Structural Change and Cumulative Causation: a Kaldorian Approach

Guilherme R. Magacho[1]

Department of Land Economy, University of Cambridge, UK

John McCombie

Department of Land Economy, University of Cambridge, UK

Abstract

This paper presents a multisectoral model based on Kaldor's approach to explain the importance of structural change and cumulative causation. Divergence in countries' growth rates in Kaldorian models are explained *either* by different degrees of increasing returns among sectors on the supply-side *or* by different income elasticities of exports and imports on the demand-side, but it is not explained by *both* factors together. In this vein, a multisector growth model that combines different sectoral income elasticities and different sectoral increasing returns is built to explain how structural changes towards high-tech industries can trigger a process of cumulative causation and ensure higher growth rates in the long run.

Keywords: Structural change, cumulative causation, balance-of-payments constrained growth models, Verdoorn's law, export-led growth, multisector growth models

JEL codes: F43, O41, L16

1. Introduction

The process of structural change is crucial to the understanding of a country's long-term economic growth rate. Although there is no doubt that production and trade structures of economies change over time, and, even more importantly, that these changes contribute to divergences in countries' growth rates, many growth models neglect the relevance of structural changes for promoting countries' growth. Endogenous growth models, for example, focus on the importance of activities such as R&D and education to understand the process of innovation and growth. However, with some notable exceptions, they are sector-indifferent,[2] which implies that changes have no role in explaining long-term growth.

The aim of this paper is to present a model to explain how structural changes can trigger a process of cumulative causation and promote a country's faster growth in the long term, as well as to apply this model to identify those sectors able to guarantee the fastest growth rates based on the results of previous studies. This paper shows that although Kaldor has stressed the importance of structural change for growth, Kaldorian (and Post-Keynesian) growth models do not fully incorporate this issue, and hence they are unable to present a convincing explanation for the origin of cumulative causation processes in open economies.

The vast majority of neo-Schumpeterian and Evolutionary growth models, similarly to endogenous growth models, focus on activities, such as research and development and innovation, rather than the different sectors of the economy. Even though there are some notable exceptions, such as Dosi et al. (1994) and Saviotti and et al. (2004), sectoral differences are restricted to differences in the supply side, i.e. technological and innovation capabilities. Differences in the demand side, such as differences in the income elasticities of demand for exports and imports, are not taken into account. Consequently, as will be shown, these models are not able to present a model in which structural changes in specific sectors can promote a cumulative causation process.

Some Kaldorian models explain how a process of cumulative causation takes place by considering a one-sector model, such as the model presented by Setterfield (2011). However, these

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[2] Palma (2005) presents a distinction between sector-specific and activity-specific models. According to the author, in endogenous growth models increasing returns may be generated by research-intensive activities, but they are not explicitly associated with the size, depth or strength of one specific sector. In this vein, although some neoclassical endogenous growth models, such as Romer (1990), consider different sectors and propose policy recommendation specific for them, they are not sectoral growth models in the structuralist sense. They do not focus on sectoral differences, but only on one sector that generates innovation for the whole economy.

models do not explain the origin of this cumulative causation process. Essentially, they explain the divergence of countries' growth rates based on past growth, but they do not explain why past growth rates have diverged. In these models, the importance of the sectoral structure of production and trade is not made explicit, and thus structural changes in favour of industrial activities, for example, do not have any impact on countries' growth rates.

On the production side, Kaldor (1966, 1967) argued that sectors have different degrees of increasing returns to scale and it is important to explain a cumulative causation process. Although some single-sector models incorporate the notion of increasing returns to scale, such as Dixon and Thirlwall (1975) did in the context of an open regional economy, it took many years for this notion to be incorporated into *multisectoral* demand-led models, and thus applied to explain why cumulative causation depends on the sectoral structure of production. See, for example, Fiorillo (2001). Fiorillo's model shows that countries' growth rates depend on the degree of sectoral specialisation. Sectoral specialisation depends, in turn, on the aggregate growth rate. Based on this, he explains cumulative causation as a sequence of sectoral changes. His model, however, does not take into account the fact that economic growth in open economies is balance-of-payment constrained. Thus, it does not consider how increasing returns impact the income-elasticities of demand for exports and imports (and vice versa) to explain cumulative causation in open economies.

Growth in the long run is balance-of-payments constrained for many countries. In its simplest form, the balance-of-payments constrained growth rate of a country, y_b, is given by Thirlwall's law (Thirlwall, 1979). This is given by the equation $y_b = \varepsilon z/\pi$, where ε is the income elasticity of the demand for exports, z is the growth of the country's trade-weighted overseas markets and π is the income elasticity of demand for imports.[3] The ratio of ε/π reflects differences in non-price competitiveness. A key to understanding long-term growth rates disparities are the factors that determine the degree of non-price competitiveness and how the income elasticities change over time. For an example as to how they can change over time, see Tharnpanich et al (2013). Consequently, changes in structural dynamics are one key factor in accounting for such changes.[4]

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[3] This equation is not a tautology, as has been erroneously suggested. (See McCombie, 2019 for a discussion).

[4] Attempts by countries to grow persistently above their balance-of-payments constrained growth rate are thwarted by balance-of-payments crises. Eichengreen et al (2016) find 45 sudden stops (when capital flows abruptly dry up) for the developing countries over the period from 1991-2015. Catão et al (2014) find that the empirical evidence suggests that, for both the advanced and developing countries, the probability of a

On the demand side, Pasinetti (1981, 1993) stressed the importance of sectoral elasticities of demand to explain structural change and the relation to unbalanced economic growth. Although his Structural Economic Dynamics (SED) model brings an important issue into the debate on the importance of structural changes for economic growth, it was only a quarter of a century later that Araujo and Lima (2007) applied the SED approach to understand the growth process in open economies (based on Thirlwall's law). These authors, however, do not consider any impact of endogenous technological progress in their models, and thus cumulative causation does not take place either in Pasinetti's SED approach or in Araujo and Lima's multisectoral version of Thirlwall's law. Araujo (2013) presents an alternative approach for this process. In his model, technological progress is assumed as endogenous in a SED model, and the balance-of-payment constraints emerge from the multisectoral Thirlwall's law. The author, however, considers that dynamic increasing returns to scale affect only price competitiveness, but, as the main determinant of international competitiveness is non-price factors (as we will see Section 2), it has little role in explaining the divergence in countries' growth rates.[5]

These two aspects of structural change (the demand- and the supply-side), however, are rarely considered together in a multisectoral model. Divergence in countries' growth rates in Kaldorian models are explained by different degrees of increasing returns among sectors on the supply-side *or* by different income elasticities of exports and imports on the demand-side. Nevertheless, it is not explained by *both* factors together. In this vein, as argued by Magacho (2017), a sectoral model that combines different sectoral income elasticities, different sectoral increasing returns and the notion that non-price competitiveness is affected by output growth, is essential to understand the relationship between countries' long-term economic growth and their structures of production and trade.

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currency crisis increases dramatically once net foreign liabilities exceed 50 percent of GDP or are about 20 percentage points greater than their historic value. An onset of a crisis is sometimes indicated by the increase in the country's risk premium, leading, for example, to reduced investment. It may necessitate the use of government macroeconomic policies to reduce the growth of the economy. The advanced countries are not immune to a balance-of-payments crisis as evidenced by UK's balance-of-payments crisis in 1976, when the IMF had to be called in. This was in spite of the pound being a reserve currency. Godley (1995) issued warnings about the US balance-of-payments deficit, and its possible consequences, that are equally relevant today. More recently, the euro-area crisis of 2010-2012 was essentially a balance-of-payments crisis, albeit ameliorated by the European Central Bank (see, for example, Higgins et al, 2014, Cecchetti et al, 2018).

[5] In his model, cumulative causation emerges from the fact that countries have different sectoral elasticities of demand according to their income per capita. As countries grow, the demand shifts towards products with higher income elasticities, as well as production. Consequently, countries can grow at faster growth rates.

Furthermore, one aspect of crucial relevance to economic growth models is its policy implications. The fact that neither endogenous growth models nor alternative approaches, such as Post-Keynesian and neo-Schumpeterian growth models, fully incorporate the existence of different sectors with different characteristics implies that policy interventions in favour of one sector have limited impact on countries' long-term growth. In order to understand it, this paper analyses how a policy intervention promoting one sector to the detriment of the others might promote faster (or slower) growth rates in the long term through a process of cumulative causation.

Besides this introduction, this paper is divided into five sections. Section 2 discusses cumulative causation in Kaldorian models and argues for the need for a sectoral approach. Section 3 presents a model that combines the issues mentioned above to explain cumulative causation in a multisectoral framework. Section 4 simulates the model for the two sectors based on parameters estimated in previous studies in order to evaluate what those sectors are that can trigger a cumulative causation process. Finally, in the last section, the concluding remarks are presented.

2. Cumulative causation in Kaldorian models

2.1. Cumulative causation and price competitiveness

Based on the Kaldorian approach, which stresses the existence of increasing returns to scale in manufacturing activities, as well as the importance of exports as an autonomous source of demand (Kaldor, 1966; 1970), Dixon and Thirlwall (1975) developed the first Export-Led Cumulative Causation (ELCC) model. The basis of this model is Verdoorn's law, which states that a more rapid growth in production increases productivity growth in the industrial sector (McCombie et al, 2002). Dixon and Thirlwall's model assumed this law for regional competition and argued that a faster productivity growth reduces production costs. As countries become more regionally (and internationally) competitive due to increases in price competitiveness, exports and production are stimulated, and thus a circular and cumulative process takes place.

Setterfield and Cornwall (2002) present a more complex version of this model. In their model, productivity stimulates economic growth by a "productivity regime", as expressed by Dixon and Thirlwall (1975). Nevertheless, economic growth is also stimulated by demand growth, which characterises a "demand regime". In this formulation, productivity growth and demand

growth constitute a system of two linear equations, and the resolution of this system yields a stable equilibrium.[6]

One of the limitations of these models is that both are considered inappropriate to describe a stable long-run equilibrium in an open economy. According to Thirlwall and Dixon (1979), the growth rate provided by the ELCC model is inconsistent with a balance-of-payments constraint (Thirlwall, 1979; McCombie and Thirlwall, 1994). As this model does not consider this constraint, it is insufficient to explain economic growth in the long term. Thus, Thirlwall and Dixon (1979) modified the original model to incorporate an import demand function, and, hence, a balance-of-payment constraint on economic growth.

