Natural, effective and BOP-constrained rates of growth: Adjustment mechanisms and closure equations

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Abstract:

The interaction between the effective (y^E) and the natural rate of growth (y^N) is a central part – implicitly or explicitly addressed – in all growth models. A stable equilibrium requires these two rates to converge; otherwise, one or more macroeconomic variables would rise or fall without bounds. In addition, the Keynesian tradition stressed the balance-of-payments (BOP) constraint as a determinant of the equilibrium growth rate in the long run (y^{BP}). This paper discusses alternative mechanisms through which these three growth rates may converge, and relates these mechanisms to different theoretical approaches to the determinants of growth. With this objective, we extend the model suggested by Setterfield (2011) to include the evolution of the North-South technology gap and the pattern of specialization as components of the Kaldorian productivity regime. Drawing from the Schumpeterian literature, we emphasize the importance of the national system of innovation (NSI) in shaping the learning parameters and outcomes of the model. A successful development strategy emerges when the NSI enhances indigenous technological capabilities that allow the Southern economy to catch-up with the technological frontier.

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The interaction between the effective (y^E) and the natural rates of growth (y^N) is a central part – implicitly or explicitly addressed – in all growth models. The effective rate of growth is the one actually observed at a certain point in time, and depends on effective demand. The natural growth rate, on the other hand, represents a potential that may or may not be attained, and is driven by supply side forces (technology, the growth of labor supply, and capital accumulation). While both growth rates do not necessarily coincide in the short run or even in the medium run, they must converge in the long run. The effective rate cannot exceed the

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ceiling imposed by the natural rate, except momentarily by overstretching the use of resources. The effective rate cannot be below the natural rate for many years, since this would imply that an increasingly larger share of valuable resources is kept idle. Some labor and capital may be unemployed in equilibrium, but the share of unemployed capital or labor cannot grow without bounds. Such disequilibrium would elicit a response from the economic system to place the economy back in an equilibrium path.[1] Identifying the compensating forces that ensure the move towards equilibrium helps us understand the different theoretical approaches to economic growth and also defines its policy implications.

Moreover, there is a third rate of growth that must be considered. The effective rate of growth is demand-driven, and hence it is necessary to consider the dynamics of the different sources of effective demand to understand the adjustment process. Keynesian growth models for open economies highlight the balance-of-payments constraint as a key determinant of the growth of effective demand. In the long run the rate of growth of exports (an addition to effective demand) and imports (a leakage to effective demand) must grow hand in hand. The other sources of effective demand must endogenously adjust to preserve the external equilibrium. Therefore, the effective rate must converge not only with the potential rate (as expressed in the natural rate), but also with the equilibrium rate of growth of effective demand (as expressed in the balance-of payments constraint or Thirlwall's Law).

The objective of this paper is to develop a framework which allows us to simply discuss how the adjustment process may occur, what mechanisms bring about the adjustment and what possible implications they have for economic policy. Our point of departure and the basic framework we adopt in this paper is the one set forth by Setterfield (2011). Building on his framework, and trying to keep its simplicity and clarity, we expand it in four directions.

First, we consider the balance-of-payments (BOP) constrained rate of growth as the demand-side driven equilibrium growth rate. Second, different mechanisms driving productivity growth are considered besides learning by doing. In particular, the insights of the technology gap literature on innovation and competitiveness are used to shed light on the Kaldorian "productivity regime". By doing so, this paper takes into consideration the impact of international asymmetries in technological capabilities on competitiveness and growth, which are at the core of the center-periphery, or North-South models, of economic development. Last but not least, the paper allows structural change to play a role in the different (effective, BOP-constrained and natural) rates of growth in a North-South setting. Structural change, technology and effective demand co-evolve – as pointed out in the rising "Keynes meets Schumpeter" literature on economic growth.[2] Center-periphery and North-South are used as exchangeable terms in the paper, and both point to the same idea, namely that there are asymmetries in technological and productive capabilities in the international economy, and that these asymmetries shape the economic performance of each country/region.

A family of models emerge from the discussion, with the same basic structure but different "closure equations" which highlight the main theoretical differences between the models. The economic intuitions of the models are emphasized in the text, while most of the technical aspects are explained in boxes in each section.

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[1] For instance, if the natural rate of growth is higher than the effective rate, unemployment or excess capacity will increase steadily, a trend that could not persist indefinitely. Inversely, if the effective rate of growth is higher than the natural rate, the economy will find the barrier of full employment and full utilization of the capital stock. Either compensating mechanisms will be at work to curb this disequilibrium path or a major crisis would reshape the system and produce a new, sustainable dynamic system.
[2] See Ciarli et al. (2010); Dosi et al. (2010); Cimoli and Porcile (2014).

1. Demand, productivity and structural regimes: the general framework

1.1. Building blocks: Kaldorian regimes and structural change

This section presents the general framework that will be used to analyze the interactions between the natural and effective rates of growth. There are three building blocks in the model: (i) the Kaldorian demand regime; (ii) the Kaldorian productivity regime; and (iii) a structural change regime which interacts with the previous two.

Each building block is directly related to different parts of the Keynesian-Schumpeterian growth model, which will be more formally discussed later, but the main insights can be rapidly summarized. First, the BOP-constrained rate of growth, based on Thirlwall's Law – see Thirlwall (2011) – represents the rate of growth consistent with the equilibrium in the current account, to which the Kaldorian growth model must converge.[3] Secondly, the productivity regime is based on the Kaldor-Verdoorn Law and the technology gap literature. Therefore, it considers not only the traditional forces of increasing returns from learning by doing, but also the possibility of international spillovers of knowledge from the advanced North to the laggard South – a pioneer contribution is Nelson and Phelps (1966); see also Fagerberg and Verspagen (2002). Lastly, the structural change regime focuses on how the pattern of specialization evolves as a result of technical change. Leads and lags in innovation and learning redefine the parameters of Thirlwall's law, and therefore the BOP-constrained rate of growth (Dosi et al., 1990; Verspagen, 1992; Cimoli and Porcile, 2014). The structural change regime represents the channel through which the Schumpeterian dynamics (supply side) affects the Keynesian BOP-constrained rate of growth (demand side).

1.2. The demand regime: the BOP-constrained rate of growth

There are two demand-driven rates of growth. One represents the effective rate of growth, in which the deficit in current account as a percentage of the GDP could be either falling or increasing. The other is the equilibrium rate of growth, driven by the external constraint, which requires exports and imports to grow at the same rate (equilibrium in current account). In the long run both rates of growth must be equal to each other, and also equal to the natural rate of growth. The effective rate of growth (y^E) is given by the Kaldorian equations (1) and (2) below – for more details, see Setterfield and Cornwall (2002):[4]

$$y^E = \alpha a + \beta x \tag{1}$$

$$x = g\varepsilon + \psi_X \dot{q} \tag{2}$$

According to these equations, the effective rate of economic growth depends on the growth of autonomous expenditure (a) and the growth of exports (x) (Kaldor, 1975; Mc Combie and Thirlwall, 1994; Blecker, 2013). The parameters α and β are a function of the

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[3] This paper follows Blecker (2013) in the analysis of the Kaldorian export-led growth and its relation with the BOP-constrained growth.

