Equation (31) shows the long-term growth rate consistent with balance of payments equilibrium. Since the international income (*z*) is an exogenous variable, considering elasticities as constant, then the key issue to be examined is the evolution of the sectoral composition of the economy, i.e., the direction and pace of structural change.[29] As Gouvêa & Lima (2010) have shown, technology-intensive goods tend to have higher income elasticities of demand. Therefore, an increase in the share of the high-tech sector in the economy can be expected to be associated with higher growth rates according to the MSTL.

From the previous section, it must be recalled that the relative size of the high-tech sector depends on its growth rate surpassing that of the low tech-sector. This pattern is observed when productivity growth accelerates in the former, in a profit-led regime, or as a result of a higher rate of growth of wages, in a wage-led regime. Since $\delta_{LT} = Y_{LT} / Y$, linearizing this equation and substituting (26) in it we have:

[27] For simplicity, sectoral price differences are disregarded.

[28] This term was proposed by Araujo & Lima (2007). Although the derivation of the model is different, the implications and interpretation of the final outcome of the model are the same.

[29] Country variations of elasticities can be linked to institutional factors. The implications of institutional factors to short term and long term growth are not pursued here.

$$(32)\ \hat{\delta}_{LT} = y_{LT} - \delta_{LT} y_{LT} - (1-\delta_{LT}) y_{HT} = (1-\delta_{LT})(y_{LT} - y_{HT})$$

where $\hat{\delta}_{LT}$ is the growth rate of the share of the low-tech sector in the economy as a whole. This growth rate determines the sectoral division of the economy, i.e., determines the direction and magnitude of the ongoing structural change. From (32) one can observe that structural change is determined by the difference between the growth rates of the two sectors.

Substituting (20) in (3), and then in (32), we now have:

$$(33)\ \hat{\delta}_{LT} = (1-\delta_{LT})(y_{LT} + \hat{k}_{HT} + g_{HT} - i_{HT} - \xi_{HT})$$

Equation (33) shows that the higher the growth rates of investment and productivity in the high-tech sector, the lower the growth rate of the share of the low-tech sector in the economy. On the other hand, the higher the capital-labor ratio growth rate and the higher the idle capacity growth rate in the high-tech sector, the greater the share of the low-tech sector. An increase in capital per worker makes it possible to achieve the same output with lower employment, which increases employment in the low-tech sector, increasing its production and hence its share in the economy. If productivity and investment growth rates in the high-tech sector are higher than the growth rate of the low-tech sector plus the capital-labor ratio and idle capacity growth rates, then the rate of growth of the low-tech sector will be negative, i.e., there will be an increased participation of the high-tech sector in the economy. We could represent it by showing that $\delta_{BTt+1} = \delta_{BTt} \pm \hat{\delta}_{BTt}$, where the subscript *t* denotes time.

Finally, if we consider that the share of each sector in the economy determines also its share in exports, and that it is inversely related to the share of imports of each sector's goods in total imports, then we have:

$$(34)\ \delta_{LT} = \rho_x \sigma_{xLT}$$

$$(35)\ \delta_{LT} = -\rho_m \sigma_{mLT}$$

where ρ_x, ρ_m are parameters of proportionality. Thus, it becomes possible to incorporate the growth rate of the sectoral share of exports and imports directly into the model. Substituting (34) and (35) in (33) we have:[30]

$$(36)\ \hat{\sigma}_{xLT} = (1-\rho_x \sigma_{xLT})(y_{LT} + \hat{k}_{HT} + g_{HT} - i_{HT} - \xi_{HT}).$$

$$(37)\ \hat{\sigma}_{mLT} = (1+\rho_m \sigma_{mLT})(-y_{LT} - \hat{k}_{HT} - g_{HT} + i_{HT} + \xi_{HT}).$$

[30] Differentiating equations (34) and (35) we have: $\hat{\delta}_{LT} = \hat{\sigma}_{xLT}$, $\hat{\delta}_{LT} = -\hat{\sigma}_{mLT}$.

In sum, considering a *profit-led* economy, increases in the productivity growth rate lead to a positive impact on the growth rate of the share of the high-tech sector in the economy by boosting investment and capacity utilization, and reducing the output in the low-tech sector.

In a *wage-led* economy, as it is the case of underdeveloped countries, an increase in the rate of growth of the share of the high-tech sector in the economy is driven by increases in wages, which elevates the output growth rate in the high-tech sector due to increases in investment and in capacity utilization, raising its productivity growth rate and therefore reducing the output growth rate in the low-tech sector.

