A Kaldor-Schumpeter Model of Cumulative Growth: Combining Increasing Returns and Non-price Competitiveness with Technological Catch-up and Research Intensity[1]

João P. Romero
Centro de Desenvolvimento e Planejamento Regional (CEDEPLAR-UFMG)
Email: jpromero@cedeplar.ufmg.br

Área 6 - Crescimento, Desenvolvimento Econômico e Instituições

Resumo: Em função da importância das contribuições das abordagens Kaldoriana e Schumpeteriana para a teoria macroeconômica do crescimento, o presente artigo propõe um modelo de crescimento que combina de forma consistente as ideias centrais dessas duas vertentes, resolvendo algumas importantes limitações do modelo Kaldor-Dixon-Thirlwall original. O modelo proposto leva em consideração os principais fatores enfatizados nas duas literaturas, mantendo a relevância tanto de fatores de oferta como de fatores de demanda na determinação do crescimento. O modelo Kaldor-Schumpeter proposto no artigo é também transposto para uma forma multi-setorial que indica: (i) que mudanças na performance de um dado setor afetam a performance de outros setores via externalidades inter-setoriais que operam através do relaxamento da restrição externa; e (ii) que um aumento na taxa de crescimento da renda externa pode exercer um impacto negativo sobre a economia doméstica, caso o efeito negativo da maior competitividade não-preço externa que resulta desse aumento seja superior ao efeito positivo de aumento da demanda externa.

Palavras-chave: Retornos crescentes de escala; Modelo Kaldor-Dixon-Thirlwall; Intensidade de pesquisa; Catch-up tecnológico; Lei de Thirlwall.

JEL: O11; O41; O30.

Abstract: Taking into account the relevance of the Kaldorian and the Schumpeterian contributions to macroeconomic growth theory, this paper proposes a growth model that consistently combines the insights of these two traditions while solving some of the most important limitations of the original Kaldor-Dixon-Thirlwall model. This model takes into account the main factors emphasized by the Kaldorian and the Schumpeterian literatures, while keeping the importance of both demand and supply-side factors for economic growth. The proposed Kaldor-Schumpeter growth model was also transposed to a multi-sectoral setting that indicates that: (i) changes in the performance of a given sector affect the performance of the other sectors through inter-sector demand externalities by easing the BOP constraint; and (ii) an increase in the growth rate of foreign output can exert a negative impact on the domestic economy, provided that the negative effect of higher foreign non-price competitiveness is larger than the positive demand effect.

Keywords: Increasing Returns; Kaldor-Dixon-Thirlwall Model; Research Intensity; Technological Catch-up; Thirlwall's Law.

JEL: O11; O41; O30.

[1] Este trabalho contou com o apoio financeiro da FAPEMIG.

A Kaldor-Schumpeter Model of Cumulative Growth: Combining Increasing Returns and Non-price Competitiveness with Technological Catch-up and Research Intensity

1. Introduction

Both the Kaldorian and the Schumpeterian approaches to economic growth have strong foundations, with important contributions to macroeconomic growth theory and considerable support from a large number of empirical works.

The two approaches carry some important similarities. Both approaches emphasize the importance of endogenous technical progress and trade for economic growth, while recognizing the crucial role of non-price competitiveness for trade performance (e.g. Kaldor, 1970; Fagerberg, 1988). Furthermore, both streams emphasize the relevance of structural differences between sectors or industries. In addition, both approaches stress the importance of cumulative mechanisms that guarantee positive growth rates in the long-term. In the Kaldorian tradition, cumulativeness comes from the impact of output growth on productivity growth (e.g. Dixon and Thirlwall, 1975), while in the Schumpeterian tradition cumulativeness comes from the impact of knowledge accumulation (which faces constant marginal returns) on productivity growth (e.g. Romer, 1990; Aghion and Howitt, 1992; 1998). And finally, both approaches predict conditional convergence (see Roberts, 2007; Griffith et al, 2004).

These similarities notwithstanding, the two traditions present an important difference. While Kaldorian theory emphasizes the importance of demand growth for long-term growth, putting less stress on the importance of supply-side factors, the opposite holds for Schumpeterian theory. Although this difference does not make the two approaches necessarily incompatible, it does create an important difficulty, since combining these theories can subvert one of the two by attributing final role to either demand or to supply alone.

A number of works have sought to combine Kaldorian and Schumpeterian insights into models of cumulative growth. Amable (1993), for instance, put together a model that takes into account the importance of both research intensity and technological transfer for productivity growth, but does not specify how productivity growth impacts output growth nor considers the role of exports in long-term growth. Targetti and Foti's (1997) model, in turn, stresses the importance of technological transfer for productivity growth, but disregards the roles of research intensity and non-price competitiveness for long-term growth. León-Ledesma's (2002) model, however, represents the most complete formalization of Kaldorian and Schumpeterian insights. The author expanded Dixon and Thirlwall's (1975) model by introducing the technology gap, research intensity and technological competitiveness into the Kaldorian model. Nonetheless, León-Ledesma's (2002) tests suggest that demand factors do not influence research intensity, while this variable has a positive impact on export growth. In contrast with the Kaldorian approach, therefore, this ends up attributing a more prominent role to supply-side factors in determining export growth. In addition, León-Ledesma's (2002) tests suggest also that research intensity does not impact on productivity growth, going against one of the key findings of the Schumpeterian literature. Thus, these issues suggest that some of the relationships adopted in the model might be problematic, casting doubt on its dynamics. Finally, it is also important to note that none of the models discussed above takes sectoral differences[2] into account nor incorporates the importance of balance-of-payments (BOP) constraint for long-term growth, as emphasized by Kaldor (1970) and Thirlwall (1979). In sum,

[2] Cimoli and Porcile's (2014) model is one of the few models that try to combine Kaldorian and Schumpeterian insights taking into account sectoral differences. However, the model is inspired in a structuralist framework that is very different from the Schumpeterian and the Kaldorian models, and that does not take into account all the factors considered in these approaches.

none of these seminal works has managed to construct a model that satisfactorily encompasses the contributions of both the Kaldorian and the Schumpeterian traditions.

This paper's contribution to the existing literature is threefold. First, the paper presents a growth model that consistently combines the key insights from the Kaldorian and the Schumpeterian traditions, while keeping the importance of both demand and supply-side factors for long-term growth. This model not only formally integrates the two approaches, but it also addresses three important limitations of the Kaldor-Dixon-Thirlwall (KDT) model developed by Dixon and Thirlwall (1975), namely: (i) that the model does not account for BOP constraint; (ii) that cumulativeness works through price competitiveness; and (iii) that the degree of returns to scale is left unexplained. The Schumpeterian contributions are incorporated into the KDT model by introducing the effect of technological transfer as a determinant of technical progress, and introducing research intensity as a determinant of the degree of returns to scale. Interestingly, the model is compatible with the existing empirical evidence on conditional convergence, with the Kaldorian and the Schumpeterian empirical literatures and with the evidence provided by Romero and Britto (2016) and Romero and McCombie (2016b). Hence, this model shows that the Kaldorian and the Schumpeterian traditions can be combined without subverting their core ideas, as long as both demand and supply-side factors are allowed to play a role in long-term growth. Second, the paper proposes a multi-sectoral version of this Kaldor-Schumpeter growth model to demonstrate that in a multi-sectoral setting with BOP constraint, increases in productivity growth in a given sector generate increases in productivity and output growth in the other sectors of the economy due to inter-sector demand externalities. Third, the paper shows that, in a multi-sectoral framework, increases in foreign output growth can exert a negative impact on the growth rate of the domestic economy, provided the resulting negative effect on domestic exports and imports through non-price competitiveness is larger than the resulting positive demand effect on domestic exports.

The remainder of the paper is divided in five sections. Section 2 presents a Kaldor-Schumpeter model of cumulative growth. Section 3 discusses the multi-sectoral version of this model. Section 4 presents the concluding remarks of the paper.

