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# Technological impacts of the exchange rate on economic growth and income distribution: a micro-macro multi-sector simulation analysis

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Rio de Janeiro, 28 de fevereiro de 2025

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## RESUMO

Nos modelos pós-keynesianos, os efeitos dos aumentos da taxa de câmbio real (RER) sobre o crescimento econômico podem ser ambíguos. O modelo de Crescimento com Restrição de Balanço de Pagamentos (BPCG) referencial não permite que variações da RER tenham impactos sobre as taxas de crescimento do produto, mas permite que isso aconteça quando se incorporam características setoriais e inovadoras na análise de médio prazo. O efeito final passa a depender de parâmetros relacionados à distribuição e ao investimento, às peculiaridades setoriais, às taxas de inovação e ao gap tecnológico externo. Este fenômeno levaria a ganhos no mercado externo associados ao crescimento da produtividade. Portanto, o objetivo desta dissertação é analisar a relação entre a RER e o crescimento econômico no modelo micro-macro multissetorial (MMM) de Vianna (2021) por meio da incorporação da imitação externa, da elasticidade endógena da renda das exportações e da possibilidade de aprendizado através do comércio. Esta dissertação está organizada em três capítulos, além de uma introdução e conclusão. No capítulo 1, analisa-se a literatura pós-keynesiana e neoschumpeteriana da perspectiva de um aumento da RER, enfatizando a distribuição e os efeitos inovativos, o catching up externo, os modelos macroeconômicos baseados em agentes e o papel do comércio para a inovação. No capítulo 2, descreve-se o MMM e são apresentadas adaptações do modelo focadas em imitação externa - com influências do comércio ao nível da firma - elasticidade de exportação endógena devido aos diferenciais de qualidade internos e externos, e market share externo que permite mais interação a nível de firma com o setor externo. Por fim, no capítulo 3, o modelo adaptado e o antigo são simulados, e replicações de Monte Carlo são usadas para analisar preliminarmente os efeitos de choques na taxa de câmbio nominal nas variáveis relevantes. Tal análise demonstra que o choque da taxa de câmbio nominal não tem um potencial de estimular o crescimento econômico no longo prazo, pois o crescimento da produtividade enfrenta obstáculos elevados a serem superados, enquanto os efeitos de qualidade não são capazes de gerar novas fontes de demanda autônoma. Embora haja um aumento inicial nas exportações líquidas, ele é acompanhado pela inflação, com ambas as variáveis recuando posteriormente. A introdução de um processo inovativo cumulativo associado à imitação externa gera uma nova dinâmica no modelo, ainda que não seja suficiente para induzir um ciclo de crescimento virtuoso a partir do choque. Ademais, a introdução do aprendizado através do comércio parece diminuir a produtividade geral. A combinação de uma trajetória de crescimento de demanda menor com uma nova dinâmica de produtividade quando os efeitos do choque na produção já são decrescentes parece ser prejudicial ao crescimento econômico. Os resultados sugerem que as estruturas setoriais e distributivas, e seus parâmetros podem impactar os resultados. Além disso, a interação entre a fronteira externa e a imitação das firmas domésticas pode gerar uma dinâmica de inovação parcialmente independente de outras variáveis econômicas. Ambos os aspectos requerem aprimoramento e uma análise mais detalhada em trabalhos futuros.



**Palavras-chave**: taxa de câmbio real, crescimento econômico; ciclos econômicos; modelos macroeconômicos baseados em agente.

**ABSTRACT**

In post-Keynesian models, the effects of real exchange rate (RER) increases on economic growth can be ambiguous. The baseline Balance of Payments Constrained Growth (BPCG) model does not permit for RER variation effects to impact output growth rates but allows it to happen when sectorial and innovative features are incorporated in medium-run analysis. The final effect becomes dependent on parameters related to distribution and investment, sectorial idiosyncrasies, innovation rates, and the technology gap. This would lead to external market gains coupled with productivity growth. Therefore, this thesis objective is to analyze the relationship between the RER and economic growth in Vianna's (2021) micro-macro multi-sector model (MMM) through the incorporation of external imitation, endogenous income elasticity of exports and the possibility of learning by trade. Beyond an introduction and a conclusion, this thesis contains three chapters. Chapter 1 reviews the post-Keynesian and neo-Schumpeterian literature from the perspective of an RER increase emphasizing distribution and innovative effects, external catching up, agent-based macroeconomic models, and the role of trade for innovation. Chapter 2 describes the MMM and introduces model adaptations focusing on the possibility of external imitation - with trade influencing it at the firm-level - endogenous export elasticity due to domestic and external quality differentials, and an external market share which allows for more firm-level interaction from the external to the domestic sector. Thus, in Chapter 3, the adapted and old models are simulated, and Monte Carlo replications are used to visualize nominal exchange rate shocks and perform a preliminary analysis. This analysis shows that the nominal exchange rate shock does not have a long-term potential for stimulating economic growth as productivity growth has a high bar to overcome, while quality effects do not show a potential to generate new autonomous demand sources. Although there is an initial increase in net exports, they are accompanied by inflation, with both variables receding later. The introduction of a cumulative innovation feature associated with external imitation generates new dynamics in the model, though it might not be enough to induce a virtuous growth cycle from the shock. Also, the introduction of learning by trade seems to decrease overall productivity. The combination of a lower demand growth path with a new productivity dynamic when there are dwindling effects to output from the shock seems to have a detrimental effect on economic growth. The results suggest that sectoral and distributive structures and their parameters can impact the results. In addition, the interaction between the external frontier and imitation by domestic firms may generate innovation dynamics that are partially independent of other economic variables. Both aspects require improvement and more detailed analysis in future works.

**Key-words**: real exchange rate; economic growth; economic cycles; agent-based macroeconomic models.

# List of Acronyms

**AB** Agent-Based

**BP** Balance of Payments

**BPCG** Balance of Payments Constrained Growth

**CIS** Community Innovation Survey

**GDP** Gross Domestic Product

**GVC** Global Value Chain

**MC** Monte Carlo

**MMM** Micro Macro Multi-Sectorial Model

**TFP** Total Factor Productivity

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# Introduction

The perception of the relationship between development and trade has been marked by prioritizing certain activities even before economics was considered a well-established subject. Economists that preceded Adam Smith and David Ricardo, such as Antonio Serra and Giovanni Botero, considered manufacturing activities to be essential for the wealth of countries (Italian *polis* at this time), while defenders of infant industry and critics of free trade, such as Friedrich List and Alexander Hamilton, considered that development would take place through the building of national technological capacities, which would then make it possible to compete in international markets, or in another way, through the expansion of activities with high innovative potential and increasing returns to scale (associated with manufacturing), it would promote development and make the country competitive internationally (REINERT; KATTEL, 2019; RÖSSNER, 2019, p. 138; REINERT, 2004; FREEMAN, 1995). This perspective has even influenced industrial and trade policies, which historically went hand-in-hand and were focused on establishing tariffs on industrial imports of (now) developed countries at similar or higher stages of development than developing countries have today (HAGEMANN, 2019; CHANG, 2004).

Among trade policies, some authors – such as the "novo-desenvolvimentistas" (FRENKEL; TAYLOR, 2006; BRESSER-PEREIRA, 2016; MARCONI; BRANCHER, 2017) and the global value chains (GVC) approach authors (GEREFFI, 2014; BALDWIN, 2012) – have suggested the possibility of currency devaluations or policies to keep domestic wages and costs low as a way of promoting insertion into foreign markets. In turn, these markets would have differentiated learning and innovation opportunities because the incentivized sectors would be industries and services with a higher technology content and also through insertion into GVCs via foreign direct investment (FDI) in association with leading firms that would press cutting-edge methods, standards and knowledge that could be acquired or spilled over to domestic firms involved in these markets (GEREFFI, 2014; SANTÁRCANGELO; SCHTEINGART; PORTA, 2017; BRESSER-PEREIRA, 2009; FRENKEL; TAYLOR, 2006) As pointed out by Toner (1999), Kaldor (1971, 1981) thought that if exports are concentrated in manufactures, as it was for the developed nations, free trade allowed not only for them acquiring foreign currency and avoiding balance of payment (BP) crisis, but also for technical change, and autonomous demand that would increase the rate of growth including of the sectors that he considered having decreasing or constant returns, such as agriculture. So, a way of developing a country was to develop an export industry that would diminish the BP constraint by expanding export income elasticity and even decrease import propensity through technical change (MCCOMBIE; THIRLWALL, 1994). Meanwhile, neo-Schumpeterians like Verspagen (1991) tried to link innovative effects from external knowledge frontiers to growth in technology gap models.

However, to promote economic growth, it is required that currency devaluations are initially positive for the product or at least lead to an economic transformation in the medium run that can offset any initial loss in growth. Still, in short-term open economic analyses, the effects of currency devaluation are ambiguous. Even though currency devaluation can lead to better price competitiveness against rival countries, internal distributional effects can offset external market gains. Besides drastic situations, for most closed economies post-Keynesian models, Lavoie (2014b) points out that distributional effects against wages are negative for the product. This idea follows from Kalecki (1954) simplification that workers spend more from their salaries than capitalists from their proceeds, and the investment incentives from increased margins are usually small and are, ultimately, offset by the decrease in consumption. Nevertheless, in the short-run for open economies, the final effect of lowering wages against rising profits (a redistribution in favor of profits) not only depends on how much the domestic product reacts to the traditional decrease in consumption *vis-à-vis* an increase in investment but also on the size of the effect on the country's external markets: the sum of a decrease in imports accompanied by domestic substitution and an increase in exports (BHADURI; MARGLIN, 1990; BLECKER 1989, 2011; SETTERFIELD, 2013; LAVOIE; STOCKHAMMER, 2013; LAVOIE, 2014d). Since the effect of a currency devaluation is an open question, each model would depend on the adopted parameters. For a given country, each devaluation would depend on empirical results (LAVOIE; STOCKHAMMER, 2013; LAVOIE, 2014b, 2014a).

For long-term period analyses, in traditional Balance of Payments Constrained Growth (BPCG) Kaldorian open economies models like Thirlwall (1979, 2011), it is usually considered that currency devaluations cannot have rate effects (only level effects), meaning that its impact on growth to be at best transient. However, when the BPCG model is relaxed to allow for international financial flows, the changing composition of sectors or products, endogenous price and income elasticities of demand, and even international technological spillovers, initial level effects evolving to a rate effect becomes a serious possibility. Those can result in different growth rates even when no medium-run technological effect exists. Also, with the Kaldor-Verdoorn (KALDOR, 1966) taking hold on outbursts of short-term level growth there is the argument that a cumulative causation dynamic (TONER, 1999) might be playing out on the long-run that makes level effects become rate effects, especially with the external market (typically considered exogenous) at play.

Thus, as a step among broader trade and industrial policies, currency devaluations results are contingent upon its effect on innovation. Also, as the neo-Schumpeterian school, Kaldorians, “novo desenvolvimentistas”, GVC approach authors, the historical developmental school (MYRDAL, 1957; ROSENSTEIN-RODAN, 1957), and the structuralist (PREBISCH, 1950) imply, it is necessary to take into consideration that innovation and technical change – the actual aims of trade and industrial policies – are stronger motors for development and might define the final result of model and actual policies. Further, innovation and technical change take place on longer stretches and depend on many non-traditional mechanisms not considered by traditional post-Keynesian economics, even among Kaldorians, as there is not a mechanical relationship between production and innovation.

Because of the necessity to incorporate innovation and the recognition that the economy is a complex adaptive system (ARTHUR, 2015), this thesis offers an overview of the neo-Schumpeterian literature. It emphasizes technology gap and macroeconomic agent-based (AB) models operating within a post-Keynesian economic structure. The emphasis on technology gap models comes from the understanding that currency devaluations work through external markets, and as such, technology gap models propose that external knowledge spillover from the North to the South countries provided that there is a technology gap between them. As innovation is considered a central piece of the puzzle, external spillovers in such a context become, therefore, a relevant source of new interactions from the system agents. Regarding AB models, those can provide a framework that can incorporate most of the predicted post-Keynesian channels that currency devaluations would propagate and include additional micro dynamics that might present emerging properties, which can be relevant to the analysis.

Also, the external innovation setting is of the utmost importance, as even the cumulative causation mechanism would be enhanced if trade-related quality and productivity gains were made. Therefore, an analysis of the theoretical possibility of innovation from the external insertion being of a unique kind is prescribed. Also, firm-level empirical evidence regarding the possibility of productivity and quality gains due to trade was proposed to check if firms could benefit from increased exposure to trade. If that were the case, export exposure would allow for increasing returns not strictly related to size, increasing the likelihood of currency devaluations influencing trade elasticities and growth, given that relative price fluctuations were possible.

As Blecker (2022) points out, because open economies are filled with different vectors and signals and, at the same time, policies like devaluation are aimed with a broader scope and length than just increasing the product at the first run, analyses that deal with a medium run are adequate to tackle the transformations that might be playing out, like innovation, technical change, sector redistribution and other changes in supply. So, there is a new strain of analytical efforts that seek to deal with a combination of theories and levels and with this “medium period” instead of the traditional long and short periods that usually treat each effect in isolation in other research. This approach allows for a more in-depth analysis of their effects on economic growth.

Aware of those efforts and seeking to avoid the partial and isolated treatment of older research, this thesis builds upon Vianna (2021) to explore the relationships in open economies, trying to focus on the relationship between innovation and its connection with external markets. Vianna's (2021) Micro-Macro-Multisectoral model (MMM) is an open-economy AB model, itself a product of the Possas and Dweck (2004) family of models. As the name suggests, it has multi-sectors and income classes. Its latest version includes a financial sector, international flows of capital, and a central bank that significantly influences the operation of the model. It considers the economy a complex system with heterogeneous agents and heuristics for decision-making that can, therefore, contain relevant characteristics, properties, and relations not revealed in analytical macroeconomic models as its complexities increase the difficulty in predicting its outcome. However, macroeconomic variables and properties arise from its operation.

Therefore, after the adaptation of the external sector of the MMM outlining the possibility of external imitation to emphasize the relations that innovations might play with trade, the effects of a currency devaluation were tested against the backdrop of those changes. As the model consists of a non-deterministic/analytical agent-based model (which as such is non-ergodic with non-linear properties, as stated by Caiani *et al.* (2016), Monte Carlo replications were carried out using the Laboratory for Simulation Development (LSD) software in order to check how the different specifications of the parts to be mapped and the parametric space of these variables affect the results. It can be added that the complexity of relationships, especially in neo-Schumpeterian contexts and with more realistic hypotheses, leads to the need for computer simulations and Monte Carlo replications since adaptive, stochastic, non-ergodic, and non-linear factors lead to different trajectories and make it more challenging to analyze the results (PYKA; FAGIOLO, 2005).

Besides this introduction, this thesis has the following organization: Chapter 1 discusses the possibilities of a currency devaluation (or depreciation) generating economic growth in the BPCG framework. Additionally, it gives an overview of the neo-Schumpeterian literature focusing on technology gap models and AB macroeconomic open economy models. Further, it discusses the possibility of learning and innovation being incentivized, initially due to size and foremost due to trade, which would consequentially enhance the cumulative causation mechanism and could lead to sustainable changes in trade elasticities; Chapter 2 describes the MMM and the changes introduced in the original model after taking into account the discussions of Chapter 1; Chapter 3 shows a simulation comparison of the proposed changes in comparison to the old MMM, with a preliminary analysis of results and a discussion; Finally, there is a concluding chapter which summarizes the review performed in the preceding chapters and discusses the new model implementation results and its implications.

# Chapter 1

# BPCG, innovation and distribution: the currency effect

This chapter discusses how currency depreciations (or devaluations)[1] could affect three related variables in post-Keynesian models: distribution, innovation and product. The motivation is that the literature considers real exchange rate (RER) change effects to have ambiguous final vectors dependent on distributional and innovation parameters and their treatment (BLECKER, 2022). In order to analyze this problem, this chapter initially focuses on the short-run open models' exchange rate effects that directly impact net exports and the functional distribution of income, which can have positive or negative final vectors depending on the institutional configuration of the economy (HEIN; VOGEL, 2008). Then, it uses the long-run Balance of payments constrained growth models (BPCG) model and its possible transitions to medium-run analysis as a tool for understanding the role of innovation and technology. To do that, it considers that there are increasing possibilities for analyzing the role of RER increases (equivalent to nominal exchange rate depreciations or devaluations if foreign and domestic prices remain the same) introduced by models that relax long-run assumptions, especially those that focus on the interplay between Kaldorian cumulative causation, the technology gap and distribution.

As this thesis considers that this interplay strongly depends on innovation effects and the technology gap, it also presents an overview of neo-Schumpeterian models. It initially focuses on innovation and the technology gap. Then, it centers on agent-based (AB) models that relate the micro and macro structures, as it considers the economy as a complex and adaptative system, which usually relies on "small" and "larger" structures interacting. Also, it points to neo-Schumpeterian models with post-Keynesian underlinings that can encompass the RER

[1] Depreciations are here understood to be a nominal decrease of the domestic currency price in foreign currency due to daily market operations in floating exchange rate regimes, not triggered by the government or central bank policy as a conscious objective. Devaluations, in contrast, are typically a result of government or central bank policies aimed at devaluing the currency, which are more common in fixed exchange rate regimes but can happen in floating exchange regimes as well (SOBEL, 2024). Unless otherwise stated, both moves are considered to have real exchange rate effects.

effects discussion as well as the innovation and catching up possibilities. The MMM (VIANNA, 2021) that is shown in Section 2.1 provides a model that that is updated in Section 2.2 using the ideas of this chapter's discussions.

Additionally, when taking into consideration the ideas of increasing returns and innovation present in the RER effects discussions, it is posited that if there is heightened innovation from size increases, which could affect demand variables other than net exports, and if there are heightened learning and innovation from trade (especially exports), a RER strategy focusing on external markets could augment the cumulative causation mechanism, which is focused on increasing returns due to productivity growth (BLECKER, 2013). Hence, both the innovation literature (and system of innovation) and the empirical literature are reviewed to check if this is indeed the case. The objective is to provide channels to improve upon the chosen model and then check if this can influence the results.

Besides this brief introduction, this chapter is set as follows: Section 1.1 discusses the role of exchange rate effects, focusing on income distribution and using the BPCG model as a reference for mapping the channels that might influence the product.; Section 1.2 brings a brief overview of the neo-Schumpeterian models and aspects. It emphasizes the AB open economy models as it is considered that those can provide a basis for capturing most of the possible exchange rate channels; Section 1.3 reviews the system innovation literature and the empirical evidence looking for possible connections between external markets and learning and innovation.

## 1.1 The exchange rate, BPCG and income distribution

Currency depreciations in open economies usually have features similar to relative wage reductions. Traditionally, in the Kaleckian framework for closed economies, as in Kalecki (1971, ch. 7, ch. 8), wage reductions work through changes in the distribution of functional income that increase the share of profits (while reducing the share of wages) and simultaneously through decreases in demand that decrease income and product. This decrease happens because labor is assumed to consume more of what they earn out of wages than capitalists consume out of profits.

Also, capitalists' consumption and investment decisions are assumed to have been made in the past, and they define the capitalists' own profits (if there were no government and workers did not save). Thus, they depend on past periods' profits with lags and usually have a low sensitivity to changes, meaning that the profit share will not heavily influence demand through the capitalist side. Thus, wage share reductions will decrease product and income. In contrast, the effect of the increase in profit share on demand will not be strong enough to offset the decrease caused by the reduction of the wage share. This will usually translate into total profits decreasing, aggravating the situation due to the decrease in demand (KALECKI, 1971; LÓPEZ; ASSOUS, 2010).[2] Whilst the saving out of wages assumption is permitted, it is usually assumed that the final effect on aggregate demand of a (real) wage reduction is unambiguously restrictive on closed economies, provided that wages are lower than the labor productivity (LAVOIE, 2016).

In canonical neo-Kaleckian growth models, as investment dynamics are more well-defined than in Kalecki (PETRI, 1993), besides an autonomous component, investment is usually dependent on capacity utilization. In contrast, profits are a minor determinant of it (LAVOIE, 2014a). It is worth noting that the influential Bhaduri and Marglin (1990) post-Kaleckian model conjectures that the profit share might have a more decisive role in investment, as a profit squeeze (in real open economies) was perceived as more of an explanation for the growth stagnation of the post-golden age era (MARGLIN; BHADURI, 1990) than capacity utilization. Thus, the final effect of wage variations on income becomes dependent on which effect is the dominant one: real wages on consumption or profit share on investment, and that would make the economy be characterized as wage-led or profit-led, respectively (LAVOIE; STOCKHAMMER, 2013).

While this profit and wage-led dichotomy is usually reserved for analysis of the results of wage changes in closed economies, it is the initial step for determining the effects of RER increases on the product for open economies. This section aims to look at how post-Keynesian short- and long-term models are affected by that increase in terms of distribution and net exports changes and then start including models that permit technology and innovation repercussions, usually reserved for a "medium-run" analysis. Those additions might ultimately change the results, which makes them important. So, this section starts by looking at the short-term effects of RER increases[3] and move to the long-term benchmark of the BPCG model (THIRLWALL, 1979) and then towards its additions, which usually rely on loosening hypothesis and allow technology and innovation dynamics to play out. This relaxation theoretically concedes that economic structures can change and include non-traditional economic forces as sources of shifts, like technical change. This setting is framed here as medium-run analysis.

In this context, although for closed economies the investment dependency on profits is a requirement[4] for the effects of reductions of real wages to be expansionary, for open economies, this dependency is not a condition for both wage reductions and currency devaluations to be expansionary. In an open economy model that considers investment more responsive to capacity utilization than profits, Blecker (1989) points out that devaluations might have similar effects to real wage reductions and markup increases. They all are not unambiguously restrictive on income or product. They depend on price elasticities of demand for exports and imports, the economy's openness, and the markup's sensibility, which is set as flexible and dependent on external competition. This flexibility allows relative price changes to impact the home country's

[2]These schemes imply a causation problem, but Kalecki (1954, ch. 7) believes that since capitalists do not choose how much profits they will earn but how much investment and consumption they will make, the causality should run from the latter two to the former.

[3]Or currency depreciations/devaluations that are not fully corrected by relative price changes.

[4]Excluded when wages are higher than productivity.

competitiveness and net exports.

The logic behind currency devaluation expansionary effects goes through an increase in external competitiveness (BHADURI; MARGLIN, 1990) that occurs through the reduction of the domestic cost that includes relative wages provided that the external sector has negatively inclined demand curves for domestic products, the domestic sector has negatively inclined demand curves for external products, and the Marshall-Lerner condition holds.[5] However, internal domestic demand can decrease as there is a reduction in real wages and the wage share of the economy (BLECKER, 1989).

The idea is that a devaluation reduces real wages through an increase in relative external prices incorporated directly or indirectly in the workers' consumption basket. As occurs in Blecker (1989), the reduction in external competition, in this case, due to wage reduction that leads to changes in relative prices in favor of the home country, can lead to an increase in the markup of domestic firms, but not fully equal to the change in prices (otherwise relative prices would not change). This markup increase would lead to distribution changes in favor of profits. Another way of visualizing how currency depreciations cause real exchange rate effects that affect distribution is to adapt Kalecki (1954) description of an industry distribution of the value-added between wages and profits to an open economy and consider it as a domestic value-added with raw materials treated entirely as imported inputs, as it is done by Hein and Vogel (2008). In this way, changes in the wage and profit share of the domestic value-added can be visualized due to changes in imported inputs to wages ratio and markups.

In Kalecki (1954, p. 28), the share of wages in domestic income $w$ is dependent on the ratio $j$ between the costs of raw materials and wages and the ratio of sales (proceeds) $k$ to direct costs ($k$ is a markup related to the degree of monopolistic competition faced by firms):

$$w = \frac{1}{1 + (k-1)(j+1)} \tag{1.1}$$

For an open economy, the ratio $j$ is a ratio between the unit costs of imported inputs and domestic unit wage. So, if production proportions stay the same, a currency devaluation (or depreciation) would increase the cost of unit imported costs relative to wages, leading to increases in $w$. However, a change in distribution could occur even when the imported costs channel is not activated, such as in Blecker (1989). He assumes that the only input is domestic labor, and that would make $j$ equivalent to 0. However, as he assumes a flexible markup that varies due to external competitiveness, which depends on relative prices, the distribution can vary given that firms' relative cost changes are bigger (smaller) than their markup gains (losses). This reasoning implies that capitalists will try to amplify their market share given their costs

[5]The Marshall-Lerner condition in which a currency depreciation might improve a country's trade balance. Starting from a BOP equilibrium position, it depends on the sum of the price elasticities of the demand for imports and exports being greater than unity (GANDOLFO, 2006).

(and *vice-versa*).

Expanding on that idea, it implies that $k$ could increase. At the same time, $w$ decreases when there is a gain in external competitiveness (and vice-versa), leading to a redistribution towards profits. Also, it implies a decrease in domestic consumption if it is assumed, as Kalecki does, that wage-labor have a higher propensity to consume than capitalists or that there is more induced consumption out of wages than out of profits. However, when there is an imported cost channel, *j* can vary due to changes in the wage bill if the imports bill remains the same.

In Hein and Vogel (2008), currency depreciation will cause a redistribution towards profits with a positive effect on investment (as they incorporate Bhaduri and Marglin (1990), a negative effect on consumption demand, and a positive effect on net exports. However, since consumption, investment, and imports also depend simultaneously on the overall effect on real GDP, which is ambiguous, the ultimate effect is also ambiguous. It is worth noting that the controversial profit response to investment still does not make a currency depreciation an unambiguous strategy for stimulating demand. However, it reduces the harmful effect of a redistribution towards profit and makes it easier to stimulate growth.

So, the conclusion in Hein and Vogel (2008) is that wage-led countries, usually holding larger markets relatively shut to external markets, diminish their wage-led characteristics (and might even become profit-led) when considering their open economy aspects. Meanwhile, profit-led relatively small open economies might have their profit-led character augmented.[6]

Also, as pointed out by Hein and Vogel (2008), productivity regimes should be considered, especially when the source of a growth stimulus is a regressive redistribution. As argued by Storm and Naastepad (2012), using the Dutch 80's and 90's case as reference, any expansionary effect of keeping a relatively low real wage could offset productivity gains related to the growth of aggregate output due to the Kaldor-Verdoorn effect. In this sense, any cumulative causation dynamics, as shown in Kaldorian export-led growth models like McCombie and Thirlwall (1994) or the older Dixon and Thirlwall (1975), would be overshadowed.

The last model is a predecessor of Thirlwall (1979) long period balance of payment constrained growth (BPCG) model. It considers that a country's growth will be limited to or have as its equilibrium long-period growth rate, depending on the interpretation, equal to the BP

[6]The Hein and Vogel (2008) logic is: if the economy is domestically wage-led, that would mean that the relative wage reduction impact to consumption will be higher than the investment increase coming from a profit share rise. Hence, domestic demand will affected negatively due to a RER increase. Then, net exports will undoubtedly be positive since exports will gain from price competition while imports will recede from both price competition and the reduction in domestic demand. For simplification, in the case where the economy is profit-led domestically, net exports become dependent on the external competition impact on external demand (dependent on the price-elasticities of demands for imports and exports) and the internal demand impact for import (dependent on the income elasticity of imports). With consumption not offsetting gains in investments, this will mean that the domestic demand will increase along with an increase in imports that the export expansion will amplify. That means that the overall demand effect depends on the income elasticity of imports, price elasticities of demand for imports and exports, the investment reaction to changes in the profit share, and the consumption reaction to changes in the wage share.

constraint. As a demand-led model, Thirlwall's (1979) model considers that demand can only be restricted externally by the financial necessity of imports, while all supply-side issues can be passively overcome by growth as it is a potent inducer of supply changes through technological progress, sectorial change, labor increases, investment, or even more imports that would lessen domestic constraints. That would make the only actual limit to growth the necessity to import in the sense that imports require foreign currency and, thus, require exports, which are dependent on foreign countries. So, running successively BP deficits could lead to a crisis as a country runs out of reserves necessary to import or to a devaluation or a currency depreciation depending on the exchange regime and the policy response from the central bank.[7] Thus, the BP constraint becomes the relevant growth rate of the economy.