The variables included in equations (36) and (37), in turn, are determined by the structural heterogeneity model presented in the previous section. Therefore, by substituting (34) and (35) in (31), the equations are incorporated into the model of structural heterogeneity as a restriction on equation (26):

$$(38)\ \ y = \delta_{LT} y_{\mathrm{LT}} + (1-\delta_{LT}) y_{\mathrm{HT}} \le \frac{[(\delta_{LT}/\rho_x)\mu_{\mathrm{xLT}} + (1-\delta_{LT}/\rho_x)\mu_{\mathrm{xHT}}]\mathrm{z}}{[(1+\delta_{LT}/\rho_m)\mu_{\mathrm{mHT}} - (\delta_{LT}/\rho_m)\mu_{\mathrm{mLT}}]}$$

Equation (38) shows that changes in the sectoral composition of the economy (δ_{LT}) also imply changes in the sectoral composition of imports and exports, making both sides of the inequality to change. Since empirical evidence suggests that $\mu_{\mathrm{xHT}} > \mu_{\mathrm{xLT}}, \mu_{\mathrm{mHT}} > \mu_{\mathrm{mLT}}$ (Gouvêa & Lima, 2010), a reduction in δ_{LT} causes an increase in the right hand side of the inequality. This increase represents a relaxation of the external constraint on growth, which allows for faster economic growth over time – determined by the left hand side of the inequality.

4. DETERMINANTS OF INNOVATION

The issue to be addressed in order to cover all the constraints on peripheral development refers to the determinants of technological innovations that, according to the model developed thus far, not only influence the rate of productivity growth in both sectors, but also - and most importantly - the rate of investment growth in the high-tech sector. Beyond the direct channels already highlighted, the consolidation of an effective NIS impacts the parameters ϕ_1, ϕ_2 and ϕ_3 in equation (20), and the income elasticities of demand for imports and exports in both sectors through the increase of the non-price competitiveness of the economy as a whole.[31]

[31] The parameters would be positively influenced by an increase in the ability to invest of entrepreneurs. Investment in the high-tech sector would also require accumulated knowledge in the sector. In sum, variations of the three above mentioned parameters are given by shifts in innovations, which represent a proxy for the level of development of the NIS. Regarding the income elasticities, the increase in non-price competitiveness would increase the income elasticities of demand for exports in both sectors, while reducing the income elasticity for imports of goods of both sectors, although more so in the HT sector. Moreover, the effects on exports and imports would also be asymmetrical due to the preference for variety. Hence, the decrease of imports would be lower than the increase of exports elasticities.

First, it is crucial to highlight the concept of NIS used here. Neo-Schumpeterian theorists usually emphasize the role of organizations (universities, research centers, firms, technological parks, etc.) that integrate what they call NIS (Nelson and Winter, 2002). More recently, this analysis has been expanded to incorporate a broader concept of institutions (Nelson, 2002, 2008). Following this trend, we take into account the concept of institutions stated by Hodgson (2006), which is also compatible with North's (1990) approach.[32] In this sense, government policies normally create formal institutions by changing "the rules of the game". Through the constitutive role of institutions (Chang, 2002), those policies create motivations and habits, which with time are incorporated as informal institutions. Through the habit of seeking and implementing investment and innovation the abilities and institutions necessary for the development process to take place are consistently created.

Taking into account the successful experience of the East Asian counties (Chang, 2006; Lall, 2006) we consider that the four most important state policies that integrate an effective NIS are: (i) industrial policy; (ii) education policy; (iii) credit policy; (iv) income inequality reduction policy.[33] By taking effective measures on those areas underdeveloped countries governments cope with all the four constraints on the development of a peripheral economy.

$$(39)\quad t_i = \zeta_1 + \zeta_2 q + \zeta_3 educ + \zeta_4 GAP$$

where $\mathrm{GAP} = \frac{\mathrm{T}}{\mathrm{T}*}$, which represents the ratio of the productivity of the leading country (T *) and the peripheral country (T). The variable *educ* represents the influence of education on the rate of growth of innovations. The variable q, in its turn, seeks to measure the impact of the industrial policy.

The impact of investment on the innovations (usually associated with *learn-by-doing*) is incorporated in the *GAP*. In the model presented in the previous section we find that increases in investment drive increases in output, which elevate productivity in the high-tech sector. This productivity growth reduces the *GAP,* and thus has a positive impact on the growth of innovation, since knowledge approaches the technological frontier.[34] Moreover, once changes in income distribution and in credit availability influence investment and idle capacity – equations (24) and (21) – they would also be captured by the *GAP* variable.[35] Hence, those variables present an indirect impact on innovations.[36]

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[32] Hodgson (2006, p. 2) defines institutions as "the system of established and prevalent social rules that structure social interactions", or simply social rules that guide the behavior of individuals.