Blecker (2010) did the same for the model developed by Setterfield and Cornwall (2002). In Blecker's version, two equilibria are obtained for a growing economy: the balance-of-payment constrained growth (BPCG) solution and the ELCC solution. The author then attempts to reconcile these two growth rates. According to him, if a country is experiencing a virtuous cycle of export-led growth, the ELCC solution prevails, but only in the medium term. However, in the long term, countries' growth rates are given by the BPCG solution.

Both the Thirlwall and Dixon (1979) and Blecker (2010) models assume that the natural rate of growth (given by productivity and labour force growth) does not affect the income elasticities for imports or exports. Essentially, the mechanism responsible for the cumulative process is price competitiveness. A faster growth of output increases productivity growth, which, in turn, increases price competitiveness because it reduces domestic relative to world inflation. Consequently, exports are stimulated and, due to multiplier and accelerator effects, output grows faster, generating a cumulative process.

However, one of the assumptions of Thirlwall's law is that there are no relative price effects in the long run, and hence the mechanism from which cumulative causation occurs in Dixon-Thirlwall's model does not play any role in BPCG models. Thereby, due to the assumption that changes in relative price changes have no effects in the long term, the natural rate of growth responds endogenously to BPCG, and thus increasing returns to scale do not affect growth rates in the long run. Countries' long-term growth rates are uniquely determined by Thirlwall's law, and the ELCC growth is only a weak attractor.

According to McCombie and Thirlwall (1994:268), many studies show that non-price factors differ substantially between similar products, and that manufacturers face a downward

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[6] Blecker (2010) notes that disequilibrium in this model implies ever-rising or ever-falling growth rates, which is not plausible in the long term.

sloping demand curve. The empirical evidence suggests that price competitiveness is not of great importance in explaining the growth of exports (and imports).

There are numerous empirical studies over the last 50 years that provide compelling evidence that this is normally the case for both developing and developed countries. (See, for example, the articles cited in Thirlwall, 2011: 341.) This finding has been subsequently confirmed by subsequent studies. A recent comprehensive survey of the values of the Marshall-Lerner condition found that "the results of our analysis are clear: The M-L [Marshall-Lerner] does not statistically hold in a large fraction of cases in which it claimed to do so" (Bahmani et al, 2013: 435). Moreover, even if the Marshall-Lerner condition is satisfied, the standard export and import demand functions demonstrate that there needs to be a continuous *depreciation* of the currency to increase the growth rate of exports and imports. This is difficult to sustain.

Lanzafame (2013), using mean group and pooled mean group estimation procedures, finds support for Thirlwall's law. He also finds a uni-direction causality from the balance-of-payments growth rate to the natural rate of growth. This is also confirmed by Vogel (2009) and León-Ledesma and Lanzafame (2010). Romero and McCombie (2016 & 2018) estimate import and export demand functions for the advanced countries, incorporating Schumpeterian effects. They find that the (quality-adjusted) price elasticities are low and generally insignificant for both Thirlwall's law and the multisectoral Thirlwall's law. Christodoulopoulou and Tkačevs (2016) find little, or no, statistically significant effect for the eurozone countries using a variety of harmonised competitiveness indicators (HCI). Other studies that find an important role for non-price competitiveness, and little for price competitiveness, include Fabrizio et al (2007) for the Central and Eastern European countries that entered the European Union in 2004. A similar study by Allard (2009) confirms this result.

A series of papers from the European's Central Bank's Research Competitiveness Network has adjusted relative prices for quality charges at a highly disaggregated level for internationally traded products. It is found that trade flows are substantially determined by non-price competitiveness. This explains the Kaldor Paradox (1978) that there is often an inverse relationship between a change in a country's export share and its rate of change in price competitiveness. See Benkovskis & Wörz (2012, 2014, 2015 and 2016) and also di Mauro et al (2016).

Pula (2011), Fu et al (2012) and Tang (2015) find, for example, that China's rapid growth of exports has largely been driven by a substantial increase in their non-price competitiveness. This confirms the broad conclusions of the econometric evidence of. Rodrik (2006) also notes,

citing the index of export sophistication calculated by Hausman et al (2007), that China's exports are substantially more sophisticated than other countries with the same level of per capita income. Variations in this sophistication index explain a substantial proportion of differences in cross-country per capita income growth rates in regressions, where relative prices are not included. "What you export matters", as Hausmann et al (2007) succinctly put it.

Fagerberg (1988) discusses what is, and what should be, "international competitiveness". He emphasises technological factors (i.e. the scope for imitation and technological competitiveness) and other non-price factors, such as ability to deliver, are the main explanations for export and import growth in the long term.

Nevertheless, it does not imply that cumulative causation does not happen in BPCG models, even in a one-sector model. The existence of cumulative causation in Thirlwall's law emerges from another perspective. Setterfield (2011) shows that instead of reducing prices, productivity growth (derived from Verdoorn's law) increases the quality of the products. Because consumers value quality, the existence of increasing returns to scale might positively affect countries' income elasticities of demand for imports and exports through non-price competitiveness.

2.2. Cumulative causation and non-price competitiveness

The most important determinant of the long-run growth rate of exports and imports, as we have seen, is non-price factors, such as the quality, reliability and speed of delivery of goods and services. McCombie and Roberts (2002:92) argue that countries' success in the world market is due to the effects of product innovation rather than to reducing the prices of existing products.

Consequently, the focus of cumulative causation models has to change from price to non-price competitiveness, as the latter is the main determinant of a country's exports and imports. In order to show that cumulative causation exists even when there are no price effects in the long term, this paper follows Setterfield's (2011) approach for Thirlwall's law with endogenous income elasticities of demand for exports and imports. The author shows that once it is assumed that income-elasticities are functions of domestic and foreign productivity levels,[7] growth rates tend to diverge in the long term, characterising a cumulative causation process.

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[7] According to Fagerberg (1988), economic growth may influence technological competition through demand-induced innovation, even though innovation activity seems to depend more on technological opportunities and the resources devoted to innovation than on demand conditions.

According to Setterfield (2011), if productivity improvements are used by firms to improve quality rather than reduce costs (and hence prices), and consumers value quality, then it makes sense to consider that the income elasticities of exports and imports are sensitive to differential productivity levels. The higher is the level of productivity, the higher is the quality of the products, and hence the greater is the non-price competitiveness (Hausmann et al, 2007). The causality purposed by Setterfield (2011) is not from productivity to prices, but from productivity to quality.

Essentially, following Thirlwall's law (Thirlwall, 1979), as we have seen, countries' long-term growth rates are determined by the ratio of the income elasticities of demand for exports and imports. This ratio, which is a measure of non-price competitiveness, increases as countries grow faster. Due to the endogeneity of elasticities to output growth, countries that grow fast due to their ratio of export and import elasticities tend to grow even faster due to an increase in this ratio.[8]

Although Setterfield's (2011) model is able to show a possible mechanism behind the growth rate divergence across countries, it does not show the origins of this divergence, because it explains countries' growth rates based on past growth rates, but it does not explain why past growth rates diverge. In this model, a faster economic growth initiates a cumulative causation process independently of its sources, and it has no effects on production and trade structures. If a country is growing faster than the rest of the world due to an increase in demand for natural resources, for example, a process of ever-increasing growth rates will take place no matter whether or not manufacturing is growing relatively slower than the rest of the world.

These results are obtained because this model abstracts from the consequences of structural change on economic growth. Once the structure of the economy remains unchanged (or these changes have no effects on economic growth), the origin of cumulative causation is not explicitly showed, and its positive and negative consequences are underestimated.

Nevertheless, as stressed by Pasinetti (1993), the empirical data unequivocally suggest that countries undergo structural change in their development process, and this has undoubted consequences on their growth rates. Thereby, even though initially ignoring structural changes is useful in facilitating the understanding of growth processes, it abstracts from the effects of one of the most important aspects of economic development.

3. A sectoral cumulative causation model in a Kaldorian framework

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[8] See Appendix 1 for a presentation of Setterfield's (2011) cumulative causation model.

By promoting structural changes in the sectoral composition of production and trade, a country can trigger a process of cumulative causation, and hence initiate a process of increasing growth rates. The dynamic interaction between sectoral income elasticities of demand and increasing returns to scale is capable of accelerating (or reducing) countries' growth rates and determining their growth pattern in the long term. The following model presents a possible channel through this can occur. Essentially, it shows that simply by promoting sectors with either high income-elasticities of demand, or with large increasing returns to scale, is not enough to trigger a cumulative causation process. The cumulative causation process comes from the interaction between both these sectoral specificities. Consequently, countries have to promote those sectors with *both* characteristics to start a process of growth rate acceleration.

There are many factors that can trigger a process of structural change in different sectors. There is now a literature on the importance of competitive exchange rates to encourage sectoral transformation in both in the Kaldorian and Post-Keynesian literature. Rodrik (2008), Razmi *et al,* (2010), Nassif *et al,* (2011), Missio *et al,* (2015) and Gabriel *et al.* (2015) argue for the importance of a competitive exchange rate to avoid specialization in less technological advanced sectors.

Rodrik's (2008) approach has been especially influential. He found that the level of undervaluation of the exchange rate was an important factor in explaining GDP per capita growth. This was, however, only for developing countries with a per capita income of less than $6,000. Nevertheless, this result could be seen as incompatible with the evidence for Thirlwall's law.

However, it is important to note that the undervaluation measure used by Rodrik is not that of the real exchange rate that is used to determine trade flows, as in export and import demand functions. Rather the exchange rate that is used is the ratio of the market exchange rate to the purchasing power parity exchange rate, normally expressed in terms of the domestic currency per US dollar. It is adjusted for the Balassa-Samuelson effect. This exchange rate is best regarded as a variant of the exchange rate defined as the ratio of a county's tradable to non-tradable goods. It is a variant because the denominator includes both tradable and non-tradables. Consequently, this exchange rate is consistent with the dependent-economy (Swan-Salter) model. However, this exchange rate assumes that the law of one price holds. Countries can export as many goods as they wish at the going world price (Montiel, 2002). In other words, it assumes away the possibility of any form of balance-of-payments constraint.

