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# The impact of international trade shocks on domestic output, income distribution, and inflation in an agent-based model

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**Abstract**
We analyze the dynamics of the domestic output, income distribution, and inflation of a small open economy subject to temporary international trade shocks. The analysis is undertaken in an open economy agent-based model that extends the model in Rolim et al. (2021). The extended version incorporates a new and unexplored dimension of the social conflict over the income distribution related to the foreign sector. Two types of international trade shocks are investigated: a shock to the foreign output growth rate (a demand shock) and a shock to the foreign inflation rate (a price shock). While both types of positive shocks increase the growth rate of exports and stimulate the domestic output, they have opposite effects on income distribution: a higher wage share and lower income Gini follows a positive foreign demand shock, and the opposite occurs in the case of a positive foreign price shock. The shocks also create inflationary pressures that present different natures. These specific effects are due to the different transmission channels of each shock and their specific impact on the bargaining position of the agents and on the real exchange rate. Our results also point to income distribution being an important mechanism through which international trade shocks influence the domestic economy.
**Keywords:** agent-based modeling, international trade, open economy, personal income distribution, functional income distribution.

**O impacto de choques internacionais sobre o produto doméstico, distribuição de renda e inflação em um modelo baseado em agentes**

**Resumo**
Analisamos a dinâmica da produção doméstica, distribuição de renda e inflação de uma pequena economia aberta sujeita a choques temporários no comércio internacional. A análise é realizada em um modelo baseado em agentes de economia aberta que estende o modelo em Rolim et al. (2021). A versão estendida incorpora uma dimensão nova e inexplorada do conflito social sobre a distribuição de renda relacionada ao setor externo. Dois tipos de choques no comércio internacional são investigados: um choque na taxa de crescimento do produto externo (um choque de demanda) e um choque na taxa de inflação externa (um choque de preços). Embora ambos os tipos de choques positivos aumentem a taxa de crescimento das exportações e estimulem a produção doméstica, eles têm efeitos opostos na distribuição de renda: uma maior participação salarial e um menor coeficiente de Gini seguem um choque positivo de demanda externa, e o oposto ocorre no caso de um choque positivo de preços externos. Os choques também criam pressões inflacionárias de natureza diversa. Esses efeitos específicos devem-se aos diferentes canais de transmissão de cada choque e seu impacto específico na posição de barganha dos agentes e na taxa de câmbio real. Nossos resultados também apontam que a distribuição de renda é um importante mecanismo pelo qual os choques no comércio internacional influenciam a economia doméstica.
**Palavras-chave:** modelagem baseada em agentes, comércio internacional, economia aberta, distribuição pessoal da renda, distribuição funcional da renda.

**JEL Classification:** C63, D31, D33, F4.

# 1 Introduction

Small open economies are frequently affected by external shocks of different types, which influence greatly their economic dynamics. Trade shocks affecting exports and imports are one category of such factors, and they are expected to have consequences not only for output growth, but also for income distribution. Indeed, trade shocks affect domestic production decisions and firms' international competitiveness, while also having implications for the labor market and thus altering the bargaining position of workers. The combination and interaction between these (and other) changes means that international trade comes with sharp distributional consequences (Rodrik, 2021). Moreover, foreign shocks such as increases in foreign price levels (e.g. higher import and oil prices) may trigger an inflationary process in the domestic economy. Thus, there is a relevant connection between domestic and foreign inflation rates (Bobeica and Jarocinski, 2019; Borio and Filardo, 2007), which is likely to exert additional distributive implications.

Empirically, the relation between trade and distribution is far from homogeneous across countries. The empirical literature investigating the relation between international trade (trade openness) or globalization often draws upon the predictions of the Stolper-Samuelson theorem (Stolper and Samuelson, 1941), according to which high- and low-income countries are expected to be affected differently by globalization since their initial factor endowments are different. This empirical literature tends to find a positive relation between globalization and inequality, but results differ depending on the how each variable is measured and the group of countries included in the sample.[1] While in case of developing countries the Stolper-Samuelson theorem predicts that inequality would decrease, there is scarce evidence in favor of such prediction (Cornia, 2014; Goldberg and Pavcnik, 2007). Nevertheless, these results also seem to be very time specific. In the case of Latin American countries, for instance, the commodities boom in the 2000s was associated with more equality in the income distribution (Sánchez-Ancochea, 2021), while the rest of the world was facing the opposite process. Such contrast is interesting because it also concerns the comparison between Latin American countries and other developing economies that benefited from the high commodity prices and high world growth rates during the period (Cornia, 2014).

Arguably, the observed trends in income distribution always result from numerous influences, with trade and globalization being additional factors affecting a complex process involving (private and public) domestic agents. Nevertheless, at least at a theoretical level, disentangling several of those factors and analyzing the effect of specific conditions contributes to the understanding of how small open economies can be affected by external shocks, and why there is a diversity of responses across countries. In this sense, this article analyzes the dynamics of a small open economy subject to temporary external shocks of different types, signs, magnitudes, and lengths in order to investigate the dynamics of output, income distribution, and inflation during and after the shocks. Two types of shocks, which have not been explored so far in the agent-based models literature, are investigated: a shock on the foreign output growth rate (a demand shock) and a shock on the foreign inflation rate (a price shock). Although these shocks commonly take place at the same time, analyzing them simultaneously makes it difficult to identify which are the transmission mechanisms in place (FitzGerald, 1996). Thus, by analyzing them separately we contribute to the understanding of the complex relation between foreign shocks and the domestic economic dynamics and also provide insights into the dynamics of specific periods in which one of these factors prevailed, such as in the recent spike in inflation rates in numerous countries following the COVID-19 pandemic and the Ukraine-Russian war (Storm, 2022). An additional dimension that we intend to capture, and which has been less emphasized in the literature so far, is the feedback effect from income distribution to the output dynamics in the domestic economy, since this can be one of the many mechanisms through which foreign shocks affect the domestic output.