In Thirlwall (1979, 2011), the expanded version of the growth rate is defined by the growth rate of the external sector and the elasticity of exports to external income, the elasticities of import to internal income, the price elasticities of exports and imports, the rate of growth of the exchange rate and the rate of growth of domestic prices and foreign prices:

$$y_{bt} = \frac{(1+\eta+\Psi)\left(p_{dt}-p_{ft}-e_t\right)+\varepsilon\left(z_t\right)}{\pi} \tag{1.2}$$

where,

$y_{bt}$ is the balance of payment constraint growth rate;

$\eta$ is the price elasticity of demand for exports;

$\Psi$is the price elasticity of demand for imports;

$p_{dt}$ is the domestic prices rate of growth;

$p_{ft}$ is the external prices rate of growth;

$e_t$ is the rate of growth of the exchange rate;

$\varepsilon$ is the elasticity to external income;

$z_t$ is the rate of growth of external income; and

$\pi$ is the income elasticity of demand for imports.

From the above equation and given that the Marshall-Lerner condition for devaluation is satisfied ( $|\eta+\Psi| > 1$), the model shows that once-and-for-all currency devaluations can only have levels, as opposed to rate, effects on the growth rate unless its base-case scenario of fixed parameters, especially related to elasticities, is relaxed (THIRLWALL, 2011, p. 323). Thirlwall (1979, p. 49-50) assumes that in the long run, there are no relative price changes relevant enough because of arbitrage or because exchange rates vary in the same proportions of price changes. Also, he assumes that the price elasticities are just enough not to satisfy the Marshall Lerner

[7]Following Kaldor (1981) which consider that the only limits to growth are the external sector and agriculture output as agriculture does not show increasing returns.

condition (elasticity pessimism Blecker (2013). Those cases would make $(p_{dt} - p_{ft} - e_t)$ equal to 0 and $|\eta + \Psi| = 1$, respectively. So, the equation, in the strongest form, reduces to $\frac{\varepsilon(z_t)}{\pi}$, as he considers that relative prices are not the adjustment mechanism for the BP, but income. Making the BP equilibrium growth rates guide the long-run growth rates without relative price changes (THIRLWALL, 2011).

However, suppose a country can modify its economic structures as it develops. In that case, it is necessary to follow the model additions that follow this line, since even Thirlwall (1979) advocates changing the income elasticities, even though he does not provide ways of changing it in his model. Also, if these structures are changing, it is not plausible that relative prices and price elasticities should be the same since this implies changes in technologies or sectorial or product composition within an economy.

In Kaldor (1957, 1966, 1981), Dixon and Thirlwall (1975) and Setterfield and Cornwall (2002), the cumulative causation framework through the Kaldor-Verdoorn effect is highlighted. In summary, it follows the Kaldorian ideas that there are increasing returns in industry and that those returns are related to the size of the market and to learning by doing effects, or dynamic increasing returns related to experience, as in Kaldor (1985). It works through productivity growth due to increased growth, which leads to better trade terms, and then exports, which increase growth as the cycle repeats.[8] However, in a BPCG context, this proposition can only operate when the real exchange rate and relative prices are allowed to fluctuate, which then permits it to affect exports through competitive gains via relative prices that will make the positive cumulative causation feedback possible (BLECKER, 2013).[9]

Furthermore, in a BPCG context, if the initial assumptions of the Thirlwall model are taken for granted, a developing country would be locked forever in a development path like the one established by Prebisch (1959) and might never catch up to developed countries. The only path for achieving a relatively larger growth would be outside the traditional economic realm.[10] Further, having a BP equilibrium growth rate lower than the rest of the world and assuming that it implies a worse technological path and that Engel's law holds would result in a deteriorating BP's growth rate because consumer preferences would be shifting toward the

[8]If relative prices can fluctuate and relative wage reductions can stimulate growth, these effects should be muted if, as suggested by Storm and Naastepad (2012), capital innovations are disincentivized by lower wages. Hence, the rationale behind the cumulative causation models might be limited as losses in innovation would offset productivity gains. In other words, decreasing capital innovations would neutralize the Verdoorn mechanism due to an increasing scale caused by wage reductions.

[9]In the issue of how supply conforms to demand, León-Ledesma and Thirlwall (2002), Setterfield (2006, 2010) and Mccombie (2011) uses the Verdoorn effect or make increases of labor supply dependent on the growth rate, which makes the BP equilibrium growth rate feasible not only "by chance" (as Thirlwall (2011, p. 329) puts it). However, the Verdoorn effect cannot affect exports if the real exchange rates are made constant (BLECKER, 2013).

[10]Additionally, as argued by Barbosa-Filho (2006) the crisis implied in violating the BP long-term growth rate for an extended period would lead to capital flight and massive depreciations in developing countries, which would force income to adjust to the BP growth rates when violating the constraint for too long. That makes it likely that structural changes would reflect onto elasticities and would make the BPCG adjustment mechanism change the BPCG long-period rate because of the constraint.

technologically intensive external goods. In other words, the BP's long-term growth rate will continually decrease. This decreasing growth rate would also mean that developing countries (besides having an initial "deficit" to overcome) would have to exhibit higher technological growth rates and compositional changes toward goods with higher income elasticity of demand if they hope to converge, changing their economic structures.

Blecker (2022) states a theory concern between a "medium run," level and rate effects differences and transitions to the long-run steady-state related to the consideration of relative price changes. Also, he shows that different post-Keynesian branches – Kaleckian, Kaldorian, Schumpeterian, and Keynesian – are also involved in this theory evolution, especially given the interplays between technology, distribution, and aggregate demand on a BPCG framework that might be affected when long-run steady states assumptions or strict assumptions taken for simplicity are given-up. There is a third point for using medium run analysis, as the initial considerations by Thirlwall (1979) about relative price changes and the elasticity pessimism assumption are less likely to hold. As Blecker (2013) summarizes, relative price adjustments are prone to happen in the short and medium term. At the same time, relative price changes are more likely to be constant over very long periods. Meanwhile, violating the Marshall-Lerner condition in the short run is likelier, but as the period considered increases, the condition gets likelier to hold. Both situations make RER increases to have effects in a BPCG framework and the cumulative causation idea more likely to operate in the medium run.

So, besides the capital and current accounts on the BP, such as Thirlwall and Hussain (1982) or Moreno-Brid (1998) additions that allow for trade deficits finance and external debt negative consequences that were first introduced to allow for a better empirical evaluation of the BP constraint as the relevant explanation for the international growth rate and consistency in the model, it is worth noting the novelty introduced by multi-sector models. By considering a multisectoral model, even without intra-sectorial elasticities changes and relative price changes, Araujo and Lima (2007) show that sectorial composition changes can imply an overall change in elasticities that would imply in different long-term BP equilibrium growth rates that might be even better fit to the empirical evidence. Those composition changes could occur simply by evolving consumption patterns or growth policies focusing on sectors with better export and import elasticities. This proposition could imply that changing BPCG's long-term growth rate elasticities with considerations to technological change could also be a better predictor of countries' performances.

As suggested by Araujo and Lima (2007), while not disregarding technological change – which their model highlights – sectoral changes can give interpretations that reconcile BPCG with empirical evidence for developing countries. This reconciliation suggests that those countries could experience a relaxation of the BP equilibrium growth rate as they modernize due to sectoral composition changes and/or technological change, even if they are experiencing relative price changes in the "wrong" directions. In a multisectoral BPCG simulation model, where multiple sectors exhibit different characteristics, such as technologic dynamism due to differential autonomous investment, Busato and Possas (2016) show that internal dynamics can postpone the external constraint for some time and affect the product. This model shows that internal sectoral dynamics can affect GDP in the medium run. Additionally, the author makes the export coefficient endogenous to simulate an endogenous income elasticity. To do so, Busato and Possas (2016) distinguishes between products that are more sensitive to price or non-price competitiveness, with the former being related to relative price changes and the latter to autonomous investment changes. One could interpret autonomous investment changes as changes in innovation and technology characteristics.

This sectoral composition rationale is already present in Kaldor (1971). In his English example, he argues for promoting exports, which are correlated to manufacturing, instead of consumption (or "internal demand management"). Kaldor (1971) states that both investment and productivity (due to increasing returns in manufacturing) might be favored through export growth and that additionally do not risk jeopardizing the BP. This is also behind models with policy recommendations for devaluations and modernization proposals. Frenkel and Taylor (2006) argue that the real exchange rate can affect relative prices between different sectors of the economy, namely the tradable sector versus the non-tradable sector, given that the exchange rate affects the former directly. Since there are different technological intensities between tradable and non-tradable sectors, a devaluation would make it possible to change the parameters of the external income elasticity of demand. When considering the manufacturing sector as the tradable sector, this view also pays tribute to Kaldor (1985, p. 70-71) classical view of manufacturing as the “engine of growth” subject to increasing returns and as the most tradable activity in the post-war world.

As stated by Barbosa-Filho (2006) and he got the point from Frenkel and Taylor (2006) and Woo’s (2004) tariffs and subsides analysis, the BPCG models at the time missed the point that if exchange rate can have a differential impact between sectors (manufacturing which would be tradable and agricultural which would be non-tradable as in Woo (2004), exchange rate variations would be relevant because the tradable sector was more prone to innovations and technological progress, and therefore should exhibit greater potential for reducing the BP constraint and increase the growth rate.[11]

Expanding the Araujo and Lima (2007) framework, Araujo (2013) presents a model with different Kaldor-Verdoorn coefficients for different isectrs. Their North and South framework allows relative price variations and elasticity changes in the medium run. These different coeffi-

[11] Following the same logic, Ferrari, Freitas and Barbosa-Filho (2013) assume that domestic high-tech tradables have a positive relationship with a devalued real exchange rate. In contrast, foreign tradables have a negative connection, thus making possible to depreciations to promote technological change and growth. Initially, an exchange rate shock leads to changes through composition effects, leading to subsequent changes in elasticities, which allows for higher growth rates. The association between the possibility of generating structural change through a devalued or depreciated exchange rate depends on whether the exchange rate stimulates high-tech tradables and whether this stimulus is connected to a virtuous technological path and investment.

cients make room for relative prices to affect the technology/productivity of the economy and, therefore, the elasticities. It also means that industries that exhibit higher price elasticities are more affected by relative price changes and can have higher Kaldor-Verdoorn effects since they will grow faster following a devaluation. Additionally, export growth can generate productivity gains through increase in market size and through spillovers and competition, reinforcing the cumulative causation mechanism. Stimulating these sectors that already have higher growth rates due to investment and technological characteristics will lead to both higher growth rates and a change in trade elasticities that will change BP's long-term growth rate.

Castellacci (2002) presents a model where the cumulative causation mechanism can accelerate growth through the traditional channel of the expansion of exports by decreasing prices through the Kaldor-Verdoorn effect. However, he incorporates Verspagen's (1992) technology gap in an endogenous innovative activity that can initiate or hinder the process. Nevertheless, this activity is independent of the Kaldor-Verdoorn effect. This means that an expansion of growth cannot cause an acceleration of innovative activity. In a sense, this happens with most BPCG models,[12] since growth occurs through cost reductions that reduce the price of exports, but that do not consider the productivity structure *per se* is changing, which would presumably reflect on the elasticities of income of exports and imports (MCCOMBIE, 2011; BLECKER, 2013; 2022). Considering that relative prices are decreasing because of the Kaldor-Verdoorn effect, it would also be reasonable to believe that relative technology growth rates, which reflect on the elasticities, are changing in favor of the country experiencing the Kaldor-Verdoorn effect more intensely.

In Cimoli and Porcile (2014), the authors propose a structuralist model that uses the BPCG framework with this Schumpeterian and Keynesian (Kaldorian) insight. They also get Verspagen (1992) U-shaped technology gap and a Kaldor-Verdoorn gap that will respond to the difference between domestic and external growth, meaning they set a North-South technological model with many goods differing for their technological intensity. Unlike most BPCG models,Cimoli and Porcile (2014) elasticities can change depending on productivity changes.[13]

They set a list of goods based on the technological intensity and establish that they will only be produced in the North or the South relative to the gap (meaning that if its technological intensity is high, the gap will be more relevant for the good and vice-versa) and on the relative costs of production of each good measured by relative wages. Thus, the export and import elasticities are changing given the technological change, and the technological change will depend on how the growth rate of domestic and external sectors plays out. At the same time,

[12] Although Castellacci (2002) is not really a BPCG, it is from the family of cumulative causation models that share many insights with BPCG models, but does not have the BP constraint (BLECKER, 2013).

[13] Cimoli, Porcile and Rovira (2010) showed that exchange rate appreciations influenced Latin America in not reducing the income gap and in deteriorating income elasticities of imports with a lowering income elasticity of exports. In that paper, they propose that Schumpeterian sectors (the most innovative ones) and Keynesian sectors (with higher growth rates) should be pursued (following Dosi, Pavitt and Soete (1990) proposal).

relative prices will determine another factor for external competition. So, the model will depend on parameters and how short- to medium-run variables and dynamics influence the growth rates and the technology path.[14] Ultimately, the authors believe that relatively low wages, being a proxy of real exchange depreciation, can promote structural change, accelerate growth, and eventually promote higher wages, and explain some empirical findings that show exchange rate depreciations as responsible for promoting catching up. It is worth noting, however, that distribution is only implicitly considered (CIMOLI; PORCILE, 2014).

This is important because as suggested by Blecker (2022) and by the relations shown in Kaldor (1957, 1972, 1981, 1985) that convey the interrelatedness of growth, investment and technology change, and the cumulative causation literature that emphasizes the Kaldor-Verdoorn effect; if there are level effects that increase output and investment in the short or medium run, it might be possible that this provokes technological changes that in turn might provoke sequential rounds of growth *a la* cumulative causation that would change the BP equilibrium growth rate that is set by elasticities and external income growth. Also, taking Toner's (1999, p. 123) view of Kaldor's long work, the connection between market size or growth and increasing returns is not only one marked by productivity growth due to statical returns but by learning by doing and technical change. This can be interpreted as a way of changing the economy's structures and, hence, the determinants of the BP equilibrium growth rate.

Following this line of reasoning, in Ribeiro, McCombie and Lima (2016) model, the BP equilibrium growth rate is defined by the ratio of the trade elasticities (income elasticity of demand for exports and for imports) and the growth of external income $\frac{\varepsilon(z_t)}{\pi}$, like other BPCG models. However, this relation is associated (through the elasticities) with the technological difference between the home country and the rest of the world. Like Cimoli and Porcile (2014), the technological gap affects technological progress, and in turn, it affects elasticities. However, following a structuralist reasoning, it is assumed that the income distribution, through the consumption patterns, affects the home country and the rest of the world's specialization and hence its trade elasticities. For simplicity, they assume that the ratio of the trade elasticities is increasing linearly due to the wage share and the technological gap. In contrast, the gap is affected non-linearly by the profit share (RIBEIRO; MCCOMBIE; LIMA, 2016, p. 9-10).

Although its final effects are ambiguous and depending on the parameters, Ribeiro, McCombie and Lima (2016) work is worth noting because it not only considers the functional income distribution, markup pricing, and its effects on aggregate demand which is the *locus* of the post-Keynesian discussion but also how it can affect the consumption patterns and the technological innovations. In the model, the consumption patterns were associated to the exchange rate and lead to changes in technology, meaning that reductions in the wage share

[14] It is worth noting that their technological path can have strong influences on growth rates, meaning that the exports and imports will be strongly affected by it. It also means that successful technological changes can cause strong currency appreciation that might curtail those external effects (CIMOLI; PORCILE, 2014, p. 222).

induced specialization in necessity goods, which implied in a lower innovation rate. At the same time an increase in the RER was associated with less consumption of imported consumption goods, which led to a decrease in the wage-share. Those relations would mean that differences in distribution and initial parameters were associated with different effectiveness of the exchange rate in promoting growth.

Also, in Ribeiro, McCombie and Lima (2017a), a higher wage share in the economy is related to a lower degree of openness since wages function as a domestic input, translating into a low ratio of imported inputs to direct costs. As a devaluation raises the prices of domestic products (exported or not) by increasing the price of intermediate inputs, a high initial wage share (with wages being a domestic input) implies small transfers from currency depreciation to intermediate inputs and then to domestic production. Therefore, it results in small losses in domestic competitiveness via imports. In other words, it would cause a negligible effect on prices and consequently a tiny decrease in the wage share, but with a possible increase in exports as a counterpart. The contrary is also demonstrated, where a low wage share and a high degree of intermediate imported goods diminish the effectiveness of a currency devaluation by increasing the price effects and decreasing the demand effects through the reduction of the wage share. This point underscores the importance of sectoral structures in computing the macroeconomic effects of depreciations, and the capacity to substitute these inputs would be an essential factor in defining the final effect of changes in relative prices, such as those caused by exchange rate changes.

From another perspective, Ribeiro, McCombie and Lima (2017b) conclusion is that a currency devaluation is ambiguous and depends on the growth regimes, an echo of the post-Keynesian debate, where a wage-led economy might thwart the ability of a devaluation to spur growth. In contrast, in a profit-led economy, this ability gets enhanced. At the same time, they show that financial flows and current accounts deficit sustainability improve for wage-led economies and have mixed effects for profit-led ones. While the price competitiveness affected by the intermediate imported goods – that was emphasized in Ribeiro, McCombie and Lima (2016, 2017b) – becomes increasingly relevant, the main point of Ribeiro, McCombie and Lima (2017b) is that a currency devaluation might not have the intended consequences, especially when considering price and distribution.

Although, like most models shown that depend on the initial assumptions and parameters, Ribeiro, McCombie and Lima (2016, 2017a, 2017b) is the case for RER increases to not work as a growth mechanism even when including cumulative causation, technological change, and elasticity endogenization. This is important because they show ways that functional distributional change forces could act in the opposite direction of net exports while highlighting unwanted effects on technology and price. Although other models also do not have entirely conclusive arguments, this is a *tour de force* against RER increases' effectiveness in promoting growth.

Following the structuralist tradition, Spinola (2020) shows another BPCG North-South model that follows Goodwin (1982) cyclical dynamics and Dutt (2002) uneven development view. He takes into account the functional distribution and the technology gap. However, he integrates the labor moving to the modernized sector, conforming to Lewis (1954) and the technology and product dichotomy between North and South economies shown in Prebisch (1959) that might lead to a deterioration of elasticities due to Engel's Law. Spinola (2020) argues that the BPCG model was constructed in contradiction with the structuralist tradition as the latter focuses on price and income adjustments while the former was built by denying price adjustments to focus only on income. By doing that, Spinola (2020) can show that even if relative prices vary in the short and medium term or are constant in the long run, the dynamics of the model might affect the growth rate.

In Spinola (2020), the possibility of catching up becomes strongly dependent on the technology path of the South, which in turn becomes dependent on the proper parameters relating to the learning efforts, absorptive capacity, and the opportunity of the South economy to move from the traditional sector to the modern sector. Additionally, he shows that by connecting the productivity structure to the terms of trade and by allowing the terms of trade to affect growth and the productive structure, with differential cut-outs related to the labor market and functional income distribution, it makes the traditional BPCG model more likely to be affected by relative price variation. It is worth noting that they consider a characteristic South labor structure and do not connect real wages to productivity.[15] Table 1.1 shows a summary of the principal RER effects. Investment was ommited for clairty as the possibility of affecting the profit share usually translates in a higher investment propensity in most models, varying the sensibility and the justification for it.

As Blecker (2022) puts it in a review of the literature: in a BPCG context, there are some disagreements about the possibility of real exchange rate devaluations to affect the growth rates positively, especially when considering income distribution effects, like Ribeiro, McCombie and Lima (2016), and this latter position is at least outnumbered. Also, there are many arguments, especially from a developing country perspective, to consider relative price changes and elasticity variability effects as they most likely can influence growth rates in a medium-run environment when considering technology change and, at a minimum, can have level effects. Additionally, the discussion is set further away from the initial Keynesian and Kaleckian position against the neoclassical school, where real wage reductions are unfavorable to growth, so Ribeiro, McCombie and Lima (2016) position would be closer to this post-Keynesian spirit. However, Ribeiro, McCombie and Lima (2020) provide empirical evidence for developing countries to justify their claims, which suggests, not conclusively, that depreciations only affect growth

[15]However, as was mentioned above, Storm and Naastepad (2012) believes, at least for a high-income country, that productivity might be related to real wages.

Table 1.1: Summary of principal RER effects

| Author | Distribution | Sectorial Differences | Verdoorn Effect | External Spillover | Endogenous Trade Elasticities |
|---|---|---|---|---|---|
| Blecker (1989) | Flexible mark-up depending on relative costs | | | | |
| Hein and Vogel (2008) | Imported costs, markup based on price competition | | | | |
| Araujo and Lima (2007) | Constant prices | Sectorial growth rates affect investment | | | Income elasticities change implicitly with sector composition |
| Araujo (2013) | Constant markups, relative wages change | Innovation rates affect growth | *Yes*, varies by sector | Exports enhance productivity | Elasticities change with income and sector composition |
| Castellacci (2002) | Constant distribution | | *Yes* | Spillover from frontier knowledge | |
| Cimoli and Porcile (2014) | Technology changes affect distribution | *Yes* | *Yes* | Spillover from frontier knowledge | Goods produced define elasticity, dependent on technology |
| Ribeiro, McCombie and Lima (2016) | Flexible markup and wage share dependent on RER through consumption goods | | *Yes* and distribution influences innovation | Spillover from frontier knowledge | Technology gap affect import elasticities, wage share affects innovation |
| Ribeiro, McCombie and Lima (2017a) | Imported input prices affect distribution | | In the long run | | |
| Spinola (2020) | Productivity positively correlated with wage share; wage share positively correlated with labor supply | | | Spillover from frontier knowledge | |

Source: own elaboration

indirectly and have a negative sign.[16]

This section sought to introduce how increases in RER, which function as cost reductions in profit and wage-led open economies short-term models, would work through functional income distribution and net exports to promote growth (or not). This is done by exploring the long-term BPCG models through the loosening of initial assumptions by incorporating factors such as innovation dynamics and structural change; it was shown that these elements influence the outcome of each model and permit the long-term BP growth rate to change due to RER increases. The section focused primarily on distributional effects, the cumulative causation mechanism that would work through increasing returns due to relative price changes and the Kaldor-Verdorn effect, and on technology gap models that allow for North-to-South knowledge or innovation

[16]By including distribution effects related to technological changes in an empirical analysis, Ribeiro, McCombie and Lima (2020) show that previous results linking structural change and growth to the exchange rate become insignificant, indicating that at least the interaction between distribution and innovation should be considered.

spillovers. Additionally, it became clear that initial values related to trade openness and profit or wage shares, parameters defining trade elasticity, and relative innovation rates would define the result.

## 1.2 A neo-Schumpeterian overview

This section reviews the neo-Schumpetrian approach, which can be considered one of the literature that composes the post-Keynesian tradition (LAVOIE, 2014c), even though it used Say's law in some of its initial models (c.f. Nelson and Winter (1982). As innovation and technology gap were brought to the center of discussion and clearly had the potential of affecting the results of an RER increase, this section discusses the approach's main tenants and what constitutes the basis of its analytical models, connecting the proposed technological and innovation segments and the technology gap proposition, which was already introduced in the last section, that influenced the BPCG open models. It also discusses how agent-based (AB) models are used to discuss the economy while emphasizing innovation and technical change, which might be relevant for encapsulating the idea proposed in this thesis. Finally, it introduces the AB model that serve as the basis of the analysis, along with the justification for using it.

The neo-Schumpeterian or evolutionary approach, through empiric evidence from case studies and analyses, focuses on innovation dynamics and can be considered to incorporate lessons on how innovation works, not only those related to the firm and industry level but also the interrelation between it and an amplified institutional framework Freeman (1994). Also, it argues that innovative performance is one of the most important determining factors in the economic performance of nations (NELSON, 1992). Neo-Schumpeterian notions rose criticizing the neoclassical school mainly on supply-side issues regarding production functions, production possibility frontiers and homogeneity among firms. Also, it advocates for the need to incorporate path-dependence and considers uncertainty and bounded rationality to be present in the system, which serves as the basis of many of its critics (WINTER, 1988; 2006; DOSI; NELSON, 1994; NELSON; WINTER, 1974; 2002; SIMON, 1986).

As neo-Schumpeterian rejected neoclassical microeconomic theories, Nelson and Winter (1982) evolutionary approach proposed that relatively invariant and behavioral routines characterized firms, where each routine defined their specific organizational processes and competencies that could change due to active search and learning. Routines constituted selection units of this evolutionary approach (DOSI; NELSON, 1994). Since firms were considered to exhibit bounded rationality and heuristic "satisficing" behavior (SIMON, 1986), there were no optimal solutions for productive decisions, mainly because questions about the validity of the productive possibility frontiers due to tacit knowledge and uncertainty related to innovation arose (WINTER, 2006). Dosi and Egidi (1991), for example, considered that firms faced substantial and procedural uncertainty and focused on the framing process (KAHNEMAN; TVERSKY, 1979), characterized by bias and shortcuts (heuristics) for establishing new routines. While innovation implied uncertainty, heuristics and routines implied that new solutions and technologies could also possess a degree of generalization or regularity.

Thus, to the extent that learning implies a decrease of uncertainty Dosi and Egidi (1991) and that technologies and routines exhibit certain regularities like dominant designs, common scientific body of knowledge, and shared understanding about processes and evaluation methods, it is also considered that firms have path-dependence and that technology and innovations are loosely constrained in technological paradigms and trajectories that at the very minimum indicates a direction of technological change Dosi and Nelson (2010, p. 66-67) without preventing the generation of new varieties of innovations outside those trajectories and paradigms (DOSI; MALERBA; ORSENIGO, 1994). Also, as innovations are connected to learning and work through the framing process, it implies that new knowledge is influenced by its proximity to the previous knowledge known to firms, affirming the cumulative and path-dependent nature of learning and hence innovation (DOSI; LABINI, 2007).

In neo-Schumpeterian trade theory, Dosi, Pavitt and Soete (1990) emphasize that the international landscape of nations is characterized by first-movers that have absolute advantages over others (more than comparative advantage). These confers them an advantage that, by the nature of technology that includes path-dependence, makes it hard to overcome. Because of this landscape and the difficulty of surpassing the leading countries and firms, Dosi, Pavitt and Soete (1990) considers that technology differences, not price differences, are the main contributors to explaining international trade and specialization patterns.

In Verspagen (1991) North-South model, he explores the possibility of the South capitalizing on knowledge produced in the North. The technology gap entails spillovers related to the size of the gap and the South's learning capability, the latter taken as a parameter. However, the gap itself also expresses the South's learning capability: if the gap is too low, it implies that the South has high learning capabilities, but there are not so many learning opportunities, whereas if it is too high, there are many opportunities but low learning capabilities; that means that the gap size can influence the ability of the country to take advantage of foreign technologies and techniques (on a U-shaped non-linear way). This technology gap idea is applied in some models showed in the previous section (e.g., Cimoli and Porcile (2014) and Ribeiro, McCombie and Lima (2016).

By incorporating Dixon and Thirlwall (1975) export-led model, Verspagen (1992) introduced both the knowledge spillover imitation and the Verdoorn effect. Additionally, it follows Fagerberg (1988) implicit suggestion that in the Thirlwall (1979) model, if non-price factors define elasticities, the trade income elasticities should reflect the innovation and adaptative capacity of each country. Thus, in Verspagen (1992), the income trade elasticity reflects a neo-Schumpeterian selection mechanism, through the replicator equation, that will select based upon each country's competitiveness grounded on technology.

This combination of evolutionary and post-Keynesian ideas also gives rise to the understanding that "intermediate" relationships between agents (actors) and larger structures can be relevant. This is based on the idea that the economic system behaves like a complex system, which allows for the contemplation of more interactions than those considered by traditional economics and avoids using optimal and equilibrium solutions.[17] This idea opens space to explore how initial conditions, economic structures, and the model mechanics interplay might influence the results (ARTHUR, 2015). Since the economy is a complex system, the models that seek to reproduce this type of system usually have emergent properties that are often not predictable through analysis, even though they are relevant to the results (CARMICHAEL; HADŽIKADIIĆ, 2019). At the same time, adaptive rules and stochastic factors increase heterogeneity as agents accumulate distinctions, even for systems with initial homogeneity of endowments and conditions (CAIANI *et al.*, 2016).