2. An aggregate Kaldor-Schumpeter growth model

The Kaldor-Dixon-Thirlwall (KDT) model developed by Dixon and Thirlwall (1975) is the canonical model of economic growth from a Kaldorian perspective. This model describes how export, output and productivity growth interact to form a circuit of cumulative growth.

Still, the KDT model has three important limitations. First, the original model puts more emphasis on price competitiveness than on non-price competitiveness. This is an important limitation, given that it makes the model inconsistent with empirical evidence on the neutrality of price competition[3] in the long-term. If relative prices are assumed to be constant in the long-term, however, the model loses its cumulative mechanism. Moreover, attempts to solve this limitation, as Setterfield's (2011) model, have never been empirically tested. Second, the central parameters of the model are not explained. The price elasticity of exports, the Verdoorn coefficient, and the elasticity of output with respect to exports are the parameters that determine the magnitude of the equilibrium growth rate. Yet, the model does not provide any explanation for what determines the magnitude of these parameters between countries (or regions) and through time. Furthermore, not much empirical research has focused on investigating the determinants of these parameters. Third, the model does not take into account differences between sectors. Although Kaldor (1966) emphasised the differences in returns to scale between manufacturing, agriculture and services, the

[3] A vast literature provide evidence that in the long run, price elasticities of demand do not have a significant effect on export growth, either because relative prices change only negligibly in the long-term, or because the Marshal-Lerner condition is not satisfied (see Blecker, 2013).

KDT model does not take such sectoral differences into consideration. Moreover, recent evidence has also shown that income elasticities of demand for exports differ between sectors (Gouvea and Lima, 2010; Romero et al., 2011; Romero and McCombie, 2016a), which suggests that the sectoral disaggregation can be twice as important.

In addition to these three internal limitations, the model does not consider the impact of two important supply-side factors that the Schumpeterian literature has found to be significant in explaining productivity growth: research intensity and technology transfer.

This section presents a Kaldor-Schumpeter (KS) growth model that addresses the limitations of Dixon and Thirlwall's (1975) model and of previous growth models that have sought to combine Kaldorian and Schumpeterian insights.

Firstly, to incorporate the BOP constraint into the original KDT model, the Hicks (1950) super-multiplier, used in the original KDT model to relate export growth to output growth, was replaced by a BOP equilibrium growth rate, as done by Thirlwall and Dixon (1979) and Blecker (2013).

Secondly, to change the channel through which cumulative causation operates, two changes were carried out: (i) relative prices are assumed to be constant in the long term, not exerting a significant impact on export and import growth; and (ii) relative productivity growth affects export and import growth via its impact on non-price competitiveness. Ideally, the demand function of a given good should take into account the features of the product and of its competitors, as well as their prices and the income of the consumers (e.g. Hausman, 1997; Nevo, 2001). However, taking into account the different characteristics of each good is an extremely difficult task, especially in macroeconomic investigations. Traditionally, the Kaldorian literature considers that non-price factors are captured in the income elasticity of demand, assuming that goods with higher demand, given relative prices, are the ones with higher quality. This specification, therefore, is a second-best option, adopted in face of unobservable differences in quality (amongst other non-price competitiveness factors). By contrast, the export and import functions used in this paper's model introduce differences in productivity to capture differences in the quality of the goods, as proposed and tested by Romero and McCombie (2016b). Thus, this specification not only takes into account technological competitiveness, as emphasized by Schumpeterian works, but it also captures the effect of other non-price factors that affect productivity.

Thus, the first three equations of the model are a simple BOP equilibrium condition, an expanded export demand function and an expanded import demand function, respectively:

$$\hat{X} = \hat{M} \quad (1)$$

$$\hat{X} = \varepsilon\hat{Z} + \gamma(\hat{Q} - \hat{Q}_f) \quad (2)$$

$$\hat{M} = \pi\hat{Y} + \delta(\hat{Q}_f - \hat{Q}) \quad (3)$$

where X is exports, M is imports, Z is foreign income, Y is domestic income and Q is productivity. The hats over the variables denote growth rates and the subscript f indicates variables or parameters for the foreign economy. In addition, ε and π are the income elasticities of demand for exports and imports, respectively. Finally, γ and δ are the non-price elasticities of demand for exports and imports, respectively.

As in the original KDT model, productivity growth is determined by the growth of output via Kaldor-Verdoorn's Law. Still, in the present model it is also assumed that technological transfer influences productivity growth (e.g. Angeriz et al., 2008; 2009), so that productivity growth in the domestic economy is given by:

$$\hat{Q} = \rho + \lambda\hat{Y} + \beta G \quad (4)$$

where $G = (Q_f - Q)/Q$ denotes the technology gap, ρ is the autonomous productivity growth, λ and is the Verdoorn coefficient.

For the foreign economy, however, productivity growth is given by the simple Kaldor-Verdoorn Law, given that the technology gap becomes zero by assuming that this is the leading economy:

$$\hat{Q}_f = \rho + \lambda_f \hat{Z} \tag{5}$$

Thirdly, following the evidence provided by Romero and Britto (2016), equations (6) and (7) make the Verdoorn coefficient partially endogenous, being determined by the level of research intensity (*T*) in each economy. Kaldor-Verdoorn's Law indicates that productivity growth is driven by demand growth, through its impact on technical progress (i.e. division of labour). Still, the law does not take into account supply-side factors that might influence the pace of technical progress. The Schumpeterian literature, in turn, emphasizes that technical progress is influenced by research intensity, which depends on the amount of resources devoted to research and other activities related to the creation of innovations (e.g. Aghion and Howitt, 1998; Madsen, 2008). Thus, if research intensity intensifies technical progress, then higher research intensity should increase the degree of increasing returns to scale. Put simply, this means that in face of demand growth, economies with higher research intensity will be able to increase division of labour more quickly, generating higher productivity growth through higher increasing returns to scale. Thus, in contrast with the expanded Kaldor-Verdoorn Law proposed by León-Ledesma (2002), in this paper's KS model, following Romero and Britto (2016), research intensity has no independent effect on productivity growth, affecting it only when associated with demand growth. Consequently, incorporating the Schumpeterian approach into the Kaldorain framework endogenizes the Verdoorn coefficient, contributing to solve one of the most important limitations of the KDT model, i.e. that the central parameters of the model, among them the Verdoorn coefficient, are not explained. It is important to note, however, that in this model, in contrast with León-Ledesma's (2002) model, research intensity is assumed to be an exogenous variable.[4]

$$\lambda = \alpha + \tau T \tag{6}$$
$$\lambda_f = \alpha + \tau T_f \tag{7}$$

where *T* is research intensity.

It is crucial to note, therefore, that the model described above presents three important differences in relation to the original KDT model. First, the KS model substitutes the Hicks super-multiplier by the BOP equilibrium growth rate as the initial determinant of output growth (e.g. Thirlwall and Dixon, 1979; Blecker, 2013). Second, the model assumes relative prices are constant, so that this term is dropped from the export and import functions and the equation that represents the determinants of price changes is dropped from the model as well (e.g. Setterfield, 2011). Third, cumulativeness is introduced into the model via the effect of productivity growth, generated through Kaldor-Verdoorn's Law, on exports and imports, assuming that productivity growth is associated with increases in non-price competitiveness (e.g. Romero and McCombie, 2016b).

Hence, the KS model described in this section incorporates two important innovations in relation to the original KDT model and its modified versions.

The first innovation of the model is to incorporate the expanded export and import functions proposed by Setterfield (2011), and discussed and tested by Romero and McCombie (2016b). These

[4] See Romero and Britto (2016) for a discussion on the exogeneity of research intensity.

functions that take into account differences in non-price competitiveness captured in relative productivity. This provides more information on the determinants of trade performance, while keeping the key aspects of Kaldorian and Schumpeterian traditions. Regarding Kaldorian theory, stressing the role of productivity growth does not mean subverting the demand-oriented approach to trade performance (*a la* Krugman, 1989), given that productivity growth is driven by demand, following Kaldor-Verdoorn's Law. Regarding Schumpeterian theory, emphasizing the more general non-price competitiveness captured in productivity growth does not mean that technological competitiveness is not relevant either, given that productivity growth is associated with technological progress and partially determined by research intensity.