[33] Education is crucial not only to increase the rate of innovations of the economy, but also to allow the transference of workers from the LT to the HT sector.

[34] In Fagerberg's (1988) model the GAP is used to demonstrate the possibility of acquiring free knowledge and is negatively related to the technological frontier. The lower the GAP, the less a country can incorporate free knowledge. Here the link is to innovation: therefore, the lower the GAP, the closer a country is to the technological frontier and the greater the possibility of creating innovations.

[35] Income distribution policies would appear in the model as exogenous increases in the rate of growth of wages.

[36] Another possibility is to consider that the reduction of the income inequality has a positive impact on the level of education of the population.

Thus, the generation of innovations, which is the result of NIS development, represents a strong impact on the speed of development of a country. It not only generates productivity growth in both sectors of the economy, but also influences investment and the profit and demand elasticities of investment.[37] Therefore, building an efficient NIS is fundamental to the development of underdeveloped countries, given the impetus it provides for growth.

It is also important to stress the difference between a dual model and a multi-sectoral model. In a model with many sectors, although investment is linked to structural change, it is not necessarily associated with an increased level of high-tech output. On the contrary, it can represent an increase of already existing traditional manufacturing sectors. In a dual model as the one presented here, it is considered that investment and/or reduction in idle capacity represent (i) structural change, (ii) productivity growth and (iii) increase of the technological content of production (non-price competitiveness). Such framework is a result of the high aggregation of the model, which has only two sectors. Higher division, however, would imply an enormous increase in model's complexity.

In this sense, it is considered that the development of the NIS is essential for these three factors actually to occur simultaneously. In general, it is arguable that, without the development of the NIS, investment will not be able to reach sufficient magnitude to create the necessary structural change.[38] Moreover, the NIS development guarantees that investment will not only modernize the existing machinery, but also increase the technological content of the goods produced.

5. CONCLUDING REMARKS

The model developed in this paper builds on the existing literature in order to provide more accurately the working dynamics of peripheral economies. In particular, four key characteristics have been stressed: (i) structural heterogeneity; (ii) low private capacity of investment and innovation; (iii) balance of payments constraint; (iv) income inequality. The most profound changes were implemented in the investment equation, and with the introduction of the equations of the Multi-Sectoral Thirlwall Law and of the growth rate of innovations.

Although these changes have increased the apparent complexity of the model, the detailed analysis of its implications sought to demonstrate that the new specification has successfully formalized relations and concepts that were scattered thought in the economic literature. The model's strength comes from the fact that it manages to keep the key results found in the models of Bhaduri & Marglin (1990), Rada (2007) and Fagerberg (1988), at the same time that it highlights the peculiar characteristics of investment in underdeveloped countries, so dear to classical theories of economic development. Therefore, concepts and intuitions from the Kaldorian-Keynesian traditions are integrated with the contributions of ECLAC-structuralist, institutionalist and neo-schumpeterian approaches.

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[37] From equations (9), (11), (24) and (37).

[38] It must be recalled that investment must be large enough not only to substitute capital that depreciates, but also to incorporate population growth and part of the low-tech workers.

Nonetheless, the main result of the paper is to illustrate that the development of an efficient NIS accelerates investment/capacity utilization and innovations, which are the engines of structural change towards a sectoral composition of local production more technologically intensive. This process would make possible to simultaneously overcome the four constraints mentioned. This idea is introduced to the model through the impacts of innovations in the productivity of both sectors and in investment in the high-tech sector. Innovations are then made endogenous by introducing an equation with its determinants.

The broad concept of NIS adopted in the paper takes into account other elements that indirectly affect innovations, such as income inequality reducing policies and industrial policies (Albuquerque, 2007; Chang, 2006). The reduction of income inequality, understood as increasing the share of wages in national income, provides new impetus to investment in *wage-led* economies as underdeveloped ones are expected to be, contributing to the acceleration of structural change and learning. On its turn, structural change leads to the relaxation of the balance of payments constraint on output growth according to the MSTL, thus enabling these transformations to continue.

Therefore, only through the development of an efficient NIS becomes possible to overcome the various constraints on periphery's development. Hence, the concept of development implied by the model is compatible with the various approaches in the literature of development economics. The end result is a more complete and relatively simple model of economic development which incorporates the various aspects of the working dynamics of peripheral economies.

Finally, it is important to emphasize that the model provides explanation for the Latin American and East Asian development experiences described by McMillan and Rodrik (2011) and Cimoli, Porcile and Rovira (2010).

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