In contrast, most of the models in the last section were not evaluated using simulations, and usually, only their mathematical properties were assessed, which hindered any analysis of emergent properties if they had micro-foundations. In those cases, math proofs can show the equation limits or the full range of possibilities that an imagined scenario can play out. Those can yield important analytical results. However, this is applicable only in specific cases. Neoclassical models, for example, only allow for this because of the use of the representative agent and the equivocated use of the reductionist method. It permits the simple sum of representative agents' actions to be taken as a whole. Nevertheless, this method is only valid if it is assumed that there is no interaction among agents or that the interaction within the system is linear. Both conditions are overlooked in the neoclassical analysis of the economics system (DELLI GATTI *et al.*, 2008).

Sometimes, it might be necessary to make numerical simulations to test different parameters against specific trajectories on post-Keynesian models. Those tests are performed since path dependence, and the non-linear associated equations make it impractical or impossible to analyze comparative statistics, while analytical solutions might hide relevant information. Also, numerical solutions may be a good tool in analyzing the system evolution, which is *praxis* in agent-based models, since besides analytical mathematical proofs being impractical due to the increase in complexity, non-linearities and stochastic components also increase the analysis' difficulty (DELLI GATTI *et al.*, 2008; DELLI GATTI; GAFFEO; GALLEGATI, 2010).

The representative agent is not used or assumed in post-Keynesian models that do not use AB and stock-flow consistent methods. Thus, no agent with a predeterminate set of solutions and interacting behavior results in the macroeconomic equations. Thus, its equations reflect the theoretical framework that considers rational agent interactions. However, the downside of not providing micro-foundations to its equation is to lose emerging properties, even if one considers

[17]Relations between structures and agents are relevant even when the economy is not considered a complex system (FINE, 2011).

the "smaller" of structures or agents that might come out if one considers the economy as a system that shows complex, non-ergodic and non-linear behavior (DELLI GATTI *et al.*, 2008).

In Ribeiro, McCombie and Lima (2017a), for example, which is an analytical post-Keynesian model, a permanent increase in the nominal exchange rate growth rate is first set as a shock. It allows domestic prices to catch up after a certain period due to labor bargaining for their initial real wage, but the equation that allows for this conclusion is not based on a set of heuristics or a maximizing behavior solution. Still, it reflects a broader theory of how the economy and its agents behave.[18][19]

AB models establish heuristics at the firm-level based on empirical evidence or stylized facts. For example, in "K+S" models of of Dosi, Fagiolo and Roventini (2006, 2008, 2010), they promote the integration of Keynesian and neo-Schumpeterian theories while trying to reproduce microeconomic and macroeconomic "stylized facts" established on Dosi, Freeman and Fabiani (1994). Simulations are, then, used to understand unpredictable issues by using firm-level regularities and rules without incurring fallacies of composition. Firms perform R&D, which is defined by a stochastic process that can result in innovations and imitations from other firms' technology, with the latter probabilities dependent on the technological distance of those technologies.

In the open economy version of the K+S, Dosi, Roventini and Russo (2019) adds several countries and industries, incorporating both innovation and cost competitiveness to confer advantages that allow access to more demand through external markets. Trade is conducted similarly to domestic market exchanges, but besides the exchange rate conversion, there is a "distance" parameter that increases both the difficulty in imitating and replicating trade costs for each country and industry, which permits countries and industries to differentiate themselves. Thus, each firm's market share is defined by a competitive equation (replicator), which considers the competitiveness established by technology and the costs of each firm in each market[20]. Firms might not participate in every market because there is a minimum necessary to operate in each market, as defined by the replicator. Accordingly, the model simulations aim to see if the series of their listed stylized facts about foreign trade and differentiation between countries emerges.

It is worth noting that this approach does not assume that there is a Verdoorn effect, a straightforward North-South spillover effect, or a scale effect. However, those might emerge due to cumulative learning reinforcing effects, the possibility of learning from more technologically advanced foreign firms, and due to investment and technology feedback if they cumulatively

[18]Although there are heuristics relating to the agents' behavior, their approach is compatible with AB models as it is possible to conceive that random exogenous shock affects price variables in AB models.

[19]An alternative approach to mimic exchange rate dynamics is done by Kohler and Stockhammer (2022). They linearize their model and run a simple numerical simulation where they set a shock to the risk appetite. This triggers pro-cyclical exchange rate dynamics, which can be used to test if the exchange rate can lead to an endogenous cycle variation. In turn, they use their model to conduct empirical tests.

[20]Each country has the same number of industries so that each market would be an industry in a country.

apply. In Dosi, Roventini and Russo (2019), there is no decrease in the learning penalty of foreign technology if they already imitated or increased participation in the specific foreign market's industry.

Caiani, Catullo and Gallegati (2018) provides another way of modeling the open economy, where they establish a non-tradable and tradable sector on a currency monetary union — firms in the tradable sector trade in an international market while the non-tradable firms trade only domestically. The former firms might experience international spillover. Additionally, the tradable sector is subject to price competitiveness from international markets. For those reasons, the tradable sector feels stronger price and technology pressures than the non-tradable one. It is worth noting that Caiani, Catullo and Gallegati (2018) also adds financial dynamics.

The MMM family of AB micro-macro models includes a greater diversity of elements from the post-Keynesian literature, including notions related to BP restrictions, innovative dynamics, and income classes. Another important factor is the investment decision, which is defined as an extrapolation of sales from the previous period and depends on the capacity used and the desired capacity and is constrained by the availability of funds (POSSAS et al., 2001; POSSAS; DWECK, 2004, 2011; BUSATO; POSSAS, 2016; VIANNA, 2021). Note that Busato and Possas (2016), which was mentioned in the last section, is a sectorial model part of this family of models but does not possess any straightforward, innovative mechanisms. Instead, the author uses autonomous investment as a proxy of innovative dynamics.

Possas and Dweck (2011) already showed how the MMM could introduce important micro-macro features relating to innovation and growth. First, one important difference between Possas and Dweck (2011) and other AB family of models is the presence of two technology parameters: labor productivity and quality. While the former is usually connected with price, if not represented proxied by price itself in other models, the latter showcases other attributes dissociated with the technical production. That means quality encompasses characteristics consumers use to define their consumption patterns and propensity to spend. Possas and Dweck (2011) presented an open economy model that posited that subsequent versions of the model should include the effects of process innovations – that affected productivity – in the trade balance. Also, although there is an important feature, if productivity growth is higher than GDP growth, there could be technological unemployment. Moreover, increases in the rate of productivity growth can increase market concentration and investment volatility, which can change the GDP cycle periodicity. Those interactions are only possible due to the model's micro-macro layout.

The latter model of the MMM family is Vianna (2021). The MMM on its latest version has several advantages that allow for a complete analysis of the effect of exchange rate variations on growth from both the post-Keynesian and neo-Schumpeterian perspective: (i) a more complex BOP dynamic; (ii) a multisectoral structure; (iii) the possibility of changes in distribution from the external market; (iv) investment decisions may be dependent on innovations as productivity changes influence capital investment; (v) consumption also depends on quality innovations; (vi) although they are not determinants of investment, profits play an indirect role in investment by enabling investment projects to be carried out, i.e., the lack of profits serves as a restriction on investment by firms, and also interacts with the availability of credit in the economy; (vii) there is the possibility that changes in the real exchange rate will lead to the capture of external demand (viii) as there is a financial sector, debt and leverage dynamics also influence the system (VIANNA, 2021).

The last paragraph shows that Vianna (2021) encompasses most of the structure used in BPCG models that might be used to understand RER variations. However, there are no BP constraint adjustment mechanisms, which slightly departs from the Kaldorian perspective in Thirlwall's (2011). Still, price and income may adjust to successive BP deficits due to the set of "institutional" rules and agent's heuristics. Two ways of adjustment are worth noticing: (i )a floating exchange rate is influenced by the trade balance, depreciating when there is a trade deficit; (ii) a high degree of imports decreases the disposable income and, thus, GDP, which can lead inclusively to financial crisis. Regarding the distribution, the MMM does not use a markup equation that directly reflects changes in external competitiveness, like Blecker (1989) and subsequent works. However, firms' reference price in its Kaleckian price equation consideration of external prices changes due to changes in the export share (VIANNA, 2021).

Additionally, the MMM, being a multi-sector AB model with both product and quality at its disposal, allows structural change due to technological shifts to play out. This possibility is important in BPCG models, as it allows growth due to differential shocks caused by changes in the exchange rate. Unlike Busato and Possas (2016), there is no change in trade elasticities due to relative quality or productivity changes. Like Dosi, Roventini and Russo (2019), though there is no explicit Kaldor-Verdoorn or scale effect, cumulative learning and investment might be reinforced due to demand increases. The cumulative causation mechanism could work in such a model if these effects occur. The possibility of changes due to quality changes permits the model to have structural changes that can connect with demand and do not associate directly with prices. In this sense, a two-pronged technology approach focusing on productivity and quality might entail more interplays and inclusive led to additional increases in demand (in comparison to the cumulative causation mechanism) when RER increases lead to virtuous technological paths. This would happen because quality increases would lead to upsurges in consumption, which would increase innovation funds, allowing for more resources to be spent on innovation.

This section gives an overview of the neo-Schumpeterian and AB models. It shows that the MMM is capable of dealing with all the transmission channels for the exchange rates that were shown in the previous section while – as an AB model – adding cumulative dynamics that characterize complex adaptative systems like the economy. Also, it presents more possibilities of RER increases affecting the model, for better or for worse, due to financial and investment dynamics, multisectoral structures and emerging properties that might characterize the interrelations among agents and between them and larger structures. Additionally, it has more innovation channels than is usually available in BPCG and cumulative causation models.

## 1.3 Technology and innovation as a source of increasing returns due to trade?

In Section 1.1, notably following Kaldorian ideas, in BPCG and cumulative causation models, technical change was implicitly related to the economic expansion through increasing returns of scale, external and internal, especially in industry. This rationale provided the support for (i) the cumulative causation mechanism that posits that an increase in the market size would lead to changes in productivity that, in turn, would lead to gains in exports due to relative price changes; (ii) changes in supply that would facilitate capacity to follow demand in BPCG models. However, (iii) changes in relative trade elasticities due to production increases were only considered in structuralists and/or neo-Schumpeterian models and usually focused on the North-South dichotomy.

Because the success of RER increases in stimulating demand and in changing growth rates would primarily depend on increases in exports and then on sectorial and technological change that would set virtuous dynamics capable of changing elasticities, it is conceivable that innovations related to size and external markets would reinforce the Verdoorn effect (if it exists). First, it is important to know if the increase in demand (meaning size increases) can lead to more technological changes than just productivity changes accounted in the Verdoorn effect, like the quality component of the MMM's innovation search, incentivizing consumption. Second, as there is more exposure to exports due to RER increases, learning by exports could be a strategic way of reaching the external frontier or external innovations in general. For this reason, this section outlines the innovation and system of innovation literature for hints of how those two dynamics might play out, giving special attention to exports. Additionally, it reviews the learning by trade empirical literature, both from exports and from imports, to better understand if empirical works consider that exposure to external markets might influence firms' innovation rates. This is done with the motivation of a better understanding of how innovation works in order to introduce changes on the MMM for running simulations.

As mentioned in the previous section, the neo-Schumpeterian literature postulates that trade cannot be established only due to price competitiveness (DOSI; PAVITT; SOETE, 1990), and Amable and Verspagen (1995) have shown that non-price factors competitiveness is significant for explaining exports growth rates, especially for long periods. If this is true, it implies that any cumulative causation mechanism would require another subjacent technological change mechanism that would entail changes in non-price factors. The technology-gap literature that subsidizes the North-South model is based on Verspagen (1991), which allows for knowledge spillovers at the country level from the North knowledge base to the South. In Verspagen (1992) and some of the models presented in the previous section, it is allowed for both the knowledge spillover and the Verdoorn effect. Since learning in the neo-Schumpeterian view happens mainly inside the firm and defines innovation, it is important to understand how this increasing returns due to knowledge might play at a micro and innovation level.[21]

Kaldor emphasized internal economies instead of Allyn Young's external-only economies. The former focused on plant and firm-based economies of scale was relevant to his economic reasoning and critic of, for example, equilibrium economics (KALDOR, 1985; HART, 2012; TONER, 1999).[22] This emphasis is also important because following Penrose (2009) and Chandler (1990), which stressed resource and department-based possibility of innovation as a type of dynamic capability that can be connected to the idea of increasing returns (TEECE, 1993; LAZONICK, 2010), the neo-Schumpeterian literature uses the firm as basis for innovation dynamics and for providing the selection mechanism that might define the microeconomic setting. As such, it is natural to draw comparison points of the feasibility of technical change and innovation as a source of increasing returns to scale.

The latter literature has the firm as the *locus* of innovation and highlights firms' technological capabilities, which defines its ability to innovate (DOSI; NELSON, 2018). It also concedes a distinctive role to interaction and diffusion, which cannot be dissociated from the idea of innovation (SCHUMPETER, 1939, p. 90; METCALFE, 1981). Additionally, it gives rise to the system of innovation literature that argues for the importance of a system approach to innovation that includes a wide range of organizations, institutions, and social and technological aspects to consider in the performance of a country (LUNDVALL, 2010), which cannot be factored into firms by itself and could be argued as introducing an external economy component in its perspective. In the end, the idea of interaction and diffusion systemically influencing innovation makes firms' innovation results and technology trajectories constrained or defined more by country and sector-wide institutional factors plus firms' specific strategies than the price factors.

The relationship between the Kaldorian idea of "dynamics economies of scale" can be easily associated with the neo-Schumpeterian notions of learning and innovation, as Kaldor (1985, p. 63-70) already associated learning and experience to the dynamics economies of scale concept, although he considered a phenomenon mainly related to the manufacturing sector. Additionally, Toner (1999, p. 123), for example, argues that Rosenberg (1982) neo-Schumpeterian notion of learning by using can be considered as another source of increasing returns in what Kaldor called

[21] It is noticeable that a North-South approach that highlights structures of production and consumption, and thus elasticities, as in Prebisch (1959), is present in the latin-american structuralist approach. At least part of the two literatures harbor similarities regarding the importance of innovation, technology change, international insertion, and government policies (CASSIOLATO; LASTRES, 2008).

[22] In Kaldor (1972, 1985), along with the external economies that were pointed already in the economic literature since Adam Smith and especially by Young (1928), which focused on the possibility of division of labor and roundabout methods, the source of increasing returns was considered to be related to engineering principles in industrial plants and modern firm scale economies.

the "dynamic scale economies". Rosenberg (1982) highlighted the interaction between the capital goods-producing sector and its consumers (machinery and tools sector) as a source of innovation and diffusion. Rosenberg (2006), for example, already argued before his chain-linked-model (KLINE; ROSENBERG, 1986) that productive technology requirements and firm investment significantly shaped science.

However, the possibility of productivity growth that is related only to scale, in the sense that productivity changes do not entail any significant production and technology changes, must not be ruled out even though it is plausible to think that productivity changes would walk hand in hand with changes in production and technology. This possibility of scale-only gains might even be shown in empirical studies.[23]

Von Hippel (1976) assigned an important role for the interaction between users and producers in commercially successful user-led innovation in a few industries.[24] Besides the usual (manufacturer) paradigm in which manufacturing firms analyzed the consumption patterns of the consumption sectors to guide their innovations, it was ascertained that consumers in some industrial sectors might play an active role in screening, promoting, and developing innovation. In contrast, the manufacturer had an outsized role in diffusing the innovation to other firms (VON HIPPEL, 1976; 1978). This suggested that technological change was somehow, and to some degree, endogenous to the productive process and in the spirit of the Kaldorian innovation interpretation of increasing returns.

However, initial innovation models considered a linear notion of the science and innovation circuit related to the science or technology push, where inventions would be crucial in providing for the technology that would shape the production process' innovations and new products offered by firms (ROTHWELL, 1994). That would imply an exogenous scientific and technological process that would lead to innovations after a diffusion and adaptation period in the economy. Although considering that previous technological advances and inventions (defined as a process or product innovation with a high degree of novelty) played an enabling role, Schmookler (1966), for example, showed that those inventions were related to the size of the market and investment and argued that there was an invention incentive related to a market demand impulse which also conveyed consumers tastes and preference. Mowery and Rosenberg (1979) argued decisively against the demand-pull argument as an explanation of the direction and rate of innovations, especially against the taste and preferences notion, which was common among surveys at the time.

[23]In Van Biesebroeck (2005), for firms in a few African countries, there is support for the possibility of learning by exporting. However, the author suggests that scale economies explored by exporters might partly explain the difference in productivity between domestic firms and exporters. Also, Crespi and Zuniga (2012) results indicate that, for a few Latin American countries, the size of firms is related to an increased chance of introducing innovations, which the authors relate to economies of scale and scope associated with the production of knowledge itself.

[24]In the neo-Schumpeterian innovation surveys analysis, user-producer interaction was already identified as an important factor for innovation, like with Project Sappho conclusions (ROTHWELL *et al.*, 1974).

Albeit not directly arguing against the market size proposition, Mowery and Rosenberg (1979) critic of works that showed a demand-led argument was heavily influenced by picking up innovations in the diffusion period. They showed that the technology push argument could not be ruled out since most inventions that were followed could be traced to initial breakthroughs in science. As Freeman (1994, p. 480) puts it, Schmookler's demand-pull view was highly challenged, mainly due to his methodology,[25] but however the controversies between the technology-push and demand-pull dispute, Schmookler (1966) did provide a relation between production and investment and the technological artifacts (patents and scientific publications related to inventions which were used as a synonym of innovation).

Still, at the same time, the argument could be used to show that innovations were not ruled by demand and that crisis periods were not related to innovations. As Freeman (1994) points out in analyzing the crisis thesis for innovations, the idea that crises were coupled with innovations was related to a temporal issue in the understanding of how innovation worked. In reality, major technological and scientific breakthroughs could actually be traced to bonanza periods and had different sources that could be traced to demand or to scientific and technology breakthroughs that were developed when the economy was performing well. However, it took a longer period to spread and diffuse in the economy. This diffusion had its own associated innovations that were registered during the crisis. At the same time, growth would be a worse explanation for innovation than the actual innovation efforts and resources that have been laid out.[26] So, the relationship between growth and innovations as a positive and regular relationship is not easy to define, even though there are, arguably, many virtuous channels, including investment, R&D, and learning related to increased productivity activity.

Anyhow, after the intensive work done by Rosenberg (1982) and the introduction by Kline and Rosenberg (1986) of the chain-linked-model, the linear innovation model was replaced to consider a systemic approach to innovation that would take into consideration interactions, feedback, and diffusion. Also, although it includes aspects of the technology-push and the demand-pull approaches, it is not considered to follow the direct relationship implied by Schmookler (1966)

[25] Mowery and Rosenberg (1979) critic of Schmookler (1966) pointed out that the diffusion process could account for most of the inventions that were picked up by Schmookler, meaning that he owned his results primarily to an initial more radical invention that was spreading to the economy and incentivizing innovations of its own.

[26] The explanation was related to Schumpeter's (1939) understanding of Kondratieff cycles as a result of technological developments. Although Schumpeter (1939, p. 81) considered that countless innovations arise as the resolution of particular challenges, there are contradictions about considering need as a major driver for innovation and, therefore, crises. Diffusion periods usually show significant improvements in innovations, which might be related to economic performance. Also, the demand for technological solutions might not be related to the economic cycle. However, the resources and demand devoted to it might be increased due to a higher economic performance. Thus, Freeman (1982) considered that there was an error in Mensch and Schnopp (1980) analysis that related innovations to crisis, both from the point of view of understanding what drove innovation (he considers government and military demand to be fundamental in the innovations tracked) and the maturation of scientific knowledge, which was developed in periods of boom, and its relationship with technical innovations and diffusion. So, their data pointed to the diffusion period and not to the radical innovations made in previous periods when the economy was performing better. Additionally, the resources employed in innovation would actually be more relatable to innovation performance than growth itself.

(FREEMAN, 1994; METCALFE, 1995). This implies that growth by itself, while it might play a role, especially in diffusion, cannot be linearly related to the innovation processes since there are non-linearities and many other institutional factors that might be relevant and are challenging to quantify. At the same time, their systemic arrangement might be more relevant than growth itself (NELSON, 1993). As a result, even some countries that at first impression might appear similar but, in fact, are different and dependent on their path and socioeconomic structures (EDQUIST; LUNDVALL, 1993).

The system of innovation approach exemplifies part of this ambiguity. Freeman (1987) emphasized the role of cooperation among government departments, conglomerates, and universities in Japan's extraordinary technological performance in high-tech sectors. In addition to Lundvall (1985, 1988), which focused on the implications of interactions and the possibility of user innovations, it gave rise to the national system of innovation literature that pointed out that innovation was, in fact, systemic and not only dependent on traditional macroeconomic conditions but also dependent on institutions and government influences, cooperation among actors and contingent on the cultural and social context, which are not traditionally in the economic helm.

Nelson (1992, 1993), for example, showed that countries' positive performance could be, in general, attributed to the innovation systems, which, for the case studies exhibited in their collection, exhibited coordinated efforts among different actors and a prevalence of high-tech R&D sectors. So, as was the case with the countries' performance studies, Von Hippel (1978) pointed out that the source of innovations varied greatly between sectors and actors. Lundvall (1988) emphasized the possibility of learning through interaction between actors and that innovation levels should be related to the organization and easiness of knowledge flows, making the cultural and geographical environment and the degrees of cooperation especially relevant.

Lundvall (1988, p, 70-71) considers that the user-producer argument might be more relevant in accentuating the role of the quality of demand than the role of the size of demand, as there were relevant innovations developed through little demand expenditures, precluding establishing any strong regularities from demand to innovations. Also, when arguing for the use of a national system of innovation perspective, by considering that technology is embodied in labor and inputs and by arguing that interaction, a prerequisite for learning and innovation, is shaped by social, cultural, and idiosyncrasies defined at the national level, Lundvall (1988) considers that technology and learning can be restricted in an international setting, especially when considering that geographical distances might restrict the flow of information and apart the production, and the learning that arise from that, from other parts of the firm and the system. Also, agglomeration effects are connected to knowledge flows and presumably are local (PORTER, 1990) and have been known to exist at least since Marshall (1920). Kaldor (1970) himself acknowledges the potential agglomeration effects on industrial production unrelated to large-scale plants. The agglomeration reasoning can intuitively be used as an argument to offset learning and innovation gains due to firms accessing users in external markets.

This last paragraph's reasoning is critical because it suggests that the possibility of "learning by exporting," which would enhance the cumulative causation mechanism, is limited or at least constrained. So, suppose currency devaluation or depreciations were to start this mechanism through exports, and this has the potential to start a technical change process that would change trade elasticities, as was suggested in the North-South models presented in the last section. In that case, the mechanism might be hindered if exports do not have an apparent innovation or technical change potential. First, the systemic approach argues against the straightforward relationship between growth and demand and innovations and technical change and, specifically, that the rate of innovation and quality of innovation might be related to those themes.

This could be an argument against an automatic increasing "knowledge" return due to scale. However, there are learning channels connected to production and interaction, which presumably would increase firm activities and market size related to an increased innovation chance. First, there are indications that, at least for radical innovations that would entail broad technical change, a set of other variables not linearly related to market size or growth is required. Second, since locally defined factors are relevant to the performance of firms, a strategy that aims at exports as a way of developing innovations and technical change can be hindered since it would be more difficult for firms to take advantage of supply and user-producer configurations due to this "institutional" differences when accessing export markets. Thus, if the localness of knowledge makes codifiable knowledge sectors likelier than tacit knowledge sectors to be exploitable as a learning channel through trade, and codifiable knowledge is not related to size, a growth of exports might not result in an increasing return due to technical change and innovation. So, it is important to investigate the empirical evidence relating to the trade learning channels: learning by exporting, which is usually associated with endogenous growth models, and learning by importing.

On the other hand, the technology regime and system of innovation literature help us understand that innovation occurs because of firm learning capabilities, builds on a firm/country's previous technology path, and requires efforts from multiple actors of the innovation system. This means that if a domestic firm is to learn from foreign markets and firms, (a) this is more likely to happen if the technologies are themselves similar, in multiple dimensions (cultural, technical, preferences) to the previous ones used by firms and as more advanced it gets it might require increasing efforts by firms in learning them; (b) that if learning is taking place, more firms and actors of the system likely have some knowledge of the technology and the probability of learning from a foreign technology must increase as there are more actors with the required of parts of the required knowledge to learn.

In endogenous growth models, such as the one developed in Grossman and Helpman

(1991), the central assumptions about technology and innovation are that these are governed by inventions and R&D. Those can be considered as nonrival goods that might avoid redundancy in the system if there is trade. However, patents and contracts hinder that property. Trade can diffuse knowledge through the economic chain through the buying of patents or through the trade of goods and services that embody the technology and R&D that was previously invested or achieved by firms in other countries, which in turn gives access to the knowledge through buying the patent itself or to increased contacts with foreign technical personnel, goods that might be imitated or foreign consumers that might provide technical improvements. Their diffusion entails technological efficiencies because the effort taken by a country, industry, or firm to make an invention does not need to be reproduced by others if it can be diffused. Then, productivity gains, similar to neoclassical comparative advantages specializations, can prevail due to trade (GROSSMAN; HELPMAN, 1991).

Although it is not compatible with the view espoused by neo-Schumpeterians and, additionally, the issues related to using R&D and patents as a proxy to innovations, which might exclude a whole class of firms and sectors participating in the innovation process and technology change (PAVITT; ROBERTS; TOWNSEND, 1984; COHEN, 2010), this diffusion of R&D and patents in neoclassical models still would provide a rationale for learning by exporting and learning by importing that could be seized in the sense that at least it provides proxies for technological activities and innovations while tracking labor productivities or Total Factor Productivity (TFP). Regardless of the controversies, in this way, many papers track productivity effects of inventions or R&D expenditures diffusion using trade-in input-output matrices since technological matrices actually track patent transactions, and R&D vectors use the input-output matrices to track sectors' direct and indirect R&D intensity (HALL; MAIRESSE; MOHNEN, 2010). Also, other empirical models try to relate innovation surveys, R&D, or productivity (however measured) with exports. It should be noted that those papers do not cover issues regarding meaningful differences among countries and technologies and usually do not control for diffusion and time to maturity issues (BELL, 2006), differences between industries, the diffusion itself as an important innovation component or a mix of those factors even when all of them might affect the results, but still provides a proxy to the technology spillovers and learning that trade might entail Keller (2010).

For overall trade, Coe and Helpman (1995) suggests that foreign R&D is more aptly to be absorbed through trade than without trade, and that has positive effects on productivity.[27] However, the case for exports-only is more complicated. Keller (2010), in a review of the literature on international trade and technology spillovers, sums up that the possibility of learning by export is tested by comparing exporting firms and domestic market firms' productivity and sometimes how foreign technology might be used through exporting and in turn affect domestic

[27]In this case, productivity is measured by TFP, which means all of the productivity that might not be assigned to the accumulation of production inputs.

technology. The perspective of learning by exporting is related to the idea that exporting firms are more productive than domestic firms. Nevertheless, this idea might be related to some selection mechanism due to more stringent foreign competition; more exposure to foreign knowledge; fixed investment and R&D (sunk) costs related to entering the external market, which in turn might justify scale economies; being already more competitive when entering the market; and to the ability to reinvest in more productivity activities when less productive firms have exited the market (GROSSMAN; HELPMAN, 1991; MELITZ, 2003). Hence, firms that export are only able to continue to be exporters if they have high productivity levels or better technological performance than the ones that exit the exporting market and might take advantage of the exit of less productive firms to snatch that freed market share and profit levels that in turn might contribute to additional productive gains.

Regarding the empirical evidence, Clerides, Lach and Tybout (1998), for example, by studying three developing countries firms, do not find any meaningful effect for learning by exporting but find the exporting firms more productive than domestic market only firms, possibly due to self-selection, meaning that more productive firms are more likely to join external markets. Bernard and Jensen (1999) in a long-period study for U.S. firms, find no learning-by-exporting evidence, but only that exporting firms might experience growth and that exporters are usually more productive already. However, De Loecker (2007) finds evidence that firms exporting to high-income countries experience productivity gains. In contrast, Utar (2011) conjectures that technological spillovers are present for exporting firms hiring technological services in foreign countries and provides evidence of a relation between spillover and these services.

Love and Mansury (2009) provide, after controlling for self-selection, that there is at least an association between exporting and innovation for business service firms in the U.S. However, they cannot conclude that the extent of exporting affects productivity. Love and Ganotakis (2013), looking into UK high-tech small and medium firms, finds a relation between exporting and innovation consistent with being present in export markets but does not find evidence of an increase in innovation intensity due to export participation. This makes them posit that the exporting market size might play a role in allowing innovation to happen but not in increasing the rate of innovation. However, Castellani (2002), for a sample of Italian manufacturing firms, finds that export intensity above a certain level is correlated to productivity growth.