Criticisms of Rodrik's approach began with Woodford (2008). Glüzmann, Levy-Yeyati and Stuzeneggaer (2012) find that for developing countries, undervaluation does not affect the

tradable , but leads to greater savings and investment. Gonclaves and Rodrigues (2017) using a later Penn World Tables data set finds no relationship. This is when the savings rate is included a control variable or outliers are excluded. Haddad and Pancaro (2010: 2) find that "in the long run, the effect of a real exchange rate undervaluation on economic growth becomes negative; and on exports, it becomes insignificant". Ribeiro et al (2019) find that when an allowance is made for the distribution of income, there is no real exchange rate misalignment effect on economic growth. Schröder (2013) finds no significant relationship when the slope coefficients are allowed to vary between the developing countries and the effect of an overvaluation and undervaluation are permitted to have different effects. Nouira and Sekkat (2012) also find little effect using a different measure of exchange-rate undervaluation.

Cimoli and Porcile (2014) also discuss the importance of price competitiveness in triggering structural change process, but rather than focusing on the real exchange rate, they discuss the impact of export subsidies and import tariffs. The authors argue that providing subsidies to specific industries that are more technology intensive than others may encourage diversification and it produces externalities that heighten productivity in the whole economic system. Similarly, as suggested by the traditional infant industry argument, a limited period of protection may encourage diversification, growth and learning. However, long periods of protection reduce the rate of learning in the economy because competition becomes less intense.

Storm and Naastepad (2015a; 2015b) highlight the importance of other policies besides those that affect directly prices to explain structural changes. According to them, real unit labor costs divergences played only a negligible role in Europe trade-imbalances. Industrial policies, such as public support helping induce innovation and investment in dynamic sectors, can be much more effective than price-competitiveness measures (Storm and Naastepad, 2015a). The authors analysed the superior competitiveness of German industries and conclude that "[its] remarkable rebound must be explained in terms of the country's superior technological performance giving rise to strong non-price competitiveness". According to them, Germany technological prowess "is founded on economic coordination and strongly market-guiding industrial policies – not cost competition" (Storm and Naastepad, 2015b: 12).

3.1. The dynamics of balance-of-payment constrained growth rate

The starting point of the model is that in the long term, growth is balance-of-payment constrained, and thus output growth depends on the weighted elasticities ratio, such as presented by Araujo and Lima (2007) in the multisectoral version of Thirlwall's law:[9]

$$y_B = \frac{\sum \omega_{Xi}\varepsilon_i}{\sum \omega_{Mi}\pi_i} z = \frac{\varepsilon}{\pi} z \quad (3.1)$$

where ω_{Xi} is the share of sector i's exports in the total exports, ω_{Mi} is the share of sector i's imports in the total imports, ε_i and π_i are the sectoral income elasticities of demand for exports and imports, respectively, and ε and π are the aggregate income elasticities of exports and imports[10].

Based on the standard demand theory that assumes multiplicative import and export functions,[11] and by considering that a country's relative prices of a given good i do not present an ever-increasing or ever-decreasing growth rates, such as assumed by Thirlwall (1979) for the economy, the growth rate of sectoral weight of exports and imports may be expressed as:

$$\frac{\omega_{Xi}^{\cdot}}{\omega_{Xi}} = p_{Xi} - p_X + x_i - x = (p_i^* - p^*) + (\varepsilon_i - \varepsilon)z \quad (3.2),$$

and

$$\frac{\omega_{Mi}^{\cdot}}{\omega_{Mi}} = p_{Mi}^* - p_M^* + m_i - m = (p_i^* - p^*) + (\pi_i - \pi)y \quad (3.3).$$

where p_{Xi}, p_X, p_{Mi}^* and p_M^* are growth rate of domestic price of good i, general domestic price, foreign price of good i and general foreign price, respectively, and p_i^* and p^* are the growth rate of world price of good i and aggregate world price, respectively.

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[9] This version of Araujo and Lima (2007)'s model is presented by Setterfield (2011).

[10] Following Setterfield (2011), they are given by: $\varepsilon = \sum \omega_{Xi}\varepsilon_i$ and $\pi = \sum \omega_{Mi}\pi_i$.

[11] These functions can have, for example, the following form: $X_{it} = A\left(\frac{P_{it}^* E_t}{P_{it}}\right)^{\psi_i} (Z_t)^{\varepsilon_i}$ and $M_{it} = B\left(\frac{P_{it}}{P_{it}^* E_t}\right)^{\eta_i} (Y_t)^{\pi_i}$, where A and B are constants

Following Setterfield (2011) and McCombie and Thirlwall (1994), who assume that technical progress increases the ratio of the income elasticities of exports and imports because it increases product differentiation and, hence, non-price competitiveness,[12] the changes in the sectoral elasticities of demand are assumed to be positively related to the productivity growth differential between the country under consideration and the rest of the world. Thereby, the growth rate of these elasticities may be written as a function of the difference between sectoral domestic and external productivity growth rates, as follows:

$$\frac{\dot{\varepsilon_i}}{\varepsilon_i} = \phi_i(q_i - q_i^*) \qquad (3.4),$$

and

$$\frac{\dot{\pi_i}}{\pi_i} = \phi_i(q_i^* - q_i) \qquad (3.5)$$

where ϕ_i is a parameter that measures the impact of productivity growth differential on income elasticities of demand for exports and imports. Since faster higher productivity growth implies higher quality, we have that $\phi_i > 0$.

According to the Kaldor-Verdoorn law, the growth of factor inputs respond to the growth of demand and a substantial proportion of productivity growth is endogenously determined by output growth. Thereby, the growth rates of the income elasticities are determined by the difference between domestic and external output growth rates,[13] as well as by the effect of the rate of exogenous technical progress, given by λ, as follows:

$$\frac{\dot{\varepsilon_i}}{\varepsilon_i} = \phi_i[(\lambda_i - \lambda_i^*) + b_i(y_i - z_i)] \qquad (3.6),$$

and

$$\frac{\dot{\pi_i}}{\pi_i} = -\phi_i[(\lambda_i - \lambda_i^*) + b_i(y_i - z_i)] \qquad (3.7).$$

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[12] This is to the detriment of a technological progress that reduces costs, such as assumed by Dixon and Thirlwall (1975) and Araujo (2013).

[13] We assume that Verdoorn's coefficients are sector-specific, but they are the same for the country under consideration and the rest of the world.

By assuming that sectoral exogenous technological change is the same domestically and for the rest of the world ($\lambda_i = \lambda_i^*$), these equations show that the faster is the growth of sector i domestically compared with the rest of the world, the faster will the sectoral income elasticity of exports increase, and the faster the income elasticity of imports will decrease. Moreover, these equations also show that the larger is the Verdoorn coefficient of sector i (which implies a greater value of b_i), the larger is the impact of a sectoral faster output growth rate on the elasticities. Consequently, the greater will be its positive impact on export and negative impact import growth rates.

A faster growth of sectoral exports and a deceleration of sectoral imports, however, do not imply that countries' BPCG rates will necessarily increase. If sector i has high income elasticities of demand for exports than the average (or low income elasticities of demand for imports), an increase in their weights positively affects the long-term growth rate, y_B. However, if this sector exhibits a low income elasticity of demand for exports than the average (or a high income elasticity of demand for imports), the result is the converse.

Therefore, with the aim of analysing the impact of a faster growth of sector i on countries' long-term growth rates, the growth dynamics of a country's BPCG rates may be expressed as:

$$\frac{\dot{y}_B}{y_B} = \frac{\dot{\varepsilon}}{\varepsilon} - \frac{\dot{\pi}}{\pi} + \frac{\dot{z}}{z} = \sum \frac{\omega_{X_i}\varepsilon_i}{\varepsilon}\left(\frac{\dot{\omega_{X_i}}}{\omega_{X_i}} + \frac{\dot{\varepsilon_i}}{\varepsilon_i}\right) - \sum \frac{\omega_{M_i}\pi_i}{\pi}\left(\frac{\dot{\omega_{M_i}}}{\omega_{M_i}} + \frac{\dot{\pi_i}}{\pi_i}\right) + \frac{\dot{z}}{z} \qquad (3.8).$$

Finally, replacing equations (3.2), (3.3), (3.6) and (3.7) in (3.8), multiplying by y_B (remembering from equation (3.1) that $y_B = \frac{\varepsilon}{\pi}z$), and considering that $\lambda_i - \lambda_i^*$ (exogenous technical progress is the same domestically and internationally), the equation of changes in a country's long-term growth rates (given by multisectoral Thirlwall's law) in terms of its sectoral structure is given by:

$$\dot{y}_B = \sum \frac{\omega_{X_i}\varepsilon_i}{\pi}[(p_i^* - p^*) + (\varepsilon_i - \omega_\varepsilon)z + \phi_i b_i(y_i - z_i)]z -$$
$$- \sum \frac{\omega_{M_i}\pi_i}{\pi}[(p_i^* - p^*) + (\pi_i - \omega_\pi)y - \phi_i b_i(y_i - z_i)]\frac{\varepsilon}{\pi}z + \frac{\varepsilon}{\pi}\dot{z} \qquad (3.9).$$

This equation presents the dynamics of a country's BPCG rates from a sectoral perspective. The first term presents the dynamics of the weighted income elasticities of demand for exports, and the second, the dynamics of the weighted income elasticities of demand for

imports. It is possible to see from this equation that differences in the sectoral growth rates compared with the rest of the world play an important role in these dynamics, and its impact depends upon the value of sectoral Verdoorn coefficient, as well as upon the sectoral income elasticities of demand for exports and imports.

3.2. Impacts of structural changes on the BPCG rates

The impact of a faster growth rate of a given sector, y_i, on a country's long-term growth rate dynamics can be analysed using equation (3.9). A faster growth of a given sector can be interpreted as a structural change in the country's sectoral compositions of output if the growth rates of the other sectors are unaffected. Hence, assuming that the growth of world output is not affected by changes in the growth rate of the country under consideration, as well as the growth rates of other sectors are not affected by a faster growth rate of the given sector, this impact can be described as:

$$\frac{d(\dot{y}_B)}{d(y_i)} = \frac{\partial(\dot{y}_B)}{\partial(y_i)} + \frac{\partial(\dot{y}_B)}{\partial(y)}\frac{\partial(y)}{\partial(y_i)} \quad (3.10).$$

This equation shows that a faster growth of sector i has two impacts on a country's long-term growth rates. First, it has a direct impact (expressed by term $\frac{\partial(\dot{y}_B)}{\partial(y_i)}$), which shows the impact of a faster growth of the sector on the income elasticities of demand for imports and exports, as well as on the weight of each sector in exports and imports. Moreover, it has an indirect impact (expressed by term $\frac{\partial(\dot{y}_B)}{\partial(y)}\frac{\partial(y)}{\partial(y_i)}$). A faster growth of a sector (when the other sectors' growth rates remain constant) increases total output growth rate, according to this sector's weight in the economy.