The second innovation of the model is to incorporate the impact of research intensity on the magnitude of the Verdoorn coefficient, as proposed and tested by Romero and Britto (2016). This innovation indicates that in face of demand growth, economies with higher research intensity will be able to increase division of labour more quickly, generating higher productivity growth through higher increasing returns to scale. Again, this contributes to better understand the determinants of productivity growth, while keeping the central aspects of Kaldorian and Schumpeterian theories. Regarding Kaldorian theory, this innovation keeps the central role of demand growth for productivity growth. Regarding Schumpeterian theory, in turn, this innovation keeps the idea that research intensity is relevant for productivity growth, just changing how this effect works.

Turning back to the model, substituting equation (6) in (4) gives the models' productivity curve (PR):

$$\hat{Y} = -\left(\frac{\rho + \beta G}{\alpha + \tau T}\right) + \left(\frac{1}{\alpha + \tau T}\right)\hat{Q} \tag{8}$$

In addition, substituting equations (2) and (3) into equation (1), and then substituting equations (5) and (7) into it yields the BOP growth rate (BP):

$$\hat{Y} = \left(\frac{\varepsilon\hat{Z} - (\gamma + \delta)[\rho + (\alpha + \tau T_f)\hat{Z}]}{\pi}\right) + \left(\frac{\gamma + \delta}{\pi}\right)\hat{Q} \tag{9}$$

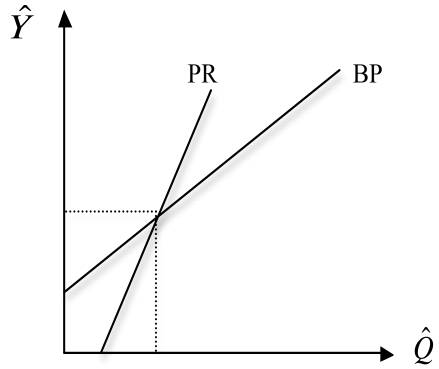
Equilibrium is found substituting equation (8) into equation (9):

$$\hat{Y}^* = \frac{\varepsilon\hat{Z} + (\gamma + \delta)[\beta G - (\alpha + \tau T_f)\hat{Z}]}{\pi - (\gamma + \delta)(\alpha + \tau T)} \tag{10}$$

Five important implications follow from equation (10). First, if relative productivity has no effect on demand, then $\gamma = \delta = 0$ and equation (10) reduces to Thirlwall's Law. Second, equation (10) has a stable equilibrium solution if $0 < (\gamma + \delta)(\alpha + \tau T) < \pi$. Third, an increase in research intensity in the domestic economy (T), ceteris paribus, increases the equilibrium growth rate. Fourth, an increase in research intensity in the foreign economy (T_f), ceteris paribus, decreases the equilibrium growth rate, given that such increase raises the growth rate of productivity in the foreign economy, which benefits imports and hinders exports from the domestic economy. Fifth, the higher the technology gap is, the higher the equilibrium growth rate is, ceteris paribus. Still, equation (10) shows also that the equilibrium growth rate of output can stay unchanged or even decrease if an increase in research intensity (T) occurs simultaneously to a decrease in the growth rate of foreign income ($\hat{Z}$). Similarly, an increase in foreign demand can exert little impact on output growth, if it is accompanied by a decrease in research intensity.

Figure 1 illustrates the equilibrium of the model. As the figure shows, this equilibrium is given by the intersection between the PR and the BP curves. On the one hand, if the rate of growth of output is higher than the equilibrium rate, then the effect of higher non-price competitiveness on exports and imports (via the increase in productivity growth) will not be large enough to offset the raise in import growth motivated by the increased output growth. Consequently, the economy will run into BOP deficits, which will force the growth rate to reduce back to the equilibrium rate. On the other hand, if the rate of growth of output is lower than the equilibrium rate, then cumulative causation will take place through Kaldor-Verdoorn's Law, so that productivity will increase, leading to higher exports and higher output growth. This process will continue until equilibrium is reached.

Figure 1
Equilibrium output and productivity growth rates in the KS model



Source: Author's elaboration.

2.1. Model's dynamics

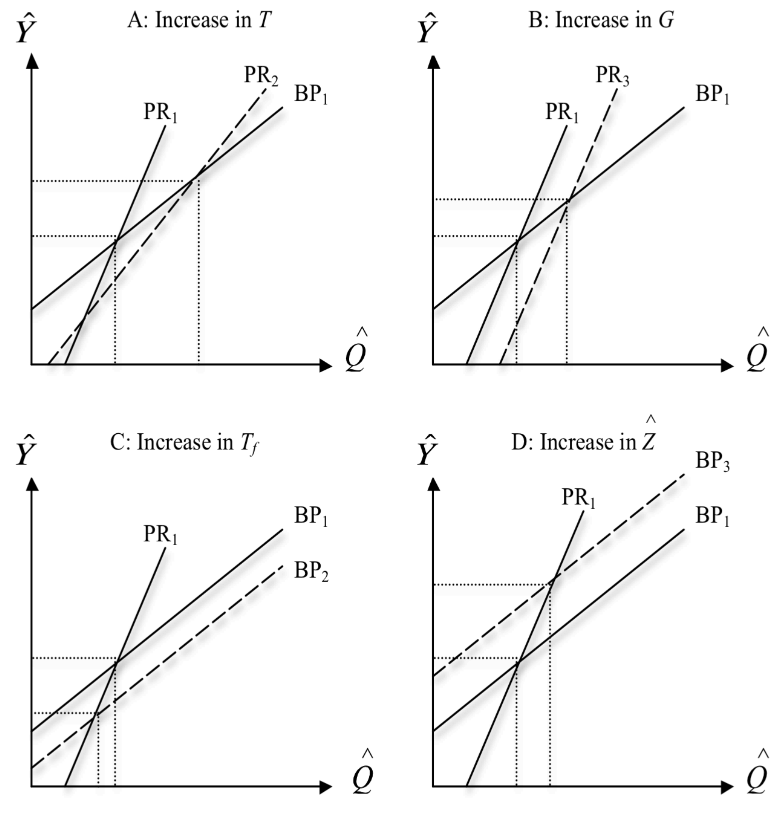
Figure 2 illustrates the effects of changes in research intensity, in the technology gap, and in the growth rate of the foreign economy.

Following equation (8), an increase in research intensity in the domestic economy (T), ceteris paribus, increases the equilibrium growth rate. This increase generates a rightward shift in the PR curve from PR_1 to PR_2 in Figure 2A, changing both the slope and the intercept of the original curve. Similarly, equation (8) also indicates that a higher the technology gap increases the country's equilibrium growth rate.

An increase in the technology gap generates a shift in the intercept of the PR curve without changing its slope. In Figure 2B, this is represented by the shift of the PR curve from PR_1 to PR_3. In addition, following equation (9), an increase in research intensity in the foreign economy (T_f) leads to a decrease in output and productivity growth rates in the domestic economy, due to the increase in non-price competitiveness that follows increases in research intensity. In Figure 2C, this increase is represented by the downward shift of the BP curve from BP_1 to BP_2.

Finally, an increase in the growth rate of the foreign economy leads to an upward shift in the BP curve, which is represented by the upward shift of BP_1 to BP_3 in Figure 2D.

Figure 2
Shifts in equilibrium output and productivity growth rates in the KS model



Source: Author's elaboration.