For Sweden, Tavassoli (2017) finds a relation between product innovation and exports, but he does not test the opposite relation. Damijan, Kostevc and Polanec (2010), using the Community Innovation Survey (CIS) and administrative records for Slovenia, propose a way of determining the causality link between exporting and innovation (and vice-versa) by investigating whether an export status switch influences a non-innovative firm to become innovative. Their result indicates that exports affect process innovation but not product innovation (c.f. Oslo Manual). Damijan, Kostevc and Rojec (2017), also using CIS, but for many EU countries, find evidence of an export correlation to product and process innovation. Although causality cannot be established, this correlation is influenced by the R&D intensity of the country and the manufacturing sector where the innovative firms are located. Those results must be taken into account since they are confined to developed countries and medium- to large-size firms in the EU, which exhibit a special trade configuration. Additionally, process innovation might be more closely related to increasing returns to scale only.

Crespi and Zuniga (2012), which used innovation surveys from a few Latin-American countries as their data, found that exporting is correlated to innovation activities. However, the introduction of technological innovation has mixed results, which include negative correlations in a couple of countries. Siba and Gebreeyesus (2017) find evidence of an exporting learning channel correlated with productivity for a long panel dataset of Ethiopian manufacturing firms, even though self-selection is ruled out. Gupta, Patnaik and Shah (2013) find neither evidence for self-selection nor learning-by-exporting for the Indian manufacturing sector.

Regarding the possibility of learning by importing, Keller (2002) shows for a few developed countries industries that technology flows proxied by R&D in an input-output setting, and to a lesser extent to patent data, are related to productivity. His results, although should vary for other countries and industries, indicate that own industry's domestic R&D is the most relevant productivity input, while other domestic industries' R&D comes in second and that foreign R&D within the same industry and from other industries play a similar role in productivities increases. His premise and conclusion indicate that R&D embodied in intermediate goods can be a source of technology and innovation that diffuse through the economy.

Malerba, Mancusi and Montobbio (2013) provides evidence of the last paragraph point. Their results indicate that, by using R&D and citations as a proxy for knowledge flows for a few sectors and countries, knowledge flows depend on the knowledge complementarity and proximity and the type of knowledge relations each sector displays. Hence, international flows are associated with more knowledge spillovers intrasectoraly than intersectorially due to more proximity between intrasectorial knowledge than intersectorial. At the same time, sectors with a higher degree of dependence on knowledge of other sectors (intersectoral), which would imply a higher degree of tacit knowledge, would depend more on knowledge spillovers at the national level. Thus, user-producers' relationships would be easier to be established due to national boundaries easiness of communication and knowledge searching (MALERBA; MANCUSI; MONTOBBIO, 2013).

Although the evidence is inconclusive, it hints that learning by exporting would have drawbacks when relying on the user-producer learning channel since knowledge spillovers are more likely to happen when the knowledge is more codifiable, making user-producer relationships less relevant. This means that the relationship suggested by Toner (1999) about Kaldor's thought between learning by using and dynamics economies of scale are arguably less relevant in a learning by export setting, in the sense of the restrictions related to the user being established in a foreign market. For developing countries, this picture must be direr, as Katz (1987) already suggested that internal knowledge creation was much more dependent on channels other than R&D, which would make learning by exporting channels not feasible in countries that cannot rely on internal R&D, or sectors that are intensive to it, as at least a certain threshold of R&D would be required to learning-by-exporting have positive effects.

However, it is undeniable that an export-led strategy was pursued by many countries that can be considered successful development cases Amsden (1989), but sometimes learning through exports may not be a strategy explicitly pursued by policymakers. For example, Chang (1993) shows that South Korean policymakers actively pushed *chaebols* to export after giving them domestic market preference. Their export aims were related to scale objectives, which inclusively led to the active curbing of "excessive competition" and its associated "social waste" through mergers to guarantee that firms would have a minimum scale of production and to acquire foreign currency to enable imports of high technology machines and tools in order to modernize the Korean industry with their embodied technological knowledge (CHANG, 1993).

From another perspective, for developing countries participating in GVCs, Tajoli and Felice (2018) shows that the importing channel might have an important role in technology transfers and knowledge spillovers from advanced economies to less technological countries, not only in high-tech sectors but also in traditional sectors, with the potential of diffusing these technologies and knowledge through the supply chain inter and intrasectorally.

The GVC literature considers that for developing countries, firms participating in GVCs present great opportunities for learning due to investment and transactions which contain more advanced technology, standards, and knowledge flows than local economies usually exhibit (GEREFFI, 2014, p. 454).[28] Although it is a specific economic setting, it exemplifies the troubles of considering an automatic relationship between exports and technical change. For example, innovating and technology budling depend upon the chain governance and firm power relations, with leading firms having incentives to protect their technology and know-how from followers, and dependent upon the degree of information complexity and codification (GEREFFI; HUMPHREY; STURGEON, 2005).[29]

For this reason, the possibility of upgrading, which can be approximate to the idea of reaching activities with a higher degree of value-added and can be related to product and process innovation, is highly dependent on the local innovation capacities (HUMPHREY; SCHMITZ,

[28]learning is usually promoted through Foreign Direct Investment (FDI) (BALDWIN, 2012). Through investments by multinational companies that are leaders or participants in GVCs, bringing their production to developing countries would lead to the possibility of learning gains through learning mechanisms via training, pressure to adopt international best practices, and transfers of key technologies, which would allow learning through local spillovers, imitation efforts and, above all, interaction between actors in the chains (GEREFFI, 2014; MARCHI; GIULIANI; RABELLOTTI, 2018).

[29]Although for foreign firms operating in domestic markets, Storper (1995) notes that usually the technology remains in the host country. At the same time, GVC literature emphasizes the insertion of GVC as there are possible benefits of receiving foreign direct investment from leading firms that can lead to development. However, as mentioned above, there are few learning opportunities from it.

2002) and to the degree of non-replicability of information, resources and productive capacities itself, with those factors influencing the learning and innovation process and output (SANTÁRCANGELO; SCHTEINGART; PORTA, 2017). Marchi, Giuliani and Rabellotti (2018) in a review of the GVC literature, highlights that learning through lead companies (it could be considered analogous to the user company) can lead to achieving relevant innovations if local firms are exploiting knowledge from other sources outside the GVC and present in its local innovation system, including other firms. It also suggests that most GVC firms' innovation performance were dismal. Marchi, Giuliani and Rabellotti (2018) shows that besides traditional standards spillovers, participating in GVCs does not consistently entail learning and technology capacity building in general. However, the gains are concentrated on leading companies and companies focusing on providing solutions and innovating for the internal market.

Through a review of the innovation and system of innovation literature connecting it with the Kaldorian ideas relating to technological change, this section showed that the system of innovation literature does not favor a special role for innovation due to demand increases, although it entertains the possibility. Regarding international learning and innovation, it was shown that the system of innovation literature considers that tacit knowledge and institutions, including social and cultural relations, do not back that external markets might entail increases in innovation rates. In respect to firm-level empirical evidence, it was shown that although initially export markets were thought not to provide any innovation advantage for exporting firms, new papers challenged that view, but the results were dependent on sectors and countries analyzed, survey and econometric issues like a difficulty of separating entry effects, which would characterize self-selection, and scrutinize firms in longer timelines. Learning by importing was consensually considered as possible.

# Chapter 2

# The MMM model with external imitation

## 2.1 The MMM description

As described above, the MMM has several advantages that provides a basis for its use in this thesis. Here is a brief description of the MMM's most important parts concerning the debated topic. Vianna's (2021) MMM is an open-economy model that takes Dweck (2006) and Possas and Dweck (2004) AB and stock-flow consistent model and adds monetary and fiscal aspects for analysis. This is interesting as it provides a basis for analyzing the above-mentioned problem. Additionally, this family of models already provides for a BPCG framework in a sense. Since Busato and Possas (2016), the multisectoral model already incorporated the BP constraint and the possibility of financial flows. However, in the MMM version, as mentioned, this constraint is not explicitly stated and might emerge as consequence from agents heuristics and their interactions, and with rules regarding macro variables.

Additionally, Busato and Possas (2016) already incorporated the possibility of investment dynamics simulating innovation trajectories and affecting the export coefficient, even though their model did not directly include innovation, which make them treat it as a proxy of autonomous investment (BUSATO; POSSAS, 2016, p. 292). The export coefficient was endogenous to autonomous investment, external income, and relative prices. The idea of making the export coefficient sentive to relative prices (and thus to RER variations) was incorporated from the argument from Ferrari, Freitas and Barbosa-Filho (2013), for example, that price elasticities would be affected by the exchange-rate level, if it was kept for a while. So, it is clear that this model family can discuss this thesis' theme.

The MMM is set on discrete time, and the productive sector basic unit is firms, which produce using capital and workers. Vianna (2021) "financial-augmented" inclusions involve financial sectors where the basic unit is banks, which can provide loans. Also, there are three consumption classes, an external sector, the government, and a central bank. The productive sector is multi-sectorial, divided between consumption, intermediate (input), and capital sectors according to their respective characteristics: producing consumption, intermediate, or capital goods. This means that firms in different sectors produce using separate steps and even different delivery timelines (this is more relevant for the capital goods sector).

In Vianna (2021), firms make a series of decisions based on the interrelated connections of the system. Thus, all firms have decision rules based on how parameters and variables representing important economic relations present themselves in the models. Hence, firms define their level of production, the prices they will charge, how many workers they will employ, how many capital goods they will order and how they will finance that investment (if with loans or if with internal funds), how many intermediate goods they will need and how much they will spend on their technological search.

The income classes earn income according to coefficients that define how much of their respective profit and wage share. The income class desired expenditure on consumption goods is defined by their last period income and propensity to consume parameter. Effective consumption is restricted by financial constrains, including liquidity preference, and the consumption sector supply availability. Also, there is an autonomous component, meaning that it is not defined by income but by each class demand that evolves due to the firm's product quality, which evolves due to the innovation effort of firms. The demand for consumption goods is divided between domestic and external demands. Additionally, the financial part encompasses not only firms but also income classes, which means that loans and deposit decisions are available to them. This means that banks receive deposits from firms and income classes with unspent funds while providing them with loans (VIANNA, 2021, p. 71-72).

The government can tax both classes' income and firms' revenue. Government expenditure can include unemployment benefits, wages and procurement of productive sector goods and be restricted by the chosen fiscal rule (VIANNA, 2021, p. 72).

In Vianna (2021), the external sector income grows semi-exogenously based on a normally distributed growth rate defined in each period, with averages influenced by domestic real growth. The export demand of each sector depends on external income and an export coefficient, foreign prices, domestic prices, and the exchange rate; therefore, it depends on relative prices and the price elasticity of each sector's exports. Imports by income classes are restricted by domestic consumption, which are limited by financial constraints and supply ability to meet demand. That means that income classes will prioritize consumption goods made in the home country and diminish their desired imports first if they face financial constraints, while they might increase imports if the domestic consumption sector cannot meet the demand.[1] At the same time, firms' input imports depend upon external prices, domestic prices, the exchange rate, and the input import price elasticity, establishing a sector-based input share of imports. For every sector, if the domestic sector production cannot meet the aggregate orders of firms and income classes, firms

[1]The last feature is not considered on the simulations performed on this thesis.

and income classes will try to acquire the remaining orders from the external sector (VIANNA, 2021).

Price decisions are based on Kalecki (1954). Firms consider their degree of monopoly, proxied by the firm's market share, their unit variable cost, and the market prices. Given their degree of monopoly, firms weigh market prices against their desired price, which consists of the unit variable cost over a markup, to choose their prices. A firm's price affect its competitiveness, which in turn affects its market share (VIANNA, 2021, p. 71). It is worth noting that overall domestic prices affect external demand.

When choosing their output level, firms consider their capital vintages productivity (which embodies labor productivity; the most productive vintages are used first), available inputs, and expected demand. Based on that decision, firms choose their labor input. Production decisions generate income and taxes allocated to income classes and the government based on respective classes' wage- and profit-share and tax rates. The input sector demand is established through the demand of the other productive sectors and their respective input coefficient (VIANNA, 2021, p. 71).

Technological search is dependent upon the available funds. This innovation "procedure" is divided into one that looks to increase product quality and another that aims to increase labor productivity. Firms might imitate their peers or innovate in this process. Labor productivity affects only the new capital goods that replace the older ones, while quality affects the firm's market share. As stated before, in the case of the consumption goods sector, it impacts the income classes' autonomous consumption.

Investment decisions are connected to long-term expected demand, availability of funds (and thus profits accrued, loans available, and interest rates), and technological search and innovation since productivity growth affect the capital goods payback rule, which firms use to define their investment decision in comparison to their long term expected demand (VIANNA, 2021).

This means that the many effects stipulated in the BPCG and cumulative causation literature are already featured theoretically in the model, at least at the micro level, with a potential to impact the macro level: relative prices can potentially increase demand and expected demand, which in turn can affect the availability of funds increasing innovation rates and productivity growth, and thus investment and demand. Increasing productivity affects prices, leading to firms' external demand growth by increasing the aggregate external demand and individual firms' market share, allowing successive growth rounds to happen *ceteris paribus*.

Following Vianna (2021, 73-77), the model steps are:

1. Interest Rate Setting

   (a) Basic Interest Rate: Central Bank fixes the basic interest rate following the monetary policy rule and then define an interest rate on deposits

   (b) Interest Rate on Deposits: negative spread over basic interest rate.
   (c) Bank's Short- and Long-Term Base Loans Interest Rate: positive spread over basic interest rate.
   (d) Firm and Class Interest Rate: banks applies first a firm-specific and then a class-specific risk premium over their rates.

2. Costs and Prices
   (a) Nominal Wages: firms adjust workers nominal wages based on past inflation and productivity growth.
   (b) Input Cost: firms calculate input costs based on a technical coefficient and past average input prices.
   (c) Variable Cost: firm's unit variable costs encompass wage and input costs, and unit normal financial costs if firm's current debt rate is higher than their desired debt rate.
   (d) Mark-up Decision: firms adjust their desired markup based on desired and effective market shares.
   (e) Price Decision: firms set their prices based on desired markup over their variable cost and average sector price (and the sector's external prices, weighted by the export share of the sector).

3. Production
   (a) Planned Production: firms plan their production based on expected demand and current level of inventories.
   (b) Exchange Rate: adjusted based on last period's balance of payments.
   (c) External Income: calculated based on an exogenous growth rate, subjected to some randomness.
   (d) External Prices: calculated for each sector based on an exogenous growth rate and/or the domestic price past growth, subject to some randomness.
   (e) Sector Exports: depend on sectoral specific coefficients, the price differentials, price and income elasticities of demand and the External Income.

4. Government Demand
   (a) Government Desired Expenses: Government calculates desired expenses in wages, unemployment benefits, consumption goods, capital goods and intermediate goods.
   (b) Government Effective Expenses: limited by the maximum chosen by the fiscal rule (set through parameters), which also determines the way government expenses are done.

5. Consumption and Class Finance

   (a) Class Desired Consumption: income classes determine their desired consumption (domestic and imported). There is an induced component based on average past disposable income, and a autonomous component based on quality growth.

   (b) Class Internal Funds: Composed by the current stock of deposits minus financial obligations (interest and amortization) and desired retained deposits (liquidity preference).

   (c) Class Available Loans: are determined by classes current stock of loans and maximum debt rate, which determines the maximum available loans.

   (d) Class Demand for Loans: based on the difference between desired expenses and available internal funds, limited to available loans.

   (e) Class Effective Consumption Demand: minimum between desired expenses and total available funds.

   (f) Effective Imports: because income classes prioritize domestic consumption, effective imports will be equal to the minimum between desired imports and available funds after effective consumption.

6. Effective Demand

   (a) Total Consumption Goods Demand: income classes' effective consumption demand, plus government consumption and exports.

   (b) Total Intermediate Goods Demand: all firms' input demand for the next period, plus government inputs and exports.

   (c) Total Capital Goods Demand: all firms' capital demand based on past investment decisions, plus government investment and exports.

   (d) Effective Sectoral Demand: based on effective domestic demand for each type of good and exports.

   (e) Firm's Demand: sectoral demand is distributed to each firm based on their market share through replicator dynamics.

7. Sales, R&D and Profits

   (a) Sales: minimum between current effective orders and effective production plus inventories of each firm.

   (b) Indirect Taxes Payment: firm's revenue is indirected taxed.

   (c) Technological Search: a share of firm's net revenue is allocated to technological search in each period, and firms perform R&D (innovation and imitation) in productivity and product quality.

(d) Net Interest Gains: firms pay interest on current loans and receive interest on current deposits.

(e) Profits: Firm's net profits are gross revenue minus tax payment, R&D expenses, production costs, plus net financial gains.

(f) Profits Distribution: if net profits are positive, firms distribute a share to income classes and retain the rest. If they are negative, no losses are distributed, and a short-term loan will be demanded.

8. Capital Adjustment and Investment Decisions

   (a) Physical Depreciation: physically depreciated capital goods are eliminated.

   (b) Productive Capacity Effective Expansion (only in firms' investment period): new capital goods ordered in past investment period are implemented.

   (c) Desired Expansion Investment (only in firms' investment period): firms'desired new productive capacity to meet long-term expected demand considers current productive capacity and future capital goods depreciation.

   (d) Desired Replacement Investment (only in firms' investment period): new capital goods considers a payback rule and the current technological frontier.

9. Firm Finance

   (a) Firm Internal Funds: based on current deposits, plus retained profits minus desired level of retained deposits (liquidity preference). Negative internal funds imply that deposits cannot cover current losses, and short-term loans must be taken.

   (b) Firm Available Loans: based on current stock of loans and maximum debt rate (total stock of loans over total stock of capital, physical and deposits).

   (c) Firm Demand for Loans: based on the difference between desired investment expenses and available internal funds (limited to available loans).

   (d) Banks Maximum Loans: based on regulatory rule and financial fragility sensitivity.

   (e) Bank Effective Loans (only if banks have limited credit supply): If there is a limited credit supply, banks apply a credit rationing based on a sectorial basis debt rate ranking.

   (f) Firm Total Funds: effective loans plus internal funds.

10. Effective Investment

    (a) Effective Investment Expenses: limited to total available funds.

11. Market Exit and Entry

(a) Exit: low market share or high debt rates can lead to exits.

(b) Debt Repayment: firms that exit the market must repay existing debt with available deposits. If that is not possible, they default the banks.

(c) Deposits Redistribution: firms that exit the market with net positive deposits distribute it to income classes as profits.

(d) Capital Stock Available: firms that exit the market leave some capital goods available for entrants.

(e) Entry (only if sectoral demand is growing): entrants will copy the average market-share and other statistics of the average firm of the sector, but capital goods will be constrained by the availability of productive capacity.

Those steps already indicates the complexity of the model and the possiblity of considering most of the exchange rate channels that were discussed previously.

## 2.2 Model changes

Although plenty of the exchange rate channels have already been incorporated, some issues still require attention. The following section shows the proposed changes to the model to provide a better framing with the Neo-Schumpeterian literature and better encompass the exchange rate effects debated. Initially, Subsection 2.2.1 contains a new innovation and imitation procedure proposal. This change seeks to make the model comply with a better understanding of stylized facts of the innovation literature. The subsection also has a new structure for external imitable firms because Chapter's 1 recognized that external innovations could affect the results, and their interaction with the exchange rate channels could be relevant to the debate. This approach also enables the endogenization of income elasticities, representing another technological path of changing growth rates. Further, to both engage in the possibility of trade influencing this external imitation and simultaneously providing firm individualized exports, external market shares were introduced. These new developments lead to changes in how demand and prices are set, as detailed in Subsection 2.2.2.

### 2.2.1 Proposed modifications on modelling the innovation process

Vianna (2021) used a two-step approach to the innovation process (technological search) for both product quality and labor productivity. The first step is called "Innovation" and the second is called "Imitation". Both steps' successes for each firm rely on drawing a random number, with the probability of success increasing as more resources are spent. In the case of innovation, its value depends on the simulation period and stochastic processes to reproduce uncertainty, while for imitation, the firm automatically drew the maximum quality or labor productivity of its respective sector. So, a key contribution of this thesis is to propose an external imitation step to the MMM. This enables addressing the problem brought by the thesis related to currency depreciation and the rationale outlined in the BPCG and cumulative causation framework in an AB framework.

First, this section introduces changes to the innovation process that are compatible with the development of an external imitation process connected with the external spillover idea from international knowledge of technology gap models. Initially, this required changes to both firm's innovation and imitation process. It also needed the introduction of external firms making innovations, which was accomplished by reproducing the same innovation procedure associated with external income growth. Then, the external imitation process was added. Additionally, an external market share for each domestic firm was included, which led to the introduction of many demand and price changes. These were done to stress both possible distributional effects from changes in relative prices and to introduce a new feature that allows firms with more international insertion to have more chance of imitating external firms. Finally, the external firms' quality comparison with the domestic firms' is used as a proxy for the income elasticity of demand, which is, hence, endogenous.

#### 2.2.1.1 Step 1: innovation

For the innovation process, the previous version relied on the period to define the magnitude of the innovation found during the technological search, regardless of the firm's previous technology. Theoretically, as initially proposed, the MMM innovation process mimics the exogenous technology push (POSSAS; DWECK, 2011), which was considered to be an old interpretation of how innovations emerge in the economy dissociated from the productive process. In other words, if firms were able to innovate, they would reach the exogenously defined technology frontier established by an exogenous parameter (*time*), subjected to some randomness. This formulation created a situation that made previous technology unconnected, at least not directly, to the firm's innovation and made path dependency, a feature of neo-Schumpeterian models, not rely on innovation features directly. For imitation, although a firm's imitation was dependent on other firms reaching the sector technology frontier, its previous technology values did not directly affect its imitation results. This means technological paths were shared among firms in each sector but not by itself. Also, using the period as a reference for magnitude becomes an issue if a firm is allowed to imitate an advanced technology, say, from an advanced external sector. In such cases, firms would not be permitted to innovate or imitate domestically as the advanced technology from the external sector would always present higher productivity or quality results than their domestic innovative efforts.

Thus, the new innovation step is defined by the following schedule for each firm, representing the search for new labor productivity.[2]

The probability of success in innovating will depend on $rnd_{j,t}$ and the firm wages. The firm will then draw a random number between 0 and 1. If it is bigger than $1 - e^{\left(-inn_i \cdot \frac{rnd_{i,t}}{wr_{i,t}}\right)}$, then the firm is successful in innovating and the dummy will assume the value of 1:

$$P\left(dummy^{inn-pr} = 1\right) = 1 - e^{\left(-inn_i \cdot \frac{rnd_{i,t}}{wr_{i,t}}\right)} \tag{2.1}$$

where

$dummy_{i,t}^{inn-pr}$ is a dummy variable that assumes the value of 0 or 1, with one meaning that a firm is successful in innovating for productivity;

$inn_i$ is the innovation proportion of R&D expenses of firm $i$;

$rnd_{i,t}$is the R&D expenses of firm $i$ in period $t$; and

$wr_{i,t}$ is the nominal wage rate of firm $i$ in period $t$.

Then, the labor productivity result of innovation will depend on the following equation:

$$\phi_{i,t}^{inn} = \phi_{i,t_{-1}}^{p} \cdot \left(1 + \ dummy_{i,t}^{inn-pr} \cdot N\left(\left(\frac{t+1}{t}\right) \cdot opp_j^{\phi},\ sd_j^{\phi}\right)\right) \tag{2.2}$$

where

$\phi_{i,t}^{inn}$ is firm $i$'s possible labor productivity in period t due to innovation;

$\phi_{i,t_{-1}}^{p}$ is firm $i$'s labor productivity frontier in period $t_{-1}$;

$opp_j^{\phi}$ is the labor productivity technological opportunities of sector $j$;

$t$ is the current simulation period; and

$sd_j^{\phi}$ is the standard deviation of the distribution of innovations for the labor productivity of sector $j$.

It is worth noting that $t$ is still used, but only to provide the same velocity of growth of the normal distribution average of the previous version of the model. This is done to avoid "tweaking" the parameters too much. Now, the previous labor productivity will influence each firm's innovation process.

#### 2.2.1.2 Step 2: domestic imitation

As mentioned, the imitation process used in Vianna (2021) automatically allocated the sector's maximum labor productivity (or quality) to the imitating firm. This, at least potentially,

[2]Every step to achieve improvements in product quality is analogous to labor productivity and will not be exposed

made firms converge easily and quickly to achieve maximum productivity in the sector. This also made imitation potentially connected to radical innovations, in the case of laggard firms, rather than incremental innovations. Those laggard firms copying other firms' processes or products would instantly become the most productive firms (*t* minus 1) in the economy. This would have been heightened if external imitation had been introduced using the same process.[3] For example, if there were just one firm that was able to imitate a really advanced technology from the external sector and 20% of firms of the respective domestic sector were successful in the imitation draw, they all would be able to adopt this new technology. This seems unplausible, especially if one considers the innovation effort as the noblest and most capable of achieving higher productivity than imitation.

Thus, the probability of success of the procedure is the same for the domestic imitation process. Again, the firm will draw a random number between 0 and 1. If it is bigger than $1 - e^{\left(-im_i \cdot \frac{rnd_{i,t}}{wr_{i,t}}\right)}$, then the firm is successful in imitating, and the dummy will assume the value of 1:

$$P\left(dummy_{i,t}^{im-pr} = 1\right) = 1 - e^{\left(-im_i \cdot \frac{rnd_{i,t}}{wr_{i,t}}\right)} \tag{2.3}$$

where

$dummy_{i,t}^{im-pr}$ is a dummy variable that assumes the value of 0 or 1, with one meaning that a firm is successful in imitating domestically for productivity;

$im_i$ is the imitation proportion of R&D expenses of firm $i$;

$rnd_{i,t}$ is the R&D expenses of firm $i$ in period $t$; and

$wr_{i,t}$ is the nominal wage rate of firm $i$ in period $t$.

But, this time, for a successful domestic imitation procedure (with the dummy equal one), the firm will search for all labor productivity frontiers of the sector in the last period and will sort it according to the inverse of the Euclidean distance between its own labor productivity frontier and those other firm's labor productivities frontiers. For a firm looking for a new technology, imitation is more likely to occur the closest this technology is to the firm's own technology. Also, the increase in the aggregate of distances makes it easier for a firm to imitate from a single firm or from a cluster of neighboring firms. The logic is that considering that a firm is looking for technology and techniques, the model will make it harder for them to learn from technology distant firms. At the same time, it will make it easier to learn from similar firms.

Then, the firm will randomly draw firm *k*'s labor productivity frontier with the probability of the draw given by the distance between the firm's *i* and *k*. Formally, for a given labor productivity frontier distance between firm *i* and *k*, the probability of firm *i* imitating firm *k*

[3] In fact, imitating higher frontiers can have similar effects even if less pronounced approaches are used.

productivity technology is given by:

$$\Pr\left(\phi_{i,t}^{im} = \phi_{k,t_{-1}}^{p}\right) = \frac{dummy_{i,t}^{im-pr}}{\left|\phi_{i,t_{-1}}^{p} - \phi_{k,t_{-1}}\right| \cdot \sum_{n=1}^{l} \frac{1}{\left|\phi_{i,t_{-1}}^{p^{-}} - \phi_{l,t_{-1}}^{p}\right|}} \tag{2.4}$$

where

$\phi_{i,t}^{im}$ is firm $i$'s possible labor productivity in period t from the domestic imitation process;

$\phi_{i,t_{-1}}^{p}$ is firm $i$'s labor productivity frontier in period $t_{-1}$;

$\phi_{k,t_{-1}}^{p}$ is firm $k$'s labor productivity frontier in period $t_{-1}$;

$\phi_{i,t_{-1}}^{p^{-}}$ is firm $i$'s labor productivity frontier (fixed in the sum) in period $t_{-1}$;

$\phi_{l,t_{-1}}^{p}$ is firm $l$'s labor productivity frontier in period $t_{-1}$.