The analysis is undertaken in an open economy agent-based model, which revises and extends the closed economy agent-based model presented in Rolim et al. (2021). A key feature of that model is that income distribution is determined by the bargaining process between domestic agents. In this reformulated version, a foreign sector is included and it is assumed that it trades consumption goods with domestic agents. Trade and international competition have direct and indirect implications for the bargaining position of domestic agents, making the foreign sector another actor in the social conflict over the income distribution (Blecker, 1989; Krugman and Taylor, 1978; Ribeiro et al., 2017). Thus, our model emphasizes a dimension that has been much less emphasized by the more traditional literature, which tends to prioritize models in which wages are set in spot markets (Rodrik, 1997, 2021). Moreover, our approach has the advantage of capturing and emphasizing the connection between the functional and personal income distribution, thus also capturing the distributive implications of changes in the price levels and in the inflation rate. Finally, the model captures the role of the real exchange rate in driving the income distribution dynamics (Ribeiro et al., 2020; Rossi and Galbraith, 2016). Overall, we contribute to the agent-based literature by investigating shocks that have important distributive consequences and have not been explored so far.

We observe that the type of shock, sign, magnitude, and length are of primary importance for understanding how income distribution is affected by foreign shocks that operate through international trade. These characteristics are also key for understanding how the dynamics of income distribution is related to that of output since shocks that

[1] See, for instance, Dorn et al. (2017) and Milanovic (2005).

stimulate export growth have very different effects on output and distribution depending on these characteristics. Our results also show that income distribution is an important mechanism through which foreign shocks influence the domestic economy dynamics.

The remaining of this article is organized as follows. In section 2 the related literature is discussed. In section 3 the model structure and the extension to the open economy model are presented. In section 4 we summarize the key stylized facts reproduced by the model, while 5 presents and discusses the simulation results for the experiments with foreign shocks. Concluding remarks follow in section 6.

# 2 Related literature

Arguably, most agent-based macroeconomic models represent closed economies, but there are important exceptions which pursue different modelling strategies according to the research questions proposed. In a way, there is a parallel between the different categories of open economy agent-based models and those of more traditional open economy macroeconomic models, which model multiple economies, two economies or regions (e.g. North-South models), or a single economy in relation with the rest of the world.

A first group of models aims to analyze the relation between multiple (more than two) countries. While this is a detailed approach, part of this literature focuses on the relation between countries that are part of the same monetary union, and therefore does not consider the role of the (level or changes in the) exchange rate. Examples of this approach are the studies by Caiani et al. (2018, 2019), in which a monetary union is modeled. In particular, the experiments on alternative wage regimes (Caiani et al., 2019) are interesting for our purposes since they explore how increases in nominal wages affect demand and labor productivity (which affects the economy's external competitiveness). Also, the model by Petrović et al. (2017) is a multi-country version of the EURACE model (Deissenberg et al., 2008) that incorporates a monetary union of two countries and two independent countries. The model by Dosi et al. (2019) is one of the few multiple-countries models that incorporates the exchange rate as an important variable affecting the relation between the different economies and the global income dispersion.

A second group of open economy agent-based models consists on two-country or two-region models. While this is a simplification relative to models from the first group, it has the advantage of facilitating the comparison between the countries and the understanding of how shocks on one economy are transmitted to the other. As in the previous groups, many of the two-country models focus on a monetary union or in the comparison between two regions. An example is the EURACE model concerning the convergence between two regions in the European Union, in which policies that can be implemented in the less developed region are analyzed (Dawid et al., 2014). Also, Cardaci and Saraceno (2019) explore the role of inequality in driving the current account deficit through its effect on the demand for credit in a country where emulation effects are stronger. This dynamics leads to a debt-led growth model that stimulates an export-led growth model (with current account surpluses) in the other country, thus leading to current account imbalances in a currency union. While in their model inequality is determined in an exogenous manner, their results provide interesting insights with respect to how inequality affects macroeconomic variables in an open economy.

A third group of models adopts an important simplification relative to the previous groups by treating the foreign sector as an aggregate sector and analyzing a small open economy. In this case, instead of modeling feedback effects between two (or more) economies, priority is given to the dynamics of the domestic economy and how it is affected by specific transmission mechanisms that link it to the foreign sector treated simply as the rest of the world (for instance, trade and financial relations). Given this emphasis, these models also consider the exchange rate, which is either kept fixed or explicitly modeled as time-varying (usually in an endogenous fashion). A representative of this group is the family of models known as "Micro-Macro Multisectoral" (MMM) model (Busato and Possas, 2016; Dweck, 2006; Dweck et al., 2020; Possas and Dweck, 2004).

Albeit also somehow drawing from models in the other groups in specific aspects, our open economy agent-based model is closer in spirit to the last group of models, since we are primarily concerned with the effects of foreign shocks that affect a single artificial small open economy. This is an adequate approach for studying economies that are not part of a monetary union and that cannot be considered large open economies, wherein feedback effects would be more relevant, and thus provides important general insights into the dynamics of a large set of economies, in particular several developing ones. In addition, our model incorporates numerous features of the conflicting-claims inflation model in the post-Keynesian literature (Rowthorn, 1977), which emerge endogenously through the interaction between heterogeneous firms and workers. In an open economy framework, this leads to a connection between the foreign and domestic inflation rates and, consequently, a more realistic approach to the determinants of inflation (Bobeica and Jarocinski, 2019; Borio and Filardo, 2007). In sum, this article contributes to the existing literature by analyzing the effect of foreign shocks on important domestic variables (output, inflation, and income distribution) and capturing their interactions and feedback effects.