[4] The growth rate is given by: $y = \tilde{\alpha} a + \tilde{\beta} x - \tilde{\gamma} m$ where $\tilde{\alpha}$, $\tilde{\beta}$ and $\tilde{\gamma}$ are, respectively, the share of expenditures non-related to trade, the export share, and the import share, in total demand. As shown in Setterfield and Cornwall (2002), the growth rate of imports is given by $m = y\pi + \psi_m \dot{q}$. In the long run $\dot{q} = 0$, so $y = \tilde{\alpha} a + \tilde{\beta} x - \tilde{\gamma} y\pi$. We define $\alpha = \tilde{\alpha}/(1 + \tilde{\gamma}\pi)$ and $\beta = \tilde{\beta}/(1 + \tilde{\gamma}\pi)$, achieving the result stated in equation (1). α and β are a function of π and $\tilde{\gamma}$, which are considered constants. While $\tilde{\alpha}$, $\tilde{\beta}$ and $\tilde{\gamma}$ may all vary in the transitional dynamics, we will assume that their changes are small and can be neglected.

relative weight of autonomous expenditure and exports, respectively, in total income, along with the income elasticity of the demand for imports (π) which for simplicity is assumed constant in the paper. The growth of exports – equation (2) – depends on the income elasticity of exports (ε), the expansion of the world economy (g), and the rate of depreciation of the real exchange rate ($\dot{q}$), in which $q = \ln\left(\frac{P^*\epsilon}{P}\right)$. P^* is the international price index, P is the domestic price index, ϵ is the price of the foreign currency (units of domestic currency per unit of foreign currency), and ψ_X is the price elasticity of exports.

The discussion of this paper applies to the long run, in which the real exchange is in equilibrium, and hence $\dot{q} = 0$ and $x = \varepsilon g$. The assumption of a stable real exchange rate reproduces that of Thirlwall's model. Such an assumption, however, has been challenged by several authors. Several works have suggested a significant impact of wage bargaining and of the real exchange rate on the income elasticity of the demand for exports and imports.[5] This view is supported by historical and empirical evidence pointing out that the real exchange rate is an important determinant of economic growth, and could not be ignored even in the long run. However, to the extent that these aspects have already been discussed in several other works, we remit the reader to the literature.[6] A discussion of the dynamics of the real exchange rate would require modeling the labor market and wage bargaining in more detail, which is beyond the scope of this paper. Therefore, we will suggest a way in which the impact of the real exchange rate on the elasticities could be included in the basic framework of our model in section 2.4, but we will not develop this insight further. As mentioned, in equilibrium exports and imports grow at the same rate, which implies $\varepsilon g = \pi y^{BP}$, where y^{BP} is the equilibrium rate of growth.[7] Under these assumptions the simplest version of the BOP-constrained rate of growth is obtained (Thirlwall's Law):

$$y^{BP} = \frac{\varepsilon}{\pi} g \tag{3}$$

In equation (3), ε/π is the income elasticity ratio. This ratio depends on the degree of diversification and technological intensity of the pattern of specialization. A more technology-intensive production structure is associated with higher technological capabilities, which allows the country to respond more effectively to changes in the global demand and competition, by raising ε (Araujo and Lima, 2007; Gouvea and Lima, 2010; Catela and Porcile, 2012; Cimole and Porcile, 2014). In other words, the higher the technological capabilities of the country, the higher are the income elasticity ratio and the equilibrium rate of growth.

The adjustment between the effective rate of growth (y^E) and the equilibrium rate of growth (y^{BP}) proceeds in different ways. One possible path is by making endogenous the growth rate of a component of effective demand that has been considered exogenous in the short run. For instance, the autonomous component of investment in the short run may depend on agents' expectations. Such expectations in turn vary with the perception on external equilibrium. If the external debt is growing and the external situation is deemed unsustainable, then this component of investment will fall (and with it effective demand) if economic actors foresight a crisis. Another mechanism is through adjustments in public expenditure. If the government thinks that the external front shows high vulnerability, it is likely that it will seek to reduce effective demand by decreasing public expenditure. We will continue to call this

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[5] See Cimoli and Porcile (2011; 2014), Lima and Porcile (2013), Bresser-Pereira et al. (2014), and Gabriel et al. (2016) for details.
[6] See Frenkel and Rapetti (2012) and Missio et al. (2015).
[7] The demand for imports is given by $m = \pi y^E + \psi_M \dot{q}$, as shown in Setterfield and Cornwall (2002).

component of effective demand, which is expectation-driven, as autonomous, in the specific sense that it does not react 'mechanically' to current changes in effective demand:

$$\dot{a} = \lambda(y^{BP} - y^E) \tag{4}$$

Equation (4) implies that the effective rate of growth converges to the long run growth rate at an adjustment speed given by λ. The adjustment mechanism is in line with that suggested by Blecker (2013, p. 26), who stresses that the balance of payments constraint growth rate may be seen as "a stable attractor for the long run equilibrium". In the same vein, Carlin and Soskice (2005) define the transition from the medium run to the long run as a transition from equilibrium in the labor market towards equilibrium in the current account. Changes in autonomous expenditures concur to sustain such a transition, although it may not be the only force at work. This view is also consistent with the assumption made in this paper (and in general in Thirlwall's Law models), that in the long run the real exchange rate is stable, and hence it cannot adjust to restore the external balance. Therefore, the only instrument left for private and public agents to stabilize a rising external deficit (as a percentage of GDP) are changes in the growth of autonomous expenditure.

1.3. The productivity regime and the natural rate of growth

The production function comprises homogeneous labor and technology, which drives labor productivity. The natural rate of growth (y^N) equals the rate of growth of labor supply ($n = \dot{N}/N$, where N is the total labor supply) plus the rate of growth of labor productivity (z). Formally:

$$y^N = n + z \tag{5}$$

As regards the growth of labor supply (n), it is a function of population growth ($\bar{n}$) and the wage rate of the economy (W). The higher the wage rate, the higher the attraction of labor from the subsistence sector within the economy and from other economies with lower wages. This wage rate is defined as the ratio between wages in the modern sector of the economy and the wage in the subsistence sector or in other (lower wage) countries.