Based on equation (3.9), the indirect impact can be expressed as:

$$\frac{\partial(\dot{y}_B)}{\partial(y)}\frac{\partial(y)}{\partial(y_i)} = \left(1 - \sum \frac{\omega_{M_i}\pi_i}{\pi}\frac{\pi_i}{\pi}\right)\omega_i z \quad (3.11),$$

where ω_i is the weight of sector i's output in total output.

Because $1 - \sum \frac{\omega_{M_i}\pi_i}{\pi}\frac{\pi_i}{\pi}$ is approximately equal to zero,[14] a faster growth of total output does not accelerate the country's long-term growth rate. The impact of a faster growth of sector i can be reduced to its direct impact, as follows:

$$\frac{\partial(\dot{y}_B)}{\partial(\dot{y}_i)} = \phi_i b_i \left[\omega_{X_i}\varepsilon_i + \omega_{M_i}\pi_i\frac{\varepsilon}{\pi}\right]\frac{z}{\pi} \quad (3.12)$$

From this equation, it is possible to verify that the long-term growth rate of a country accelerates when the sectors under consideration grow faster. However, this acceleration in the BPCG rate depends on the sectoral Verdoorn coefficient and the sectoral income elasticities of demand for imports and exports. The greater are the Verdoorn coefficient and the income elasticities of the sector under consideration, the greater is the impact on the BPCG rate.

On the export side, a faster growth of the sector under consideration affects positively its income elasticity, because it increases the non-price competitiveness of this sector. Consequently, the weighted income elasticity of demand for exports will increase, positively affecting the country's long-term growth rate. On the import side, a faster growth of the sector under consideration has a negative impact on its income elasticity of demand for imports. Here, the increase in the sector's non-price competitiveness reduces its income elasticity of demand for imports. This is because the country will demand less of the imports of this product, as the country is be able to produce it more competitively domestically. Consequently, the weighted income elasticity of demand for imports will decrease, reducing the BPCG rate.

Up to this point, it has been assumed that a faster growth of a given sector does not affect the growth rate of other sectors. However, if one considers, alternatively, that a faster growth of one sector is offset by a reduction in another sector's growth rate (that will be termed sector j) to keep the actual growth rate of the country, y, constant, equation (3.1) has to be modified. The impact of sector i's faster growth can be split into the direct impact, such as before, and the impact through sector j's growth rate:

$$\frac{d(\dot{y}_B)}{d(\dot{y}_i)} = \frac{\partial(\dot{y}_B)}{\partial(\dot{y}_i)} + \frac{\partial(\dot{y}_B)}{\partial(\dot{y}_j)}\frac{\partial(\dot{y}_j)}{\partial(\dot{y}_i)} \quad (3.13).$$

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[14] If income elasticity of demand for imports is the same among sectors, $\frac{\pi_i}{\pi} = 1$ (or $\pi_i = \pi$) (and thus the impact of structural changes on the dynamics of countries' BPCG is null), the difference between the income elasticities must be very high to the indirect impact have some significant effect on the dynamics of countries' BPCG rates.

Taking into account the impact on other sectors' growth rates is important because it shows that, in contrast to one-sector models, a multi-sectoral approach can explain how a process of cumulative causation may take place, even if the actual growth rate of a country remains constant.

Considering that $y = \omega_i y_i + \omega_j y_j$, where ω_i and ω_j are the weights of sectors i and j, the impact of a faster growth of sector i on the dynamics of a country's BPCG rate is given by:

$$\frac{d(\dot{y}_B)}{d(y_i)} = \phi_i b_i \left[\omega_{X_i} \varepsilon_i + \omega_{M_i} \pi_i \frac{\omega_\varepsilon}{\omega_\pi} \right] \frac{z}{\omega_\pi} - \frac{\omega_i}{\omega_j} \phi_j b_j \left[\omega_{X_j} \varepsilon_j + \omega_{M_j} \pi_j \frac{\omega_\varepsilon}{\omega_\pi} \right] \frac{z}{\omega_\pi}$$

(3.14)

Equation (3.14) shows that there are the two effects of a faster growth of one sector on the other. One is positive, due to a faster growth of sector i, and one negative, due to a decrease in sector j's output growth rate. The net impact depends on the relative sizes of the Verdoorn coefficient and the relative elasticities. In the case where $b_i > b_j$, $\varepsilon_i > \varepsilon_j$, and $\pi_i > \pi_j$, the impact of a faster growth of sector i will be an acceleration in the country's growth rate. On the other hand, if $b_i < b_j$, $\varepsilon_i < \varepsilon_j$, and $\pi_i < \pi_j$ the impact of a faster growth of sector i will be negative, reducing the BPCG rate.

At this point, we reach the main contribution of a multi-sectoral model. In single-sector models, a faster output growth is necessary to start a cumulative process. In a multi-sectoral model, this is not necessarily true. A cumulative causation process can be triggered by structural changes even if the growth rate of output is, at first, not affected. Because sectors have different income elasticities of demand for exports and imports, and they have different Verdoorn coefficients, specialisation in some sectors can boost the balance-of-payment equilibrium growth rate. Once it leads to a faster growth of output, a process of cumulative causation takes place.

Equation (3.14), however, does not show explicitly a cumulative causation process, because it does not establish any link between the BPCG rate and the actual growth rate. Only if the actual rate of growth is determined by the BPCG rate will this intervention trigger a process of cumulative causation in which a country's growth rate can diverge in the long term.

3.3. Technological gap and the opportunities to catch up

Equations (3.4) and (3.5) assume Verdoorn's law to explain how productivity growth is positively affected by a faster growth of output and, hence, how differences between domestic and external output growth rates can explain the dynamics of income elasticities. However, it has been assumed that exogenous technological change is the same in the country under consideration and in the rest of the world. Consequently, the fact that exogenous technological change may be different among countries has so far been ignored. On the one hand, exogenous technological change is determined by the scientific discoveries and R&D, which are strictly exogenous in the model. On the other hand, the rate of technical progress might also depend on the country's distance to the innovation frontier. In this sense, it is also important to consider how the technological gap may affect productivity growth. Consequently, the specification of the Verdoorn law specification should control for this.

The relation between technological gap and the "growth bonus" has been discussed by many authors based on different approaches (Cornwall and Cornwall, 2002; Fagerberg, 1994; Fagerberg and Verspagen, 2002; Barro and Sala-i-Martin, 1997). Essentially, they stressed that countries with a lower technological level compared with countries on the innovation frontier have the possibility of imitation and innovation and thus growing faster.   It follows that backwardness can be an advantage for productivity growth.[15]

Assume now that λ_i has a strictly exogenous component, which is given by the exogenous technological change of the rest of the world , λ_i^*, but it also has a component that is determined by the technological gap, G_i. Equations (3.4) and (3.5) can be re-written to take into account the impact of technological gap on productivity growth as follows:

$$\frac{\dot{\varepsilon_i}}{\varepsilon_i} = \phi_i[(\lambda_i' - \lambda_i^*) + f(G_i) + b_i(y_i - z_i)] \qquad (3.15),$$

and

$$\frac{\dot{\pi_i}}{\pi_i} = -\phi_i[(\lambda_i' - \lambda_i^*) + f(G_i) + b_i(y_i - z_i)] \qquad (3.16).$$

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[15] Cimoli and Porcile (2013) discuss the technological gap from a structuralist perspective. According to them, the technological gap can be consequence of the specialization pattern. Whilst the productive structure of the Center/North is more diversified, the Periphery/South remains highly specialized in a few (less technology-intensive) sectors. Although interesting, this approach differs from the one adopted here as we are focusing on technological gaps within sectors.

where $\lambda_i' - \lambda_i^* = 0$, and f is a strictly positive function; Consequently, the impact of sectoral gap on productivity growth is always positive. That is to say:

$$\frac{df(G_i)}{dG_i} > 0 \implies \frac{dG_i}{dq_i} > 0 \quad (3.17).$$

Using equations (3.15) and (3.16), equation (3.9) may be re-specified as:

$$\dot{y}_B = \sum \frac{\omega_{X_i}\varepsilon_i}{\omega_\pi}[(p_i^* - p^*) + (\varepsilon_i - \omega_\varepsilon)z + \phi_i\gamma_i(y_i - z_i) + \phi_i f(G_i)]z -$$
$$- \sum \frac{\omega_{M_i}\pi_i\omega_\varepsilon}{\omega_\pi^2}[(p_i^* - p^*) + (\pi_i - \omega_\pi)y - \phi_i\gamma_i(y_i - z_i) - \phi_i f(G_i)]z + \dot{z}$$
$$(3.18).$$

The impact of a faster growth of sector i will be the same as in equations (3.12) and (3.14). However, as discussed in the end of subsection 2, these equations do not explicitly show a cumulative causation process. This is because there is no link between actual and BPCG rates. In the context that actual growth rates are determined by BPCG rates, a faster growth of a sector will have a positive impact on its elasticity of exports and a negative impact on its elasticities of imports. If the sector under consideration exhibits higher income elasticities than the average, a process of cumulative causation will take place because the BPCG will increase. In turn, this will positively affect the actual growth rate (of all sectors).

Nevertheless, this process of cumulative causation is constrained by the technological gap. Because the sector under consideration is growing faster than the rest of the world, productivity of this sector will grow faster, and the technological gap will reduce. Consequently, if the level of productivity is sufficiently high, the ratio of the income elasticities will stop increasing. Thus, although a process of cumulative causation happens and a country's growth rate becomes higher than before, instead of presenting ever-increasing growth rates, the country's growth rate will be constant in the long term.