# 3 Model structure

The model is a reformulated version of the model set forth in Rolim et al. (2021). The main difference is its extension to an open economy framework, which involves the addition of a foreign sector and its interactions with the domestic economy.[2] The structure and the interactions between the agents are represented in figure 1. The model is composed by six types of agents:[3]

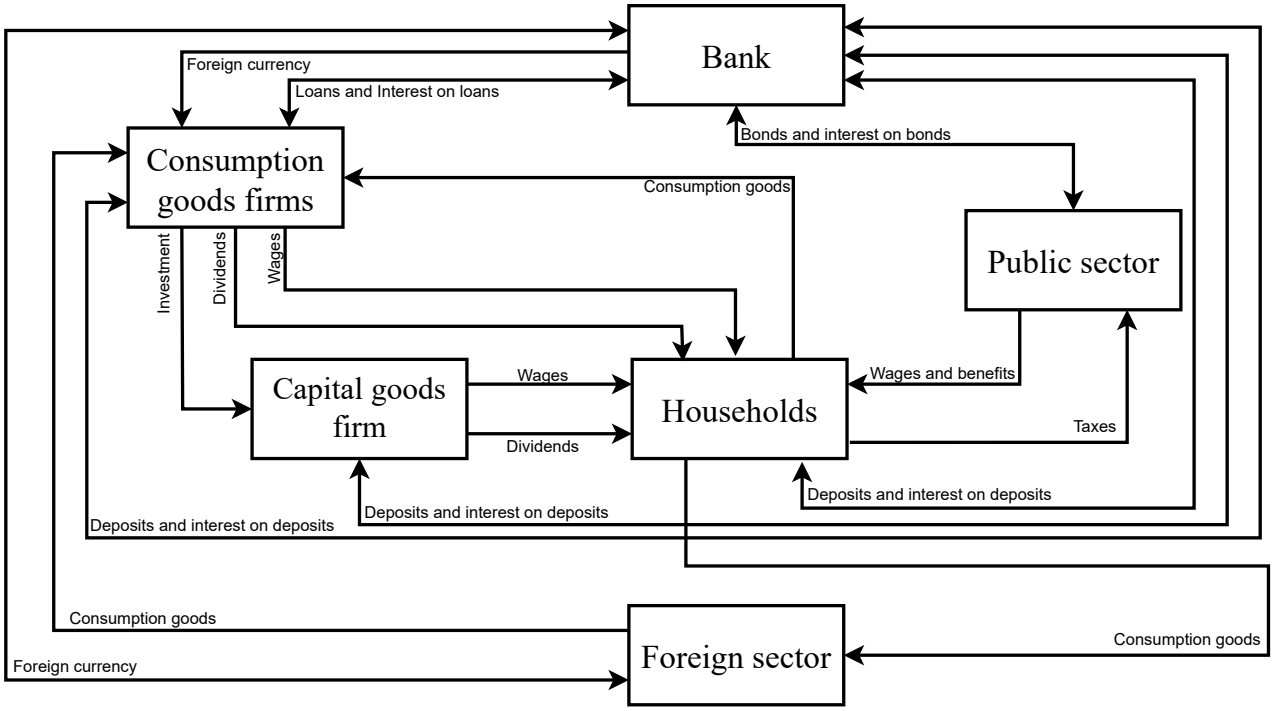



**Fig. 1**: Open economy model structure

Note: arrows point from paying sector to receiver sector. Source: authors' own elaboration.

- A monopolist **capital goods firm**, which produces machines and undertakes research and development (R&D) activities. It distributes to its owners all its net profits.
- A set of $N^c$ **consumption goods firms**, which produce a homogeneous good using labor and machines. They invest in capital goods and may ask for a loan to finance production or investment. These firms sell consumption goods to households and, if they are exporters, to the foreign sector.
- A monopolist **bank**, which grants loans to consumption goods firms, buys bonds from the government and holds firms' and households' deposits. The bank is the agent that trades foreign currency with foreign and domestic agents and it is the sole agent that can accumulate foreign reserves as assets or get indebted with the foreign sector.
- A set of $N^h$ **households** divided in $N^{cap}$ capitalists, $N^{dir}$ direct workers, and $N^{ind}$ indirect workers. Workers sell their labor to firms and receive wages in return, while capitalists own the firms and receive profit dividends (each firm is owned by $\rho_1$ capitalist households). Unemployed workers receive a tax-exempt unemployment benefit from the government. Households buy consumption goods from domestic firms and from the foreign sector through an intermediary (imports) and keep their savings as domestic deposits at the bank. They also pay taxes on profit dividends and wages.
- A **public sector** composed by a central bank and a government. The government employs a fixed number of direct and indirect workers, pays unemployment benefits to unemployed workers, collects taxes, and issues bonds to cover its deficits. The central bank holds the government's reserves account in domestic currency and acquires government bonds.

[2] Unless explicitly mentioned otherwise, all variables and agents are the domestic ones.

[3] The following subscripts are used throughout this article: $h$ for households, $c$ for consumption goods firms, $m$ for machines, $k$ for the capital goods firm, $f$ for both firms, $b$ for the bank, $g$ for the public sector, and $x$ for the foreign sector. The superscripts $res$, $man$, $ind$, $dir$, and $cap$ refer to researchers, managers, indirect workers, direct workers, and capitalists, respectively, while $j$ refers to households from all classes. The superscripts $D$, $d$ , and $e$ identify demand, desired, and expected variables, respectively. The superscripts \$ and $x$ define nominal values in the domestic and foreign currencies respectively. Finally, the subscript $t$ identifies the time period, which encompasses the production, commercialization, and investment periods.

- A **foreign sector** represented as an aggregate sector. Its variables are affected in such a negligible way by the domestic sector that they can be taken as exogenous to the dynamics of the domestic variables.[4] It is characterized by a price level $p^x_{x,t}$, which captures the average price level prevailing in world markets for the homogeneous consumption good that is traded between the foreign and domestic economies. This world price level grows over time, and its growth rate is given by $\hat{p}_x$. The foreign sector is also characterized by a real output level $Y_{x,t}$, whose growth rate is given by $g_x$. For simplicity, there is no cyclical fluctuation in $g_x$. There is also a nominal interest rate in the foreign sector given by $i_x$.