$$n = \bar{n} + \sigma(W) \tag{6}$$

A central concern of classical growth theory (Dutt, 1990; Foley and Michl, 1999) and classical development theory (Prebisch, 1950; Lewis, 1954; Levine, 2005) is the elasticity of labor supply (σ) with respect to the relative wage between the modern and the traditional sectors. It is generally considered that in developing economies there is a large reserve of labor that could be easily mobilized to feed the formal labor market. This labor reserve sustains employment growth with minimal changes in real wages. In practice, this view is challenged by the need to educate and train workers coming from the informal and/or laggard segments of the economy. In this paper, only the two extreme cases will be considered: that of infinite elasticity of labor supply ($\sigma = \infty$, section 2.1), and that of zero elasticity of labor supply, which implies an exogenous rate of growth of labor supply ($n = \bar{n}$, in all the other sections). The first case is the traditional Lewisian economy, and the second is the conventional assumption in most macroeconomic models. In the Lewisian economy, the subsistence sector plays a passive role: it only ensures that the supply of labor (and hence the natural rate of growth) is endogenous, and it does not affect other aspects of the economic dynamics – for a more detailed analysis of the different ways in which the subsistence sector may affect the modern sector see

Ros (2001, chapter 2). In the second case, the assumption of an exogenous rate of growth of labor supply is the usual assumption in the Solovian models. The relative wage between the modern sector and the subsistence sectors depends on the rate of employment in the modern sector:

$$W = \omega(E) \tag{7}$$

In equation (7), $E = L/N$, $0 \le E \le 1$, where L is total employment and N total labor supply in the economy. The wage ratio is a function of the level of employment, being ω the elasticity of the wage ratio to employment. Note that when the elasticity of labor supply is infinite ($\sigma = \infty$), E approaches zero. In this case, the difference in wages between the modern and the traditional sector is then the subsistence wage ($\overline{W}$) times a constant factor v that captures the cost of migration to the modern sector: $W = v\overline{W}$ (or the cost of migration from a low-wage country to a high-wage economy).

Productivity growth (z) is driven by different types of learning that spur innovation and the adoption of advanced technology. The first source is (*i*) learning by doing, as expressed in the Kaldor-Verdoorn Law. The higher is the rate of growth, the higher the accumulation of experience in production, investments in new technology, and opportunities for innovation and diffusion of technology. In addition, more workers are transferred from the subsistence to the modern sector, where learning is faster. To capture the effects of the Kaldor-Verdoorn law, we assume that the intensity of learning by doing (and productivity growth) is a function of the level of activity of the economy – of which the employment rate E is a proxy.

The second driver of learning and productivity growth are (*ii*) complementarities and externalities arising from the flow of knowledge across sectors. Positive externalities are stronger when the economic structure is more diversified towards knowledge intensive sectors. As the share of these sectors in total value-added increases, so do the opportunities for innovation and cross-fertilization between sectors, labor and technology. Formally, this effect is captured in the model by the income elasticity of exports (ε), as this variable is a positive function of the knowledge intensity of the specialization pattern – this is captured by the income elasticity ratio ε/π, where π is assumed to be constant.

A third variable affecting learning is (*iii*) the technology gap (T) defined as the ratio between technological capabilities in the leading country and technological capabilities in the laggard country ($T = T^N/T^S$). T^N represents technological capabilities in the North and T^S technological capabilities in the South. The technology gap provides opportunities for learning foreign technology, and therefore for catching up with the technological frontier. International spillovers of technology are an important source of learning for laggard countries that invest in strengthening their absorptive capabilities (Abramovitz, 1986; Narula, 2004). These spillovers are not spontaneous, but rather the result of persistent efforts in investing in mastering and improving foreign technology in the laggard economies.

The factors shaping productivity growth can be formally represented as follows:

$$z = z(E, \varepsilon, T, s) \tag{8}$$

Equation (8) describes a modified Kaldor's "productivity regime", where E is the employment rate, ε is the income elasticity of exports, T is the technology gap, and s is a shift parameter that represents domestic efforts at technological learning. A higher s implies higher productivity growth for a given E, ε and T. The effects of the first two sources of learning – learning by doing (E) and learning from diversification (ε) – are addressed in section 2, while

catching up (reducing T) is in section 3. In the rest of this section, T is not considered in the argument of equation (8). The parameter s varies with the industrial and technological policy, and reflects what the Schumpeterian literature calls the national system of innovation (NSI) (Nelson, 1993; Lundvall, 2007).

Recalling that the rate of employment is $E = L/N$, in growth rates we have $e = l - n$ (or $l = e + n$), being $e = \dot{E}/E$, $l = \dot{L}/L$ and $n = \dot{N}/N$. It is straightforward[8] that the growth of labor demand equals the difference between the rate of economic growth and that of labor productivity, i.e. $y^E - z$. In the long run e must be zero, if y^E exceeds y^N, the ceiling of full employment ($E = 1$) will be reached; and if y^E is below y^N, then the rate of unemployment would rise continuously, a situation that cannot be sustained for a long period.

$$e = y^E - y^N \tag{9}$$

So far, the system of equations comprises eleven endogenous variables (y^E, a, x, y^{BP}, ε, y^N, E, e, n, W and z), six exogenous parameters[9] ($\pi, \alpha, \beta, \lambda, \omega, s$), and only nine independent equations. To solve the model, two additional equations are needed. In the next section, we will define "closure equations", based on specific assumptions which represent different theoretical approaches to the interaction between learning, growth and structural change – and therefore on how the economy adjusts.

2. Alternative scenarios and closure equations

The adjustment scenarios depend on the specific assumptions regarding the behavior of income elasticities, labor supply, technology, and labor productivity growth. Whether these variables are endogenous or exogenous they play a different role for the supply and the demand side variables in long run growth, with distinct policy implications.

2.1. The Lewis-Prebisch-Thirlwall (LPT) case

The simplest case is the one in which the income elasticity of exports is exogenous ($\varepsilon = \bar{\varepsilon}$) and labor supply is infinitely elastic à la Lewis ($\sigma = \infty$), and hence the increase of labor supply closes any gap between production and productivity growth, i.e. $n = l = y^E - z$ (see box 1). Any increase in effective demand above productivity growth elicits a proportional increase in labor supply (and hence in the natural rate of growth) that matches labor demand, as labor moves from the subsistence sector to the modern sector of the economy. Growth takes the form of a horizontal production expansion through labor absorption with no structural change. BOP-constrained growth (à la Prebisch-Thirlwall) is fully validated: changes in autonomous demand lead the economy towards the BOP-constrained growth path (convergence of effective and BOP-constrained growth), while labor migration fills in any gap between the natural and effective rates of growth.

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[8] By substituting equation (5) in equation (9), which results in $e = y^E - z - n$.
[9] Recall that α and β depend on exogenous constants and that $\tilde{\alpha}$ and $\tilde{\beta}$ experience small changes that are ignored.