2.2. Simulations

In order to quantify the implications of the KS model, the parameters estimated by Romero and Britto (2016) and Romero and McCombie (2016b) were used as reference to perform simulations and analyse the magnitude of the impacts of each variable: $\rho = 0$, $\beta = 0.03$, $\pi = 2.08$, $\varepsilon = 2.35$, $\alpha = 0.37$, $\delta = 1.46$, $\gamma = 0.90$ and $\tau = 0.23$. Thus, assuming plausible and fixed values for T_f, T, G and $\hat{Z}$, i.e. 0.6, 0.2, 0.1 and 0.03, respectively, the model's stable equilibrium condition is fulfilled (i.e. $0 < (\gamma + \delta)(\alpha + \tau T) < \pi$).

Using the values listed above indicates that a considerable increase in research intensity is necessary to generate a meaningful effect on the equilibrium growth rate. With the initial values listed, the equilibrium growth rate is 3.82 per cent. An increase in the domestic research intensity from 0.2 to 0.3, however, leads to an increase in the equilibrium growth rate to 4.02 per cent. This means that and increase of 0.1 in the number of patents created per millions of hours worked generates an increase in GDP growth of 0.2 percentage points.[5] The same applies to increases in research intensity in the foreign economy. An increase in foreign research intensity from 0.6 to 0.7 reduces the equilibrium growth rate to 3.67 per cent, which represents a negative variation of 0.15 percentage points. Finally, an increase in the growth rate of the foreign economy from 3 to 4% leads to an increase in the equilibrium growth rate to 4.87%.

[5] Similar figures are obtained if the R&D to GDP ratio is used instead of patents per millions of hours worked as the measure of research intensity.

Given the importance of research intensity in this model, however, two aspects of this variable should be noted. Firstly, although this variable is considered exogenous in the model, it is possible to assume that it is in fact influenced by institutional factors, such as property rights protection, political system, education system, production linkages, etc. As Setterfield (1997: 372) argued, economies might need some particular institutions to realise certain scale economies. Similarly, in the KS model, particular institutional arrangements might be necessary to increase the level of research intensity, which determines the level of economies of scale. Secondly, the fact that research intensity has no significant effect on productivity growth dissociated from output growth can be attributed to the fact that without output growth it is hard to translate inventions into innovations, which refers back to Smith's (1776) argument that the size of the market determines the degree of division of labour.

The technology gap, in turn, has a non-linear impact on the equilibrium output growth rate, as found in previous works (e.g. Griffith et al, 2004).[6] The closer to the technological frontier a country is, the smaller is the contribution of the gap to productivity and output growth. Thus, holding domestic research intensity (*T*) constant at 0.2, an increase in the gap form 0.1 to 0.2 increases the equilibrium growth rate from 3.82 to 4.58 per cent (0.76 difference). Yet, an increase in the gap from 0.2 to 0.3 increases the equilibrium growth rate to 5.44 (0.86 difference). Thus, this examination indicates that the contribution of the gap to growth is much higher than the contribution of research intensity. Nonetheless, it is important to note that in the present model, the gap is assumed to exert a positive effect on productivity growth regardless of the characteristics of the economy. However, technological absorption most likely depends on the absorptive capacity of each country (see Abramovitz, 1986; Verspagen, 1991; Cohen and Levinthal, 1990; Griffith et al, 2004). Hence, this important qualification must be kept in mind when interpreting the effects analysed above.

3. A Multi-Sectoral Kaldor-Schumpeter growth model

In this section, the model proposed in the previous section is disaggregated into a Multi-Sectoral Kaldor-Schumpeter (MSKS) model.

Firstly, in order to subdivide the economy into sectors, the seven equations used in the aggregated KS model are now applied to each sector *i*. For simplicity, it is assumed that $\rho = 0$ and β is the same for all $i = 1,...,k$ sectors.

$$\hat{X} = \hat{M} \tag{11}$$
$$\hat{X}_i = \varepsilon_i \hat{Z} + \gamma_i (\hat{Q}_i - \hat{Q}_{fi}) \tag{12}$$
$$\hat{M}_i = \pi_i \hat{Y} + \delta_i (\hat{Q}_{fi} - \hat{Q}_i) \tag{13}$$
$$\hat{Q}_i = \lambda_i \hat{Y}_i + \beta G_i \tag{14}$$
$$\hat{Q}_{fi} = \lambda_{fi} \hat{Z}_i \tag{15}$$
$$\lambda_i = \alpha_i + \tau_i T_i \tag{16}$$
$$\lambda_{fi} = \alpha_i + \tau_i T_{fi} \tag{17}$$

Then, three auxiliary relationships are added to the model.

Equations (18) and (19) simply state that *aggregate* imports and exports are weighted averages of the respective sectoral variables:

[6] This effect is normally captured by the effect of the log of technology gap on the growth rate of productivity (e.g. Griffith et al, 2004).

$$\hat{M} = \sum_{i=1}^{k} \theta_i \hat{M}_i \tag{18}$$

$$\hat{X} = \sum_{i=1}^{k} \phi_i \hat{X}_i \tag{19}$$

where θ_i and ϕ_i are the shares of each sector in total imports and exports, respectively.

Equation (20), in turn, indicates that output growth rate in each sector of the domestic economy depends on the growth rate of foreign demand (i.e. exports) and on the growth rate of domestic demand:[7]

$$\hat{Y}_i = \mu_i \hat{Y} + \nu_i \hat{X}_i \tag{20}$$

Substituting equations (15) in (12), and then substituting the resulting expression and equation (20) in (14) yields the sectoral productivity curve (SPR):

$$\hat{Y} = -\left(\frac{\lambda_i \nu_i (\varepsilon_i \hat{Z} - \gamma_i \lambda_{fi} \hat{Z}_i) + \beta G_i}{\lambda_i \mu_i} \right) + \left(\frac{1 - \lambda_i \gamma_i \nu_i}{\lambda_i \mu_i} \right) \hat{Q}_i \tag{21}$$

In turn, substituting equations (18) and (19) into the BOP equilibrium condition (11), and then substituting equations (12), (13) and (15) into the expression and rearranging its terms gives the multi-sectoral BOP growth rate (MSBP):

$$\hat{Y} = \left[\frac{\left(\sum_{i=1}^{k} \phi_i \varepsilon_i \hat{Z} - (\phi_i \gamma_i + \theta_i \delta_i) \lambda_{fi} \hat{Z}_i \right) + \left(\sum_{j=1}^{k-i} (\phi_j \gamma_j + \theta_j \delta_j) \hat{Q}_j \right)}{\left(\sum_{i=1}^{k} \theta_i \pi_i \right)} \right] + \left[\frac{(\phi_i \gamma_i + \theta_i \delta_i)}{\left(\sum_{i=1}^{k} \theta_i \pi_i \right)} \right] \hat{Q}_i \tag{22}$$

where $\hat{Q}_j$ is the growth rate of productivity of the $j \neq i$ sector of the economy. In other words, sector i is separated from the other j sectors in the numerator so that equation (22) has a form similar to equation (9) of the KS model.

The equilibrium of the model is found substituting equation (21) into equation (22) and substituting equations (16) and (17) into it:

$$\hat{Y}* = \frac{\left(\sum_{i=1}^{k} \phi_i \varepsilon_i \hat{Z} + (\phi_i \gamma_i + \theta_i \delta_i) \{ [(\alpha_i + \tau_i T_i) \nu_i \varepsilon_i \hat{Z} - (\alpha_i + \tau_i T_i) \nu_i \gamma_i (\alpha_i + \tau_i T_{fi}) \hat{Z}_i + \beta G_i] / [1 - (\alpha_i + \tau_i T_i) \nu_i \gamma_i] - (\alpha_i + \tau_i T_{fi}) \hat{Z} \} \right)}{\left(\sum_{i=1}^{k} \theta_i \pi_i - \mu_i (\phi_i \gamma_i + \theta_i \delta_i)(\alpha_i + \tau_i T_i) / [1 - (\alpha_i + \tau_i T_i) \nu_i \gamma_i] \right)} \tag{23}$$

Equation (23) is the Multi-Sectoral version of the equilibrium equation (10) of the aggregated KS model. Note that in equation (23), as in equation (10), the first part of the numerator