As this article focuses on the effects of international trade on a small open economy, the behavior of the consumption goods firms, which can be in direct competition with the foreign sector, is of particular importance. In line with the literature on firms' performance in international markets (Bernard et al., 1995, 2012), the model structure is such that only a fraction of the firms will be exporters. These firms price discriminate across markets (Krugman, 1986), so one of the components of export prices is the price level prevailing in the world economy. Households buy imported consumption goods from the foreign sector through an intermediary at a price level in domestic currency set according to the foreign price level and the nominal exchange rate. The nominal exchange rate, which represents the price of the foreign currency expressed in domestic currency, evolves following the previous period trade balance and the nominal interest rate differential between the domestic and foreign sectors. For simplicity, we assume that there is no international labor or physical capital mobility and that only domestic currency can be used as means of payment in the domestic sector.[5]

The social conflict over the domestic income distribution is now affected by a larger multitude of factors, extending considerably the dimensions included in Rolim et al. (2021). While the dynamics of nominal labor unit costs, which reflects the interplay between productivity growth and nominal wages, is once again a key determinant of the relative strength of each class, it is itself affected by the foreign sector. If foreign demand stimulates economic activity and employment, an increase in workers' bargaining power is likely to take place, while at the same time it may trigger endogenous growth in labor productivity through the innovation process. Also, firms react to the international competition in the domestic and foreign markets by adjusting their mark-up rates. Finally, the nominal exchange rate and the foreign price level are key factors determining the functional and personal income distribution through their direct effect on exporters' income in domestic currency (Rossi and Galbraith, 2016).

The next subsections summarize the main equations of the entire model (domestic and foreign agents).

## 3.1 Capital goods firm

The monopolist capital goods firm produces machines employing a technique characterized by direct labor productivity $y^k_t$. The new machines' productivity is equal to $y^{c,\star}_t$. These machines are sold to the consumption goods firms and they produce a maximum $Q^{fc}_m$ units of consumption goods for a maximum of $T^k$ periods, after which they are scrapped.

The innovation process undertaken by the capital goods firm is based on two successive random draws (Dosi et al., 2010; Nelson and Winter, 1982). The probability of success in innovating is given by:

$$\theta_t = 1 - e^{-\zeta L^{res}_{k,t}} \tag{1}$$

where $1 > \zeta > 0$ is a parameter capturing the firm's search capability and $L^{res}_{k,t}$ is the number of researchers employed by the firm (determined by an R&D investment equivalent to $\rho_2 < 1$ of the current nominal demand). In case of success, the new technology is characterized by the pair $y^{c,in}_t$ and $y^{k,in}_t$:

$$y^{c,in}_t = y^{c,\star}_t(1 + x^c_t) \tag{2}$$

$$y^{k,in}_t = y^k_t(1 + x^k_t) \tag{3}$$

where $x^c_t$ and $x^k_t$ are random draws from a $Beta(\alpha, \beta)$ distribution over the $[-x, x]$ support. The firms decides whether it adopts the new pair $(y^{c,in}_t, y^{k,in}_t)$ or stays with the previous one by selecting the technology that minimizes the sum of the price of the machine and the total production cost at the consumption goods firms' desired capacity utilization rate ($u^d$) times a payback factor:

$$min(p_k(y^k_{t-1}) + b\Gamma^{\$}(y^{c,\star}_{t-1}, u^d),\ p_k(y^{k,in}_{t-1}) + b\Gamma^{\$}(y^{c,in}_{t-1}, u^d)) \tag{4}$$

where $p_k$ is the capital goods price function, $b$ is the exogenous payback factor, and $\Gamma^{\$}$ is the consumption goods firms' total cost function.

[4] As mentioned, this is grounded on our understanding that such methodological strategy is adequate for understanding the effect of external shocks in several developing economies. For multi-country agent-based models, see the works listed in section 2.

[5] In other words, there is no foreign direct investment from or to the domestic sector. Note also that the domestic consumption goods firms only acquire capital goods from the domestic capital goods firm, which does not export these goods. As future research, an extension of the model could also include international trade of capital goods.

Direct workers are hired to produce the capital goods and indirect workers are hired as supervisors or managers and researchers. The labor demand for each type of worker is given by equations 5 and 6 respectively:

$$L_{k,t}^{D,dir} = \left\lceil \frac{\sum_{c=1}^{N^c} I_{c,t}^{D}}{y_t^k} \right\rceil \tag{5}$$

$$L_{k,t}^{D,ind} = \left\lfloor \frac{\rho_2 \sum_{c=1}^{N^c} I_{c,t}^{D,\$}}{w_{k,t}^{ind,\$}} \right\rfloor + \left\lfloor \rho_3 L_{k,t}^{D,dir} \right\rfloor \tag{6}$$

where $I_{c,t}^{D}$ is the number of capital goods demanded by the consumption goods firms (in real terms), $\rho_2 \sum_{c=1}^{N^c} I_{c,t}^{D,\$}$ is the R&D budget, $w_{k,t}^{ind,\$}$ is the indirect workers' wage level, and $\rho_3$ is the fixed number of managers per direct worker.

The firm's production level is given by the floor of the number of direct workers it hires in the period multiplied by their productivity, which is adjusted by a correction factor that depends on the actual ratio of managers to direct workers in comparison to the required ratio. This adjustment captures the effect of management shortcomings whenever the firm cannot hire as many managers as required to supervise the direct workers and organize the production process. Formally, production is given by:

$$Q_{k,t} = min \left\{ \lfloor L_{k,t}^{dir} y_t^k [1 - h(L_{k,t}^{man,D}/L_{k,t}^{dir,D} - L_{k,t}^{man}/L_{k,t}^{dir})\mathbf{1_Q}] \rfloor, \sum_{c=1}^{N^c} I_{c,t}^{D} \right\} \tag{7}$$

where $h$ is the sensitivity of the actual productivity level to the difference between the actual ratio of managers to direct workers and the required ratio and $\mathbf{1_Q}$ is an indicator function that takes the value of one if the actual ratio is below the required ratio and zero otherwise. As the firm never produces more than demanded by the consumption goods firms (for simplicity, there is no strategic accumulation of inventories), the second part of the equation captures the maximum production level, given by the demand for capital goods ($\sum_{c=1}^{N^c} I_{c,t}^{D}$).

The price of the new machines depends on a fixed mark-up rate applied to the unit labor costs, as follows:

$$p_{k,t}^{\$} = (1 + \mu_k) \frac{(w_{k,t}^{dir,\$} + \rho_3 w_{k,t}^{ind,\$})}{y_t^k} \tag{8}$$

where $\mu_k$ is a fixed mark-up rate and $w_{k,t}^{j,\$}$ is the wage rate for each type $j = dir, ind$ of worker.