Box 1 – *The Lewis-Prebisch-Thirlwall (LPT) case*

Closure equations

(LPT1) $\varepsilon = \bar{\varepsilon}$
(LPT2) $n^* = y^* = z^*$

Equilibrium values of the endogenous variables

(LPT3) $y^* = y^{BP} = \frac{\bar{\varepsilon}}{\pi} g$
(LPT4) $x^* = \bar{\varepsilon} g$
(LPT5) $a^* = \frac{1}{\alpha\pi} [\bar{\varepsilon} g (1 - \beta\pi)]$
(LPT6) $E = L/N \cong 0$
(LPT7) $z^* = z(\bar{\varepsilon})$
(LPT8) $W = v\bar{W}$
(LPT9) $y^N = y^E = y^{BP}$

Motion equation and stability

(LPT10) $\dot{a} = \lambda \left(\frac{\bar{\varepsilon}}{\pi} g - \alpha a - \beta \bar{\varepsilon} g \right)$

The system is stable since $\frac{\partial \dot{a}}{\partial a} = -\lambda\alpha$, where α and λ are both positive.
In this model, growth is entirely determined by Thirlwall's Law, and the natural rate fully adjusts to the effective rate through increases in labor supply, which is infinite. The given (peripheral) structure determines economic growth and productivity growth, while changes in the growth of autonomous demand ensure BOP equilibrium.

No supply constraints emerge as the economy expands: there is a large pool of labor ready to move and feed the labor market. As the stock of labor N is very large, the rate of employment is close to zero ($E = L/N \cong 0$), and does not contribute to elicit productivity growth or stimulate new investments. Box 1 presents the model under the assumptions of infinitely elastic labor supply and exogenous growth rate of exports,[10] in which growth is fully determined by the pattern of specialization (ε/π) and the rate of growth of the international economy (g). Productivity growth is constant for it depends on the pattern of specialization (knowledge intensity of the production basis as captured by $\bar{\varepsilon}$) and efforts at learning (s), which are constant (see equation LPT7). The model illustrates the forces driving growth in an economy in which the structure is rigid while labor is abundant. It is likely that in such an economy $\bar{\varepsilon}$ is very low, and hence the rate of reallocation of the labor force to the modern sector would advance at a slow pace. Informality and duality may persist for a rather long period. The crucial challenge to this economy is to raise $\bar{\varepsilon}$, so that it succeeds in exhausting the labor stock in the subsistence sector and in increasing labor productivity. This, however, as it will be discussed in the next section, could hardly be achieved without reducing the technology gap with the technological frontier country leaders.

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[10] The rate of growth of exports (x) is exogenous because g and ε are exogenous.

2.2. The Kaldor-Prebisch-Thirlwall (KPT) case

As in the LPT case, in the Kaldor-Prebisch-Thirlwall (KPT) case income elasticities are exogenous. Differently from the LPT, there is not infinite supply of labor. Technological learning and productivity growth both rise with economic growth à la Kaldor, while the rate of growth of labor supply is an exogenous constant ($\sigma = 0$). In the KPT framework it is productivity growth – and not the growth of labor supply – that makes the natural rate of growth converge with the effective rate of growth. A closure equation along these lines is suggested by Setterfield (2011).

Causality goes from the BOP-constrained growth rate to the effective growth rate, and from that to productivity, and hence to the natural rate of growth. The model is Prebischian-Thirwallian because BOP-constrained growth holds (as in the LPT model) in equilibrium; and it is Kaldorian because the supply side reacts based on the endogenous forces of learning by doing (which expands production *pari passu* with effective demand).

Assuming that equation (8) is linear, and s is the fraction of autonomous expenditure (a) that goes to research and development (R&D) and other productivity-enhancing technological activities, we have:

$$z = sa + bE + v\varepsilon \tag{10}$$

In equation (10), b is the Kaldor-Verdoorn coefficient and v the increasing returns to diversification coefficient. The Kaldorian productivity regime is thus redefined, so as to allow private and public investments in R&D and human capital to contribute to the process of learning. The higher these investments are, the more intense learning and productivity growth are. The parameter s is considered a function of policies aimed at strengthening the national system of innovation (NSI). Learning is not automatic or spontaneous, but there is a crucial role for public policy in accelerating technical change.

Equation (10) allows us to find explicit solutions for the model, as presented in box 2.

Box 2 – *The Kaldor-Prebisch-Thirlwall (KPT) case*

Closure equations

(KPT1) $\varepsilon = \bar{\varepsilon}$
(KPT2) $n = \bar{n}$

Equilibrium values of the endogenous variables

(KPT3) $y^* = y^{BP} = \frac{\bar{\varepsilon}}{\pi} g$
(KPT4) $x^* = \bar{\varepsilon} g$
(KPT5) $a^* = \frac{1}{\alpha\pi}[\bar{\varepsilon}g(1 - \beta\pi)]$
(KPT6) $E^* = \frac{1}{b}[(\alpha - s)a^* + \bar{\varepsilon}(\beta g - v)]$
(KPT7) $z^* = sa^* + bE^* + v\bar{\varepsilon}$
(KPT8) $W^* = \omega(E^*)$
(KPT9) $y^* = y^E = y^N$

Motion equations and stability

(KPT10) $\dot{a} = \lambda\left(\frac{\bar{\varepsilon}}{\pi}g - \alpha a - \beta\bar{\varepsilon}g\right)$

(KPT11) $e = (\alpha - s)a + \beta\bar{\varepsilon}g - bE - v\bar{\varepsilon} - \bar{n}$

(KPT12) $J = \begin{vmatrix} -\lambda\alpha & 0 \\ \alpha - s & -b \end{vmatrix}$

Growth is entirely determined by Thirlwall's Law and the natural rate fully adjusts to the effective rate. But, the convergence between the two rates is produced by Kaldorian increases in productivity, not by the Prebisch-Lewis infinite supply of labor as it is in the LPT. However, productivity increases may not come out so automatically, as discussed below.

The trace of the Jacobian is negative and the determinant positive; hence the model is stable.

In the model, the response of productivity to the level of activity is strong enough as to allow production to keep pace with effective demand. The model largely relies on the productivity-enhancing effects of Kaldor-Verdoorn. However, the cumulative forces of learning by doing may not suffice to produce all the required adjustment in y^N. The full employment ceiling may be met before the economy reaches the BOP constraint. It is then necessary to discuss more precisely the role of technological policy, as addressed in the next subsection.

2.3. Technological policy, growth and employment

The speed with which effective demand and productivity growth respond may be very different. Productivity moves at a slower pace than the effective demand. This implies that short lived turbulences may emerge during the transitional dynamics towards the equilibrium path defined by the BOP-constrained rate of growth. The problems of mismatch between these forces may not even be solved in the long run. The institutional requirements for productivity-led adjustment are highly demanding. A strong technological policy is necessary to ensure the rapid response of productivity to the changes in effective demand in order to prevent the economy from facing supply-side constraints.