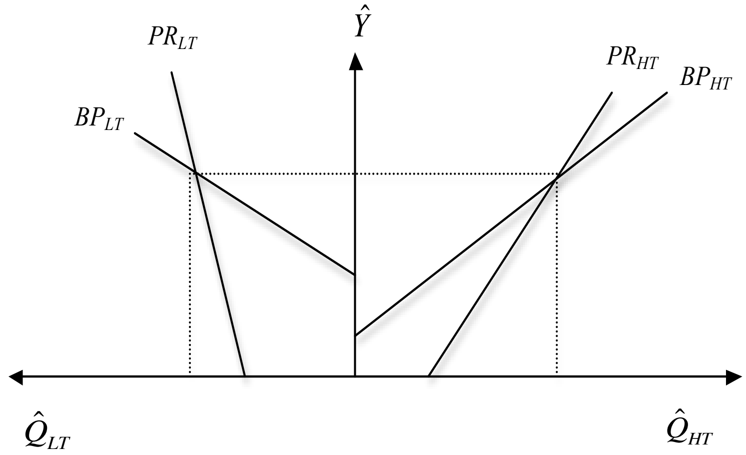
[7] Introducing a similar equation for the foreign economy does not change the results of the model. Nonetheless, this increases considerably the complexity of the model's equilibrium.

is associated with the growth rate of the foreign economy. Also analogously to equation (10), the second part of the numerator shows the impact of technology transfer on output growth, as well as the negative impact of the growth of the foreign economy on the growth rate of the domestic economy. Furthermore, the denominator is also similar, with its positive and negative parts multiplied by additional terms. The complexity of equation (23) stems from the fact that in a sectoral framework, output growth in a given sector can take place without growth of exports from this sector, provided BOP equilibrium holds. In other words, structural change in the domestic economy is possible while respecting the BOP constraint. This possibility, captured in equation (20), generates the additional terms in the equilibrium solution (23). Nonetheless, all the results found for the aggregate KS model apply to the MSKS model. First, an increase in research intensity in the domestic economy (T), ceteris paribus, increases the equilibrium growth rate. Second, an increase in research intensity in the foreign economy (T_f), ceteris paribus, decreases the equilibrium growth rate, given that such increase raises the growth rate of productivity in the foreign economy, which benefits imports and hinders exports from the domestic economy. Third, the higher the technology gap is, the higher the equilibrium growth rate is, ceteris paribus. And fourth, as in the KS model, equation (23) becomes Araújo and Lima's (2007) Multi-Sectoral Thirlwall's Law (MSTL) if it is assumed that relative productivity has no effect on exports and imports, i.e. $\gamma_i = \delta_i = 0$.[8]

Figure 3 illustrates the equilibrium of the model dividing the economy in two sectors: low-tech (LT) and high-tech (HT). This equilibrium is given by the joint intersection between the PR and the BP curves of the two sectors. The figure shows that in equilibrium, the two sectors jointly determine the equilibrium growth rate of aggregate output. Yet, each sector has different growth rates of output and productivity, determined by the parameters of the equations associated with each sector. As in the KS model, the shifts of the curves illustrated in Figure 2 also apply to each sector of the economy in the MSKS model. Thus, following equation (23), ceteris paribus, increases in research intensity and in the technology gap in any sector increase the equilibrium growth rate.

Figure 3

Equilibrium output and productivity growth rates in a two-sector KS model



Source: Author's elaboration.

It is crucial to note, however, that introducing relative productivity in export and import functions does not change the classical Kaldorian approach, which emphasizes the importance of the income elasticities of demand for long-term growth.

[8] Some of the implications of the present model are similar to the Pasinettian-Kaldorian Multi-Sectoral model developed by Araújo (2013).

Although part of the non-price competitiveness factors associated with the production of each sector *i* is removed from the income elasticities with the introduction of relative productivity in the demand functions, this variable captures only *intra-sector* non-price competitiveness, not taking into account *inter-sector* non-price competitiveness. This stems from the specification adopted for the demand functions, which does not take into account the cross non-price elasticities of demand. This specification allows income elasticities of demand to differ between sectors. Hence, as income grows, demand for different products grows at different rates following consumers' preferences *between products*, in spite of the quality of each product in relation to the quality of its competitors *within its product category* (see Romero and McCombie, 2016b).

Since elasticities are different between sectors in the MSKS model, as in Araújo and Lima's (2007) MSTL, the MSKS model suggests that an increase in the share of sectors with higher income elasticities increases the equilibrium growth rate. Still, in the MSKS model, the growth effect of sectoral shifts in trade shares works not only through the income elasticity of demand for exports (ε_i), but also through: (i) each sector's response of increasing returns to scale to research intensity (τ_i); (ii) non-price elasticity of exports (γ_i); and (iii) demand elasticities of output (μ_i and ν_i). Nonetheless, the values of these parameters most likely change in the same direction in different sectors. In other words, sectors with large income elasticities of demand for exports will probably tend to have large responses of increasing returns to research intensity, as well as large non-price elasticities of exports and demand elasticities of output.

3.1. Model's dynamics

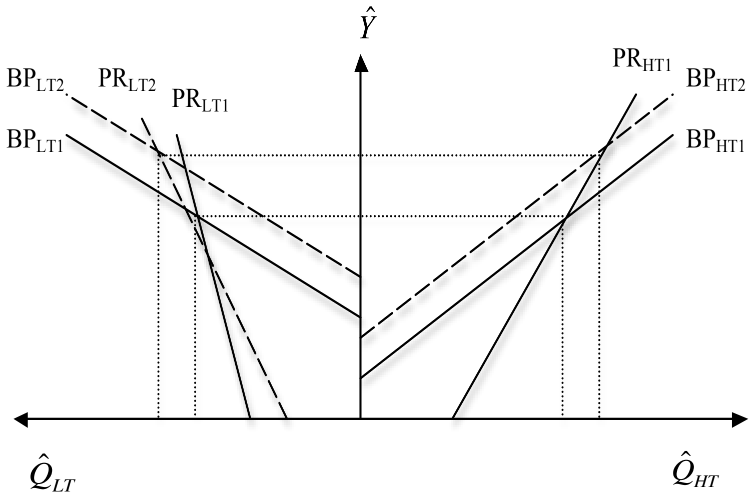
In addition to sustaining the implications of the aggregate KS model, the MSKS model generates two other interesting implications:

(i) the model stresses the importance of inter-sector demand externalities in a context of BOP constraint;
(ii) the model shows that the effect of foreign output growth on the domestic economy is not necessarily positive, given that an increase in output growth in a given sector has not only a positive demand effect on the domestic economy, but also a negative effect of the domestic economy via the resulting increase in foreign non-price competitiveness.

The most interesting aspect of the MSKS model outlined in this paper is that it suggests that changes in a given sector impact on the performance of the other sectors through inter-sector demand externalities. This result follows from the fact that in the BOP equilibrium equation (23), increases in the growth rates of productivity in sectors $j = 1,...,k$ change the intercept of this curve for sector $i \neq j$. In other words, an increase in the growth rate of productivity in a given sector of the domestic economy eases the BOP constraint, which allows higher growth rates of domestic demand, impacting on the growth rates of sectoral output (equation (20)) and of sectoral productivity (equation (14)) in other sectors. Analogously, the opposite holds for increases in the growth rate of productivity in any given sector of the foreign economy.

Figure 4 uses a two-sector KS model to illustrate the growth effect of an increase in research intensity in one of the sectors of the domestic economy. In this figure, an increase in research intensity in the low-tech sector of the domestic economy leads to a rightward shift of the PR_{LT} curve from PR_{LT1} to PR_{LT2} (equation (21)). The resulting increase in productivity growth in the low-tech sector, however, generates an upward shift of the BP curve in the high-tech sector from BP_{HT1} to BP_{HT2} (equation (22)). This generates an increase in productivity growth in the high-tech sector, which leads to a shift in the BP curve in the low-tech sector from BP_{LT1} to BP_{LT2}, generating an additional increase in this sector's productivity growth. In other words, an increase in research intensity in the low-tech sector of the domestic economy leads to an increase in this sector's productivity growth rate, which eases the BOP constraint, increasing the growth rates of output and productivity in the high-tech sector. Nonetheless, a higher productivity growth rate in the high-tech sector eases once again the BOP constraint, increasing the growth rates of output and productivity in the low-tech sector. Thus, this movement continues until a new simultaneous equilibrium in both sectors is reached, now associated with a higher equilibrium growth rate of aggregate output.