This process of cumulative causation, however, is extremely complex in a multi-sectoral model. This is because it involves variables in levels, such as weights of the sectors and the technological gap, and variables in growth rates. Consequently, the analysis will be continued through simulations in the next sections.

4. Simulations: results for a two-sector model

With the aim of assessing the impact of structural changes on a country's long term-growth rate, the model developed in the last section is simulated assuming different parameters for the sectoral income elasticities and the Verdoorn coefficient. From the results of these simulations, it will be possible to analyse what are the necessary conditions for these structural changes to affect positively a country's BPCG rate through a cumulative causation process.

The basic assumption of the model developed in the last section is that the multisectoral version of Thirlwall's law is the determinant of both long-term and short-term (or actual) growth rates. In the simulation, the latter, however, is assumed to be determined with a lag. This is because the mechanisms that make actual rate of growth to adjust towards the BPCG do not take place instantly.

Thereby, re-writing this model in discrete time, we have that:

$$y_t = y_{Bt-1} = \frac{\sum \omega_{X_{it-1}} \varepsilon_{it-1}}{\sum \omega_{M_{it-1}} \pi_{it-1}} z_{t-1} \qquad (4.1),$$

where the lower cases stand for growth rates (in discrete time).

If one assumes the sectoral weights of export and import growth rates given by equations (3.2) and (3.3), this might generate a problem of consistency because these equations are only linear approximations. Hence, the summation of each sector's weight may be higher (or lower) than unity. Thus, let us start by considering the growth rate of each sector's exports and imports (in volume terms) separately:

$$x_{it} = \varepsilon_{it} z_t = (\varepsilon_{it-1} + \Delta\varepsilon_i) z_t \qquad (4.2),$$

and

$$m_{it} = \pi_{it} y_t = (\pi_{it-1} + \Delta\pi_i) y_t \qquad (4.3).$$

The rationale behind equations (3.4) and (3.5) assumes that sectorial income elasticities of exports and imports are determined by the level of productivity (because it reflects the quality of goods). Moreover, productivity growth is determined by Verdoorn's law and the technological

gap (all in the previous period[16]). Consequently, the income elasticities may be written as a function of the differences between domestic output growth and that of the rest of the world:

$$\Delta \varepsilon_i = \varepsilon_{it-1} \phi_i [b_i(y_{it-1} - z_{it-1}) + f(G_{it-1})] \quad (4.4),$$

and

$$\Delta \pi_i = -\pi_{it-1} \phi_i [b_i(y_{it-1} - z_{it-1}) + f(G_{it-1})] \quad (4.5).$$

Replacing equations (4.4) and (4.5) in (4.2) and (4.3), respectively, the growth rate of exports and imports, in volume terms, can be expressed as a function of the following variables: the past income elasticities, the differential between domestic and external sectoral output growth rates (in the previous period), the level of technological gap, the world growth rate and the actual growth rate. It follows that:

$$x_{it} = \varepsilon_{it-1} \phi_i [1 + b_i(y_{it-1} - z_{it-1}) + f(G_{it-1})] z_t \quad (4.6),$$

and

$$m_{it} = \pi_{it-1} \phi_i [1 - b_i(y_{it-1} - z_{it-1}) - f(G_{it-1})] y_t \quad (4.7).$$

From these equations, it is possible to determine the level of exports and imports.[17] The growth rate of foreign price of good i is inversely proportional to productivity growth of sector i, as follows:[18]

$$p_{it}^* = -(\lambda_i^* + b_i z_{it-1}) \quad (4.8),$$

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[16] According to Setterfield (1997), competitiveness gains are associated with the realisation of induced technical progress (Verdoorn's law), and they require the accumulation of new capital, which will only come into productive use in some future period. Therefore, we assume that changes in elasticities are associated with growth rates in the previous period.

[17] They are given, respectively, by $X_{it} = X_{it-1}(1 + x_{it})$ and $M_{it} = M_{it-1}(1 + m_{it})$.

[18] The rationale of this assumption relies on the idea that although productivity growth does not reduce a country's relative prices, affecting only quality of goods, a world increase in productivity of a given good reduces its relative price globally. It is important to keep the model stable, otherwise the weights of exports of those sectors with high demand elasticities would rapidly increase.

Consequently, it is possible to obtain the weight of each sector in total exports and imports and, thus, the weighted income elasticity ratio, which are given by:

$$\omega_{X_{it}} = \frac{P_i X_i}{\sum P_i X_i} = \frac{P_{it-1}^*(1+p_{it}^*)X_{it-1}(1+x_{it})}{\sum P_{it-1}^*(1+p_{it}^*)X_{it-1}(1+x_{it})} \quad (4.9),$$

and

$$\omega_{M_{it}} = \frac{P_i^* M_i}{\sum P_i^* M_i} = \frac{P_{it-1}^*(1+p_{it}^*)M_{it-1}(1+m_{it})}{\sum P_{it-1}^*(1+p_{it}^*)M_{it-1}(1+m_{it})} \quad (4.10).$$

Sectoral growth rates will be determined by two different processes in different periods. First, there will be periods when the economy will be growing without intervention, and thus sectoral growth rates will be determined by their income-elasticities of demand. Secondly, there will be periods where one sector is under direct policy intervention (and thus its growth rate will be exogenously given) and the other sectors will grow at a rate that keeps the overall growth rate compatible with the BPCG rate.[19] In both cases, the overall economy will be growing at the same rate: the BPCG rate. The difference is that whilst without intervention the distribution of sectoral growth rates is given by their relative income elasticities of demand, during the periods of intervention, one sector grows at a given growth rate and the other sectors compensate for this growth rate to keep overall growth rate compatible with the BPCG rate.

In mathematical terms, the growth rate of sector i is exogenously given during the periods of intervention and during the period of non-intervention its growth rate given by its demand,[20] as follows:

$$y_{it} = \frac{\pi_{it}^*}{\pi_t^*} y_t \quad (4.11).$$

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[19] By intervention, it is assumed that a superior institution is able to determine the growth rate of a given sector. This procedure is adopted only for explanatory reasons. The aim is to show how the impact of a faster growth of a given sector, to the detriment to the others, impacts on a country's growth rate.

[20] We assume that sectoral growth rate relatively to aggregate growth rate is exogenously given by the world income elasticity of demand for imports of a given sector divided by the aggregate income elasticity of demand for imports. This assumption is only to make the model as simple as possible. An alternative assumption for sectoral growth rates could be the one presented by Trigg and Araujo (2014), which considers output multipliers. However, it will make the model even more complex, and it goes beyond the aim of this work.

Other sectors' growth rates are calculated assuming that the structure of production of the country under consideration is the same as the structure of the rest of the world's exports and imports. This implies that overall growth rates are the same independently of whether sector i is under intervention or not:

$$y_{jt} = \frac{y_t - y_{it}\omega_{it}}{\omega_{Mjt}} = \frac{y_t - y_{it}\omega_{Xit}^*}{\omega_{Xjt}^*} \qquad (4.12).$$

Finally, we define the variable that measures the technological gap based on the sectoral income elasticities ratio as $G_i = \frac{\varepsilon_i^*/\pi_i^*}{\varepsilon_i/\pi_i}$. This means that there will be no gap ($G_i = 1$) if the sectoral income elasticities ratio of a country is the same as that of the rest of the world.[21] The gap will be larger as the international ratio of income elasticity decreases. We assume that:[22]

$$f(G_i) = \sigma_i\left(e - e^{1/G_i}\right) = \sigma_i\left(e - e^{\varepsilon_i/\pi_i}\right) \quad (4.13),$$

where σ_i is the impact of technological gap on productivity growth rate and $\varepsilon_i^* = \pi_i^*$, equations (4.5) and (4.9) to (4.13) are sufficient to start the simulation, as all variables can be determined by lagged variables.[23]

However, in order to keep the model consistent in the long term, it is assumed that sectoral output growth in the rest of the world is equal to its growth of demand, which implies that:

$$z_{it} = \frac{\pi_{it}^*}{\pi_t^*} z_t \qquad (4.14),$$

and that equations (4.9) to (4.13) also apply for the rest of the world.

Furthermore, it is assumed that at the starting period (where $t = 0$), the domestic growth rate is equal to the rest of the world's growth rate. Initially, the weight of each sector in exports

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[21] Because income elasticities are a measure for non-price competitiveness, and they reflect the quality of the goods produced, such as discussed in Section 2, this definition for technological gap is more suitable than the usual definition based on productivity differences.

[22] It means that the impact of the technology gap on productivity is null if there is no gap, but this impact grows exponentially as the gap grows. Moreover, it is assumed that there is no world technological gap the gap is being measured in terms of world technology.

[23] With the exception of sectoral world output growth, which is considered as exogenously given.

and imports is the same ($\omega_{X_{it=0}} = \omega_{M_{it=0}}$) domestically and for the rest of the world, as well as each sector's export and import elasticities ($\varepsilon_{it=0} = \pi_{it=0}$).

4.1. Specialisation in sectors with high elasticities and Verdoorn coefficient

With the aim of analysing the impact of an intervention in favour of one sector to the detriment of the other on a country's long-term growth rate the simulation assumes two different cases: with and without intervention. In both cases the economy starts with the same structure and the same elasticities of the rest of the world.

In the case of no intervention, during all series sectoral growth rates are given by the BPCG rate multiplied by the sectoral relative income-elasticities of demand, such as presented by equation (4.11). As discussed before, it is important to guarantee that sectoral supply and demand growth rates are the same. In the case of intervention, three different periods are considered. During the first five years there is no intervention, and hence both sectors are growing at the growth rate given by (4.11), which is the BPCG rate multiplied by the sectoral relative income elasticity of demand. During five years of policy intervention (from periods 6 to 10), sector i is growing at an exogenously given growth rate that is higher than the period without intervention, whilst the other sector, j, is growing at a lower growth rate to compensate for sector i's faster growth rate. This is necessary to keep the overall growth rate equal to the BPCG rate. Finally, after the intervention (from period 11 onwards), both sectors return to growing at the BPCG rate multiplied by the sectoral relative income-elasticities of demand. However, because during the period of intervention sectoral growth rates were different in the country under consideration and in the rest of the world (even though the overall growth rate was unchanged), the BPCG rate may have changed and the economy may grow either faster or slower than if there were no intervention.