## 3.2 Consumption goods firms

The model is composed of a set of $N^c$ consumption goods firms that produce a homogeneous nonperishable good using labor and capital goods. All firms sell in the domestic market, while a subset of exporting firms also have access to the international market. In both cases, the consumption goods market is characterized by imperfect competition and firms' sales depend on their market shares.

Firms form their expectations based on the past level of (domestic and foreign) demand ($Q_{c,t}^{e} = Q_{c,t-1}^{D}$). Given this expected demand, they set the desired production level ($Q_{c,t}^{d}$) by considering also a fixed desired share of inventories ($n^{IN}$) relative to the expected demand and the inventory level from the previous period.

Also in this case the direct workers are hired to produce the goods, while the indirect workers supervise those workers and manage the firms. Consequently, indirect workers are hired in proportion to the number of direct workers and in proportion to the size of the firm. The labor demand for direct and indirect workers is given by equations 9 and 10 respectively:

$$L_{c,t}^{D,dir} = \left\lceil \frac{Q_{c,t}^{d}}{\bar{y}_{c,t}^{c,*}} \right\rceil \tag{9}$$

$$L_{c,t}^{D,ind} = \lfloor \rho_4 L_{c,t}^{D,dir} + \rho_5 L_{c,t}^{dir,fc} \rceil \tag{10}$$

where $\bar{y}_{c,t}^{c,*}$ is the average direct labor productivity of the most productive machines required to produce $Q_{c,t}^{d}$,[6] $1 > \rho_{4,5} > 0$ are parameters, and $L_{c,t}^{dir,fc}$ is the demand for direct labor at the full capacity production level (proxy to the size of the firm).

Firms' production is given by equation 11. Also in this case, there is an adjustment factor to the productivity level if the actual ratio of managers to direct workers is below the required ratio.

$$Q_{c,t} = L_{c,t}^{dir} \bar{y}_{c,t}^{c} [1 - h(L_{c,t}^{ind,D}/L_{c,t}^{dir,D} - L_{c,t}^{ind}/L_{c,t}^{dir})\mathbf{1_Q}] \tag{11}$$

[6] The most productive machines are always used first.

Firms set prices by adding a variable mark-up rate over unit labor costs computed at the desired capacity utilization level. Since firms are exposed to international competition, their mark-up rates also reflect their perceived international competitiveness in each specific market. Therefore, in addition to the mark-up components considered in Rolim et al. (2021), the price of exported goods also includes a component capturing international competition, as described below.

Firms invest to adjust their capital stock to the desired level and to replace machines that have become technologically obsolete and hence will be scrapped. In the first case, firms calculate their desired capital stock in $t+1$, which depends on the desired capacity utilization rate ($Q_{c,t}^{fc,d} = Q_{c,t}^{e,t+1}/u^d$). The capacity adjustment investment is the difference between the desired production capacity for $t+1$ and what will be the productive capacity in this period if no investment is undertaken. While firms always replace all machines older than $T^k$ (as long as they do not wish to reduce their capital stock), they are more cautious with respect to the expansion of their productive capacity. Thus, the expansion investment is given by the difference between the current full capacity and the desired production capacity in $t+1$ multiplied by the investment adjustment speed ($1 > v > 0$). The replacement investment demand is determined by a payback rule (Dosi et al., 2010; Dweck et al., 2020). A machine is replaced by a new one if its payback period (equation 12) is positive and lower or equal to the fixed threshold $b$.

$$b_{m,t} = \frac{p_{k,t}^{\$}}{\Gamma^{\$}(y_{m,t}^{c}, u^d) - \Gamma^{\$}(y_t^{c,\star}, u^d)} \tag{12}$$

Whenever their internal resources are insufficient to cover their expenses in the beginning of the period (before production and sales take place), firms ask for a loan from the bank. The bank grants all the requested loan as long as the ratio of firms' interest payment to their average revenue in the previous four periods (adjusted to the current price level) is below a maximum ratio $R$. Otherwise, it grants the maximum between the amount required to reach $R$ or the amount required to cover firms' outstanding debt. In the latter case, the current debt is rolled over to the next period but the firms do not receive additional resources.

Consumption goods firms exit the market whenever their market share of the domestic market relative to the domestic firms ( $ms_{c,t}/\sum_{c=1}^{N^c} ms_{c,t}$) is below a threshold given by the $ms^{min}$ parameter, their production capacity is zero, or when they have no deposits available and cannot ask for loans to cover their production or investment projects. Each exited firm is replaced by a new firm. New firms enter the market with a desired production capacity equal to a fraction $1 > \delta > 0$ of the average capital stock of the established firms. They receive all loans requested and are not subject to any exit criterion for $T^c > 1$ periods after their first production period.

### 3.2.1 Sales to the domestic market

Prices of goods sold in the domestic market are set following the same procedure as that in Rolim et al. (2021) and there are two components to firms' mark-up rate. The first component reflects their position *vis-à-vis* other firms (including the foreign sector), as reflected in the evolution of their market shares (equation 13). This equation is adopted in many agent-based models in the literature, such as Dosi et al. (2010) and Dweck et al. (2020). In an open economy context, it means that, whenever the market share of the foreign sector increases, the domestic firms face a reduction in their market share (at least on average), which makes their prices sensitive to international competition in the domestic market. The second component depends on the evolution of the nominal unit labor costs (equation 14), capturing a relevant strategy undertaken by firms when their costs change that leads to an imperfect pass-through of costs on to prices (Bertola et al., 2012; Carlsson and Skans, 2012). This component can be interpreted as summarizing firms' position *vis-à-vis* workers.

$$\mu_{c,t}^{*} = \mu_{c,t-1}^{*}\left[1 + \nu_1\left(\frac{ms_{c,t-1}}{ms_{c,t-2}} - 1\right)\right] \tag{13}$$

$$m_{c,t} = \nu_2 m_{c,t-1} - \nu_3\left(\frac{\Delta\Gamma_{c,t}^{u,\$}(u^d)}{\Gamma_{c,t-1}^{u,\$}(u^d)}\right) \tag{14}$$

where $1 > \nu_1 > 0$ is the sensitivity of the mark-up to the domestic market share, $1 > \nu_2 > 0$ is the persistence in the mark-up deviation, $1 > \nu_3 > 0$ is the sensitivity of the mark-up deviation to changes in unit costs, and $\Gamma_{c,t}^{u,\$}(u^d)$ is firms' unit costs at the desired capacity utilization rate. The final mark-up rate for domestic prices is applied on unit costs computed at the desired capacity utilization rate and is given by $\mu_{c,t}^{*} + m_{c,t}$.[7]