Figure 4
Shift in equilibrium output and productivity growth rates in a two-sector KS model: increase in research intensity in the low-tech sector



Source: Author's elaboration.

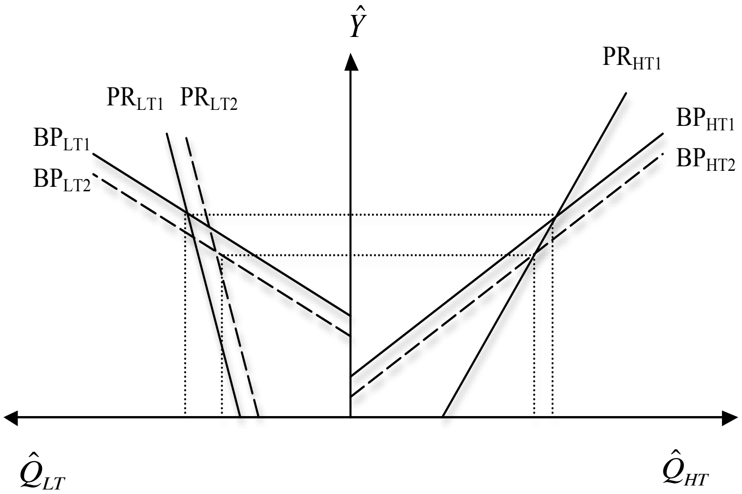
The dynamics of the MSKS model illustrated in Figure 4 stress the importance of inter-sector demand externalities in a multi-sectoral BOP constrained framework. In Araújo and Lima's (2007) MSTL, higher equilibrium growth rates are achieved through shifts in the sectoral composition of trade. In the MSKS model discussed in this paper, higher equilibrium growth rates are achieved either through structural change, as in Araújo and Lima's (2007) model, or through increases in productivity growth in any sector of the economy, even when sectoral shares are assumed constant. This model shows, therefore, that in a BOP constrained framework, when multiple sectors are considered, better export performance in any given sector leads to higher growth rates of output and productivity in the other sectors as well, given the positive effect that an attenuation of the BOP constraint exerts on the growth rates of all sector.

Evidently, in a multi-sectoral framework, the magnitude of the externalities generated by an increase in productivity growth in a given sector will depend on the value of the parameters for this sector. In sectors with higher non-price elasticity of demand (γ_i), the effect will be larger, given that an increase in productivity will lead to a larger attenuation of the BOP constraint. Moreover, the demand externalities will also be larger in countries with larger demand elasticities of output (μ_i) and larger research intensity (T_i).

Interestingly, the fact that the MSKS model presented in this paper takes into account the effects of inter-sector demand externalities implies also that increases in research intensity in a given sector of the foreign economy have negative effects in all sectors of the domestic economy.

Figure 5 illustrates the negative effect that an increase in research intensity in the low-tech sector of the foreign economy exerts on productivity and output growth in each sector of the domestic economy. Following equations (21) and (22), such increase not only shifts the PR curve to the right, from PR_{LT1} to PR_{LT2}, but it also shifts the BP curve downwards, from BP_{LT1} to BP_{LT2}. The shift in the BP curve in the low-tech sector, however, shifts the BP curve from BP_{HT1} to BP_{HT2} in the high-tech sector, reducing the growth rates of productivity and output in this sector as well. In the end, therefore, both sectors experience reductions in output and productivity growth.

Figure 5
Shift in equilibrium output and productivity growth rates in a two-sector KS model: increase in research intensity in the low-tech sector of the foreign economy



Source: Author's elaboration.

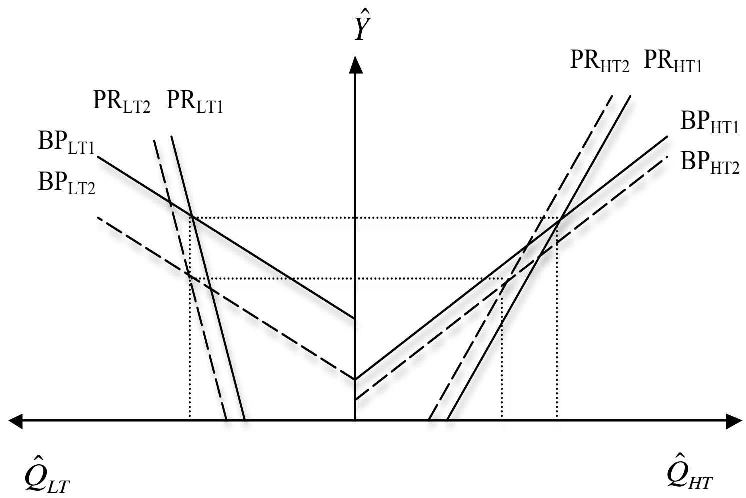
The second unique implication of the MSKS model, in turn, refers to the ambiguous effect of an increase in the growth rate of foreign output. Equations (21) and (22) show that an increase in output growth in a given sector has both a positive and a negative effect on aggregate output growth.[9] This ambiguous effect stems from the fact that although an increase in output growth in the foreign economy increases the demand for products from the domestic economy (equation (12)), it also increases the non-price competitiveness of the foreign economy (equation (15)), harming the export performance of the domestic economy. In the PR curve, output growth in a given sector of the foreign economy has, ceteris paribus, a positive effect on the growth of the domestic economy if $\varepsilon_i \Delta\hat{Z} > \gamma_i \lambda_{fi} \Delta\hat{Z}_i$, where Δ denotes variation. In the BP curve, in turn, an increase in output growth in a given sector of the foreign economy has, ceteris paribus, a positive effect on the growth of the domestic economy if $\phi_i \varepsilon_i \Delta\hat{Z} > (\phi_i \gamma_i + \theta_i \delta_i)\lambda_{fi} \Delta\hat{Z}_i$.

Figure 6 illustrates the possible scenario of a negative growth effect stemming from an increase in the growth rate of output in the high-tech sector of the foreign economy. Hence, in this figure it is assumed that $\varepsilon_{HT}\Delta\hat{Z} < \gamma_{HT}\lambda_{fHT}\Delta\hat{Z}_{HT}$, $\phi_{HT}\varepsilon_{HT}\Delta\hat{Z} < (\phi_{HT}\gamma_{HT} + \theta_{HT}\delta_{HT})\lambda_{fHT}\Delta\hat{Z}_{HT}$, $\Delta\hat{Z}_{LT} = 0$ and sectoral shares are constant. Thus, following equations (21) and (22), an increase in the growth rate of output in the high-tech sector shifts the PR_{HT} curve upwards, from PR_{HT1} to PR_{HT2}, and the BP_{HT} curve downwards, from BP_{HT1} to BP_{HT2}. These shifts lead to a downward shift in the BP_{LT} curve, from BP_{LT1} to BP_{LT2}, reducing the growth rates of productivity and output in this sector as well. Yet, because $\varepsilon_{LT}\Delta\hat{Z} > \gamma_{LT}\lambda_{fLT}\Delta\hat{Z}_{LT}$, the PR_{LT} curve shifts downward as well, from PR_{LT1} to PR_{LT2}, compensating for the tightening of the BOP constraint. Note, therefore, that although in this example the increase in foreign output growth exerts negative effects on both the PR and the BP

[9] Note that the growth rate of aggregate output is simply the weighted average of the growth rates of sectoral output, where the weights are the shares of each sector in total output (i.e. $\hat{Z} \equiv a\hat{Z}_{HT} + (1-a)\hat{Z}_{LT}$).

curves, a negative impact on one of the curves could be enough to negatively impact the growth rate of the domestic economy, if the negative impact overrides the positive.