To formalize the critical role of the NSI in the KPT model, we assume that it is captured by the share of autonomous expenditure directed at building the technological capabilities that foster productivity growth (s in equation 10). The system of differential equations is the same as in the previous sub-section:

$$\dot{a} = \lambda\left(\frac{\bar{\varepsilon}g(1-\beta\pi)-\alpha a}{\pi}\right) \tag{11}$$

$$e = (\alpha - s)a + \beta\bar{\varepsilon}g - bE - v\bar{\varepsilon} - \bar{n} \tag{12}$$

Figure 1 shows the phase diagram under different technological policies – i.e. under different values of s. When policy increases the share of autonomous expenditure invested in learning, it is more likely that equilibrium could be attained before the economy reaches the supply-side constraint. This is illustrated in figure 1, which represents the isoclines corresponding to equations (11) and (12). There is just one value of a which makes $\dot{a} = 0$, represented by the vertical line a^*. The isocline in which the employment rate is constant ($e = 0$) is $E = [(\alpha - s)a + \beta\bar{\varepsilon}g - v\bar{\varepsilon} - \bar{n}]b^{-1}$ which is positively sloped assuming $\alpha > s$. The

increase in the technological effort, from s_1 to s_2 and s_3, where $s_1 < s_2 < s_3$, moves the $e = 0$ curve downwards, as it requires a lower E to sustain the same growth rate of autonomous expenditure a. The full employment level is represented by a horizontal line at $E = 1$.

Figure 1 – *Productivity and demand regimes with technological policy*
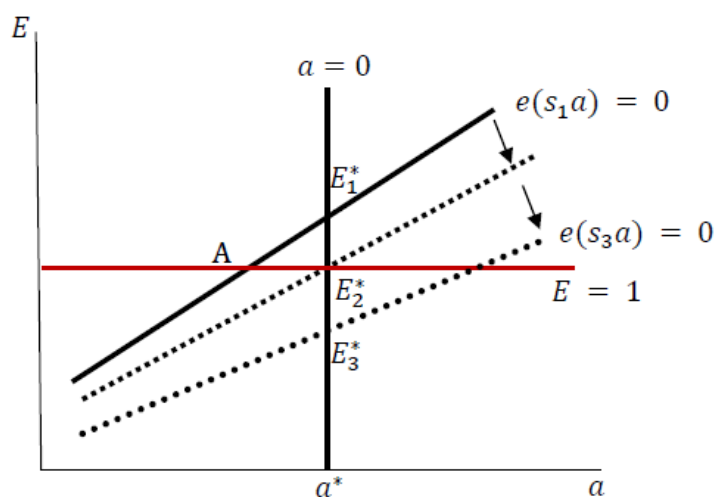
Note: the effect of the technological policy is to move $e = 0$ to the right, making it possible to attain a higher rate of productivity growth when $E = 1$. In the curve $e = 0$ it is assumed that $\alpha > s$.

Three alternative scenarios can be constructed. In the first scenario learning is so low (a low s) that productivity growth does not match the growth of effective demand when $E = 1$ (the required equilibrium level E_1^* would be above the ceiling of full employment). In such scenario, the dynamics of the model does not work, because the effective rate will never reach the BOP growth rate. The dynamic model is not valid, generating a supply side constraint in which autonomous expenditure must adjust to satisfy $E = 1$ with economic growth equal to the natural rate.

In a second scenario, technological policy raises s and shifts the $e = 0$ curve downwards so as to attain equilibrium with full employment (in point $E_2^* = 1$ on the dashed curve). The economy grows at the rate defined by the BOP constraint, while technological variables ensure that productivity responds accordingly.

The third and last scenario emerges when policy focuses just on productivity growth, and neglects structural change. A poorly diversified economy, with a low-income elasticity ratio, offers little stimulus from the point of view of effective demand. Differently, efforts at increasing productivity growth and rationalization of productive activities imply that the natural rate equals the effective rate at an employment level (E_3^*), below full employment (round dotted curve). If there is no parallel effort to change the pattern of specialization and the elasticity ratio, a pure technological policy may suggest higher unemployment, rather than faster growth. This scenario illustrates the dynamics of several Latin America economies, which rapidly opened to international trade in the Nineties. The opening to trade elicited a

rationalization response from many firms in order to survive international competition. To the extent that this was not associated with a change in the pattern of specialization, it led to a rise in unemployment (Cimoli et al., 2010).

2.4. The Krugman-Palley (KP) case

Krugman (1989) coined the expression 45-degree rule to refer to the same stylized fact of economic growth which the Keynesian literature had called BOP-constrained growth rate. Krugman's 45-degree rule and Thirlwall's Law are identical, as both state that in the long run $y^*/g = \varepsilon/\pi$. However, for Krugman, the demand elasticities for export and imports solely depend on the rate of technical change. As a result, the variables related to technology and productivity entirely explain the long run growth rate, with no role for demand side variables.

The simplest form of formalizing this approach is by making two assumptions about the rate of growth of exports (x) and about the labor productivity growth (z). The first is that the rate of growth of exports is a negative function of the employment rate (E, see equation KP1, where f is an exogenous constant and h the response of the exports elasticity to a rise in the employment rate). This is equivalent to assume that the ratio of the income elasticity of exports and imports is a negative function of the employment rate, as suggested by Palley (2009).[11] As the economy approaches the full utilization of its production capabilities, it tends to export less and import more. The second assumption is that the natural rate of growth is exogenous (KP2) and equal to $\bar{z}$ (see box 3; to simplify notation, $\bar{n}$ is assumed to be zero).

Combining these two assumptions (endogenous elasticities and exogenous technical change), when the economy grows above its natural rate and the level of employment rises, the growth of exports falls, and the effective rate of growth moves towards the natural rate. In parallel, autonomous expenditure adjusts downwards to follow the declining export capacity – and hence the BOP-constrained growth rate converges to the natural rate. In terms of direction of causality, productivity growth has the upper hand, while all the other variables adjust to it. The pressure that a higher rate of employment poses on the production capacity lowers exports and reduces the BOP-constrained growth rate.

Note that the Krugman-Palley case is an example of how the level of the real exchange rate is associated with the rate of growth (no causality implied). A higher E implies a higher W. If we consider the wage level as a proxy for the behavior of the price level and the real exchange rate in the peripheral economy, then the story might be read as follows: when the economy approaches full employment and the employment rate (E) increases, then the real exchange rate (q) appreciates, and there is a fall in the income elasticity of exports (per equation KP1). Thus, the Krugman-Palley case produces a negative association between the level of the real exchange rate and the elasticity of exports (and the elasticity ratio, since π is constant).

It is important to distinguish this case from the Prebisch-Thirlwall model. In the latter, the infinite supply of labor implies that E and the real exchange rate do not react to higher growth. This could be interpreted as showing the advantages for growth when maintaining a high and stable real exchange rate. However, the two stories are rather different. In the Krugman-Palley story, *we assume* that elasticities depend on E. In the Prebisch-Thirlwall story, growth does not depend on the level of the real exchange rate in equilibrium. Industrial and technological

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[11] The original Palley model has been criticized by Oreiro (2016) for being over-determined. We use a simpler version of Setterfield (2011) that avoids this problem.

policies are the central policy recommendations to change the elasticities and boost growth. Managing the real exchange rate is a co-adjuvant tool to attain full employment during the transitional dynamics. Causality goes from the structure to the real exchange rate, and not the other way around.