In comparing against the imitation approach that returns the maximum productivity available, this format makes the imitation outcome $\phi_{i,t}^{im}$ less erratic in value terms. It also emphasizes learning, path dependency, and technology regimes as features of innovation and diffusion. It is worth noting that when a firm is too detached from other firms' productivities, *i.e.* its productivity distance is far away from others, making it likelier to imitate firms that are in its proximity. This means that having a positive outlier firm for productivity will reinforce the probability of domestic imitation occurring from its low-productivity neighbors. In this sense, a more balanced distribution of firms would be better for imitation outcomes. Also, this procedure makes it more likely that the productivity outcomes distribution is more dispersed with more productivity inequality.

These last two features are important since the evidence points out that more developed countries can modernize some sectors while not forgetting to lift up less dynamic sectors. Further, the evidence points out that countries that fail to overcome the middle-income trap are the ones that have focused on a few technologically modern sectors. However, its success cannot spread to outdated ones (LAVOPA; SZIRMAI, 2018). Thus, the more balanced the distribution, the more positive the productivity overall, and there is a possibility that the country shows a more unequal distribution of productivity.

#### 2.2.1.3 Step 3: external imitation

Differently from the innovation and domestic imitation processes, the external imitation might be dependent (a simulation scenario) on the firm insertion on external markets and its level of imports. The probability of the procedure being successful is the same. Again, the firm will draw a random number between 0 and 1. However, this probability will be influenced by this trade insertion feature. If it is bigger than $1 - e^{\left(\frac{-xim_i \cdot a_{i,t}^{xim} \cdot rnd_{i,t} \cdot \psi_j}{wr_{i,t}}\right)}$ then the firm is successful in imitating and the dummy will assume the value of 1:

$$P\left(dummy_{i,t}^{xim-pr}=1\right)=1-e^{\left(\frac{-xim_i\cdot a_{i,t}^{xim}\cdot rnd_{i,t}\cdot\psi_j}{wr_{i,t}}\right)} \tag{2.5}$$

where

$dummy_{i,t}^{xim-pr}$ is a dummy variable that assumes the value of 0 or 1, with one meaning that a firm is successful in imitating externally for productivity;

$xim_i$ is the external imitation proportion of R&D expenses of firm $i$;

$rnd_{i,t}$ is the R&D expenses of firm I in period $t$;

$\psi_j$ is a external imitation difficulty parameter of sector $j$; and

$wr_{i,t}$ is the nominal wage rate of firm i in period $t$.

The external market share, real exports, and firm's imports influence the likelihood of the external imitation process:

$$a_{i,t}^{xim}=\left(xms_{i,t_{-1}}\right)\epsilon_j^{xms}+\left(\mathrm{trp}_{i,t_{-1}}\right)\epsilon_j^{x} \tag{2.6}$$

where

$a_{i,t}^{xim}$ is the external imitation sensibility due to international insertional of firm's $i$ on period $t$;

$xms_{i,t_{-1}}$ is the external market share participation of firm $i$ on period $t_{-1}$;

$\epsilon_j^{xms}$ is the external imitation sensibility of sector *j* due to the external market share participation;

$\mathrm{trp}_{i,t_{-1}}$ is the trade openness of firm *i* on period $t_{-1}$; and

$\epsilon_j^{x}$ is the external imitation sensibility of sector *j* due to the trade openness.

The same logic of the domestic imitation procedure applies to the external imitation procedure, and firm *i* will randomly draw external firm *k* labor productivity frontier. Given the labor productivity frontier distance between firm *i* and external firm *k*, the probability of firm *i* imitating the external firm *k* is given by:

$$Pr\left(\phi_{i,t}^{xim}=x\phi_{k,t_{-1}}^{p}\right)=\frac{dummy_{i,t}^{xim-pr}}{\left|\phi_{i,t_{-1}}^{p}-x\phi_{k,t_{-1}}^{p}\right|\cdot\sum_{n=1}^{l}\frac{1}{\left|\phi_{i,t_{-1}}^{p^{-}}-x\phi_{l,t_{-1}}^{p}\right|}} \tag{2.7}$$

where

$\phi_{i,t}^{xim}$ is firm *i*'s possible labor productivity in period *t* from the external imitation process;

$\phi^{p}_{i,t_{-1}}$ is firm $i$'s labor productivity frontier in period $t_{-1}$;

$x\phi^{p}_{k,t_{-1}}$ is firm $k$'s external labor productivity frontier in period $t_{-1}$;

$\phi^{\bar{p}}_{i,t_{-1}}$ is firm $i$'s labor productivity frontier (fixed in the sum) in period $t_{-1}$;

$x\phi^{p}_{l,t_{-1}}$ is firm $l$'s external labor productivity frontier in period $t_{-1}$;

#### 2.2.1.4 The new productivity (and quality) frontier

Since firms are now allowed to imitate external firms, the new productivity frontier for the firm will be the maximum between the firm's previous frontier and the three innovative processes:

$$\phi^{p}_{i,t} = \max\left(\phi^{inn}_{i,t}, \phi^{im}_{i,t}, \phi^{xim}_{i,t},\ \phi^{p}_{i,t_{-1}}\right) \tag{2.8}$$

where

$\phi^{p}_{i,t}$ is firm $i$'s productivity frontier in period $t$;

$\phi^{inn}_{i,t}$ is firm $i$'s possible labor productivity in period $t$ due to innovation;

$\phi^{im}_{i,t}$ is firm $i$'s possible labor productivity in period $t$ from the domestic imitation process;

$\phi^{xim}_{i,t}$ is firm $i$'s possible labor productivity in period $t$ from the external imitation process; and

$\phi^{p}_{i,t}$ is firm $i$'s productivity frontier in period $t_{-1}$.

#### 2.2.1.5 External technological paths and endogenous income elasticity of exports

It is necessary to take a detour to introduce the third step in the new 3-step innovation process because the external imitation requires a description of the external economy's technological paths. First, external firm objects are introduced in the LSD program used in the simulation. This has the fortunate side effect of making it easier to introduce firm-level variables for the external sector on future works, as besides this new productivity and quality processes introduced, the old model included only sector or macro variables for the rest of the world. For external firms' labor productivity and product quality, their growth is not modeled like that of domestic firms because their participation in the economy is not modeled. Thus, the many relations that might influence their innovative process are not explicitly considered.[4] However, for consistency, they follow similar distributions and heuristics as domestic firms in their innovative process. External firms' labor productivity frontiers and product qualities are also proportional to external income, as it is

[4]For now, these external firms work as an "as-if" argument for producing the external labor productivity technologies and product qualities that might be imitable by domestic firms.

generally assumed that innovation, productivity, and income are related. Therefore, external labor productivity (and quality) is related to external income (as previously, only labor productivity will be shown):

$$xrnd_(j,t) \ = \frac{y_t^x}{F}\lambda_j^x \tag{2.9}$$

where

$xrnd_{i,t}$ is firm *i*'s external R&D expenses in period $t$;

$y_t^x$ is the external income in period $t$;

$F$ is the number of external firms ;

$\lambda_j^x$ is the external revenue R&D proportion parameter for sector $j$.

Then, $xrnd_{i,t}$ is used to influence the chance of the external firm frontier to advance in the period in the same fashion as the domestic innovation process:

$$P\left(dummy_{i,t}^{xinn-pr} = 1\right) = 1 - e^{(-xinn_j \cdot xrnd_{i,t})} \tag{2.10}$$

where

$dummy_{i,t}^{xinn-pr}$ is a dummy variable that assumes the value of 0 or 1; and

$xinn_j$ is the innovation proportion for labor productivity of external sector $j$.

The external firm draws a random number between 0 and 1 to define the dummy value. If this random number is bigger than $1 - e^{\left(-xinn-pr_j \cdot xrnd_{i,t}\right)}$, then the dummy will be equal to one, and the external firm will be able to increase its frontier under the following equation:

$$x\phi_{i,t}^{inn} = x\phi_{i,t_{-1}}^{p} \cdot \left(1 + \ dummy_{i,t}^{xinn-pr} \cdot N\left(\left(\frac{t+1}{t}\right) \cdot opp_j^{x\phi}, sd_j^{x\phi}\right)\right) \tag{2.11}$$

where

$x\phi_{i,t}^{xinn}$ is external firm *i*'s possible labor productivity due to innovation;

$x\phi_{i,t_{-1}}^{p}$is external firm *i*'s labor productivity frontier period $t_{-1}$;

$opp_j^{x\phi}$ is the external labor productivity technological opportunities of sector $j$;

$t$ is the current simulation period; and

$sd_j^{x\phi}$ is the standard deviation of the external innovation distribution of sector $j$.

If $x\phi_{i,t}^{xinn}$ is higher than the previous external firm productivity frontier, it will become the actual one. Formally, then, the new external firm new labor productivity frontier on period t will be:

$$x\phi^{p}_{i,t} = \max\left(x\phi^{xinn}_{i,t}, x\phi^{p}_{i,t_{-1}}\right). \tag{2.12}$$

Those external labor productivity frontiers are now evident to domestic firms and may be copied by them. So, even though there is not any external firm being modeled with all the aspects of domestic firms, this method is a solution that allows domestic firms to look for possible external technologies and choose to imitate them, provided that if they find an external technology and this technology labor productivity (or quality) is higher than both its innovation and domestic imitation process results and the firm's previous frontier. Additionally, concerning previous versions of this family of models, this reinforces other changes to the imitation process heuristics that allow for a more nuanced diffusion and highlight the path-dependency character of the economy and innovation.

This form of generating external technologies combined with the external imitation process departs from Verspagen's (1991) North-South model; simultaneously, it preserves the technology gap spillover. First, the learning capability is still related to the distance of the firm's own technology to the external technology, and the likelihood of imitating the most advanced technologies will increase for firms closer to the external frontier. Also, suppose the firm productivity is above average. In that case, fewer external technologies will be available for imitation that are useful for the firm. However, it might be that its proximity to an above-average particular external firm's labor productivity or quality makes the firm better off. This will simulate an increased domestic learning capability. This is an AB firm-level movement that reflects Verspagen's (1991) equation since, in his approach, a low-technology country initially has many technology opportunities. However, it does not have the learning capabilities to learn them, while as it modernizes, it increases its learning capability, but the technology opportunities diminish. However, in this way, firms and the domestic sector might face better opportunities if they are close to the external frontier.

The income elasticity will also be endogenous to the model since now there is an external average quality that states the quality of the products of each sector of the external market. The rationale is the same as the one used for the consumption classes: product quality influences consumption, which will guide the income elasticity equation. The new income elasticity of exports will consider the external sector firm's average quality as a proxy for the export elasticity of each sector:

$$\bar{xq}^{q}_{j,t} = \frac{\sum x\phi^{q}_{i,t}}{xF_{j,t}} \tag{2.13}$$

where

$barxq^{q}_{j,t}$ is the external average quality of the external sector $j$ in period $t_{-1}$;

$x\phi^q_{i,t}$ is the quality of firm $i$ in period $t$; and

$xF_{j,t}$ is the number of external firms in sector $j$ in period $t$.

The exports' income elasticity adjustment equation will compare the growth of the external average quality against the growth of domestic average quality of sector $j$:

$$\epsilon^{y,x}_{j,t} = \epsilon^{y,x}_{j,t_{-1}} \cdot \left(1 + \mu^{y,x}_j \left(\frac{\bar{q^p_{j,t_{-1}}} - \bar{q^p_{j,t-2}}}{\bar{q^p_{j,t-2}}} - \frac{xq^p_{j,t_{-1}} - xq^p_{j,t-2}}{xq^p_{j,t-2}}\right)\right) \tag{2.14}$$

where

$\epsilon^{y,x}_{j,t}$ is the income elasticity of sector $j$'s exports in period $t$;

$\epsilon^{y,x}_{j,t_{-1}}$ is the income elasticity of sector $j$'s exports in period $t_{-1}$;

$\mu^{y,x}_j$ is the is the income elasticity adjustment parameter of sector $j$'s exports;

$\bar{q^p_{j,t_{-1}}}$ is the average quality of sector $j$ in period $t_{-1}$;

$\bar{q^p_{j,t-2}}$ is the average quality of sector $j$ in period $t_{-1}$;

$xq^p_{j,t_{-1}}$ is the external quality of sector $j$ in period $t_{-1}$; and

$xq^p_{j,t-2}$ is the external quality of sector $j$ in period $t_{-1}$.

### 2.2.2 Demand and external sector changes

The following section will show changes due to demand, not strictly due to innovation and technology. First, it is proposed that domestic firms have independent external market shares in the model structure. Also, suppose external imitation might imply that firms have a different probability of imitating due to the firm's external market share. In previous versions of the model, the market share was indistinguishable between domestic and external shares. In that case, providing domestic and external market shares is necessary. The external one will evolve similarly to the domestic market share (which will behave like the old one in this model). However, it will be considered that the technology competitiveness is more relevant for adjusting the shares, as it is considered that companies with low competitiveness are shunned out of external markets or unable to enter them. This is the first approximation of the selection bias mechanism discussed in the first section. So, the external demand for each sector will be equal to the sum of sector real exports times the external market share of each firm of the sector:

$$o^{exp}_t = \sum_{i=1}^{J} \left(exp^r_{j,t} \cdot xms_{i,t}\right) \tag{2.15}$$

where

$o_t^{exp}$ is the real external demand (exports) in period $t$;a

$F$ is the total number of firms in period $t$;

$exp_{j,t}^r$ is the real external demand (exports) of sector $j$ in period $t$; and

$xms_{i,t}$ is the external market share of firm $i$ in period $t$.

This external market share will be defined by replicator dynamics as is usual with evolutionary models:

$$xms_{i,t} = xms_{i,t_{-1}} \left(1 + \mu_j^{xms} \left(\frac{co_{i,t}}{x\bar{co}_{j,t}} - 1\right)\right) \tag{2.16}$$

where

$xms_{i,t}$ is the external market share of firm $i$ in period $t$;

$xms_{i,t_{-1}}$ is the external market share of firm $i$ in period $t_{-1}$;

$\mu_j^{xms}$ is external market share adjustment parameter of sector $j$;

$co_{i,t}$ is the competitiveness of firm i in period $t$; and

$x\bar{co}_{j,t}$ is the average competitiveness of the sector j in period t weighted by the external market share.

With the adjustment parameter $\mu_j^{xms} > \mu_j^{ms}$, firms will now have distinct market shares for the domestic and external markets.[5] Also, the exports for each sector will be determined by this market share in accordance with the aggregate exports that are defined by a fixed sectoral exports coefficient, the current level of external income, the real exchange rate, and elasticities of demand for income and price:

$$exp_{j,t}^r = \epsilon_j \cdot \left(\frac{\bar{p_{j,t}} \cdot er_t}{p_{j,t}^x}\right)^{\epsilon_j^{p,x}} \cdot (y_t^x)^{\epsilon_{j,t}^{y,x}} \tag{2.17}$$

where

$exp_{j,t}^r$ is the real external demand (exports) of sector $j$ in period $t$;

$\epsilon_j$ is the exports coefficient of sector $j$;

$\bar{p_{j,t}}$ is the average price of sector $j$ in period $t$;

$er_t$ is the exchange rate of the economy in period $t$;

[5]It is worth noting that an alternative formulation was considered. It consisted of allotting a competitive bonus for the external imitation that firms were doing, as it would imply that those firms imitating externally a lot would have more knowledge of external markets that would translate into more external market share. However, this was given up for simplicity because it would be counterintuitive to have companies with less productivity or product qualities with more external market share. Additionally, it would create a strong reinforcing dynamic since the external imitation equation might be tested depending on the external market share.

$p^x_{j,t}$ is the foreign price of sector $j$ products in period $t$;

$y^x_t$ is the real external income on period $t$;

$\epsilon^{p,x}_j$ is the price elasticity of sector $j$'s exports; and

$\epsilon^{y,x}_{j,t}$ is the income elasticity of sector $j$'s exports in period $t$.

This income elasticity is now endogenous to the model due to the intruduction of the innovation process of external firms. For the consumption goods sector, domestic demand is now determined by the sum of each income class consumption and government consumption:

$$o_{c,t} = \sum_{h=1}^{H} c^r_{h,t} + c^r_{g,t} \tag{2.18}$$

where

$o_{c,t}$ is the (real) domestic orders of the consumption goods sector in period $t$;

$H$ is the number of income classes;

$c^r_{h,t}$ is the real effective domestic consumption demand of class $h$ in period $t$; and

$c^r_{g,t}$ is the real effective consumption demand of the government in period $t$.

For the intermediate goods sector, domestic demand is determined by the government demand for inputs and the sum of input demand of all firms, which is based on the next period's expected production, the fixed input technical coefficient, and the current level of stock of inputs, already discounting the amount to be used in current production:

$$o_{in,t} = \sum_{i=1}^{F_i} \left(1 - \iota^{in}_{i,t}\right) inp^d_{i,t} + inp^r_{g,t} \tag{2.19}$$

where

$o_{in,t}$ is the (real) domestic orders of the intermediate goods sector in period $t$;

$F_i$ is the total number of firms of the input sector;

$\iota^{in}_{i,t}$ is the propensity to import inputs of firm i in period $t$;

$inp^d_{i,t}$ is the input demand of firm $i$ in period $t$; and

$inp^r_{g,t}$ is the real input demand of the government in period $t$.

Finally, for the capital goods sector, domestic demand is determined by the sum of effective investment decisions of all firms, considering private and government investment already limited by financial constraints. Firms only demand capital goods during an investment period, and investment periods are not simultaneous for all firms. Instead, they are mismatched, but every production period is an investment period for at least some firms:

$$o_{k,t} = \sum_{i=1}^{F_k} i^r_{i,t} + i^r_{g,t} \tag{2.20}$$

where:

$o_{k,t}$ is the sectoral orders (in real terms) of the capital goods sector in period $t$;

$F_k$ is the total number of firms of the capital sector;

$i^r_{i,t}$ is the real effective investment of firm $i$ in period $t$; and

$i^r_{g,t}i$ s the government's real effective investment (capital demand) in period $t$.

Total sectoral demand is then divided among firms based on their relative market shares:

$$o_{i,t} = ms_{i,t} \cdot o_{j,t} + exp^r_{j,t} \cdot xms_{i,t} \tag{2.21}$$

where $o_{i,\ t}$ is the total sectoral orders of firm $i$ in period $t$;

$ms_{i,t}$ is the market share of firm $i$ in period $t$;

$o_{j,t}$ is the domestic orders (in real terms) of sector $j$ in period $t$;

$exp^r_{j,t}$ is the real external demand (exports) of sector $j$ in period $t$; and

$xms_{i,t}$ is the external market share of firm $i$ in period $t$.

Also, from the last equation, domestic share be equal to:

$$ds_{i,t} = \frac{ms_{i,t} \cdot o_{j,t}}{o_{i,t}} \tag{2.22}$$

where

$ds_{i,t}$ is the domestic share of firm $i$ in period $t$,

and the export share is equal to:

$$xs_{i,t} = \frac{exp^r_{j,t} \cdot xms_{i,t}}{o_{i,t}} \tag{2.23}$$

where

$xs_{i,t}$ is the external share of firm $i$ in period $t$.

Now, firms will have both a domestic market share and an external market share that will follow their relative competitiveness, formalized in replicator dynamics equations and differ in the adjustment parameter. The domestic market share will be equal to:

$$ms_{i,t} = ms_{i,t_{-1}} \left(1 + \mu_j^{ms} \left(\frac{co_{i,t}}{c\bar{o}_{j,t}} - 1\right)\right) \tag{2.24}$$

where

$ms_{i,t}$ is the market share of firm $i$ in period $t$;

$ms_{i,t_{-1}}$ is the market share of firm $i$ in period $t_{-1}$;

$\mu_j^{ms}$ is market share adjustment parameter of sector $j$;

$co_{i,t}$ is the competitiveness of firm $i$ in period $t$; and

$c\bar{o}_{j,t}$ is the average competitiveness of the sector $j$ in period $t$.

It is worth remembering that $\mu_j^{xms} > \mu_j^{ms}$. Also, the price for the firm will be changed to reflect the fact that firms do not exhibit a homogenous exposure to the external sector. The price equation follows Kalecki (1954) and reflects their degree of monopoly. In this sense, firms will look at the market average price and their desired price to decide the price they will charge. Although the previous version of the model already modifies Kalecki's equation to include the external market as a relevant market for the firm, now the external price weight will be able to vary on the firm-level simultaneously with the external market share:

$$p_{i,t}^{ref} = p_{j,\bar{t}_{-1}} \cdot \left(1 - \theta_i^x \left(xs_{i,t_{-1}}\right)\right) + p_{j,t_{-1}}^x \cdot er_{t_{-1}} \cdot \theta_i^x \cdot xs_{i,t_{-1}} \tag{2.25}$$

where

$p_{i,t}^{ref}$ is the reference price of firm $i$ in period $t$;

$p_{j,\bar{t}_{-1}}$ is the average price of sector $j$ in period$t_{-1}$;

$\theta_i^x$ is the external price weight parameter of firm $i$;

$xs_{i,t_{-1}}$ is the external share of firm $i$ in period $t_{-1}$;

$p_{j,t_{-1}}^x$ is the sector $j$ external price in period $t_{-1}$; and

$er_{t_{-1}}$ is the exchange rate in period $t_{-1}$.

The desired markup considers the evolution of the market share. With the introduction of the external market share, the desired markup will also consider both (domestic and external) market shares. First, an average between them is calculated:

$$ams_{i,t} = ms_{i,t} \cdot ds_{i,t} + xs_{i,t} \cdot xms_{i,t} \tag{2.26}$$

where

$ams_{i,t}$ is the average market share of firm $i$ in period $t$.

This average is then used to calculate the desired markup:

$$mk_{i,t}^{d} = \begin{cases} mk_{i,t_{-1}}^{d}\left(1+\psi_{j}^{mk}\left(\frac{ams_{i,t_{-1}}-ams_{i,t-2}}{ams_{i,t-2}}\right)\right), & \text{if } ams_{i,t_{-1}} > ams_{i,t_{-1}}^{d}, \\ mk_{i,t_{-1}}^{d}, & \text{otherwise.} \end{cases} \quad (2.27)$$

where

$mk_{i,t}^{d}$ is the desired mark-up of firm $i$ in period $t$;

$mk_{i,t_{-1}}^{d}$ is the desired mark-up of firm i in period $t_{-1}$;

$\psi_{j}^{mk}$ is the market share adjustment parameter of sector $j$;

$ams_{i,t_{-1}}$ is the average market share of firm $i$ in period $t_{-1}$;

$ams_{i,t-2}$ is the average market share of firm $i$ in period $t-2$; and

$ams_{j}^{d}$ is the desired market share parameter of sector $j$.

With this new desired markup, the firm's desired price will be:

$$p_{i,t}^{d} = mk_{i,t}^{d} \cdot uvc_{i,t} \quad (2.28)$$

where

$p_{i,t}^{d}$ is the desired price of firm $i$ in period $t$;

$mk_{i,t}^{d}$ is the desired mark-up of firm $i$ in period $t$; and

$uvc_{i,t}$ is the unit variable cost of firm $I$ in period $t$.

Hence, the price equation of the firm will have the same format as the previous version of the model but with the updated desired prices and reference prices to reflect the introduction of the external market share:

$$p_{i,t}^{*} = \theta_{i} \cdot p_{i,t}^{d} + (1-\theta_{i})\, p_{i,t}^{ref} \quad (2.29)$$

where

$p_{i,t}^{*}$ is the effective price of firm $i$ in period $t$;

$\theta_{i}$ is the price strategy (degree of monopoly) parameter of firm $i$;

$p_{i,t}^{d}$ is the desired price of firm $i$ in period $t$; and

$p_{i,t}^{ref}$ is the reference price of firm $i$ in period $t$.

As was mentioned in the last chapter, it is important to notice that there is no innate markup flexibility mechanism in the MMM due to external competition and both theses changes and the Vianna's MMM version do not follow Blecker (1989). The possibility of some individual firm exposure to external demand affecting effective markup is only accomplished due to an increase in the firm external market share, which happens to the detriment of another firm. This could generate internal dynamics, but the effects should, on average, cancel out.[6] However, as the external share affects the reference price, an increase in exports relative to GDP might decrease the effective markup if the sector's foreign price is smaller than the domestic average price. So, additionally, it is worth noticing that, in all simulation scenarios, it is not straightforward if relative price changes might influence the effective markup as Blecker's (1989) flexible markup, as composition changes between firms who have different desired markup, domestic prices, foreign prices, exchange rate, are interacting.

Further, although the same channel used in Hein and Vogel's (2008) model to influence the distribution is possible in the model, as it lies on the ratio of imported inputs and wages, the model wage-bargain parameters can make all increases in inflation fully transferable to wages in just a few periods. This transference would annulate any distributional changes through this channel fairly quickly. Also, because the wage-bargain parameter related to productive gains is usually fixed and considered to be less than unity, technological gains are not fully incorporated into wages, thus increasing the profit share.

Additionally, as mentioned before, because there is no proper sense of the external sector, there is no way of calculating the external sector inflation rate in a "natural" way. For price measures, the model includes a price variable for each sector that grows semi-exogenously and is influenced by domestic prices. So, it is necessary to assume some ad-hoc weights to measure the external sector price index and, hence, the RER. So, for weighing the external sector prices, a weight equivalent to the domestic sector sales over total domestic sales is given to the equivalent sector of the rest of the world.

This last section saw the introduction of new features on the MMM to be better able to capture the possibilities of growth and innovation that were laid out in the previous section. The introduction of a new innovation component which was based on the firm's last productivity and quality was in line with the neo-Schumpeterian cumulative interpretation of learning and innovation. Additionally, changing the imitation process from an automatic "fly-to-the-maximum" reinforced this narrative and permitted that domestic firms imitated external firms, which were introduced, that were not state-of-the-art. Also, to allow for the insertion of external markets increasing the chance of external imitation and for having distributional and price effects, an external market share was introduced. It led to many changes in demand, markup and price components, as well to the recognition that firms facing external competition were subjected to more stringent competition than firms that did not. Additionally, the introduction of external firms making innovations enabled to endogenized the external income elasticity of demand,

[6]This was not feasible on Vianna's MMM version, but markup changes could theoretically happen due to changes of market concentration, which might emerge as a consequence of more external insertion.

which was done by comparing the external to the domestic firm’s quality.

# Chapter 3

# Simulation results and preliminarly analysis

Given the above discussion and the model changes, simulations testing the effect of an exchange rate depreciation were performed in this section. For that, three simulation scenarios were developed, taking advantage of the flexibility of the LSD program and aiming at tackling the different possibilities sprouting from the inconclusiveness of both the theoretical and empirical discussions. The simulation results, the model proposed changes for the LSD code, and the R-scripts for analysis are available at http://github.com/peurocha. The LSD program is copyrighted by Marco Valente and Marcelo Pereira and is distributed freely using a GNU General Public License. The code was written by adapting Vianna's 2021 code which can be found on his github[1] and the example models pre-set in the LSD program. R-scripts used for analysis and generated graphics are adapted from the existing R-scritps also in the LSD.

Following Vianna (2021), all firms start homogenously, which makes all firm values, like averages, maximums, and minimums, equal to their respective sectoral averages. Additionally, market shares equal the inverse of the number of firms in each sector. In this way, the number of parameters to be calibrated is reduced. This procedure is important because nearly all calibration methods have some degree of discretion, which is also reduced in this way and reduces bias from the calibration procedure. Also, in Vianna (2021), as a way to generate endogenous trajectories and trends, there is no past growth; hence, expected demand is equal to current demand. That also means that investment is absent initially, so there is no capacity expansion at the beginning of the simulation.

In this initial state, demand equals sale, and there are no delivery delays and changes in inventories. Additionally, the external and government sectors begin balanced. As mentioned by Vianna (2021), this departure from the initial conditions, which happens in the first period of the simulation, already generates powerful dynamics in that very first period. The model's initial

[1] https://github.com/thttnn/MMM v.3

homogeneity, coupled with the stochastic components embedded in the agent's heuristics, allows the rise of heterogeneity due to the cumulative effects of those decisions and interactions within the system.

In order to conduct the experiment, we have followed some principles (i) numerical simulations of a computational model were necessary given that the MMM is a non-ergodic AB model with a high degree of complexity; (ii) only minor changes to the MMM older models previous parameters should be implemented; (iii) the RER growth rate could not be set on the MMM due to the principles of the AB construction and the model's inherent design, which entails that the RER is an *ex-post* variable; (iv) the rationale outlined in section two suggests that rate effects of the exchange rate can result in growth but level effects could present a significant query in the literature. Consequently, the simulation test proposed was through an exogenous nominal exchange rate shock.