Figure 6
Shift in equilibrium output and productivity growth rates in a two-sector KS model: increase in output growth in the high-tech sector of the foreign economy



Source: Author's elaboration.

3.2. Simulations

As carried out in section 3, in order to quantify the implications of the MSKS model, the parameters estimated by Romero and Britto (2016) and Romero and McCombie (2016b) were used as reference. Thus, using these estimates, the MSKS model becomes composed of two sectors, a low-tech sector (LT) and a high-tech sector (HT), while the values of the parameters for each sector are: $\beta_{LT} = \beta_{HT} = 0.04$, $\pi_{LT} = 2.36$, $\pi_{HT} = 1.96$, $\varepsilon_{LT} = 2.11$, $\varepsilon_{HT} = 2.65$, $\alpha_{LT} = 0.27$, $\alpha_{HT} = 0.43$, $\delta_{LT} = 1.28$, $\delta_{HT} = 1.96$, $\gamma_{LT} = 0.54$, $\gamma_{HT} = 1.38$, $\tau_{LT} = 0.33$, and $\tau_{HT} = 0.29$. In addition, assuming plausible values for the rest of the parameters: T_{fLT}=0.6, T_{fHT}=0.9, T_{LT}=0.2, T_{HT}=0.3, G_{LT}=0.1, G_{HT}=0.2, $\hat{Z}$=0.03, $\hat{Z}_{LT}$=0.02, and $\hat{Z}_{HT}$=0.05. Still, to quantify the dynamics of the MSKS model, it is also necessary to obtain estimates of the parameters of equation (20) for each sector. Basic estimates of equation (20) for low-tech and high-tech industries are presented in the Appendix, providing the following values for the parameters: $\mu_{LT} = 0.64$, $\mu_{HT} = 0.73$, $\nu_{LT} = 0.15$ and $\nu_{HT} = 0.41$. It is important to note, however, that in contrast with the other parameters, which have been carefully investigated, further work is necessary to assess with more confidence the magnitude of the parameters of equation (20).

As in the KS model, using the values listed above indicates that a considerable increase in research intensity is necessary to generate a meaningful effect on the equilibrium growth rate. With the values listed, the equilibrium growth rate is 4.33 per cent.

An increase in domestic research intensity from 0.2 to 0.3 in the low-tech sector increases the equilibrium growth rate to 4.45 per cent. This means that an increase of 0.1 in the number of patents created per millions hours worked in the low-tech sector generates an increase in output growth of 0.22 percentage points. The growth rates of productivity in the low-tech and in the high-tech sectors, in turn, increase from 1.69 and 4.52, to 1.85 and 4.59, respectively. This illustrates the positive demand externality generated in the high-tech sector as a result of an increase in productivity growth in the low-tech sector.

Alternatively, if the increase in research intensity takes place in the high-tech sector instead of the low-tech, going from 0.3 to 0.4, the equilibrium growth rate increases to 4.68 per cent, with a variation of 0.35 percentage points. Hence, this shows how the different magnitudes of the parameters associated with each sector influence the magnitude of the growth enhancing effect. In this case, the growth rates of productivity in the low-tech and in the high-tech sectors increase to 1.77 and 5.02, respectively. This shows once again the effect of the inter-sectoral externality generated by an increase in productivity growth in a given sector. In this case, however, the sum of the variations in the growth rates is higher: 0.58 percentage points compared to 0.23 in the first scenario.

Increases in research intensity in the foreign economy have a negative effect on the equilibrium growth rate of the domestic economy. An increase in research intensity in the low-tech sector of the foreign economy from 0.6 to 0.7 decreases the equilibrium growth rate from 4.33 to 4.27 per cent, with reductions also in sectoral output and productivity growth. Yet, the magnitude of this effect is very small.

In turn, an increase in the output growth rate of the low-tech sector in the foreign economy from 0.02 to 0.03 has a large impact on the equilibrium growth rate of the domestic economy, increasing it from 4.33 to 5.87. This positive effect occurs because $\varepsilon_i \Delta\hat{Z} > \gamma_i \lambda_{fi} \Delta\hat{Z}_i$ and $\phi_i \varepsilon_i \Delta\hat{Z} > (\phi_i \gamma_i + \theta_i \delta_i)\lambda_{fi} \Delta\hat{Z}_i$, highlighting the importance of foreign demand for long-term growth, in spite of the negative effect of foreign output growth on domestic output growth via increased foreign non-price competitiveness.

An increase in the output growth rate of the high-tech sector in the foreign economy from 0.05 to 0.06, however, exerts a negative impact on the equilibrium growth rate of the domestic economy, decreasing it from 4.33 to 4.22. This negative effect occurs because $\Delta\hat{Z}_{LT} = 0$, $\varepsilon_{HT} \Delta\hat{Z} < \gamma_{HT} \lambda_{fHT} \Delta\hat{Z}_{HT}$ and $\phi_{HT} \varepsilon_{HT} \Delta\hat{Z} < (\phi_{HT} \gamma_{HT} + \theta_{HT} \delta_{HT})\lambda_{fHT} \Delta\hat{Z}_{HT}$, which generates a negative non-price competitiveness effect large enough to offset the positive demand effect, as illustrated in Figure 6.

4. Concluding remarks

Taking into account the relevance of the Kaldorian and the Schumpeterian contributions to macroeconomic growth theory, this paper proposed a growth model that consistently combines the insights of these two traditions while solving some of the most important limitations of the original Kaldor-Dixon-Thirlwall model. The most interesting characteristic of this model is the fact it takes into account the main factors emphasized by the Kaldorian and the Schumpeterian literatures, while keeping the importance of both demand and supply-side factors for economic growth. From the demand side, long-term growth is determined by foreign output growth and by domestic productivity growth, while the latter is influenced by output growth, forming a circuit of cumulative causation through non-price competitiveness. From the supply side, the effect of output growth on productivity growth, i.e. the degree of returns to scale, depends on the level of research intensity, which means the capacity of each economy to take advantage of growing demand to increase technical progress depends on research intensity. Furthermore, productivity growth is also influenced by technological transfer. Thus, although demand (especially foreign demand) is still crucial for growth, as the Kaldorian tradition highlights, supply-side factors as research intensity and technological transfer are also key determinants of long-term growth rates.

The proposed Kaldor-Schumpeter growth model was also transposed to a multi-sectoral setting. Firstly, this multi-sectoral framework highlights that changes in the sectoral composition of trade influence the magnitude of long-term growth rates. Secondly, this model shows that in a multi-sectoral framework with BOP constraint, changes in the performance of a given sector affect the performance of the other sectors through inter-sector demand externalities. More specifically, an increase in productivity growth in a given sector, by increasing this sector's non-price competitiveness and its export growth, eases the BOP constraint, which allows higher growth of domestic demand, generating higher productivity and output growth in the other sectors of the economy. Thirdly, the model also shows that an increase in the growth rate of foreign output can exert a negative impact on the domestic economy, provided that the negative effect that this increase generates on the trade performance of the domestic economy (through higher foreign non-price competitiveness) is larger than the positive demand effect created.

To sum up, the models proposed in this paper provide several contributions to growth theory. They not only address important limitations of the canonical Kaldorian growth model, but they also consistently integrate the Schumpeterian contributions into the Kaldorian framework without subverting the demand-side orientation of this approach. Finally, the analysis of the models' dynamics revealed the role of inter-sector demand externalities in the process of economic growth, something that has not been consistently elaborated in the Kaldorian tradition, showing also that foreign output growth not necessarily exerts a positive impact on the domestic economy, as considered in the simple BOP constrained growth models.