Aggregate domestic demand for domestic goods is split between firms according to their market share. Firms' market shares of the domestic market evolve following a "quasi" replicator dynamics and depend on their competitiveness ($E_{c,t}$), which is given by the average between the normalized price level ($p_{c,t}^{n}$) and normalized unfilled demand level ($l_{c,t}^{n}$) (Dosi et al., 2010; Dweck et al., 2020; Silverberg et al., 1988). Formally, firms' competitiveness is given by equation 15 and their market share is given by equation 16, as follows:

[7] This value is limited by the minimum mark-up rate accepted by firms, which is given by $\mu^{min} > 0$.

$$E_{c,t} = \frac{(1 - p^n_{c,t}) + (1 - l^n_{c,t})}{2} \tag{15}$$

$$ms_{c,t} = ms_{c,t-1}\left(1 + \nu_4 \frac{E_{c,t} - \bar{E}_t}{\bar{E}_t}\right) \tag{16}$$

where $\nu_4 > 0$ is a parameter capturing the market share sensitivity to competitiveness and $\bar{E}_t$ is the average competitiveness of consumption goods firms weighted by firms' market shares in $t-1$. Firms' sales to the domestic market are then given by their market share multiplied by total domestic demand for consumption goods.

### 3.2.2 Sales to the foreign market

A subset of firms will sell to the foreign market in addition to selling to the domestic market, thus gaining access to an additional demand. In line with the literature on firms performance in international markets and reflecting the inherent difficulties in accessing new markets (Bernard et al., 1995, 2012), only firms that have already acquired a considerable size of the domestic market will adventure themselves in the new market represented by the foreign sector, with a certain probability of succeeding in this effort. Additionally, large firms that have already gained access to the foreign market remain as exporters. Formally, this means that, in case a firm was an exporter in the previous period and its market share of the domestic market is greater than or equal to $ms^{exp}$, it will be an exporter in the current period. Firms that were not exporting in the previous period and whose market share of the domestic market is lower than $ms^{exp}$ remain as non-exporters. The exporter status of firms in intermediate cases (exporters whose market share of the domestic market is lower than $ms^{exp}$ and non-exporters whose market share is greater than or equal to $ms^{exp}$) is defined by a Bernouilli draw with probability of success (become an exporter) given by $\iota_1 ms_{c,t-1} / \sum_{i=1}^{N^c} ms_{c,t-1}$, where $\iota_1 > 0$ is a parameter capturing the sensitivity of the probability to export to firms' market share and $\sum_{i=1}^{N^c} ms_{c,t-1}$ is the domestic firms' aggregate market share of the domestic market (excluding exports).[8]

We assume that the domestic and international consumption goods markets are segregated enough so that firms can follow the so-called pricing to market strategy (Krugman, 1986). Pricing to market is one of the reasons why the law of one price is not observed, in addition to transportation costs and tariffs (Rogoff, 1996). As shown by Aucremanne and Druant (2005) and Fabiani et al. (2006), pricing to market is widely adopted by firms and its most relevant determinant is the price of the competitors.

This means that our consumption goods firms price discriminate across these two markets: they apply a specific mark-up rate for setting the reference price in foreign currency and consider also the foreign price level when setting their export prices. The former factor means that firms take advantage of a favorable international scenario to increase their mark-up rates in the foreign market, while the latter factor leads to a limited pass-through from the nominal exchange rate and domestic costs to prices as firms seek to keep their market shares in foreign markets (Warmedinger, 2004). The degree of pricing to market indicates firms' power in that market, which is lower if firms react more to the international price level.

Formally, firms consider an adjustment factor in their mark-up rates depending on their performance in the international market, which is captured by the growth rate of their real exports demand. This adjustment factor is given by equation 17:

$$m^{'}_{c,t} = \nu_2 m^{'}_{c,t-1} - \nu_5 \left(\frac{\Delta X^D_{c,t-1}}{X^D_{c,t-2}}\right) \tag{17}$$

where $\nu_5$ is the sensitivity of the mark-up rate to exports growth and $X^D_{c,t}$ is real export demand. The final mark-up rate for the reference export price is applied on unit costs computed at the desired capacity utilization rate and is given by $\mu^*_{c,t} + m_{c,t} + m^{'}_{c,t}$.

Since exporters also consider the price level prevailing in the international market ($p^x_{x,t}$), export prices denominated in foreign currency are given by:

$$p^x_{c,t} = k p^x_{x,t} + (1 - k)\frac{(1 + \mu^*_{c,t} + m_{c,t} + m^{'}_{c,t})\Gamma^{u,\$}_{c,t}(u^d)}{\epsilon_t} \tag{18}$$

[8] In the first period of the simulation, the exporter status of all firms is determined through the Bernouilli draw.

where $1 \geq k \geq 0$ is a parameter capturing the degree of pricing to market and $\epsilon_t$ is the nominal exchange rate.[9] This equation creates a link between the real exchange rate and firms' mark-up rates, which are now partially endogenous, for which empirical support is provided by Berman et al. (2012).