<div align="center">Box 3 – The Krugman-Palley (KP) case</div>

Closure equations

(KP1) $\varepsilon = f - hE$
(KP2) $z = \bar{z}$

Equilibrium values of the endogenous variables

(KP3) $y^* = y^N = \bar{z}$
(KP4) $x^* = (f - hE^*)g$
(KP5) $a^* = \frac{1}{\alpha}[\bar{z}(1 - \beta\pi)]$
(KP6) $E^* = \frac{fg - \bar{z}\pi}{hg}$
(KP7) $W^* = \omega(E^*)$
(KP8) $y^* = y^E = y^{BP}$

Motion equations and stability

(KP9) $\dot{a} = \lambda\left(\frac{(f-hE)}{\pi}g - \alpha a - \beta(f - hE)g\right)$
(KP10) $e = \alpha a + \beta(f - hE)g - \bar{z}$
(KP11) $J = \begin{vmatrix} -\lambda\alpha & \lambda hg\left(\beta - \frac{1}{\pi}\right) \\ \alpha & -\beta hg \end{vmatrix}$

The determinants of growth change radically in this case as compared to the previous models. Here the effective rate adjusts to the natural rate. The rate of growth continues to be the one defined by Thirlwall's Law, but causality runs in the opposite direction.

The trace of the Jacobian is negative since all parameters are positive. The determinant equals $\lambda\alpha hg\left(\frac{1}{\pi}\right)$, and it is positive. The system is therefore stable.

All models shown so far assume either no structural change, or a change in elasticities just as a result of changes in the level of employment. There is no link between technology, structural change and elasticities. Such an assumption is highly unrealistic, and excludes the Schumpeterian side of the story, namely the critical role of technology in international competitiveness. Technical change affects the pattern of specialization through the construction of indigenous capabilities and the creation of dynamic comparative advantages. This is the focus of the next section.

3. Growth, structural change and the dynamics of the technology gap

The same rate of productivity growth in a developing economy may entail very different consequences for competiveness and growth if the technological frontier moves above or below this rate. Building dynamic comparative advantages depends on reducing the technology gap with the main competitors in the international economy. Leads and lags in technological innovation and the international diffusion of technology define the set of goods that each country can competitively produce. The pattern of specialization is not given – to paraphrase the famous dictum of Joan Robinson – by God and factor endowments, but depends on endogenous processes of learning and catching up with the technological leaders.

In developing economies (the South), the diversification of the production structure (and the ensuing pattern of specialization) is closely related to the ability to absorb, master, adapt and improve foreign technology. Changing the international division of labor requires changing the technology gap and the knowledge-intensity of the production structure in the laggard economies. Luck in the commodity lottery (Diaz-Alejandro, 1986) may contribute to sustain growth for some time, but competing in the most dynamic markets in the long run requires technical and structural change.

The positive association between international competitiveness and technological capabilities can be formalized based on Cimoli (1988), Verspagen (1991) and Cimoli and Porcile (2011), as follows:[12]

$$\varepsilon/\pi = \varepsilon(T), \varepsilon_T < 0 \tag{13}$$

Equation (13) defines the 'structural change regime', a critical dimension of growth in developing economies, which may be added to the classical Kaldorian regimes (demand regime and productivity regime). T is the technology gap, defined as $T = T^N/T^S$. Laggard countries (the South) may benefit from international technology spillovers from countries on the technological frontier (the North). Taking logs in the technology gap equation and differentiating it with respect to time, we obtain the rate of growth of the technology gap (t):

$$t = t^N - t^S \tag{14}$$

In equation (14) t^N is the rate of technical change in the North and t^S that in the South. Catching-up defines a scenario in which $t < 0$, while falling behind implies $t > 0$. The rate of change of the technology gap depends on a set of variables that the Schumpeterian literature has highlighted (see subsection 1.3; the focus here is on the third part of this subsection, international spillovers).

One of these variables is the initial level of the technology gap. The specific form of the function that relates learning in the laggard economy with the initial level of the technology gap, $s(T)$, is a matter of debate. A linear form for this relationship (Fagerberg, 1988), by which the larger the initial level of the technology gap, the lower is the rate of change of the technology gap – and the higher the rate of catching up with the leader (i.e. $s_t < 0$) – is interesting for its simplicity. The evidence favors a nonlinear specification (Fagerberg and Verspagen, 2002): spillovers increase with the gap up to a certain critical point of T, after which spillovers decrease with T.

Policies are crucial for catching up. Imitation is by no means effortless, passive or automatic. It requires significant investments in the South to absorb foreign technology. The

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[12] The first derivative of $\varepsilon(T)$, $v(T)$ and $z(T)$ regarding T are written as ε_T, v_T and z_T respectively.

international diffusion of technology goes hand by hand with minor innovations and continuous investments in (formal or informal) R&D and education, in order to adapt the foreign technology to the particular (economic, social and physical) conditions faced by the catching up country (Katz, 1984; Metcalfe, 1994; Cimoli and Dosi, 1995; Fransman, 1995; Lundvall, 2007; Cimoli et al., 2010). Otherwise, the diffusion of technology would be very slow and localized, giving rise to a scenario of lagging behind.

Besides technological spillovers, there are two additional effects of the technology gap that is necessary to consider in the analysis. A high technology gap implies, through equation (13), that the Southern economy is less diversified, and therefore comprises a lower share of knowledge-intensive activities in total production. Therefore, the process of learning out of knowledge complementarities across sectors is hampered. Moreover, since a lower $\varepsilon(T)$ also implies a lower rate of growth (compatible with external equilibrium) in the long run, learning by doing will then be weaker in the laggard economy. These forces are captured (as in the previous section) by the Kaldor-Verdoorn coefficient b and the increasing returns to diversification coefficient v. The negative effects of a higher T on effective demand and diversification in part compensate for the positive influence on learning from international technological spillovers.

In the next subsections two cases are discussed: the case of linear technological spillovers (3.1) and the case of nonlinear technological spillovers (3.2). To include a new state variable (T) and at the same time keep the model tractable, it is assumed that the economy is always upon its BOP-constrained growth path (i.e. autonomous expenditure, and particularly fiscal policy, automatically fills in the gap between the effective rate of growth and the equilibrium rate of growth). Therefore, y^E equals y^{BP} at any point in time. State variables in the new dynamic system are the technology gap (T) and the employment rate (E).