Simulation scenarios with minimal disruptive parameters were proposed to show the workability regarding the exchange rate channels of the model changes. As it was important to see the influence of introducing the new features on the model against the background discussion of this thesis, the proposition was a comparison of three independent scenarios contrasting the features proposed on Section 2.2 and containing each a no-shock and exchange rate shock set of runs. The shock setting included only one *ad-hoc* shock only, which in the simulation scenario increased the nominal exchange rate by ten percent in a predetermined period. For analyzing the exchange rate channel feasibility in the model, focusing on the technological paths and the interplay between the variables, comparisons between the shock and the non-shock scenario were made. This was done to check for preliminary results of an RER shock and the interaction with the new features. If significant growth effects were interacting with productivity gains, for example, that would boost net exports continuously, and would indicate that the new model made the cumulative causation channel dominant.

Parameter values followed the best configuration reported by Vianna (2021). To be able to perform a introductory *ceteris paribus* test for the possibility of exchange rate shocks affecting the GDP growth rate and technological variables, a baseline simulation is run against a simulation with a nominal exchange rate depreciation happening in the same period. This first scenario had minimum changes to the demand and price structures (except the reference price) and kept the old imitation framework. Additionally, two other simulation scenarios were proposed. One included all the changes depicted in the last section but not the possibility of trade (or "learning by trade") influecing external imitation. The third scenario was the same as the second, but it allowed firms' trade insertion to influence external imitation. All simulation scenarios are shown in Figure 3.1.

The simulation scenarios were run as follows: 100 Monte Carlo (MC) simulations with 400 periods. Each period is considered to be equivalent to a quarter. So, 400 periods would be equivalent to 100 years. One hundred periods were discarded from the analysis due to the strong initial dynamics. This was done eliminate the effects of the simmetry conditions imposed in the model's initialization. Thus, the whole analysis would be equivalent to 75 years. In the baseline, there was no exchange rate shock, whilst in every simulation scenario, there was one nominal exchange rate depreciation shock. The depreciation was 10% of the nominal exchange rate and was introduced in the period 200th (period 100th in the graphics). When the depreciation happened, it overruled the exchange rate variation rule for that period, thus replicating a permanent shock.[2][3]

All scenarios obeyed the initialization procedure steps stated before, and MC averages of the simulations (for each scenario) were used to analyze macro and sectorial dynamics. The ratio between the baseline (no shock runs) and the exchange rate shock runs was also used, as it provides a guide of changes that cannot be seen by comparing curves graphically. All relevant parameters can be seen in the Appendix. Table 3.1 summarizes the simulation scenarios.[4]

Table 3.1: Simulation scenarios

| | External Market Share | Domestic Innovation/Imitation | External Imitation | Income Elasticity due to Quality | Learning by Trade |
|---|---|---|---|---|---|
| Simulation Scenario 1 | Off | "Old Model" | Off | Off | Off |
| Simulation Scenario 2 | On | "New Model" | On | On | Off |
| Simulation Scenario 3 | On | "New Model" | On | On | On |

Source: Own elaboration.

In the first Simulation Scenario, the only equation-wise difference from Vianna (2021) is that the external share of the firm, instead of the whole sector, will now affect the reference price. Accordingly, firms' price equations will be slightly different. Moreover, the external market share adjustment parameter $\mu_j^{xms}$ is equal to the domestic parameter $\mu_j^{ms}$, making a firm's domestic and external market share equal. Hence, all subsequent changes that arise from the domestic market shares being different from the external market share are blocked. It also prevents technologically advanced firms from having greater external market shares.

The imitation and innovation processes are the same as Vianna (2021), and thus, in Figure 3.1, they are classified as "old model". There is no external imitation, and the income elasticity of exports is kept as a fixed parameter, so external technology influences and interactions are discarded in this "old model" version. In Figure 3.1, the "new model" label references the innovation and imitation processes changes introduced in Section 2.2. Following Section 2.2, Simulation Scenario 2 allows for a firm-specific external market share, external imitation and endogenous income elasticity of exports, besides the "new model". In contrast, Simulation Scenario 3 allows for all of the prior features plus learning by trade. The comparison between

[2]Thus, it can be considered a depreciation and not a devaluation, as it was not a conscious government or central bank policy.

[3]When external imitation was allowed, it was only permitted to occur from period 100th onwards, as it is believed that introducing external imitation at the beginning of the simulation without the "settling" of the model would influence the initialization procedure and would not allow to for external firms and domestic firms to have sufficient technological differences.

[4]Other results are available upon request.

this scenario with the others is important, because, as argued, learning by trade could enhance the potential effects of a RER increase, because those would work through the external market. So, although there would be a decrease in imports, the increase in exports would have the potential to increase innovative effects if that was the case.

## 3.1 Simulations dynamics

The exchange rate shock can be seen in Figure 3.1. The top graphics in the figure show the RER series comparing the shock (red) to the baseline (black). The bottom exhibits the ratio between the two sets. The nominal exchange rate shock makes the RER increase almost 10% in all three scenarios. The scenarios where changes were introduced did not fully roll back the RER to the baseline as the "old model" scenario, which can be seen in the Simulation 1 column. These can be attributed to average productivity gains due to the shock that was not captured in the first scenario. In all cases, the RER was already increasing, mainly because foreign prices rose faster than domestic ones. The RER graphics hint that. As productivity dynamics play out in the long term, after an initial increase in exports, if productivity gains do not build up, the economy cannot keep domestic prices lower and, thus, exports higher, so the RER tends to go back to baseline levels. This happens because productivity gains must offset the trade balance effect (so long as there is no great increase in GDP and consequentially imports are kept at bay) in the nominal exchange rate, and lower domestic price increases, which slowly appreciates the RER.[5] If the RER appreciates, implying in a lackluster productivity performance, exports suffers the same fate and will decrease in relation to the baseline.

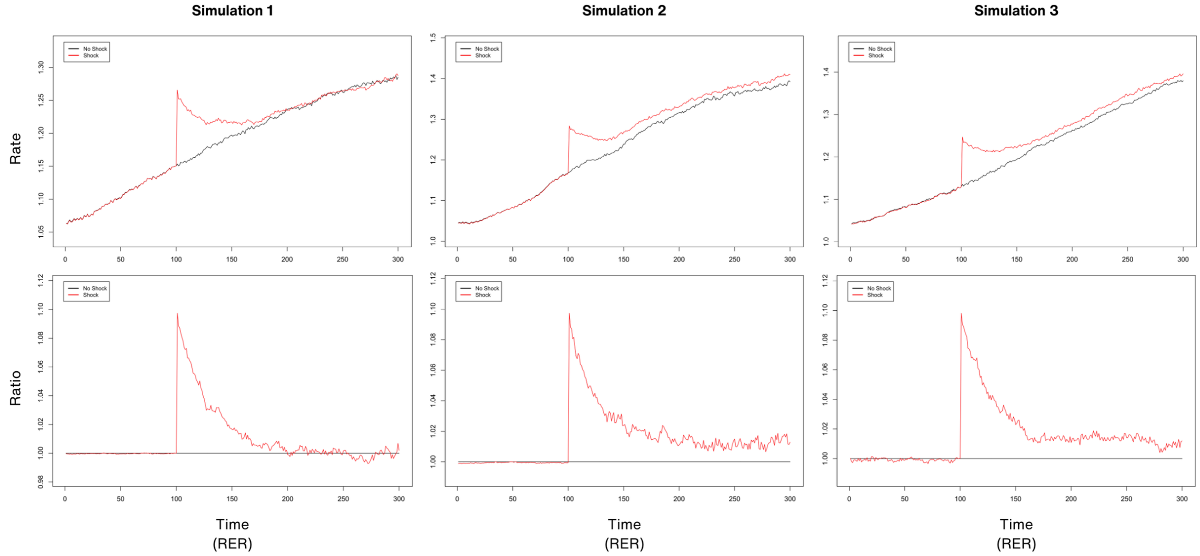
In all three scenarios, the shock's initial impact was to increase net exports following the theory laid in Section 1.1. Exports rise, and imports decline. Figure 3.2 shows the (real) export shock. The initial shock is similar in all scenarios. The first simulation shows that the shock to exports is compensated in about 50 periods. Simulation Scenario 2 can maintain exports higher than the baseline, while the third scenario dynamics have a shorter circle. It initially prevents it from returning to baseline levels like the first scenario, but by the end of the simulation, it completely reverses to the baseline.

Another straightforward impact in all scenarios is the increase in inflation.[6] The higher inflation rate takes more or less than 50 periods to fade in all scenarios. As fresh dynamics play, inflation is markedly increasing and takes a while to return to "normal". Figure 3.3 shows the inflation behavior. It is fair to say that there are new inflation dynamics in scenario two: although

[5]This implies the necessity of an increasing productivity rate to keep exports increasing because the greater the surplus in the trade balance, the greater the nominal exchange rate appreciation. Also, if productivity translates into prices, that would mean that the domestic sector would actually require higher productivity rates than the external sector. However, external price dynamics are not modeled here.

[6]The increase in inflation is stark, and due to the kryptonite nature of the topic, it is easy to assume that no policymaker would accept a tradeoff between that much inflation and growth.

Figure 3.1: RER (top) and ratio of shock to baseline (bottom) for each simulation scenario



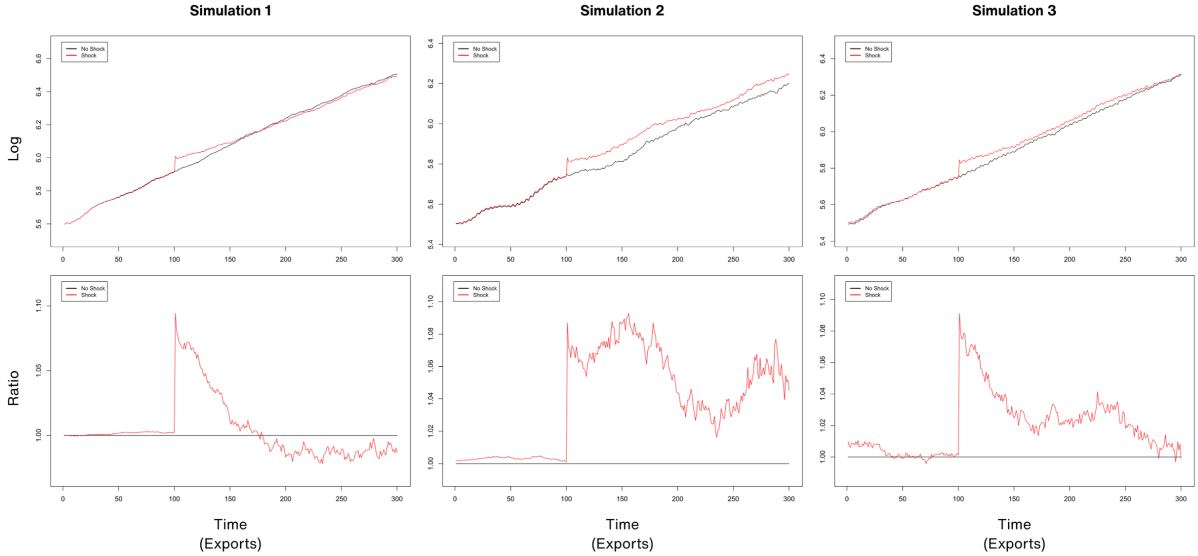

Source: own elaboration.

the shock reverses to the baseline in all cases, there is an increasing inflation rate for all shock series, which is subdued in scenario two.

Even if net exports and inflation behave as predicted, In Simulation Scenario 1, increases in the ratio of unit imported costs to unit wage hardly affect the wage share because the consumer price inflation passthrough parameter is set to one, which makes the wage share to give it back all its decrease in just a few periods. Also, Kalecki's $j$ is not clearly affected by an exchange rate shock because a drop in import quantity offsets the increase in import prices. This happens because the $j$ consists of the ratio of unit costs of imported inputs to unit wages. As such, there could be fewer imports by unit of product due to the decrease in real imports. Changes in the wage share and in the markup in relation to the baseline can be seen in Figure 3.4. Note the scale to see no significant changes in all scenarios.

Furthermore, as remarked earlier, the average markup, which would be the other method of affecting the wage and profit share, has no straightforward positive correlation with an increase in exports. This allows other dynamics to play out. Indeed, the average markup begins the new dynamic from the shock diminishing relative to the baseline. This happens in all scenarios because firms change prices with lags concerning cost changes, which means that their effective markup is lower immediately after a shock. Additionally, not all firms update their prices in each period, which increases this mismatch. Those two factors translate into seesawing markups in relation to the baseline due to the initial inflation burst. However, the markups in Simulation Scenario 1 reflect a mismatch from the baseline caused by the shock, while the other scenarios show some potential to reflect changes, but they are not significant. Those two facts, an ambiguous effect in $j$ and hardly any change in markups, make the distributional channel of an exchange rate shock not manifest itself in any scenario. In Figure 3.4, wage shares hardly differ from the shock to the baseline. So, the theoretical prognosis of consumption decreases does not materialize (at least for

Figure 3.2: Exports series in log (top) and ratio of shock to baseline (bottom) for each simulation scenario




Source: own elaboration.

the parameters tested). Any slight slip in consumption is not strong enough to offset the initial increase in net exports.

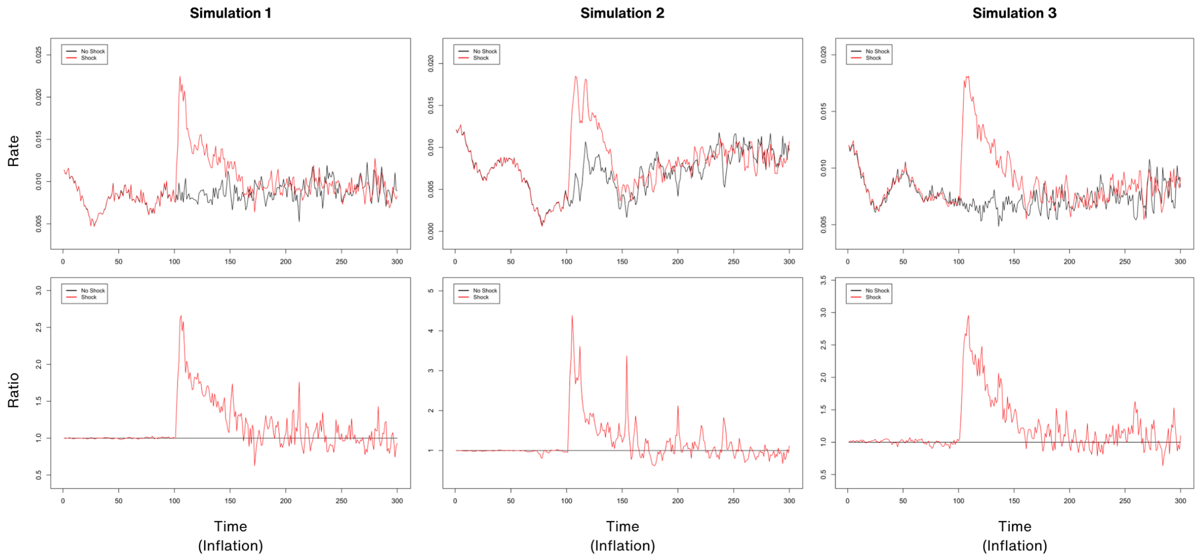
Since the wage share is not really disturbed, GDP (real) grows initially because there is material basis for a domestic consumption decrease. This lasts for at least 50 periods and can be seen in Figure 3.5. In all cases, a new GDP cycle appears to have been introduced. In the first and the third scenarios, they both appear to be at the same level as the baseline, as real GDP begins to slow and actually fall back after this impulse passes. In Simulation Scenario 2, there is a considerable cumulative build-up in GDP after the shock (see scales) that introduces a new GDP cycle, but at a higher level.

It is worth noticing that in the immediate aftermath of the shock, productivity actually decreases in relation to the baseline, although rather slightly (check the bottom of Figure 3.7). This happens because there is a decrease in available inputs since domestic inputs production contains an imported share. This materializes in a sharp decrease in productivity in the input sector. This can be seen in the second row of Figure 3.6. The last row shows the consumption sector, which is the most relevant for productivity (see scales). Simulation 3 consumption sector productivity shows the highest difference from the baseline.

In Simulation Scenario 1, in accordance with other effects shown, productivity varies a bit more than usual, but they eventually hoover back in the vicinity of the baseline[7]. So, no technological change or other associated effects are being reinforced. However, in Simulation Scenario 2, the setting is the opposite (see scales again), and although it follows the GDP

[7]In Simulation Scenario 1, as there is no discernable growth in productivity, the initial exchange rate shock, when taken in conjunction with the inflation passthrough parameter set to one, fades and the RER rolls down to baseline levels, which also makes exports roll back to the baseline.

Figure 3.3: Inflation rate (top) and ratio of shock to baseline (bottom) for each simulation scenario



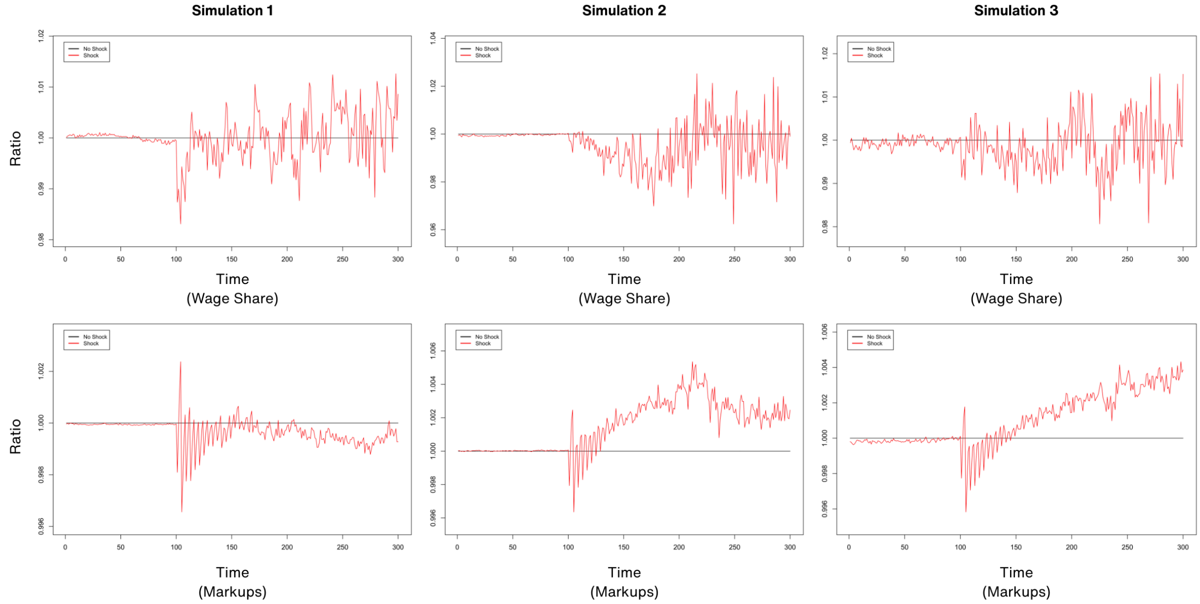

Source: own elaboration.

cycle, productivity is only significantly higher than the baseline at its peak ratio. Although the technological channel with the changes proposed was reinforced, which is not surprising since the technology push of the old formulation almost ruled out any chance of the model showing an endogenous technology dynamic, the productivity channel cummulativeness is still nascent. The top row of Figure 3.7 compares the domestic and external average productivity. It shows domestic productivity approaching the external average in the second and third scenario (slower) for both baseline and shock. The first scenario is the slowest as it follows the parameters set[8] and because there is no external imitation. However, even if there were external imitation, it would seldom make any difference as any special innovations in one period hardly affect cumulatively subsequent innovations.

A comparison of the first row of Figure 3.6 with the first row of Figure 3.7 shows interesting dynamics. First, both the number of firms, as more firms are performing the innovation process, and each sector size, which increases the resources spent in innovation, give clues to the sharp productivity distinction among sectors in Simulation Scenarios 2 and 3. Second, as each sector gets closer to the external frontier,[9] new innovation dynamics are at play. This follows from the discussed external imitation spillover dynamics. In the simulation context, the closer a firm is to the frontier, the higher the probability of finding it, reflecting a firm's previous technology mastery and a higher learning capability. However, it diminishes the technological possibilities for finding better productivity than what would be expected from internal innovation (or imitation). That would happen because if a firm is approaching the external productivity average, it would reflect, at the very minimum, a decrease in gains from external imitation. After all, the differential between external and domestic firms would be smaller than otherwise and

[8]The external firms' innovation parameter is significantly higher than the domestic one.
[9]Note that the values shown in the graphics are for the average, not the frontier.

Figure 3.4: Wage share (top) and average markup (bottom) ratio of shock to baseline (bottom) for each simulation scenario



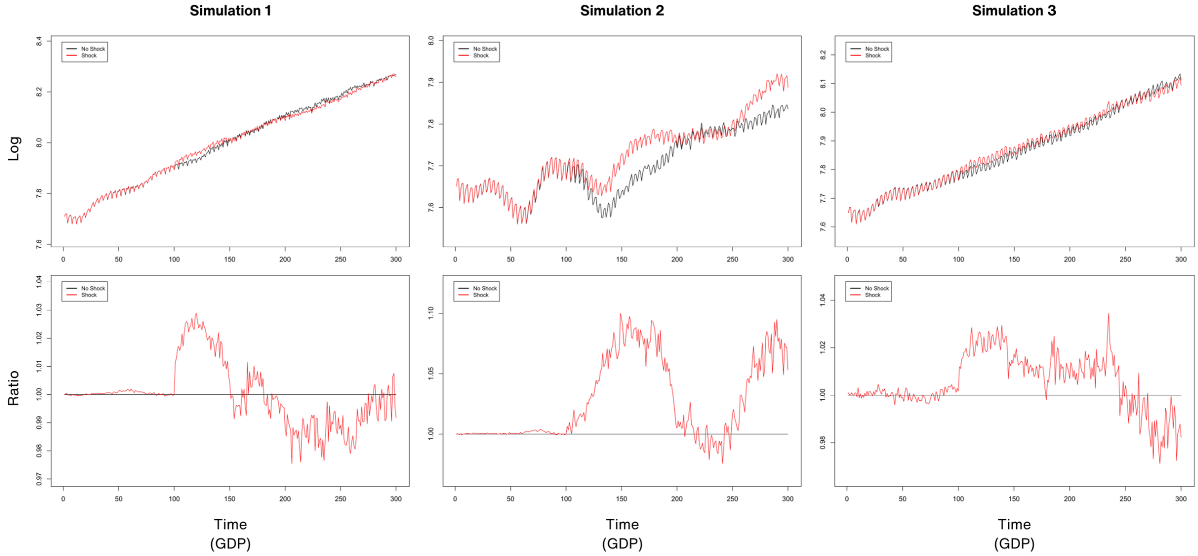

Source: own elaboration.

could even result in no gain at all in the cases where a domestic firm productivity frontier is higher than the external firm it is imitating. Logically, this can generate new innovation dynamics even if there is a dull performance in the model's other variables. Additionally, even though a sector catching up might increase the innovation rate at a certain distance from the external frontier, it might, at some point, decrease this bonus. Investigating the range and scope of this sweet spot is outside the scope of this thesis, but keep in mind that it influences the results.

In Simulation Scenario 3, there is an incipient increase in productivity in relation to the baseline. As mentioned, this was driven by the consumption sector (which reflects an increase in the normalized HHI due to market concentration). Concentration reinforces the increase in average productivity as laggard firms exit. Simulation Scenario 2 represents a good contrast to Simulation Scenario 3 as productivity increases materialize more broadly, and before the initial net export shock fades, the increase in the consumption sector productivity seen in Simulation 3 is actually accompanied by a decrease in exports. This means that productivity gains occur when the GDP's new cyclical dynamics go through depression periods. In Simulation Scenario 2, the initial growth in exports and the decrease in imports generate most of the dynamics. As there is an increase in net exports, all other demand components increase. This generates changes in productivity. The rise in GDP prevents the sectors in the shock scenario from concentrating, and the normalized HHI for all sectors remains stable.

In Simulation 2, the increase in productivity is not accompanied by a large increase in quality, which makes the new endogenous income elasticity of exports irrelevant (at least for the tested parameters) and prevents exports from behaving more autonomously from this source. Immediately after the shock, all sectors' average productivity decreased in relation to the

Figure 3.5: GDP series in log (top) and ratio of shock to baseline (bottom) for each simulation scenario



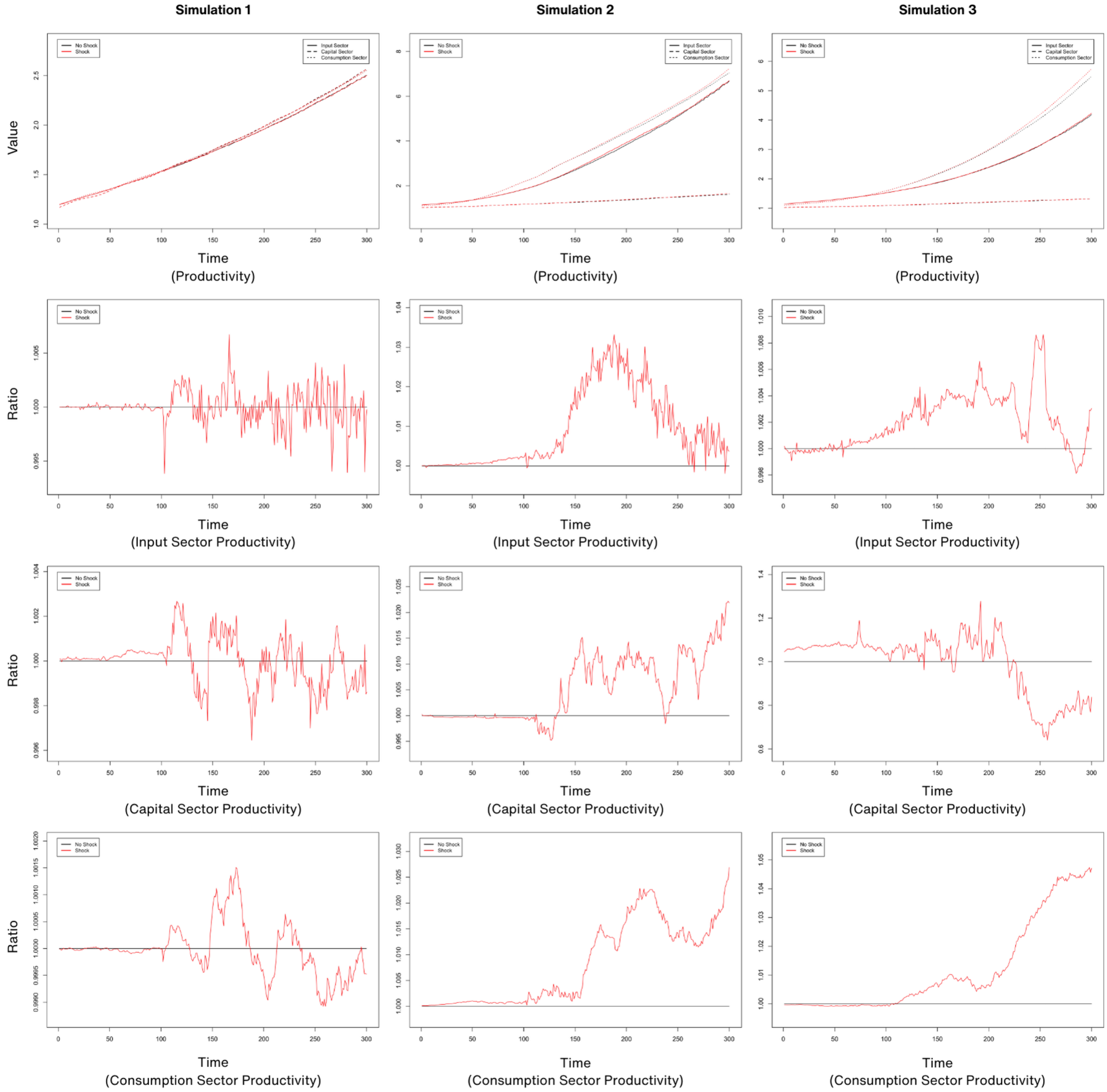

Source: own elaboration.

baseline, as explained before. However, quality averages do not vary significantly. As mentioned before, the quality average does not depend on investment directly, and capital production, which is influenced by the ratio of inputs available and investment, is not factored in its calculation.[10] Hence, its dynamics depend only on the firms' innovative activities – and resources spent. However, in all scenarios, although there are new cycles, the boost in demand from net exports fails to materialize in a higher degree of innovative activity.