Simulations 1 and 2 assume an economy composed of two sectors that produce tradable goods. [24,25] One of these sectors has the higher Verdoorn coefficient (and thus the higher degree of increasing returns), which take a value of 0.8, and the higher income elasticities of demand for imports and exports, which take a value of 2.5. The other, consequently, has the lower Verdoorn coefficient (0.4) and the lower income elasticities (1.5). Even though these are theoretical simulations, the sector with the higher elasticities and Verdoorn coefficient may be interpreted as

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[24] Appendix B presents the parameters assumed in all estimations.

[25] We assume that the x-axis is just logical or simulation time rather than calendar time.

high-tech manufacturing or capital goods industry in middle- and high-income countries. The other sector may be interpreted as low-tech manufacturing and consumption goods sectors.

Many studies have found that high-tech sectors have higher income elasticities of demand for imports and exports than low-tech sectors (Gouvea and Lima, 2010; Romero, Silveira and Jayme Jr., 2012; Romero and McCombie, 2016 Romero and McCombie, 2018), and others that capital goods have higher income elasticities than consumption goods (Gouvea and Lima, 2013; Magacho and McCombie, 2015). Moreover, according to Magacho and McCombie (2017), in middle- and high-income countries the Verdoorn coefficients for high-tech sectors and capital goods are higher than for low-tech sectors and consumption goods.

Figure 1 presents the results of the first simulation, which is an intervention in the sector with high elasticities and a high Verdoorn coefficient. From this simulation, it is possible to understand the mechanisms through structural changes which may trigger a cumulative process of increasing growth rates. The upper left graph shows that a five-year intervention on relative sectoral growth rates can start a cumulative growth process, even if, at first, this intervention does not affect the total output growth rate.

Figure 1 – Simulation 1: impact of an intervention in the sector with the highest income elasticities and the highest Verdoorn coefficient
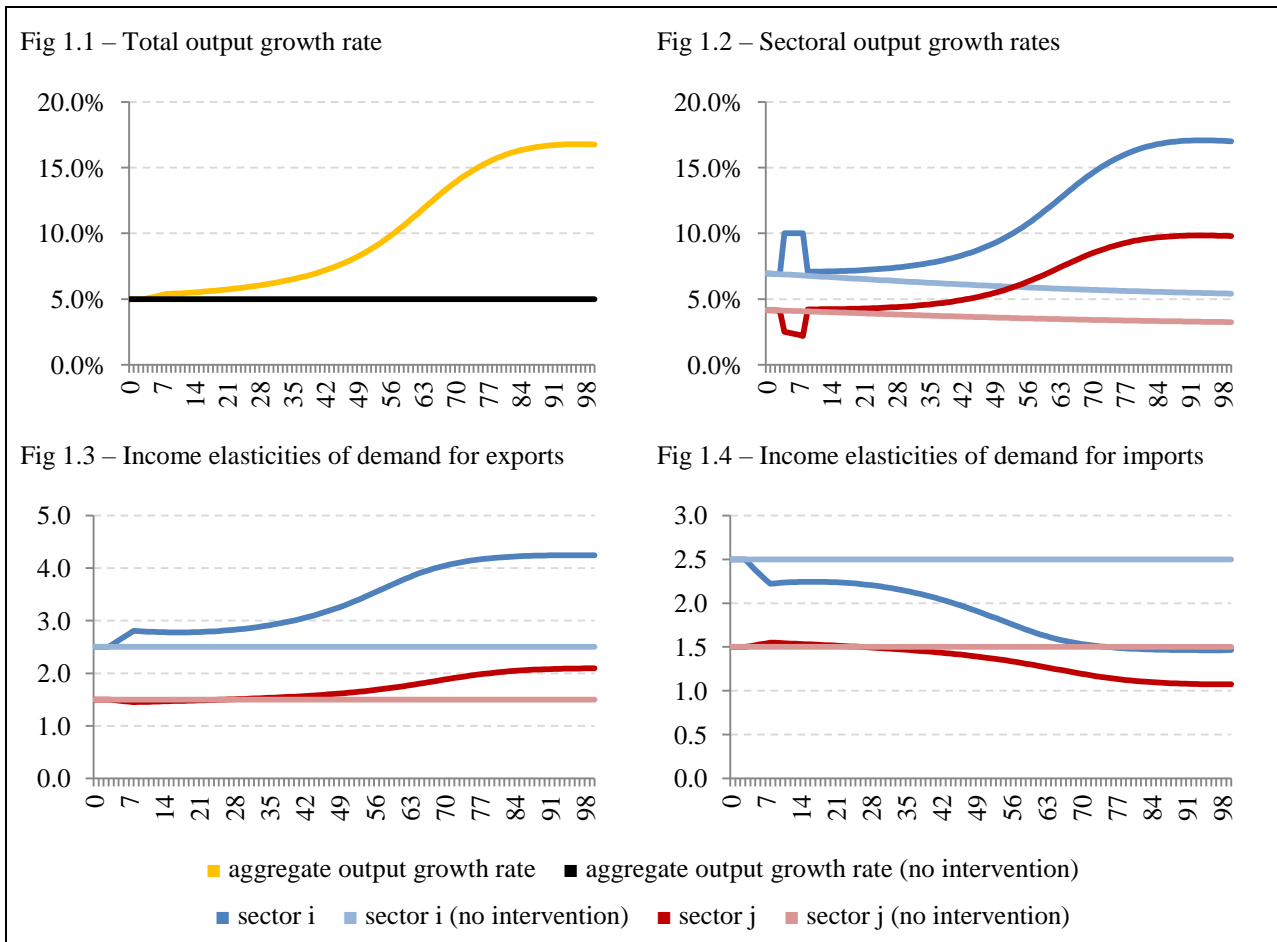
As the graph of sectoral output growth rate (upper right) shows, a five-year positive impact on sector *i's* growth rate positively affects the long-term growth rate of this sector because it initiates a cumulative process. However, it does not negatively affect the other sector. Conversely, sector *j* is positively affected in the long term, in spite of being negatively affected during the period of intervention.

This process happens because, during the period of intervention, the faster growth rate of sector *i* positively affects its own income elasticity of demand for exports. It negatively impacts on its own income elasticities of demand for imports, due to the existence of increasing returns to scale. The converse impact on sector *j*'s income elasticities, however, is less important because as this sector presents a lower degree of increasing returns, the impact on its own elasticities is relatively smaller. Consequently, the economy as a whole grows faster due to an overall increase in the of the weighted income elasticities. Because the economy is growing relatively faster than

the rest of the world, the income elasticities of demand for exports in both sectors increase permanently and the income elasticities of demand for imports decrease, triggering a process of cumulative causation.
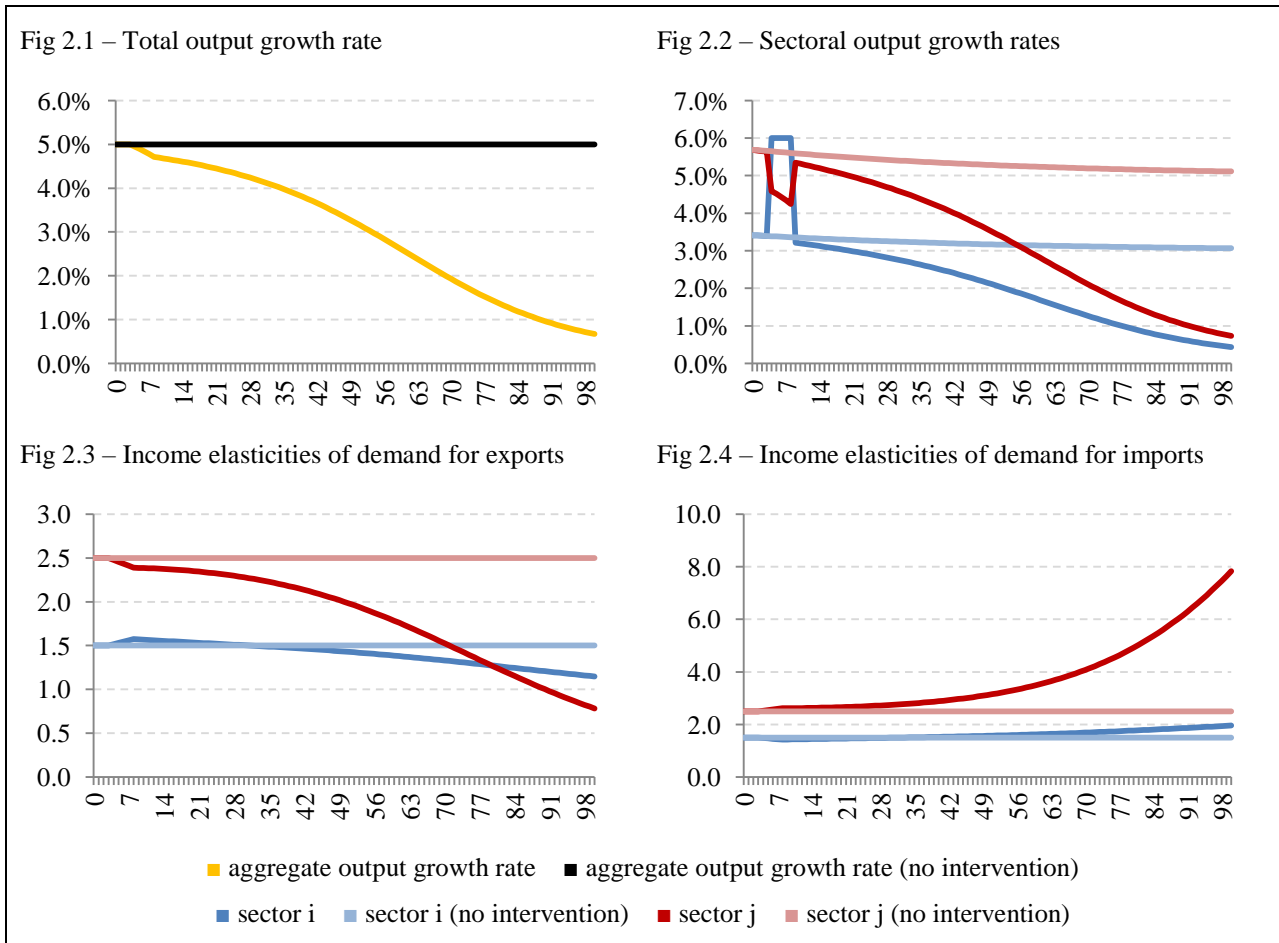
Essentially, sector i's ratio of the income elasticities is positively affected by the growth of the sector itself and by the growth of the economy as a whole. Sector j's elasticity ratio is negatively affected by the growth of the sector itself, but, on the other hand, it is positively affected by the growth of the economy as a whole. Thereby, an intervention that promotes a structural change in favour of the sector with the larger Verdoorn coefficient and the higher income elasticities of demand initiates a cumulative process of faster growth rates.