3.1. Linear technological spillovers

Based on the previous discussion, the dynamics of the technology gap can be written as follows:

$$t^s = s(T) + bE + v\varepsilon(T) \tag{15}$$

$$t = \lambda[t^N - s(T) - bE - v\varepsilon(T)] \tag{16}$$

Recall that $s(T)$, with $s_t > 0$, represents international spillovers, b is the Kaldor-Verdoorn coefficient, v are returns to diversification; $\varepsilon(T)$, with $\varepsilon_T < 0$, represents the structural change regime; and t^N is the (exogenous) rate of learning in the leading economies.

Economic growth in equilibrium will be given by:

$$y^{BP} = \varepsilon(T)g, \varepsilon_T < 0 \tag{17}$$

We consider two different approaches to the dynamics of productivity growth. The first approach is to relate productivity growth to the *rate* of technological change, i.e. $z = z(t^S)$, $z(t^S) > 0$. The second approach is to relate productivity growth to the *level* of technological capabilities in the countries, i.e. $z = z(T)$, $z_T < 0$, the higher the technology gap, the lower the rate of productivity growth.

To simplify the analysis, we assume that the function $z(\cdot)$ is linear and $z(t^S) = t^S$, the assumption of a rate to rate relationship between productivity and technology generates the

following motion equation for the growth of employment in the laggard economy, where $e = \xi[\varepsilon(T)g - t^s]$:

$$e = \xi[\varepsilon(T)g - s(T) - bE - v\varepsilon(T)] \tag{18}$$

Equations (16) and (18) form a system of differential equations which renders the equilibrium values of E and T, as represented in figure 2.

Figure 2 – *Adjustment with linear technological spillovers: the rate to rate case*
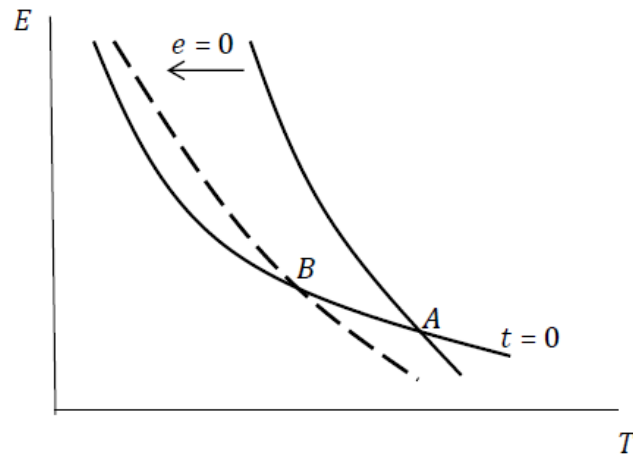
There is a role in the model for a structural change policy. If such a policy reduces ε_T (*i.e.* the economy is more diversified, and therefore effective demand is higher with the same level of the technology gap), this reduces the slope of the $e = 0$ curve to produce an equilibrium with less unemployment and a lower technology gap (from A to B). Although the model produces the natural rate of growth in equilibrium (growth equals productivity growth in the South, which in turn equals productivity growth in the North, $y^E = t^N$), and hence is supply-side dominated, structural change and demand side variables do have a role in defining the level of the technology gap and the level of the employment rate. A permanent shock on the income elasticity ratio, or a policy aimed at diversification, redefines growth and the relative stock of capabilities in equilibrium.

The model, however, is not stable, but produces a saddle equilibrium point – see the Jacobian in equation (19).

$$J = \begin{vmatrix} \lambda(-s_T - v\varepsilon_T) & -\lambda b \\ \xi[\varepsilon_T(g - v) - s_T] & -\xi b \end{vmatrix} \tag{19}$$

In fact, the determinant of the matrix is $\lambda\xi b\varepsilon_T g$. Since ε_T is negative, and λ, ξ, b and g are all positive, the determinant is negative and the equilibrium is a saddle point. The scenario that emerges from a model with these features is one of divergence, unless the economy is by chance placed on the stable arm, and remains there in the absence of shocks or disturbances.

Differently, if a level to ratio effect is admitted (from the level of the technology gap to the rate of productivity growth), a different scenario will arise. In this case, $z = z(T)$, $z_t < 0$, which leads to the following motion equation for the employment rate in the South:

$$e = \xi[\varepsilon(T)g - z(T)] \tag{20}$$

The system formed by equations (16) and (20) is represented in figure 3.

Figure 3 – *Adjustment with linear technological spillovers: the level to rate case*
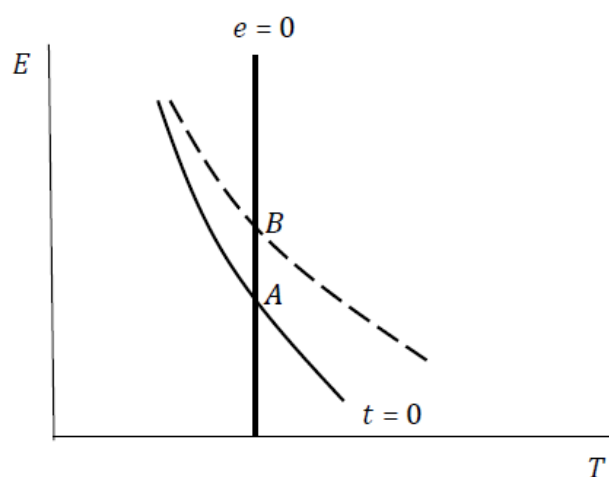
A policy of structural change that reduces ε_T also reduces the slope of the $t = 0$ curve and defines a new equilibrium, with a higher level of employment and the same level of the technology gap. In addition, an increase in world demand reduces the technology gap (moves the $t = 0$ curve to the left) and raises the employment level.

The Jacobian of the system is given by:

$$J = \begin{vmatrix} \lambda(-s_T - v\varepsilon_T) & -\lambda b \\ \xi(\varepsilon_T g - z_T) & 0 \end{vmatrix} \tag{21}$$

Here we have $\lambda > 0$, $\xi > 0$ $s_T > 0$, $z_T < 0$, $v > 0, b > 0$ and $\varepsilon_T < 0$. Stability requires $(s_T/v) > -\varepsilon_T < (-z_T/g)$. The rate of growth of the economy will equal productivity growth, which in turn is driven by supply side variables – such as the rate of growth of the world economy (g). While the growth of the technological capabilities is exogenous in the model, given by the growth rate of capabilities in the leading economies ($t^N = t^S$), it is not the same for the other variables. The productivity growth rate, natural growth rate, employment equilibrium rate, and the economic growth rate depend as well on demand-side variables.