For net exports to lead growth, that would require the external sector income growth rate to rise faster and/or successive productivity increases, which would increase the RER and/or domestic firms' quality innovation rates to be faster than the external firms, which would make the endogenous income elasticity of demand for exports to increase. Although the domestic economy had a higher innovation rate than the external sector by the end of the replications in scenarios two and three, the change in this elasticity was too slow and had been decreasing most of the time. Thus, the initial boost to consumption and investment also fades as there is a lack of new demand increases. So, suppose there is rising productivity due to one of the sectors being closer to the external frontier. When the initial effect of increasing resources eventually disappears, that might lead to market concentration more easily as financial constraints also diminish innovations and investment and might, by itself lead to the exit of laggard firms. Notice that there is an interplay between these factors because firms closer to the frontier in the boost were more likely to imitate

[10]Average productivity is influenced by innovation (in general), past investment and total production. Innovation enables firms to invest in new, more productive capital vintages. The productivity of the firm is calculated based on each capital vintage productivity weighted by that vintage production, and firms use the most productive capital vintages first before going to the next one, which means that an increase in production could decrease the productivity of a firm *vis-à-vis* the same capital vintages configuration. One could also say that previous investments in less (or higher) productive capital vintages could impact productivity. In contrast, sector quality averages are calculated based only on the firm's quality "frontier" and its market share.

Figure 3.6: Average productivity (top row) and average sector productivity ratio of shock to baseline (bottom) for each simulation scenario and for each sector

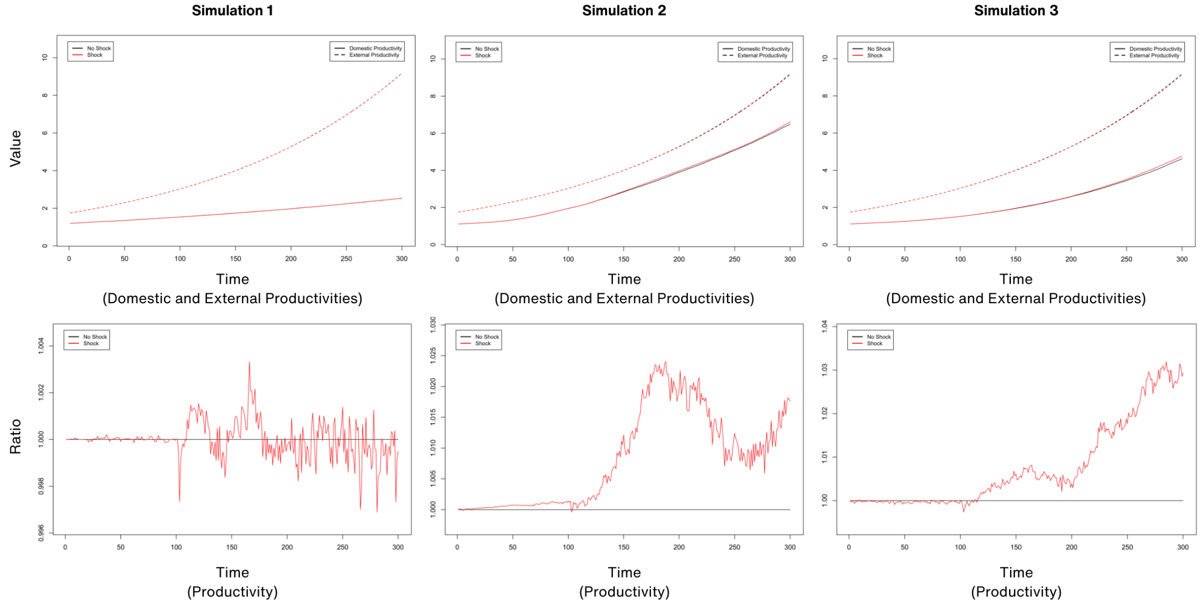



Source: own elaboration.

external firms. Now, the new innovation equations cherish cumulativeness, which can generate a decrease in demand if the surviving firms cannot meet the demand. Thus, it would be more favorable to the economy if the productivity gains led to or were accompanied by autonomous increases in demand that might prevent financial constraints and market concentration.

As learning by trade can be considered optional because of the lack of decisive evidence regarding an increase in innovation rates due to external market participation, an alternative scenario with learning by trade was proposed. By the rationale proposed in this thesis, this would maximize any technological effects of an RER increase in Simulation Scenario 3. Surprisingly, both quality and productivity remain way below the external frontier when compared with Simulation Scenario 2, meaning that for the parameter tested, learning by trade is actually leading

Figure 3.7: External and domestic productivity (top) and average domestic productivity ratio of shock to baseline (bottom) for each simulation scenario




Source: own elaboration.

to a decreasing rate of innovation. This subdued technological change delays the tendency of the market concentration of the consumption sector. The shock possibility of promoting growth in the model is limited to Scenario 2. However, as the productivity in the consumption sector of Simulation 3 starts to get faster growth rates due to the cumulative nature of the new equation and the closeness (in relation to other sectors) to the external frontier and the exports boom is actually fading, this seems to be harmful to growth. Also, complementarly the learning by trade feature could be leading to firm differentiation, which in turn would explain the market concentration for the consumption sector, especially because it is closer to the external frontier. The overall increase in volatility forbids GDP to distance itself from the baseline by the end of the simulation (in fact, it goes below).

## 3.2 Discussion

Although it is not possible from the above preliminarly results to draw precise conclusions about RER increases as a way of promoting growth and technological change, the simulations enable some considerations about the MMM transmission channels, and the feasibility of RER increases in promoting growth. First, it is worth noting that MMM, with or without changes, was not able to capture the distributional effects suggested in the theory. Changes in imported unit costs did not affect Kalecki's $j$ as predicted in Hein and Vogel (2008). Probably, this happened due to a high inflation passthrough parameter, which led wages to crawl back any change in relative prices quickly, and because there was a decrease in import quantities, which offset the increase in prices in domestic currency. Additionally, there was no flexible markup dependent on external competition, so the distribution could not vary due to the exchange rate shock. Although there were changes in firms' external market share that could somehow affect the markup, a significant increase in exports, or demand in general, had no significant impact on markups. From the viewpoint of the discussion in Section 1.1, this is a point of improvement for future works as it is plausible to believe that firms facing prodigious increases in demand – and not just increases in market share – would feel inclined to change its markup. Likewise, in addition to exploring the parametric space more rigorously, future research should consider analyzing and improving the relation between wages and imports, and the endogenization of the distributive conflict.

Moreover, introducing the external imitation hinted at the possibility of new macro dynamics driven by technology. First, it was clear that the exchange rate channel with a flexible rate could only work if there were endogenous productivity increases, which were not possible in the old *technological push* innovation approach. Second, In Simulation Scenario 2, the increase in GDP synchronized with productivity increases prevented countervailing forces from market concentration and financial fragility to reduce GDP. However, as the productivity took more time in Simulation Scenario 3 to start differentiating – as the new innovation formulation is cumulative – the rise in productivity and market concentration led to later stages of decreases in demand, matching with the baseline. Also, the RER dynamic depended on productivity; hence, when productivity could not rise much and went back to baseline levels, net exports followed this movement. Although this cannot be taken for granted from the simulations, this movement reinforces the idea that RER increases effects lean on the technological effects it produces because, logically, the lack of the distribution channel could only hinder those effects.

Furthermore, the prominent differences in productivity and quality among sectors were related to the number of firms and its predetermined size. The consumption sector had higher productivity and quality averages because of its sheer number of firms and its higher size. The input sector followed through, and the capital sector was the least technologically intensive. Those differences were reinforced by the proximity with the average external productivity and quality because the probability of imitating the most productive external firms increased. So, although this supplied interesting results when technology parameters were kept the same, this could be a source of further investigation if, for example, the capital sector were to be closer to the external frontier and/or more concentrated. The discussion in Section 1.1 reinforced the need to study sectoral differences, so this issue must be tackled in future works.

# Conclusion

This work sought to discuss the question of the final effect of a nominal exchange rate depreciation on economic growth. It was shown that in post-Keynesian economic theory, an initial effect of a nominal exchange rate depreciation would depend on open economy parameters related to income distribution that would make the economy especially sensitive to the profit share and to the exposure of the external sector, which included the price-elasticities of exports and imports and to the initial openness of it. However, on long-period analysis, short-term effects would only have level effects that could not affect growth rates. Expanding on this, employing a BPCG framework, it was shown that the initial sidelining of the level effects affecting the BPCG growth was already present in the literature, and although the long-term suggestion of the baseline BPCG model that there cannot be growth rate increases due to relative prices changes (and consequentially, due to shocks on the exchange rates that would cause the RER to depreciate or devalue) the possibility of level effects that involved technological and innovation outlines were considerably important to the discussion and to the final result related to rates. Thus, this thesis tracked why the possibility of RER increases affecting growth was sidelined, highlighting this tech-innovation character.

First, the possibility of relative price changes was outright ditched in BPCG models, while the seminal Thirlwall's (1979) paper assumed the elasticity pessimism idea and that there were no relative price changes. Those, even when taken alone, forbid that any cumulative causation mechanism might come into play and affect the growth rate and elasticities (BLECKER, 2013). Second, as other assumptions were relaxed, for example, with the introduction of sectors or products (ARAUJO; LIMA, 2007; ARAUJO, 2013), it followed the suggestion that devaluations would sway the long-period growth rates not only through differential influence on sectors with better income elasticities but also by prompting the investment and innovation rate of more technologically prone sectors that could set differential growth paths that would ultimately affect the growth rate.

Thus, the literature review in Chapter 1 showed how different models explored the interaction between RER increases, external demand and domestic demand effects through distribution. It was argued that the post-Keynseian literature considers that differential sectors' effects, external catching up, and innovation can influence the outcome of the output. Even income distribution could interplay with innovation to affect the final results. The results, in turn, also demonstrate the debate's inconclusiveness regarding the possibility that RER variation affects the growth rate. Thus, based on the understanding that the economy is a complex adaptative system and those micro-macro mechanisms might present different dynamics and even reinforce the cumulative causation mechanism, a neo-Schumpeterian discussion was introduced focusing on technology gaps and AB models as those contained two important characteristics. The former introduced the possibility of learning from the external sector, which was the relevant market in an RER increase strategy. Besides being able to capture most of the channels introduced in Section 1.1, the latter focuses on dealing with other dynamics that could enlarge both those channels and introduce new important points to the debate, including the introduction of new growth cycles pushed by technological and financial dynamics.

Furthermore, a review of the innovation literature and the empiric firm-level learning by exporting and importing was proposed. First, it was debated if an increase in size could also increase innovation rates, providing a reinforcing mechanism for RER increases. Then, it was conjectured that innovation characteristics, such as uncertainty, tacit knowledge and an amplified institutional framework that reinforces national systems of innovation would thwart learning from trade. So, a third step was taken, which was the review of the empirical firm-level literature regarding learning by exporting and importing. All those steps were done because the effects of the initial RER increase worked through exports and depended on learning and innovation. That would mean that any exceptional characteristics of the external market regarding innovation could sustainably motivate GDP growth. However, no conclusive increase in learning and innovation rates was found from this review, especially for the possibility of learning by exporting.

The learning by exporting possibility was found to be inconclusive because although exports were connected with higher productivity and even, in some cases, innovation rates for firms, these results could be attributed to: the problem of self-selection, different countries with different trajectories, differences among sectors, differences in measuring productivity and innovation that could impact the final results; the possibility that there were increasing returns to scale and not learning taking place; and other specifications problems related to the measurement of innovation that are known to be difficult for a long time. For learning by importing, the literature identified the possibility of learning from importing, primarily from capital goods (or machinery and equipment) related to old learning channels.

Hence, an alternative approach to the problem was proposed: to adapt the MMM, to do a preliminary analysis of how a micro-macro multisector model could deal with a nominal exchange rate depreciation, provided that both the post-Keynesian and BPCG framework channels were included, as well as the possibility of the external learning channels being enhanced or not. In order to explore preliminarily how a devalued RER could affect the growth rates, a simulation analysis was put forward. This analysis considered compared both the old MMM and the proposed changes.

Because the RER increases channels worked through an increase in exports and a decrease in imports due to increases in both export and import prices, the wage share was supposed to be negatively affected. This could lead to an offsetting tendency in GDP through consumption. Nevertheless, both in the old and the new MMM, that was not the case because the MMM did not include flexible markup related to external demand growth rate (or any demand growth rate) and distributive conflict was not modeled, which led to ambiguous effects in Kalecki's *j*, because of a decrease in imported inputs over an increase in GDP offsetting imported price increases, while wages fairly quickly accompanied prices. Inflation was, as expected, unambiguously affected in the short-run, but then it converged all cases.

Additionally, it was noted that productivity guided the RER, preventing it from decreasing if it was high enough because productivity influenced prices. Thus, productivity increases prevented the RER from decreasing from both a lower price and from the trade balance effect, which depreciated the nominal exchange rate due to the trade surplus. This also prevented a decrease in net exports, but quality increases were not substantial enough to lead a virtuous circuit of demand growth and change in elasticities; thus, both net exports and GDP growth, later on, were not affected by the initial export boom, except, arguably, for Simulation Scenario 2 – which had the greater increases in productivity in relation to the baseline just after the shock – presented a GDP growth cycle at higher levels.

Furthermore, external imitation provided other new dynamics in terms of technology. The proximity to the external sector created the possibility of new technology dynamics happening even in depression periods, which decreased resources spent on innovation and investment. So, if net exports were to lead growth successfully, it would require that initial productivity gains from the initial shock kept rising fast enough to offset an appreciating nominal exchange rate and lead to decreasing price increases that could increase net exports. Alternatively, it would require that initial quality gains generate increases in the resources available to innovation as increases in quality induced increases in demand. Those were likelier to happen if they happened in conjunction and could lead to new innovation dynamics due, say, to reaching closer to the external frontier. However, those did not materialize. Productivity gains (in relation to the baseline), which took some time to build up, started to fade in Simulation Scenario 2. In Simulation Scenario 3, productivity gains only started to show in the consumption sector when no autonomous demand source could accommodate that demand increase in relation to the baseline. Quality, in contrast, did not show any marked increase whatsoever.

As it was noted, this productivity growth emergence when there was a decrease in demand could be harmful to demand due to side effects from market concentration and an inability of the remaining firms to match the whole of aggregate demand, leading to delivery failures. The possibility of external imitation could now influence this mismatch between productivity growth and demand growth. Also, a surprising result is that the introduction of learning by trade, which influences external imitation, led to a adverse performance in growth, net exports, and productivity in Simulation Scenario 3 when compared to 2. This was reinforced by a dismal quality performance (which also happened in the second scenario) after the initial shock. Thus, there were no additional autonomous demand increases from income classes, and the endogenous income elasticity of exports was rendered irrelevant, preventing any demand increases from coming from this channel. Therefore, the inability to generate a new quality dynamic, which, as argued, represented a pure form of innovative activity as it was less related to investment, supports the need, in subsequent studies, for a better understanding of those effects for a wide range of parameters.

In summary, although it requires further analysis, RER increases might not constitute a reliable long-term strategy for economic growth. As technology has an important role in any RER increase strategy, it becomes clear it would fall on technology to shoulder the significant barriers to overcome. Moreover, besides the model and analysis limitations, which suggest both improvement points and broader testing of the parametric space that should be conducted in future works, this preliminary analysis indicates that new incorporations and analyses in the distribution channel should include ways of allowing changes unrelated to productivity. Furthermore, the interaction between the external technology frontiers and domestic firm imitation shows interesting new dynamics that need to be investigated at both the sectorial and firm levels. In addition, introducing new external firms with technological trajectories should serve as the basis for expanding the external sector to have its own dynamics and for domestic firms' external demand to be more individualized, which could also influence the result. This should also guide future work.

# Bibliography

AMABLE, B.; VERSPAGEN, B. The role of technology in market shares dynamics. **Applied Economics**, v. 27, n. 2, p. 197–204, 1995.

AMSDEN, A. H. **Asia's Next Giant: South Korea and Late Industrialization**. New York: Oxford University Press, 1989.

ARAUJO, R. A. Cumulative causation in a structural economic dynamic approach to economic growth and uneven development. **Structural Change and Economic Dynamics**, Elsevier, v. 24, p. 130–140, 2013.

ARAUJO, R. A.; LIMA, G. T. A structural economic dynamics approach to balance-of-payments constrained growth. **Cambridge Journal of Economics**, Oxford University Press, v. 31, p. 755–774, 2007.

ARTHUR, W. B. Complexity economics: A different framework for economic thought. In: **Complexity and the Economy**. New York: Oxford University Press, 2015. p. 1–29.

BALDWIN, R. Global supply chains: Why they emerged, why they matter, and where they are going. In: ELMS, D. K.; LOW, P. (Ed.). **Global Value Chains in a Changing World**. Geneva: WTO Publications, 2012. p. 13–60.

BARBOSA-FILHO, N. H. Exchange rates, growth and inflation. In: **Annual Conference on Development and Change**. Campos do Jordão, Brazil: [s.n.], 2006. p. 1–25.

BELL, M. Time and technological learning in industrialising countries: how long does it take? how fast is it moving (if at all)? **Int. J. Technology Management**, v. 36, p. 25–39, 2006.

BERNARD, A. B.; JENSEN, J. B. Exceptional exporter performance: Cause, effect, or both? **Journal of International Economics**, v. 47, n. 1, p. 1–25, February 1999.

BHADURI, A.; MARGLIN, S. Unemployment and the real wage: The economic basis for contesting political ideologies. **Cambridge Journal of Economics**, v. 14, n. 4, p. 375–393, December 1990.

BLECKER, R. A. International competition, income distribution and economic growth. **Cambridge Journal of Economics**, v. 13, p. 395–412, Sep. 1989. Available at: <http://www.jstor.org/stable/23598124>.

____. Open economy models of distribution and growth. In: HEIN, E.; STOCKHAMMER, E. (Ed.). **A Modern Guide to Keynesian Macroeconomics and Economic Policies**. Cheltenham, UK and Northampton, MA, USA: Edward Elgar, 2011. chap. 9, p. 215–234.

____. Long-run growth in open economies: export-led cumulative causation or a balance-of-payments constraint? In: HARCOURT, G. C.; KRIESLER, P. (Ed.). **The Oxford Handbook of Post-Keynesian Economics, Volume 1: Theory and Origins**. New York: Oxford University Press, 2013. p. 390–414. ISBN 9780199984404.

____. New advances and controversies in the framework of balance-of-payments-constrained growth. **Journal of Economic Surveys**, v. 36, p. 429–467, 4 2022. ISSN 14676419.

BRESSER-PEREIRA, L. C. **Globalization and Competition: Why Some Emergent Countries Succeed while Others Fall Behind**. New York: Cambridge University Press, 2009. 1–256 p.

____. Reflexões sobre o novo desenvolvimentismo e o desenvolvimentismo clássico. **Revista de Economia Politica**, Centro de Economia Politica, v. 36, p. 237–265, 4 2016. ISSN 18094538.

BUSATO, M. I.; POSSAS, M. L. Restrição externa e crescimento: Simulando um modelo multissetorial aberto. **Economia e Sociedade**, v. 25, n. 2 (57), p. 279–313, agosto 2016.

CAIANI, A.; CATULLO, E.; GALLEGATI, M. The effects of fiscal targets in a monetary union: A multi-country agent-based stock flow consistent model. **Industrial and Corporate Change**, p. 1–31, 2018.

CAIANI, A. *et al.* Agent based-stock flow consistent macroeconomics: Towards a benchmark model. **Journal of Economic Dynamics and Control**, Elsevier B.V., v. 69, p. 375–408, 8 2016. ISSN 01651889.

CARMICHAEL, T.; HADŽIKADIIĆ, M. The fundamentals of complex adaptive systems. In: CARMICHAEL, T.; COLLINS, A. J.; HADŽIKADIIĆ, M. (Ed.). **Complex Adaptive Systems: Views from the Physical, Natural, and Social Sciences**. [S.l.]: Springer Verlag, 2019. p. 1–16.

CASSIOLATO, J. E.; LASTRES, H. M. M. **Discussing Innovation and Development: Converging Points between the Latin American School and the Innovation Systems Perspective?** [S.l.], 2008. Available at: <https://ideas.repec.org/p/aal/glowps/2008-02.html>.

CASTELLACCI, F. Technology gap and cumulative growth: Models and outcomes. **International Review of Applied Economics**, v. 16, p. 333–346, 7 2002. ISSN 02692171.

CASTELLANI, D. Export behavior and productivity growth: Evidence from italian manufacturing firms. **Weltwirtschaftliches Archiv**, v. 138, n. 4, p. 605–628, 2002.

CHANDLER, A. D. **Scale and Scope**. Cambridge, Mass.: Harvard University Press, 1990.

CHANG, H.-J. The political economy of industrial policy in korea. **Cambridge Journal of Economies**, v. 17, p. 131–157, 1993.

____. **Chutando a escada: A estratégia do desenvolvimento em perspectiva histórica**. São Paulo: Editora Unesp, 2004.

CIMOLI, M.; PORCILE, G. Technology, structural change and bop-constrained growth: A structuralist toolbox. **Cambridge Journal of Economics**, v. 38, p. 215–237, 1 2014. ISSN 0309166X.

CIMOLI, M.; PORCILE, G.; ROVIRA, S. Structural change and the bop-constraint: Why did latin america fail to converge? **Cambridge Journal of Economics**, v. 34, n. 2, p. 389–411, March 2010. Published online: 05 March 2009.

CLERIDES, S. K.; LACH, S.; TYBOUT, J. R. Is learning by exporting important? micro-dynamic evidence from colombia, mexico, and morocco. **The Quarterly Journal of Economics**, v. 113, n. 3, p. 903–947, August 1998.

COE, D. T.; HELPMAN, E. International r&d spillovers. **European Economic Review**, v. 39, n. 5, p. 859–887, 1995. Available at: <http://www.sciencedirect.com/science/article/pii/001429219400100E>.

COHEN, W. M. Fifty years of empirical studies of innovative activity and performance. In: HALL, B. H.; ROSENBERG, N. (Ed.). **Handbook of the Economics of Innovation**. [S.l.]: Elsevier, 2010. v. 1, p. 129–213.

CRESPI, G.; ZUNIGA, P. Innovation and productivity: Evidence from six latin american countries. **World Development**, v. 40, n. 2, p. 273–290, 2012.

DAMIJAN, J.; KOSTEVC Črt; ROJEC, M. Exporting status and success in innovation: Evidence from cis micro data for eu countries. **The Journal of International Trade & Economic Development**, v. 26, n. 3, p. 377–399, 2017.

DAMIJAN, J. P.; KOSTEVC Črt; POLANEC, S. From innovation to exporting or vice versa? **The World Economy**, v. 33, n. 3, p. 374–398, 2010.

DE LOECKER, J. Do exports generate higher productivity? evidence from slovenia. **Journal of International Economics**, v. 73, n. 1, p. 69–98, 2007.

DELLI GATTI, D.; GAFFEO, E.; GALLEGATI, M. Complex agent-based macroeconomics: A manifesto for a new paradigm. **Journal of Economic Interaction and Coordination**, v. 5, p. 111–135, 12 2010. ISSN 1860711X.

DELLI GATTI, D. *et al.* Emergent macroeconomics: An agent-based approach to business fluctuations. In: **New Economic Windows**. Milano: [s.n.], 2008.

DIXON, R.; THIRLWALL, A. P. A model of regional growth-rate differences on kaldorian lines. **Oxford Economic Papers**, v. 27, p. 201–214, 1975.

DOSI, G.; EGIDI, M. Substantive and procedural uncertainty: An exploration of economic behaviour in changing environments. **Journal of Evolutionary Economics**, v. 1, n. 2, p. 145–168, 1991.

DOSI, G.; FAGIOLO, G.; ROVENTINI, A. An evolutionary model of endogenous business cycles. **Computational Economics**, v. 27, p. 3–34, 2 2006. ISSN 09277099.

____. The microfoundations of business cycles: An evolutionary, multi-agent model. **Journal of Evolutionary Economics**, v. 18, p. 413–432, 8 2008. ISSN 09369937.

____. Schumpeter meeting keynes: A policy-friendly model of endogenous growth and business cycles. **Journal of Economic Dynamics and Control**, v. 34, p. 1748–1767, 10 2010. ISSN 01651889.

DOSI, G.; FREEMAN, C.; FABIANI, S. The process of economic development: Introducing some stylized facts and theories on technologies, firms and institutions. **Industrial and Corporate Change**, v. 3, n. 1, p. 1–45, 1994. Available at: <http://icc.oxfordjournals.org/>.

DOSI, G.; LABINI, M. S. Technological paradigms and trajectories. In: HANUSCH, H.; PYKA, A. (Ed.). **Elgar Companion to Neo-Schumpeterian Economics**. Cheltenham, UK: Edward Elgar Publishing, 2007. p. 332–346.

DOSI, G.; MALERBA, F.; ORSENIGO, L. Evolutionary regimes and industrial dynamics. In: MAGNUSSON, L. (Ed.). **Evolutionary and Neo-Schumpeterian Approaches to Economics**. Norwell, MA: Kluwer Academic Publishers, 1994, (Recent Economic Thought). p. 203–229.

DOSI, G.; NELSON, R. R. An introduction to evolutionary theories in economics. **Journal of Evolutionary Economics**, v. 4, n. 3, p. 153–172, 1994.

____. Technical change and industrial dynamics as evolutionary processes. In: HALL, B. H.; ROSENBERG, N. (Ed.). **Handbook of the Economics of Innovation**. Oxford: Elsevier, 2010. v. 1, p. 51–127.

____. Technological advance as an evolutionary process. In: NELSON, R. R. *et al.* (Ed.). **Modern Evolutionary Economics: An Overview**. Cambridge: Cambridge University Press, 2018. p. 35–73.

DOSI, G.; PAVITT, K.; SOETE, L. **The Economics of Technical Change and International Trade**. New York: New York University Press, 1990.

DOSI, G.; ROVENTINI, A.; RUSSO, E. Endogenous growth and global divergence in a multi-country agent-based model. **Journal of Economic Dynamics & Control**, v. 101, p. 101–129, 2019.

DUTT, A. K. Thirlwall's law and uneven development. **Journal of Post Keynesian Economics**, M.E. Sharpe, Inc., v. 24, n. 3, p. 367–390, 2002. Accessed: 08/11/2012. Available at: <http://www.jstor.org/stable/4538783>.

DWECK, E. **Uma Análise da Interação Micro-Macro com base em um Modelo Dinâmico e Multissetorial de Simulação**. Thesis (Ph.D. Thesis) — Instituto de Economia, Universidade Federal do Rio de Janeiro (IE-UFRJ), 2006.

EDQUIST, C.; LUNDVALL, B. Comparing the danish and swedish systems of innovation. In: NELSON, R. R. (Ed.). **National Innovation Systems: A Comparative Analysis**. [S.l.]: Oxford University Press, 1993. p. 265–298.

FAGERBERG, J. International competitiveness. **Economic Journal**, v. 98, n. 391, p. 355–374, 1988.

FERRARI, M. A. R.; FREITAS, F. N. P.; BARBOSA-FILHO, N. H. O papel da taxa de câmbio real nos modelos de restrição externa: uma proposta de releitura com elasticidades endógenas. 2013.

FINE, B. The general impossibility of neoclassical economics. **Ensayos Revista de Economía**, XXX, p. 1–22, May 2011.

FREEMAN, C. Innovation and long cycles of economic development. In: **Proceedings of the International Seminar on Innovation and Development at the Industrial Sector**. Campinas, Brazil: [s.n.], 1982.

____. **Technology, Policy, and Economic Performance: Lessons from Japan**. London: Pinter Publishers, 1987. 155 p. ISBN 0861879287.

____. The economics of technical change. **Cambridge Journal of Economics**, v. 18, p. 463–514, 1994. Available at: <http://www.jstor.orgURL:http://www.jstor.org/stable/24231814http://www.jstor.org/stable/24231814?seq=1&cid=pdf-reference#references_tab_contents>.

____. The 'national system of innovation' in historical perspective. **Cambridge Journal of Economics**, v. 19, n. 1, p. 5–24, February 1995.