This intervention, however, will not imply ever-increasing growth rates. Because the positive impact of the technological gap on productivity decreases as productivity grows, the income elasticities of demand for imports will eventually stop decreasing and the income elasticities of demand for exports will stop increasing. Hence, the ratio of the aggregate export and import elasticities will become constant in the long run, although in a higher level than it was in the beginning.

4.2. Specialisation in sectors with low elasticities and Verdoorn coefficient

Simulation 2 analyses the impact of promoting the sector with the lower Verdoorn coefficient and the lowest income elasticities, considering the same Verdoorn coefficients and income elasticities for sectors i and j of Simulation 1. This may be interpreted as an intervention in favour of low-tech manufacturing or consumption goods in middle- and high-income countries. Figure 2 presents the results. As can be seen from the graph, in the upper left-hand side quadrant intervention that stimulates a faster growth of this sector (to the detriment of the other sector) negatively affects the economy's growth rate. It initiates a process of cumulative causation in which the country's growth rate continuously declines.

Figure 2 – Simulation 2: impact of an intervention in the sector with the lowest income elasticities and the lowest Verdoorn coefficient

Fig 2.1 – Total output growth rate

Fig 2.2 – Sectoral output growth rates

Fig 2.3 – Income elasticities of demand for exports

Fig 2.4 – Income elasticities of demand for imports

■ aggregate output growth rate   ■ aggregate output growth rate (no intervention)
■ sector i   ■ sector i (no intervention)   ■ sector j   ■ sector j (no intervention)

The reason for this is the converse of that discussed above. A faster growth of the sector with the lowest income elasticities positively affects its own income elasticity of exports and negatively affects its own income elasticities of imports. This promotes a faster growth of this sector itself. However, because the sector with the higher Verdoorn coefficient is growing at a slower rate compared with the rest of the world, its elasticity of exports is decreasing and its elasticity of imports is increasing. The net impact on the weighted income elasticity ratio is negative, and hence output will grow at lower rates. Consequently, the income elasticities of demand for imports in both sectors will increase, and the elasticities of exports will decrease, negatively affecting the weighted income elasticities. This, in turn, will trigger a cumulative causation process of decreasing growth rates.
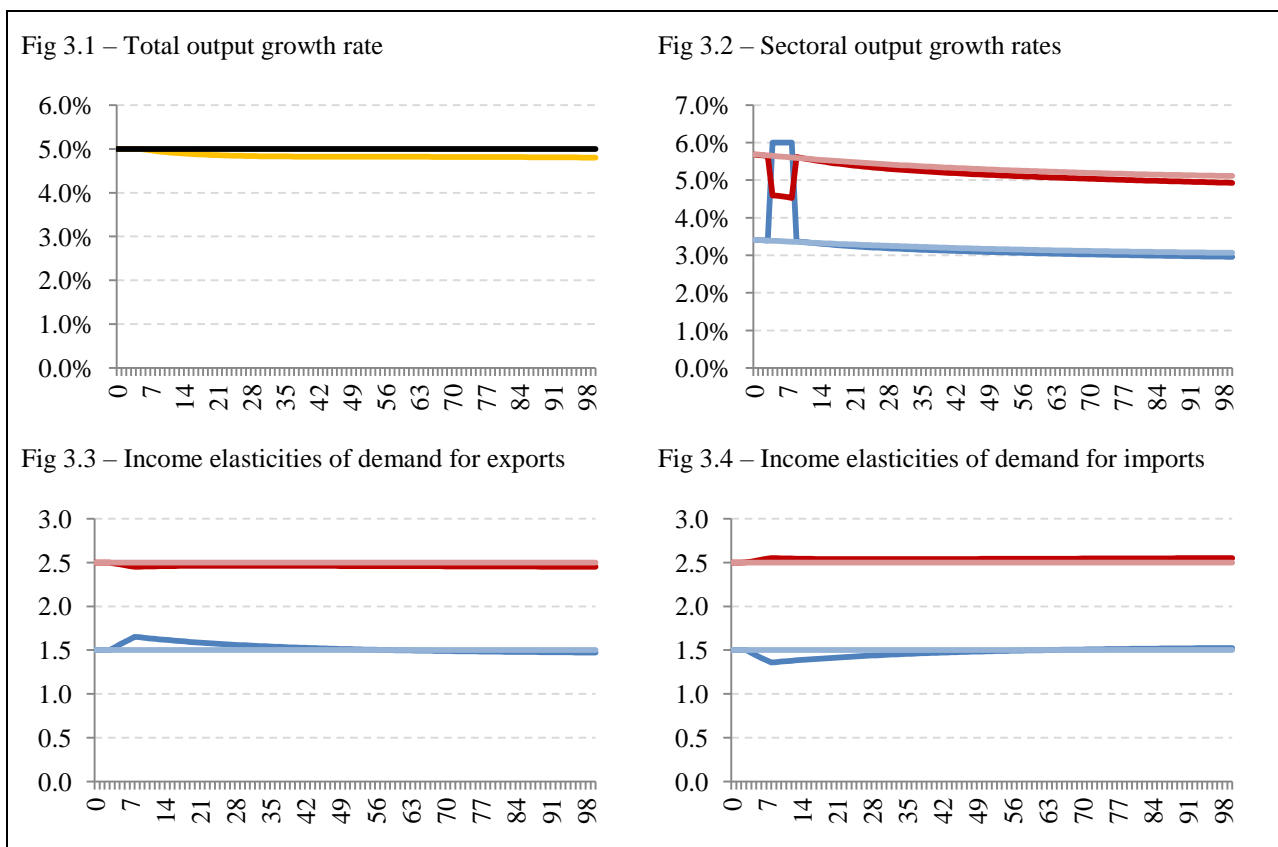
4.3. Specialisation in sectors with low elasticities and high Verdoorn coefficient

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Simulations 3 and 4 also consider two sectors, *i* and *j,* that produce tradable goods, but, in contrast to those presented before, one of these sectors exhibits the higher Verdoorn coefficient and the lower income elasticities, and the other, the lower Verdoorn coefficient and the higher income elasticities.

This analysis can also be interpreted based on the findings of the previous studies. The results of Magacho and McCombie (2017) showed that, for low-income countries, low-tech industries and consumption goods have higher degrees of increasing returns than high-tech industries, whilst the results of many studies showed that income elasticities are higher in high-tech industries and capital goods than low-tech industries and consumption goods (Gouvea and Lima, 2010; 2013; Romero, Silveira and Jayme Jr, 2012; Magacho and McCombie, 2015).

Figure 3 presents the results for Simulation 3, which considers a five-year intervention in favour of the sector with the lowest income elasticities but the highest Verdoorn coefficient, such as low-tech industries in low-income countries. In contrast to the simulations presented before, the results presented here are not conclusive, because it depends on the values of the elasticities and the Verdoorn coefficient.

Figure 3 – Simulation 3: impact of an intervention in the sector with the lowest income elasticities but the highest Verdoorn coefficient

Fig 3.1 – Total output growth rate

Fig 3.2 – Sectoral output growth rates

Fig 3.3 – Income elasticities of demand for exports

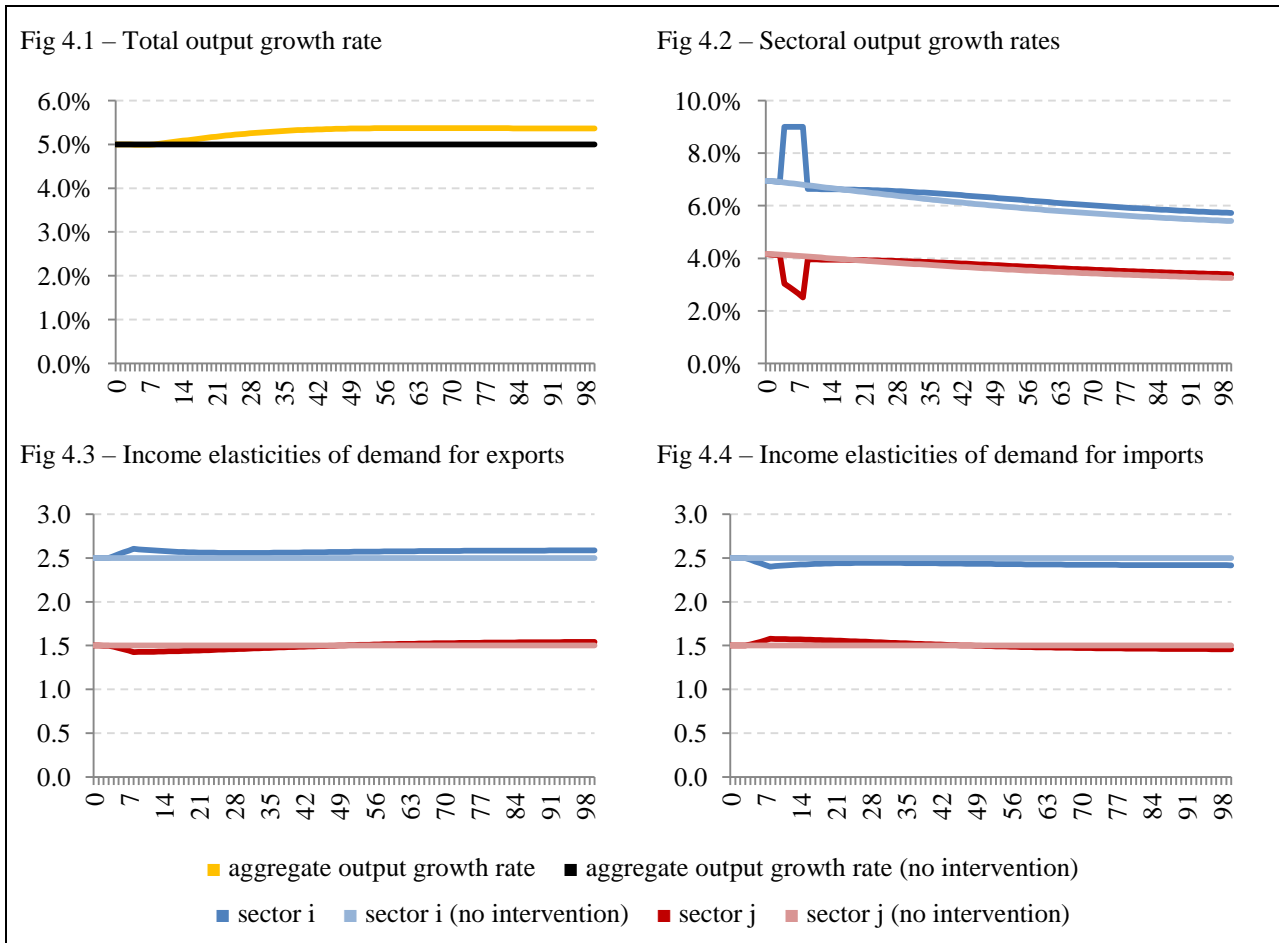Fig 3.4 – Income elasticities of demand for imports