3.2 Nonlinear technological spillovers

In this section, we address the case of a nonlinear $s(T)$ function. At low levels of the technology gap, a rise in the gap increases technological spillovers towards the laggard economy. After a critical level, however, an increase in the gap reduces technological spillovers due to the lack of the indigenous capabilities required to learn from the countries on the technological frontier. Formally:

$$t^S = bE + T(\phi_0 - \phi_1 T) \tag{22}$$

Maximum spillovers are obtained by the laggard when $T = \phi_0/2\phi_1$. The differential equations system here takes the following form:

$$t = \lambda[t^N - bE - T(\phi_0 - \phi_1 T)] \tag{23}$$

$$e = \xi[\varepsilon(T)g - z(T)] \tag{24}$$

The Jacobian of the system is given by:

$$J = \begin{vmatrix} \lambda(2\phi_1 - \phi_0) & -\lambda b \\ \xi(\varepsilon_T g - z_T) & 0 \end{vmatrix} \tag{25}$$

Stability requires two conditions: firstly, that $\varepsilon_T > (z_T/g)$, and secondly the equilibrium technology gap (T^*) is smaller than the technology gap, which produces maximum spillovers (i.e. $T^* < \phi_0/2\phi_1$) – generating a negative trace. Figure 4 represents the case of nonlinear technological spillovers. A technological policy that increases the level of maximum spillovers (by increasing, for instance, the parameter ϕ_1) shifts the curve $t = 0$ upwards (from the solid to the dashed curve) and generates higher levels of employment (from point A to point B in figure 4). In the same vein, a policy of structural change that increases the income elasticity ratio (and effective demand for a given rate of growth of the world economy), shifts the $e = 0$ curve to the left, and produces a higher employment rate with a lower technology gap (from point A to point C in figure 4).

Figure 4 – *Adjustment with nonlinear technological spillovers*
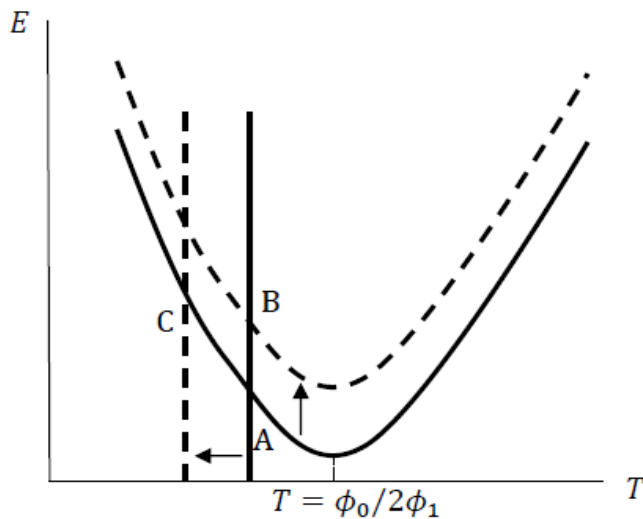
Finally, a technological shock that rises the technology gap beyond the critical value $\phi_0/2\phi_1$ will lead to an unstable system and generate growing divergence through time. The dynamics of the system may then be radically affected by the implementation (or the absence) of an industrial policy, as well as by a change in the expansion rate of the world economy.

Hence, a policy that reduces (raises) $\phi_0(\phi_1)$ may produce more than a quantitative change, but rather a qualitative change in the behavior of the system.

4.   Concluding remarks

This paper discusses different adjustment mechanisms to ensure the convergence between the effective rate of growth, the natural rate of growth and BOP-constrained rate of growth. We first analyzed such mechanisms assuming that there are no international technological spillovers. The natural rate is endogenous when there is a large subsistence sector (an infinite pool of labor) that allows labor supply to close the gap between the effective and the natural rates of growth. If income elasticity of exports and imports are exogenous and labor supply is not elastic, the natural rate of growth may still be endogenous, if productivity growth closes the gap between the effective and the natural rates. However, the intensity of the Kaldorian learning by doing may not suffice to produce the convergence between these rates, unless perhaps in the presence of powerful industrial and technological policies that enhance the ability of workers and firms to learn. Note, however, that if policy focuses exclusively on productivity growth and neglects structural change, the economy will remain poorly diversified and the policy can result in a higher rate of unemployment. Another scenario emerges when the export and import elasticities are a negative function of the employment rate: if the economy grows above its natural rate (employment rises), the growth of exports falls, and the effective rate of growth moves towards the natural rate. Autonomous expenditure adjusts downwards along with the BOP-constrained growth rate towards the natural rate.

Secondly, we discussed the adjustment process when there are international technological spillovers. The technology gap co-evolves with the pattern of specialization and the rate of employment in such a way that, supply-side and demand-side variables interact to shape the effective rate of growth (assumed to always equal the BOP-constrained rate of growth) and the natural rate of growth. We addressed two cases, which are those most frequently discussed in the literature, namely linear and nonlinear technological spillovers. In the nonlinear case, beyond a critical level of the technology gap, an increase in the gap reduces technological spillovers due to the lack of the indigenous capabilities required to learn from the countries on the technological frontier. In all cases, the key role of the NSI is highlighted to allow the economy to spur the rate of productivity growth and change the pattern of specialization. We also stressed that structural change policies aimed at boosting aggregate effective demand (moving towards sectors with higher income elasticity of exports) are crucial to sustain rapid productivity growth without compromising full employment.

Ultimately, the paper highlights the importance of developing indigenous technological capabilities and reducing the technological gap to make convergence (catching up between South and North) possible. On the other hand, many key policies and analytical questions remained outside the scope of the paper. Some of these questions could be addressed with the tools provided by this type of technology gap – structural change – BOP-constrained growth model. In particular, the various mechanisms through which the real exchange rate could affect the structural parameters of the model requires further research, as well as empirical work that may help calibrate and simulate the results of the model with real data.

Appendix — List of variables

y^E – Effective growth rate
y^N – Natural growth rate
y^{BP} – Equilibrium growth rate
x – Growth of exports
m – Growth of imports
π – Income elasticity of the demand for imports
ε – Income elasticity of the demand for exports
ε/π – Income elasticity ratio
α – Share of autonomous expenditure in total income
β – Share of exports in total income
a – Growth of autonomous expenditure
g – Expansion of the world economy
ϵ – Price of the foreign currency (units of domestic currency per unit of foreign currency)
E – Employment rate
e – Rate of change of the employment rate
q – Real exchange rate
$\dot{q}$ – Rate of depreciation of the real exchange rate
P^* – International price index
P – Domestic price index
ψ_x – Price elasticity of exports
ψ_m – Price elasticity of imports

n – Rate of growth of labor supply
$\bar{n}$ – Population growth
z – Rate of growth of labor productivity
W – Wage rate of the economy
σ – Elasticity of labor supply
L – Total employment
N – Total labor supply in the economy
T – Technology gap
T^N – Technological capabilities in the North
T^S – Technological capabilities in the South
t – The rate of change of the technology gap
t^s – Rate of technological change in the South
t^n – Rate of technological change in the North
s – Domestic efforts at technological learning
l – Growth of labor demand
λ – Speed of adjustment from the short run to the long run
ω and υ – Migration cost to modern sector
b – Kaldor-Verdoorn coefficient
v – Returns to diversification
ϕ_0 and ϕ_1 – Non-linear International Spillovers Parameters (Minimun and Maximun).
ξ – Speed of the catch-up process

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