FRENKEL, R.; TAYLOR, L. **Real Exchange Rate, Monetary Policy and Employment**. United Nations, Department of Economic and Social Affairs, 2006. (DESA Working Paper, 19). Available at: <http://www.un.org/esa/desa/papers>.

GANDOLFO, G. **International Trade Theory and Policy**. Berlin, Germany: Springer, 2006. ISBN 9783540253767.

GEREFFI, G. A global value chain perspective on industrial policy and development in emerging markets. **Duke Journal of Comparative & International Law**, v. 24, p. 433–458, 2014.

GEREFFI, G.; HUMPHREY, J.; STURGEON, T. The governance of global value chains. **Review of International Political Economy**, v. 12, n. 1, p. 78–104, 2005.

GOODWIN, R. M. A growth cycle. In: FEINSTEIN, C. H. (Ed.). **Essays in Economic Dynamics**. London: Palgrave Macmillan, 1982. p. 165–177. Originally presented at the First World Congress of the Econometric Society, Rome, 1965, and first published in *Socialism, Capitalism and Economic Growth*, edited by C. H. Feinstein, 1967.

GROSSMAN, G. M.; HELPMAN, E. **Innovation and Growth in the Global Economy**. Cambridge, Massachusetts; London, England: The MIT Press, 1991. 359 p.

GUPTA, A.; PATNAIK, I.; SHAH, A. **Learning by Exporting: Evidence from India**. [S.l.], 2013. (ADB Working Paper Series on Regional Economic Integration, 119).

HAGEMANN, H. German, american and french influences on list's ideas of economic development. In: HAGEMANN, H.; SEITER, S.; WENDLER, E. (Ed.). **The Economic Thought of Friedrich List**. London: Routledge, 2019. chap. 5, p. 58–73.

HALL, B. H.; MAIRESSE, J.; MOHNEN, P. Measuring the returns to r&d. In: HALL, B. H.; ROSENBERG, N. (Ed.). **Handbook of the Economics of Innovation**. [S.l.]: Elsevier, 2010. v. 2, p. 1033–1082.

HART, N. Increasing returns and economic progress. In: **Equilibrium and Evolution: Alfred Marshall and the Marshallians**. London: Palgrave Macmillan, 2012. p. 169–181. ISBN 978-1-349-33776-7.

HEIN, E.; VOGEL, L. Distribution and growth reconsidered: Empirical results for six oecd countries. **Cambridge Journal of Economics**, Oxford University Press, v. 32, p. 479–511, 2008. ISSN 14643545.

HUMPHREY, J.; SCHMITZ, H. Comment est-ce que l'insertion dans des chaînes de valeur mondiales influe sur la revalorisation des regroupements industriels? **Regional Studies**, v. 36, p. 1017–1027, 12 2002. ISSN 00343404.

KAHNEMAN, D.; TVERSKY, A. Prospect theory: An analysis of decision under risk. **Econometrica**, v. 47, n. 2, p. 263–291, 1979.

KALDOR, N. A model of economic growth. **The Economic Journal**, Wiley-Blackwell for the Royal Economic Society, v. 67, p. 591–624, 12 1957. Available at: <http://www.jstor.org/stable/2227704>.

____. **Causes of the Slow Rate of Economic Growth of the United Kingdom**. Cambridge: Cambridge University Press, 1966. Inaugural Lecture.

____. **Advanced Technology in a Strategy of Development**. Geneva: International Labour Office, 1970. Result of the Round Table Discussions on the Manpower Problems Associated with the Introduction of Automation and Advanced Technology in Developing Countries (1-3 July 1970).

____. Conflicts in national economic objectives. **The Economic Journal**, Royal Economic Society, v. 81, n. 321, p. 1–16, 1971. Available at: <http://www.jstor.org/stable/2229754>.

____. The irrelevance of equilibrium economics. **The Economic Journal**, Royal Economic Society, v. 82, n. 328, p. 1237–1255, 1972. Available at: <http://www.jstor.org/stable/2231304>.

____. The role of increasing returns, technical progress and cumulative causation in the theory of international trade and economic growth. **Économie appliquée**, PERSEE Program, v. 34, p. 593–617, 1981. ISSN 0013-0494.

____. **Economics without Equilibrium**. Armonk, New York: M. E. Sharpe, 1985. (The Okun Memorial Lectures at Yale University). ISBN 0-87332-336-X.

KALECKI, M. **Theory of Economic Dynamics: An Essay on Cyclical and Long-Run Changes in Capitalist Economy**. London: George Allen & Unwin, 1954. Reprinted by Routledge, 2010.

____. **Selected Essays on the Dynamics of the Capitalist Economy 1933–1970**. Cambridge: Cambridge University Press, 1971. 1–192 p. Published in July 1971.

KATZ, J. M. Domestic technology generation in ldcs: A review of research findings. In: ____. **Technology Generation in Latin American Manufacturing Industries**. New York: St. Martin's Press, 1987. p. 13–55. ISBN 978-1-349-07212-5.

KELLER, W. Trade and the transmission of technology. **Journal of Economic Growth**, Springer, v. 7, n. 1, p. 5–24, 2002. ISSN 13814338, 15737020. Available at: <http://www.jstor.org/stable/40216051>.

____. International trade, foreign direct investment, and technology spillovers. In: HALL, B. H.; ROSENBERG, N. (Ed.). **Handbook of the Economics of Innovation**. [S.l.]: Elsevier, 2010. v. 2, chap. 19, p. 793–829.

KLINE, S. J.; ROSENBERG, N. An overview of innovation. In: LANDAU, R.; KLINE, S. J. (Ed.). **The Positive Sum Strategy: Harnessing Technology for Economic Growth**. [S.l.]: The National Academies Press, 1986. p. 275–305.

KOHLER, K.; STOCKHAMMER, E. Flexible exchange rates in emerging markets: shock absorbers or drivers of endogenous cycles? **Industrial and Corporate Change**, v. 00, p. 1–22, 2022.

LAVOIE, M. Accumulation and capacity. In: **Post Keynesian Economics: New Foundations**. London: Routledge, 2014. p. 347–455.

____. Effective demand and employment. In: **Post Keynesian Economics: New Foundations**. London: Routledge, 2014. chap. 5, p. 275–346.

____. Essentials of heterodox and post-keynesian economics. In: **Post Keynesian Economics: New Foundations**. London: Routledge, 2014. p. 1–71.

____. Open-economy macroeconomics. In: **Post Keynesian Economics: New Foundations**. London: Routledge, 2014. p. 456–540.

____. Convergence towards the normal rate of capacity utilization in neo-kaleckian models: The role of non-capacity creating autonomous expenditures. **Metroeconomica**, v. 67, n. 1, p. 172–201, 2016. University of Ottawa, January 2015; revised October 2015.

LAVOIE, M.; STOCKHAMMER, E. Wage-led growth: Concept, theories and policies. In: LAVOIE, M.; STOCKHAMMER, E. (Ed.). **Wage-led Growth**. London: Palgrave Macmillan, 2013, (Conditions of Work and employment series no. 41). p. 13–39. Available at: <https://www.ilo.org/publications/wage-led-growth-equitable-strategy-economic-recovery>.

LAVOPA, A.; SZIRMAI, A. Structural modernisation and development traps: An empirical approach. **World Development**, Elsevier, v. 112, p. 59–73, 2018.

LAZONICK, W. The chandlerian corporation and the theory of innovative enterprise. **Industrial and Corporate Change**, Oxford University Press, v. 19, n. 2, p. 317–349, 2010. ISSN 0960-6491.

LEWIS, W. A. Economic development with unlimited supplies of labour. **The Manchester School**, v. 22, n. 2, p. 139–191, 1954.

LEóN-LEDESMA, M. A.; THIRLWALL, A. P. The endogeneity of the natural rate of growth. **Cambridge Journal of Economics**, Oxford University Press, v. 26, n. 4, p. 441–459, July 2002. Available at: <https://www.jstor.org/stable/23602024>.

LOVE, J. H.; GANOTAKIS, P. Learning by exporting: Lessons from high-technology smes. **International Business Review**, v. 22, n. 1, p. 1–17, 2013.

LOVE, J. H.; MANSURY, M. A. Exporting and productivity in business services: Evidence from the united states. **International Business Review**, v. 18, n. 6, p. 630–642, 2009. Available at: <http://www.sciencedirect.com/science/article/pii/S0969593109001164>.

LUNDVALL, B. **Product innovation and user-producer interaction**. Aalborg: Aalborg Universitetsforlag, 1985. 73 p. (Industrial Development Research Series, 31).

____. Innovation as an interactive process: From user–producer interaction to national systems of innovation. In: DOSI, G. *et al.* (Ed.). **Technical Change and Economic Theory**. London: Pinter Publishers, 1988. p. 349–369.

____. User-producer relationships, national systems of innovation and internationalisation. In: **National Systems of Innovation: Toward a Theory of Innovation and Interactive Learning**. London: Anthem Press, 2010. p. 47–70. ISBN 9781843318903.

LÓPEZ, J. G.; ASSOUS, M. Kalecki's theory of profits and output. In: **Michal Kalecki**. London: Palgrave Macmillan, 2010. p. 23–41. ISBN 978-14039-8555-2.

MALERBA, F.; MANCUSI, M. L.; MONTOBBIO, F. Innovation, international r&d spillovers and the sectoral heterogeneity of knowledge flows. **Review of World Economics**, 2013.

MARCHI, V. D.; GIULIANI, E.; RABELLOTTI, R. Special issue article do global value chains offer developing countries learning and innovation opportunities? **European Association of Development Research and Training Institutes (EADI)**, v. 30, p. 389–407, 2018.

MARCONI, N.; BRANCHER, M. The economic policy of new developmentalism. **Revista de Economia Contemporanea**, Universidade Federal do Rio de Janeiro, v. 21, 5 2017. ISSN 19805527.

MARGLIN, S. A.; BHADURI, A. Profit squeeze and keynesian theory. In: MARGLIN, S. A.; SCHOR, J. B. (Ed.). **The Golden Age of Capitalism: Reinterpreting the Postwar Experience**. Oxford: Oxford University Press, 1990. p. 153–186. Chapter 5.

MARSHALL, A. **Principles of Economics**. 8th. ed. London: Macmillan and Co., 1920.

MCCOMBIE, J. S. L. Criticisms and defences of the balance-of-payments constrained growth model: some old, some new. **PSL Quarterly Review**, v. 64, p. 353–392, 2011. Available at: <http://ssrn.com/abstract=2049746>.

MCCOMBIE, J. S. L.; THIRLWALL, A. P. Export-led growth and the balance-of-payments constraint. In: **Economic Growth and the Balance-of-Payments Constraint**. Hampshire, UK: Palgrave Macmillan, 1994. p. 421–455.

MELITZ, M. J. The impact of trade on intra-industry reallocations and aggregate industry productivity. **Econometrica**, v. 71, n. 6, p. 1695–1725, November 2003.

MENSCH, G.; SCHNOPP, R. Stalemate in technology, 1925-1935: The interplay of stagnation and innovation. In: SCHRöDER, W. H.; SPREE, R. (Ed.). **Historische Konjunkturforschung**. Stuttgart: Klett-Cotta, 1980. p. 60–74.

METCALFE, J. S. **Technology systems and technology policy in an evolutionary framework**. 1995. 25-46 p.

MORENO-BRID, J. C. On capital flows and the balance-of-payments-constrained growth model. **Journal of Post Keynesian Economics**, Taylor and Francis, v. 21, n. 2, p. 283–298, 1998.

MOWERY, D.; ROSENBERG, N. The influence of market demand upon innovation: A critical review of some recent empirical studies. **Research Policy**, v. 8, n. 2, p. 102–153, 1979.

MYRDAL, G. **Economic Theory and Underdeveloped Regions**. London: Gerald Duckworth, 1957.

NELSON, R. R. National innovation systems: a retrospective on a study. **Industrial and Corporate Change**, Oxford University Press, v. 1, n. 2, p. 347–374, 1992.

NELSON, R. R. (Ed.). **National Innovation Systems: A Comparative Analysis**. New York: Oxford University Press, 1993. 541 p. University of Illinois at Urbana-Champaign's Academy for Entrepreneurial Leadership Historical Research Reference in Entrepreneurship. ISBN 978-0195076172. Available at: <https://global.oup.com/academic/product/national-innovation-systems-9780195076172?utm_source=chatgpt.com>.

NELSON, R. R.; WINTER, S. G. Neoclassical vs. evolutionary theories of economic growth: Critique and prospectus. **The Economic Journal**, Royal Economic Society, v. 84, n. 336, p. 886–905, 1974.

____. **An Evolutionary Perspective of Economic Change**. Cambridge, Massachusetts: The Belknap Press of Harvard University Press, 1982.

____. Evolutionary theorizing in economics. **Journal of Economic Perspectives**, American Economic Association, v. 16, n. 2, p. 23–46, 2002.

PAVITT, K.; ROBERTS, B. M.; TOWNSEND, P. G. Sectoral patterns of technical change: Towards a taxonomy and a theory. **Research Policy**, Elsevier, v. 13, n. 6, p. 343–373, 1984.

PENROSE, E. **The Theory of the Growth of the Firm**. 4th. ed. New York: Oxford University Press Inc., 2009.

PETRI, F. Critical notes on kalecki's theory of investment. In: MONGIOVI, G.; RüHL, C. (Ed.). **Macroeconomic Theory: Diversity and Convergence**. Cheltenham, UK: Edward Elgar Publishing, 1993. p. 189–207.

PORTER, M. E. The competitive advantage of nations. **Harvard Business Review**, v. 68, n. 2, p. 73–93, March-April 1990. Available at: <https://hbr.org/1990/03/the-competitive-advantage-of-nations>.

POSSAS, M. L.; DWECK, E. A multisectoral micro-macrodynamic model. **Economia, Anpec**, v. 5, n. 3, dezembro 2004. Selecta do XXXII Encontro Nacional de Economia, João Pessoa, PB.

____. Crescimento econômico num modelo micro-macro de simulação. **Economia e Sociedade**, Campinas, v. 20, n. 1 (41), p. 1–31, abr. 2011.

POSSAS, M. L. *et al.* Um modelo evolucionário setorial. **Revista Brasileira de Economia**, v. 55, n. 3, setembro 2001.

PREBISCH, R. **The Economic Development of Latin America and Its Principal Problems**. [S.l.], 1950.

____. International payments in an era of coexistence: Commercial policy in the underdeveloped countries. **The American Economic Review**, American Economic Association, v. 49, n. 2, p. 251–273, 1959.

PYKA, A.; FAGIOLO, G. **Agent-Based Modelling: A Methodology for Neo-Schumpeterian Economics**. Augsburg, 2005. (Volkswirtschaftliche Diskussionsreihe, 272). Available at: <https://opus.bibliothek.uni-augsburg.de/opus4/71178>.

REINERT, E. S. German economics as development economics: From the thirty years war to world war ii. In: **How Rich Nations Got Rich: Essays in the History of Economic Policy**. London: Hachette, 2004. chap. Introduction, Essay II, p. 1–16.

REINERT, E. S.; KATTEL, R. Friedrich list and the non-financial origins of the european crisis. In: HAGEMANN, H.; SEITER, S.; WENDLER, E. (Ed.). **The Economic Thought of Friedrich List**. London: Routledge, 2019. chap. 10, p. 137–151.

RIBEIRO, R. S. M.; MCCOMBIE, J. S.; LIMA, G. T. Exchange rate, income distribution and technical change in a balance-of-payments constrained growth model. **Review of Political Economy**, Routledge, v. 28, p. 545–565, 10 2016. ISSN 14653982.

____. A reconciliation proposal of demand-driven growth models in open economies. **Journal of Economic Studies**, Emerald Group Publishing Ltd., v. 44, p. 226–244, 2017. ISSN 01443585.

____. Some unpleasant currency-devaluation arithmetic in a post keynesian macromodel. **Journal of Post Keynesian Economics**, Routledge, v. 40, p. 145–167, 4 2017. ISSN 15577821.

____. Does real exchange rate undervaluation really promote economic growth? **Structural Change and Economic Dynamics**, Elsevier B.V., v. 52, p. 408–417, 3 2020. ISSN 0954349X.

ROSENBERG, N. Learning by using. In: **Inside the Black Box: Technology and Economics**. Cambridge: Cambridge University Press, 1982. p. 121–140.

____. Quão exógena é a ciência? **Revista Brasileira de Inovação**, v. 5, n. 2, p. 245–271, 2006.

ROSENSTEIN-RODAN, P. N. **Notes on the Theory of the 'Big Push'**. Cambridge, MA, 1957.

ROTHWELL, R. Towards the fifth-generation innovation process. **International Marketing Review**, v. 11, n. 1, p. 7–31, 1994.

ROTHWELL, R. *et al.* Sappho updated - project sappho phase ii. **Research Policy**, v. 3, p. 258–291, 1974.

RÖSSNER, P. R. Manufacturing matters: from giovanni botero (c.1544–1617) to friedrich list (1789–1846), or: The history of an old idea. In: HAGEMANN, H.; SEITER, S.; WENDLER, E. (Ed.). **The Economic Thought of Friedrich List**. Oxon, UK: Routledge, 2019. p. 102–121.

SANTÁRCANGELO, J.; SCHTEINGART, D.; PORTA, F. Cadenas globales de valor: una mirada crítica a una nueva forma de pensar el desarrollo. **CEC**, v. 4, n. 7, p. 99–129, 2017.

SCHMOOKLER, J. **Invention and Economic Growth**. Cambridge, MA: Harvard University Press, 1966.

SCHUMPETER, J. A. **Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process**. New York: McGraw-Hill Book Company, 1939. 461 p.

SETTERFIELD, M. Thirlwall's law and palley's pitfalls: A reconsideration. In: ARESTIS, P. *et al.* (Ed.). **Growth and Economic Development: Essays in Honour of A.P. Thirlwall**. Cheltenham: Edward Elgar Publishing Limited, 2006. p. 47–59.

____. Endogenous growth: A kaldorian approach. In: . [S.l.: s.n.], 2010.

____. Exploring the supply side of kaldorian growth models. 2013.

SETTERFIELD, M.; CORNWALL, J. A neo-kaldorian perspective on the rise and decline of the golden age. In: SETTERFIELD, M. (Ed.). **The Economics of Demand-Led Growth: Challenging the Supply-Side Vision of the Long Run**. Cheltenham, UK: Edward Elgar Publishing, 2002. p. 67–86.

SIBA, E.; GEBREEYESUS, M. Learning to export and learning from exporting: The case of ethiopian manufacturing. **Journal of African Economies**, v. 26, n. 1, p. 1–23, 2017.

SIMON, H. A. Rationality in psychology and economics. **The Journal of Business**, v. 59, n. 4, p. 209–224, 1986.

SOBEL, M. Don't confuse dollar depreciation with devaluation. **OMFIF**, July 2024. Available at: <https://www.omfif.org/2024/07/dont-confuse-dollar-depreciation-with-devaluation/>.

SPINOLA, D. Uneven development and the balance of payments constrained model: Terms of trade, economic cycles, and productivity catching-up. **Structural Change and Economic Dynamics**, Elsevier B.V., v. 54, p. 220–232, 9 2020. ISSN 0954349X.

STORM, S.; NAASTEPAD, C. **Wage-led or Profit-led Supply: Wages, Productivity and Investment**. Geneva, 2012. (Conditions of Work and Employment Series, 36). Available at: <https://www.ilo.org/global/research/publications/WCMS_186023/lang--en/index.htm>.

STORPER, M. Regional technology coalitions: An essential dimension of national technology policy. **Research Policy**, v. 24, n. 6, p. 895–911, 1995.

TAJOLI, L.; FELICE, G. Global value chains participation and knowledge spillovers in developed and developing countries: An empirical investigation. **The European Journal of Development Research**, v. 30, p. 505–532, 2018.

TAVASSOLI, S. The role of product innovation on export behavior of firms: Is it innovation input or innovation output that matters? **European Journal of Innovation Management**, 2017.

TEECE, D. J. The dynamics of industrial capitalism: Perspectives on alfred chandler's scale and scope. **Journal of Economic Literature**, American Economic Association, v. 31, n. 1, p. 199–225, 1993. ISSN 0022-0515.

THIRLWALL, A. P. The balance of payments constraint as an explanation of international growth rate differences. **Revista de Economia Politica**, Banca Nazionale del Lavoro Quarterly Review, p. 45–53, March 1979.

____. Balance of payments constrained growth models: history and overview. **PSL Quarterly Review**, v. 64, p. 307–351, 2011.

THIRLWALL, A. P.; HUSSAIN, M. N. The balance of payments constraint, capital flows and growth rate differences between developing countries. **Oxford Economic Papers**, Oxford University Press, v. 34, n. 3, p. 498–510, 1982.

TONER, P. **Main Currents in Cumulative Causation: The Dynamics of Growth and Development**. Great Britain: Macmillan Press, 1999. 1–229 p.

UTAR, H. The role of foreign technical and professional services in learning by exporting. 2011.

VAN BIESEBROECK, J. Exporting raises productivity in sub-saharan african manufacturing firms. **Journal of International Economics**, v. 67, p. 373–391, 2005.

VERSPAGEN, B. A new empirical approach to catching up or falling behind. **Structural Change and Economic Dynamics**, v. 2, n. 2, p. 359–380, 1991.

VERSPAGEN, B. **Uneven Growth Between Interdependent Economies: An Evolutionary View on Technology Gaps, Trade and Growth**. Thesis (Doctor in Philosophy) — Maastricht University, 1992.

VIANNA, M. **Monetary Policy and Stabilization in a Multisectoral Micro-Macro Dynamic Simulation Model**. Thesis (Ph.D. Thesis) — Instituto de Economia, Universidade Federal do Rio de Janeiro (IE-UFRJ), 2021.

VON HIPPEL, E. The dominant role of users in the scientific instrument innovation process. **Research Policy**, v. 5, n. 3, p. 212–239, 1976.

____. A customer-active paradigm for industrial product idea generation. **Research Policy**, v. 7, p. 240–266, 1978.

WINTER, S. On coase, competence, and the corporation. **Journal of Law, Economics, and Organization**, v. 4, n. 1, p. 163–180, 1988.

____. Toward a neo-schumpeterian theory of the firm. **Industrial and Corporate Change**, v. 15, n. 1, p. 125–141, 2006. Original: 1968.

WOO, W. T. Some fundamental inadequacies of the washington consensus: Misunderstanding the poor by the brightest. In: **Conference on Stability, Growth and the Search for a New Development Agenda: Reconsidering the Washington Consensus**. Santiago, Chile: [s.n.], 2004. Revised version presented in November 2004.

YOUNG, A. A. Increasing returns and economic progress. **The Economic Journal**, Royal Economic Society, v. 38, n. 152, p. 527–542, 1928. Available at: <https://www.jstor.org/stable/2224097>.

# Appendix A

# Relevant simulation parameters

The following shows the diverging parameters used in each scenario.

Table A.1: Simulation scenarios – parameters for each scenario

| | **Sim 1** | **Sim 2** | **Sim 3** |
|---|---|---|---|
| External market share adjustment | 1 | 1.05 | 1.05 |
| Domestic imitation difficulty | 1 | 1 | 1 |
| External imitation difficulty | 0 | 0.01 | 0.01 |
| Income elasticity adjustment | 0 | 0.025 | 0.025 |
| External imitation - external market share | 0 | 0 | 0.05 |
| External imitation - trade participation | 0 | 0 | 0.05 |

Source: own elaboration.

The following shows the parameters used for all simularion scenarios.

Table A.2: Country parameters

| **Parameters** | **Country** |
|---|---|
| Annual frequency | 4 |
| Initial depreciation share to GDP | 0.1 |
| Initial export share to GDP | 0.1 |
| Initial depreciation share to GDP | 0.2 |
| Class structure | 3 |
| Interest investment | 2 |
| Entry | 1 |

Source: own elaboration.

Table A.3: External sector parameters

| **Parameters** | **External Sector** |
|---|---|
| Income growth | 0.0025 |
| Income standard deviation | 0.01 |
| Price growth | 0.003 |
| Price standard deviation | 0.01 |
| Quarterly interest rate | 0.003 |
| Firms | 66 |
| Initial price | 1 |
| Initial productivity frontier | 1 |
| Input productivity opportunity | 0.0028 |
| Input productivity standard deviation | 0.01 |
| Initial quality frontier | 1 |
| Input quality opportunity | 0.0028 |
| Input quality standard deviation | 0.01 |

Source: own elaboration.

Table A.4: Productive sectors – firms, markups and market share parameters

| **Parameters** | **Input** | **Capital** | **Consumption** |
|---|---|---|---|
| Initial number of firms | 120 | 80 | 200 |
| Desired market share | 0.15 | 0.25 | 0.1 |
| Replicator: elasticity delay | 0.6 | 0.6 | 0.6 |
| Replicator: elasticity price | 1 | 1 | 1 |
| Replicator: elasticity quality | 0.5 | 0.5 | 0.5 |
| Competitiveness adjustment | 1 | 1 | 1 |
| Markup adjustment | 0.001 | 0.001 | 0.001 |

Source: own elaboration.

Table A.5: Productive sectors – pricing and wages parameters

| Parameters | Input | Capital | Consumption |
|---|---|---|---|
| Price frequency | 4 | 4 | 4 |
| Financial cost passthrough | 1 | 1 | 1 |
| Strategic price weight | 0.5 | 0.5 | 0.5 |
| External price weight | 1 | 1 | 1 |
| Inflation passthrough | 1 | 1 | 1 |
| Productivity passthrough | 0.8 | 0.8 | 0.8 |
| Bargain power productivity adjustment | 0.01 | 0.01 | 0.01 |

Source: own elaboration.

Table A.6: Productive sectors – technology parameters

| Parameters | Input | Capital | Consumption |
|---|---|---|---|
| Innovation proportion | 0.5 | 0.5 | 0.5 |
| Initial productivity | 1 | 1 | 1 |
| Initial quality | 1 | 1 | 1 |
| R&D revenue proportion | 0.01 | 0.01 | 0.01 |
| Productivity opportunity | 0.0025 | 0.0025 | 0.0025 |
| Quality opportunity | 0.0025 | 0.0025 | 0.0025 |
| Innovation standard deviation | 0.01 | 0.01 | 0.01 |

Source: own elaboration.

Table A.7: Income classes parameters

| Parameters | Class 1 | Class 2 | Class 3 |
|---|---|---|---|
| Autonomous consumption adjustment | 0.8 | 0.5 | 0.1 |
| Direct tax | 0.3 | 0.3 | 0.3 |
| Import elasticity price | 0.5 | 0.7 | 0.9 |
| Initial propensity to import | 0 | 0 | 0 |
| Initial max debt rate | 1 | 1 | 1 |
| Population share | 0.01 | 0.29 | 0.7 |
| Profit share | 0.5 | 0.4 | 0.1 |
| Propensity to spend | 0.5 | 0.8 | 1 |
| Wage share | 0.5 | 0.8 | 1 |
| Variable: import share (lag=1) | 0.4 | 0.2 | 0.1 |

Source: own elaboration.

Table A.8: Government parameters

| **Parameters** | **Government** |
|---|---|
| Initial debt to GDP ratio | 0.5 |
| Capital share | 0.4 |
| Consumption share | 0 |
| Input share | 0 |
| Max debt ratio | 0.7 |
| Min debt ratio | 0.3 |
| Max surplus target | 0.1 |
| Min surplus target | -0.1 |
| Surplus target adjustment | 0.001 |
| Real consumption growth | 0.0025 |
| Real input growth | 0.0025 |
| Real investment growth | 0.0025 |
| Real wage growth | 0.0025 |

Source: own elaboration.

Table A.9: Financial sector parameters

| **Parameters** | **Value** |
|---|---|
| Elasticity default | 0 |
| Elasticity interest long term | 0 |
| Elasticity interest short term | 0 |
| Elasticity rationing | 0 |
| Expectations | 0 |
| Initial leverage | 1 |
| Banks | 10 |
| Price strategy long term | 1 |
| Price strategy short term | 1 |
| Profit distribution rate | 0.9 |
| Class risk premium | 0 |
| Long term risk premium | 0 |
| Short term risk premium | 0 |
| Debt rate sensitivity | 0.1 |
| Default sensitivity | 0.1 |
| Deposits spread | 0.1 |
| Long term spread | 0.05 |
| Long term spread adjustment | 0 |
| Short term spread | 0.01 |

Source: Own elaboration.