The quantity exported by firms depends on their market share of the foreign market, as formally expressed in equation 19:

$$ms'_{c,t} = \iota_2(1 - e^{(-p^x_{x,t}/p^x_{c,t})^{(\iota_3)}}) \tag{19}$$

where $\iota_{2,3} > 0$ are parameters capturing, respectively, the maximum market share limit reflecting legal barriers, tariffs, local tastes, and preferences that limit domestic firms' market share of the foreign sector and the price sensitivity of the domestic firms' market share. As the total real demand for consumption goods from the foreign sector is equal to $c_x Y_{x,t}$, with $c_x$ being the foreign sector's propensity to consume, the export demand for exporting firms in real terms is equal to:

$$X^D_{c,t} = ms'_{c,t} c_x Y_{x,t} \tag{20}$$

Firms' realized exports depends on whether their supply capacity (previous inventories level plus current period production) is enough to fulfill the total (domestic and foreign) demand for their production. If supply is greater than or equal to demand ($Q_{c,t} + Q^{IN}_{c,t-1} \geq Q^D_{c,t}$), firms' realized exports are equal to the demand for exports ($X^D_{c,t}$) and their total sales are equal to total demand ($Q^s_{c,t} = Q^D_{c,t}$) . Yet, if that is not the case ($Q_{c,t} + Q^{IN}_{c,t-1} < Q^D_{c,t}$), firms sales are limited by their supply capacity ($Q^s_{c,t} = Q_{c,t} + Q^{IN}_{c,t-1}$) and they have to choose how to allocate it to their foreign and domestic customers. We assume that firms follow a simple rule of thumb according to which the same share of each type of demand is fulfilled, as reported in equation 21 for exports.[10]

$$X_{c,t} = \frac{Q^s_{c,t}}{Q^D_{c,t}} X^D_{c,t} \tag{21}$$

## 3.3 Bank

The banking sector is composed by a monopolist bank, which grants credit to creditworthy firms, holds remunerated deposits and buys bonds from the government. For simplicity, the bank sets the interest rate for deposits and loans equal to the interest rate set by the central bank ($i_t$). The bank is also the only agent that acts in the exchange market, trading domestic and foreign currencies for domestic and foreign clients. As explained in section 3.8, it is assumed that the exchange rate is affected by commercial and financial factors, but the latter are not explicitly modeled given our focus on commercial flows. Thus, the bank either accumulates foreign currency or gets indebted with the foreign sector in order to guarantee that the foreign reserves demanded by private agents are available.[11]

## 3.4 Households

As in the original model reported in Rolim et al. (2021), households are split into three heterogeneous social groups: direct workers, indirect workers, and capitalists (Mohun, 2016). The share of each group in the total of households is calibrated to reproduce the Brazilian social structure (Baltar and Rolim, 2018). These social groups are characterized by specific relations with the production process, which also associated with different income levels.

The desired wage by workers depends on the macroeconomic environment, their individual employment experience, and their previous wage level. It is based on the previous strictly positive wage received by the workers (i.e. the wage received in the workers' last job) adjusted by the inflation rate (if positive). Then, workers who were employed in the previous period increase this wage by a parameter $\gamma_1$ times the growth rate of the economy in the previous period (if positive), while workers who were unemployed in the previous period adjust the wage downward proportionally to the number of periods since their last employment multiplied by the parameter $\gamma_2$, as shown in equation 22:

[9] Note that this equation also includes two extreme options. If $k = 1$ firms are price-takers in the international market, while if $k = 0$ they do not discriminate prices between the domestic and foreign markets (if also $\nu_5 = 0$). In the former scenario, a domestic currency depreciation has a direct effect on the exporters' revenue in domestic currency, leading to a higher (*ex-post*) mark-up rate. This has direct implications to the income distribution, as emphasized by Rossi and Galbraith (2016). In the latter scenario, a domestic currency depreciation may also increase exporters' revenue, but this occurs through their increased international competitiveness (since export prices denominated in foreign currency may be lower). In intermediate scenarios (when $1 > k > 0$), a combination of both effects is observed. Also in this case the price level has a minimum floor set by the minimum mark-up rate accepted by firms ($\mu^{min}$).

[10] For instance, if $Q^s_{c,t}/Q^D_{c,t} = 0.5$, 50% of the foreign demand and 50% of the domestic demand is fulfilled. Note that this implies that firms do not fulfill relatively more of the type of demand whose price is higher in domestic currency (due to price discrimination, export prices converted to domestic currency can be different from prices in the domestic consumption goods market). Nevertheless, the more important adjustment is simply an increase in the desired production level in the following period.

[11] For simplicity, this credit is infinitely elastic at the current international interest rate. Thus, in this framework, the domestic monopolistic bank is not internationally credit-constrained. As mentioned, this derives from our focus on trade flows. A relevant extension of our model would be to explicitly model these and other financial constraints in order to better incorporate financial relations between the domestic and foreign sectors.

$$w_{h,t}^{d,\$} = \begin{cases} w_{h,t}^{d,*,\$}(1+\gamma_1 g_{t-1}\mathbf{1_g}) & \text{if } T_{h,t}^{w}=0, \\ w_{h,t}^{d,*,\$}(1-\gamma_2 T_{h,t}^{w}) & \text{otherwise.} \end{cases} \tag{22}$$

where $w_{h,t}^{d,*,\$}$ is the most recent strictly positive nominal wage adjusted by the inflation rate, $T_{h,t}^{w}$ is the number of periods the worker has been unemployed since her last employment (if employed in $t-1$, $T_{h,t}^{w}=0$), $g_{t-1}$ is the previous period private aggregate demand growth rate,[12] $\mathbf{1_g}$ is and indicator function that takes the value of one if $g_{t-1}>0$ and zero otherwise, and $\gamma_{1,2}>0$ are parameters that capture the sensitivity of the desired wage to the output growth rate and to the individual unemployment status respectively.[13]

Whenever the wage offered by the current employer is below their individual desired wage and below the average wage in the market, workers consider looking for a new job. This decision is based on a random draw from a Bernoulli distribution with the probability of success given by a parameter $s$ multiplied by the percentage difference between the wage offered by the current employer and the average wage in the market. When employed workers search for new job positions while still being employed, they accept a job offer if the wage offered is above the wage offered by their current employer. On the other hand, unemployed workers are always looking for new job positions and accept any offer made by firms.