An intervention promoting a structural change in favour of the sector with the lowest income elasticities positively affects the income elasticity ratio of this sector, but it affects negatively the income elasticity ratio of the other sector. As in the former simulations, one sector is positively affected and the other is negatively.

Nevertheless, in contrast to those simulations, because the sector with the lowest income elasticity presents the higher Verdoorn coefficient, the positive effect on this sector's elasticity ratio is greater than the negative impact on the elasticity ratio of the other sector. Consequently, although the weight of those sectors with the lowest income elasticities will increase in total exports and decrease in total imports, the elasticity ratio of this sector will increase. Consequently, depending on the values of parameters, the latter effect may compensate for the former, and the weighted elasticities ratio will not be affected.

4.4. Specialisation in sectors with high elasticities and low Verdoorn coefficient

Finally, Simulation 4, presented in Figure 4, shows the impact of an intervention in favour of the sector with the highest income elasticities but the lower Verdoorn coefficient. Based on the findings of previous studies, this sector may represent high-tech industries for low-income countries. Similar to the result obtained in the last simulation, the impact of a structural change in favour of this sector on total output growth rate is inconclusive: it all depends on values of the parameters.

Figure 4 – Simulation 4: impact of an intervention in the sector with the highest income elasticities but the lowest degree of increasing returns

Fig 4.1 – Total output growth rate

Fig 4.2 – Sectoral output growth rates

Fig 4.3 – Income elasticities of demand for exports

Fig 4.4 – Income elasticities of demand for imports

■ aggregate output growth rate   ■ aggregate output growth rate (no intervention)

■ sector i   ■ sector i (no intervention)   ■ sector j   ■ sector j (no intervention)

Although a faster growth rate of the sector with the highest elasticities increases its own income elasticity of exports and its share in total exports, as well as it decreases its own elasticity of imports and its share on total imports, the consequences of these may be offset by the impact of the other sector. Because the sector negatively affected by the intervention presents the highest degree of increasing returns, its elasticities respond relatively faster to its growth rates and, thus, the weighted elasticities may respond negatively to this intervention.

As in the former simulation, the net impact depends on the relative size of the parameters. If the difference in the Verdoorn coefficient is great enough to compensate for the difference in elasticities, the weighted elasticities will decrease and hence the total output growth rate will drop. Nevertheless, if the difference in elasticities is great enough to compensate for the difference in the Verdoorn coefficient, total output growth rate will increase, triggering a cumulative process of increasing growth rates.

The results obtained in these four theoretical simulations demonstrate that both sectoral income elasticities of demand and sectoral Verdoorn coefficients are important in explaining the process of cumulative causation. An intervention in favour of sectors with the greater Verdoorn coefficients and with largest income elasticities, such as the high-tech industries and capital goods in the middle- and high-income countries, can trigger a process of cumulative causation of increasing growth rates. On the other hand, an intervention in favour of sectors with lower Verdoorn coefficients and below average income elasticities initiates a process of cumulative causation with decreasing growth rates. Finally, an intervention in sectors with lower Verdoorn coefficients and higher income elasticities than the average (or vice-versa) may produce both results (increasing and decreasing growth rates) depending on the values of parameters.

5. Concluding remarks

Although the process of structural change is at the root of Kaldor's explanation for economic growth, many Kaldorian models do not incorporate it directly and, consequently, they are unable to present a complete explanation for the origin of the cumulative causation processes. Setterfield (2011), for example, presented an important model that shows a possible mechanism behind the growth rate divergence across countries. His model, however, does not explain how structural changes can trigger a process of cumulative causation, because it is not constructed in a multisectoral framework. According to this model, a country that is achieving a faster growth rate due to an increase in demand for agriculture products, for example, will achieve a faster and an increasing growth rate, even if the manufacturing sector is shrinking. Despite providing an interesting rationale for the existence of cumulative causation in a BPCG model, Setterfield's approach does not show the importance of specific sectors for long-term growth because it does not incorporate a structural analysis.

Alternatively, the Kaldorian models constructed within a multisectoral framework, despite providing insights about the relevance of sectoral specificities for long-term growth, are unable to show how the interaction between these specificities is important in triggering a cumulative causation process. The multisectoral version of Thirlwall's law, for example, shows the importance of structural composition of exports and imports to explain countries' growth rate divergence. However, this model does not incorporate endogenous technological change and its impacts on these elasticities, and hence it does not show the interaction between these two sectoral characteristics.

In this paper, the process of economic growth and cumulative causation were examined from a sectoral perspective. The main conclusion is that the divergence in countries' growth rates can be explained by the sectoral structure of countries' production and trade because sectors have different income elasticities of demand for exports and imports, such as presented in the multisectoral version of Thirlwall's law. They also have different degrees of increasing returns, such as evidenced by the Verdoorn law. On the one hand, an intervention in favour of sectors with the highest income elasticities of demand and the higher Verdoorn coefficient promotes a faster and an increasing rate of economic growth (even if, at first, the total output growth rate is not affected). On the other hand, specialisation in sectors that present the lowest Verdoorn coefficient and the lowest elasticities promotes a reduction in countries' growth rates. Finally, if the specialisation takes place in sectors with a high Verdoorn coefficient but with low elasticities (or vice-versa) the result is not conclusive: it depends on the relative size of these parameters.

Using the values for the parameters obtained in the previous studies for the sectoral income elasticities of demand for import and export and for the Verdoorn coefficient, it has been seen that specialisation in high-tech and capital goods industries is important to promote a faster economic growth in the long term for middle- and high-income countries. Because these sectors have the highest income elasticities and largest Verdoorn coefficients for these countries, promoting a structural change towards them can trigger a cumulative process. The faster growth of output of these sectors increases productivity, which, in turn, increases the income elasticities of exports and decreases income elasticities of imports. Consequently, because economic growth is ultimately determined by the balance-of-payments constraint, specialisation in these sectors promotes a faster growth of the economy as a whole, which increases productivity and non-price competitiveness of all sectors.

Therefore, a structural approach for the explanation of a cumulative causation is important for understanding economic growth in the long term. Although an aggregate approach for the divergence of countries' growth rates can provide important insights, some relevant features can only be seen from a sectoral perspective, with special regards for the origin of this cumulative causation processes.

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Appendices

Appendix A – A cumulative causation model based on Thirlwall's law

Setterfield (2011) starts by assuming that income elasticities are functions of domestic and foreign productivity levels,[26] as follows:

$$\varepsilon = aQ \qquad \text{(A.1)},$$

and

$$\pi = bQ^* \qquad \text{(A.2)}$$

where Q and Q^* are the domestic and world productivity levels, respectively.

Defining the income elasticities ratio as $\kappa = \frac{\varepsilon}{\pi}$, and so, combining the expressions above, we have:

$$\dot{\kappa} = \kappa(q - q^*) \qquad \text{(A.3)}.$$

Assuming that domestic and international growth rates present increasing returns to scale following a typical Verdoorn form, equations (A.4) and (A.5) measure the impact of output growth on productivity growth, and they show that it is strictly related to the degree of increasing returns, as follows:

$$q = \lambda + by \qquad \text{(A.4)},$$

and

$$q^* = \lambda^* + b^*z \qquad \text{(A.5)},$$

where b is Verdoorn coefficient.

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[26] According to Fagerberg (1988), economic growth may influence technological competition through demand-induced innovation, even though innovation activity seems to depend more on technological opportunities and the resources devoted to innovation than on demand conditions.

As $\lambda^* = \lambda$ and $b^* = b$, as assumed in Setterfield (2011), changes in the income elasticities ratio can be expressed as:

$$\dot{\kappa} = \kappa b (y - z) \qquad \text{(A.6)}.$$

Finally, because in the long term $y = \kappa z$ (Thirlwall, 1979), it follows that:

$$\dot{\kappa} = \kappa \gamma (\kappa - 1) z \qquad \text{(A.7)}.$$

This result shows that for $\kappa = 1$, the income elasticities ratio is stable. However, for $\kappa > 1$ there will be an increase of income elasticities ratio, and for $\kappa < 1$ there will be a decrease. It means that growth rates tend to diverge in the long term, which characterises a cumulative causation process.

Appendix B – Parameters adopted in the simulations based on estimated values

	Sim. 1	Sim. 2	Sim. 3	Sim. 4
b_i	0.8	0.4	0.8	0.4
b_j	0.4	0.8	0.4	0.8
$\varepsilon_i = \pi_i$	2.5	1.5	1.5	2.5
$\varepsilon_j = \pi_j$	1.5	2.5	2.5	1.5
z	5.0%	5.0%	5.0%	5.0%
$\sigma_i = \sigma_j$	0.006	0.006	0.006	0.006
$\phi_i = \phi_j$	1.0	1.0	1.0	1.0
$\omega_{X_{i,t=0}} = \omega_{M_{i,t=0}}$	30%	30%	30%	30%
$\omega_{X_{i,t=0}} = \omega_{M_{j,t=0}}$	70%	70%	70%	70%