Appendix

Table A1 reports estimates of equation (20) for low-tech and high-tech sectors using the same database adopted by Romero and McCombie (2016b). Due to the high correlation between the logarithms of aggregate income and sectoral exports (0.59), alternative regressions were estimated including only export growth as explanatory variable. A Two-Step Feasible Efficient System GMM estimator was used to avoid simultaneity between the explanatory variables and the dependent variable (see Blundel and Bond, 2000; Roodman, 2009), controlling also for the existence of fixed effects. In all the regressions Hansen's J Test indicates the orthogonality of the instruments cannot be rejected at the 5% level of significance. Moreover, in all the regressions but one (column (i)), Arellano and Bond's (1991) AR Test accepts the null hypothesis of no-autocorrelation.

Table A1

Response of industry output to increases in local and foreign demand

Sample	Low-Tech Industries (i)	Low-Tech Industries (ii)	High-Tech Industries (iii)	High-Tech Industries (iv)
Ln of Aggregate Output	0.640***		0.726++	
	(0.169)		(0.351)	
Ln of Exports	-0.0660	0.154++	0.196	0.413***
	(0.0773)	(0.0790)	(0.148)	(0.0910)
Constant	-7.295	4.941**	-15.77*	-1.297
	(3.779)	(1.736)	(6.785)	(2.119)
No. Observations	336	336	126	126
No. Instruments/Lags	7/3-4	3/4	11/2-5	3/3
Arellano-Bond AR Test	0.017	0.329	0.171	0.362
Hansen J Test	0.052	0.084	0.521	0.548

Note: The dependent variable is the Ln of Industry Value Added. Values in parentheses are standard deviations. The values reported for the tests are p-values. The p-value reported for the Arellano-Bond AR Test refers to the first lag used as instrument in the regression. Significance: ++=10%; *=5%; **=1%; ***=0.1%.
Source: Author's elaboration.

References

Aghion, P.; Howitt, P. (1992) A Model of Growth Through Creative Destruction, *Econometrica*, 60(2), p. 323-351.

Aghion, P.; Howitt, P. (1998) *Endogenous Growth Theory*, Cambridge MA: MIT Press.

Amable, B. (1993) Catch-up and convergence: a model of cumulative causation, *International Review of Applied Economics*, 7(1), pp. 1-25.

Amable, B.; Verspagen, B. (1995) The Role of Technology in Market Share Dynamics, *Applied Economics*, 27(2), pp. 127-204.

Angeriz, A.; McCombie, J. S.; Roberts, M. (2008) New Estimates of Returns to Scale and Spatial Spillovers for EU Regional Manufacturing, 1986-2002, *International Regional Science Review*, 31(1), pp. 62-87.

Angeriz, A.; McCombie, J. S.; Roberts, M. (2009) Increasing Returns and the Growth of Industries in the EU Regions: Paradoxes and Conundrums, *Spatial Economic Analysis*, 4(2), pp. 127-48.

Araújo, R. (2013) Cumulative causation in a structural economic dynamic approach to economic growth and uneven development, *Structural Change and Economic Dynamics*, 24, pp. 130-140.

Araújo, R.; Lima, G. T. (2007) A structural economic dynamics approach to balance-of-payments-constrained growth, *Cambridge Journal of Economics*, 31(5), pp. 755-74.

Blecker, R. (2013) "Long-run growth in open economies: export-led cumulative causation or balance-of-payments constraint?, in Harcourt, G. C.; Kriesler, P. (eds) *Oxford Handbook of Post Keynesian Economics* (4 vols.), Oxford University Press.

Cimoli, M.; Porcile, G. (2014) Technology, structural change and BOP-constrained growth: a structuralist toolbox, *Cambridge Journal of Economic*, 38, pp. 215-237.

Dixon, R.; Thirwall, A. P. (1975) A Model of Regional Growth-rate Differences on Kaldorian Lines, *Oxford Economic Papers*, 27(2), pp. 201-214.

Fagerberg, J. (1988) International Competitiveness, *Economic Journal*, 98(391), pp. 355-374.

Gouvea, R. R.; Lima, G. T. (2010) Structural change, balance-of-payments constraint, and economic growth: evidence from the multisectoral Thirlwall's Law, *Journal of Post Keynesian Economics*, 33(1), pp. 169-204.

Griffith, R.; Redding, S.; Van Reenen, J. (2004) Mapping the two faces of R&D: productivity growth in a panel of OECD Industries, *Review of Economics and Statistics*, 86(4), pp. 883-895.

Hausman, J. (1997) Valuation of new goods under perfect and imperfect competition, in (Ed.) Bresnahan, T.; Gordon, R.; *The Economics of New Goods*, Studies in Income and Wealth, 58, Chicago: NBER.

Hicks, J. R. (1950) *A Contribution to the Theory of the Trade Cycle*, Oxford: Clarendon Press.

Kaldor, N. (1966) *Causes of the Slow Rate of Economic Growth of the United Kingdom: an Inaugural Lecture*, Cambridge: Cambridge University Press.

Kaldor, N. (1970) The Case for Regional Policies, *Scottish Journal of Political Economy*, 17, 337-48.

Krugman, P. (1989) Differences in income elasticities and trends in real exchange rates, *European Economic Review*, 33, pp. 1031-1054.

León-Ledesma, M. A. (2002) Accumulation, innovation and catching-up: an extender cumulative growth model, *Cambridge Journal of Economics*, 26, pp. 201-216.

Madsen, J. B. (2008) Semi-endogenous versus Schumpeterian growth models: testing the knowledge production function using international data, *Journal of Economic Growth*, 13(1), pp. 1-26.

Nevo, A. (2001) Measuring Market Power in the Ready-to-Eat Cereal Industry, *Econometrica*, 69(2), pp. 307-342.

Roberts, M. (2007) The Conditional Convergence Properties of Simples Kaldorian Growth Models, *International Review of Applied Economics*, 21(5), pp. 619-632.

Romer, P. (1990) Endogenous Technological Change, *Journal of Political Economy*, 98(5), p. S71-S102.

Romero, J. P.; Britto, G. (2016) Increasing Returns to Scale, Technological Catch-Up and Research Intensity: An Industry-level Investigation Combining EU KLEMS Productivity Data with Patent Data, *Cambridge Journal of Economics*, forthcoming.

Romero, J. P.; McCombie, J. S. L. (2016a) The Multi-Sectoral Thirlwall's Law: Evidence from 14 Developed European Countries using Product-Level Data, *International Review of Applied Economics*, 30(3), pp. 301-25.

Romero, J. P.; McCombie, J. S. L. (2016b) Thirlwall's Law and the Specification of Export and Import Demand Functions: An Investigation of the Impact of Relative Productivity Growth on Trade Performance, *Cambridge Centre for Economic and Public Policy Working Papers Series*, CCEPP WP 02-2016.

Romero. J. P.; Silveira, F.; Jayme Jr., F. G. (2011) Brazil: structural change and balance-of-payments-constrained growth, *CEPAL Review*, 105, pp. 185-208.

Roodman, D. (2009) How to do xtabond2: An introduction to difference and system GMM in Stata, *The Stata Journal*, 9(1), pp. 86-136.

Setterfield, M. (1997) 'History versus equilibrium' and the theory of economic growth, *Cambridge Journal of Economics*, 21, pp. 365-378.

Targetti, F.; Foti, A. (1997) Growth and productivity: a model of cumulative growth and catching up, *Cambridge Journal of Economics*, 21, pp. 27-43.

Thirlwall, A. (1979) The Balance of Payments Constraint as an Explanation of International Growth Rate Differences, *BNL Quarterly Review*, 128(791), pp. 45-53.

Thirlwall, A.; Dixon, R. J. (1979) A Model of Export-Led Growth with Balance of Payments Constraint, in Bowers, J. K. (ed) *Inflation, Development and Integration: Essays in Honour of A. J. Brown*, Leeds: Leeds University Press.

Verdoorn, P. J. (1949) Fattori che regolano lo sviluppo della produttività del lavoro, *L'Industria*, 1, pp. 3-10.