Households consumption is the maximum between a fraction of their previous real consumption and a desired consumption level that depends on their income (considering class-specific propensities to consume) and wealth (deposits):

$$C_{h,t}^{D,\$} = max\left(c_1 \frac{C_{h,t-1}^{D,\$}}{\bar{p}_{t-1}^{C,\$}}\bar{p}_t^{C,e,\$},\ c_2^j((w_{h,t}^{\$}+\Pi_{h,t-1}^{h,\$})(1-\tau)+d_{h,t}^{\$})) + c_3 D_{h,t}^{\$,*}\right) \tag{23}$$

where $1>c_1>0$ is the real consumption persistence, $\bar{p}_t^{C,e,\$}$ is the weighted average price in $t$,[14] $\bar{p}_{t-1}^{C,\$}$ is the weighted average price in the previous period, $1>c_2^j>0$ is the propensity to consume out of income for each class $j=dir,ind,cap$, $w_{h,t}^{\$}$ is the wage earned by the household, $\Pi_{h,t-1}^{h,\$}$ is the profit dividends from the previous period, $d_{h,t}^{\$}$ is the tax-exempt unemployment benefit received by unemployed workers, $\tau$ is the tax rate on income, $c_3$ is the propensity to consume out of wealth, and $D_{h,t}^{\$,*}$ is the households' deposits in the beginning of the period (minus the past profits). Since households cannot get indebted, their consumption level may be limited by their current resources.

## 3.5 Public sector

The public sector is composed of a government and a central bank. The government collects taxes on households' income at a tax rate $\tau$ and on interest payments on deposits at a tax rate $\tau^i$. It pays unemployment benefits to unemployed workers at a value equal to the minimum wage ($w_t^{min,\$}$), which is adjusted by the average wage inflation rate in the previous period.[15] When a worker becomes unemployed, the unemployment benefit is paid for a maximum of $T^u$ periods or until she finds a new job. The public sector also hires a fixed number of direct and indirect workers as public servants ($L_g^{dir}$ and $L_g^{ind}$), who are paid the average wage paid for their class in the consumption goods sector. These workers are not subject to any turnover.

The central bank follows the inflation targeting regime and adjusts the nominal interest rate depending on the inflation gap (realized inflation rate minus inflation target).[16] We assume that there is a partial adjustment process of the interest rate, so that the actual nominal interest rate depends on the desired nominal interest rate (i.e., the nominal interest rate level that reflects the current inflation gap) and the past nominal interest rate, as follows in equation 24. This inertial behavior of the nominal interest rate is adopted to avoid a high frequency of large fluctuations in the rate.

$$i_t = (1-\lambda_1)[\bar{\hat{p}}_{t-1}+\lambda_2(\bar{\hat{p}}_{t-1}-\hat{p}^T)]+\lambda_1 i_{1-1} \tag{24}$$

where $\lambda_1$ is the smoothing parameter of the nominal interest rate, $\bar{\hat{p}}_{t-1}$ is the average inflation rate in the previous $T^p$ periods, $\lambda_2$ is the sensitivity to the inflation gap, and $\hat{p}^T$ is the inflation target.[17]

[12] Since these agents are negotiating with the firms, they consider the growth rate in private aggregate demand.

[13] There is a maximum real growth rate for the desired wage which is given by $\hat{w}^{max}$. Also, the desired wage by workers has a lower limit represented by the minimum wage.

[14] This is an expected value because it considers firms' market share in $t-1$, while the realized average price level is based on their effective share of sales in the current period. The foreign sector is considered in both cases.

[15] As in the case of workers' desired wage, there is a maximum growth rate for the minimum wage in real terms, which is given by $\hat{w}^{max}$.

[16] For simplicity, we assume that the monetary authority does not consider the output gap.

[17] There is also a minimum nominal interest rate $i^{min}>0$ in order to assure that it is always strictly positive. This reflects the effective lower bound adopted by the central bank.

### 3.6 Labor market

The labor market structure is the same as that reported in Rolim et al. (2021). Thus, firms follow an internal pay structure (Bewley, 2007; Galuscak et al., 2012), according to which workers from the same class at the same firm earn the same wage. There is downward rigidity in nominal wages (Bewley, 2007; Dickens et al., 2007). At each period, firms have a desired wage, which is based on the previous nominal wage and the change in the unemployment rate, as follows:[18]

$$w_{f,t}^{j,d,\$} = w_{f,t-1}^{j,\$}(1 + \gamma_3(\eta_{t-1} - \eta_{t-2})) \tag{25}$$

where $w_{f,t-1}^{j,\$}$ is the previous wage level, $\gamma_3$ is the sensitivity of firms' desired wage to the unemployment rate, and $\eta_t$ is the employment rate.

The wage level is a weighted average between the desired wage by firms and the wage desired by workers assessed through a random survey with a proportion $n^{s,j}$ of the demand for workers. The survey is a metaphor to how firms gather information from the labor market when setting nominal wages (Bewley, 2007; Cullen et al., 2022). The weight given to the latter depends on workers' bargaining power, which is given by a parameter $\phi$ (capturing institutional factors) multiplied by the employment rate (capturing cyclical factors), as follows in equation 26:

$$w_{f,t}^{j,\$} = (1 - \phi\eta_{t-1})w_{f,t}^{j,d,\$} + \phi\eta_{t-1}w_{f,t}^{j,s,\$} \tag{26}$$

where $1 > \phi > 0$ is a fixed parameter capturing the sensitivity of workers' bargaining power to the employment rate. Firms that could not hire all workers in the previous period interpret the wage adjustment rule described in equation 26 as having been insufficient and thus increase this value proportionally to a parameter $\gamma_4 > 0$ times the percentage of unfilled job positions relative to the total demand for workers in the previous period.

Given the nominal wage level and firms' labor demand, a random list of firms is formed with the capital goods firm always being in the first position. The first firm tries to match with an indirect and a direct worker by randomly selecting a worker of each type. Workers accept an offer if the offered wage is above their reservation wage; otherwise, the hiring round will have been unsuccessful. After this, the second firm starts its hiring round and so on until all firms in the list have executed one hiring round for each type of worker. The process iterates until all firms have filled all open positions or reached the maximum number of hiring rounds for each type of worker, given by a multiple $n^w \geq 1$ of the number of open positions. Note that workers are fired if firms' demand for workers is lower than the current number of employees (i.e., there is no labor hoarding) or to meet the employees turnover target (given by the $1 > \vartheta > 0$ parameter)

### 3.7 Foreign sector

We assume that the foreign sector sells imported goods to households through an intermediary that is part of the domestic consumption goods market. The price of imported goods in domestic currency is given by the foreign price level multiplied by the nominal exchange rate, as follows:[19]

$$p_{x,t}^{\$} = p_{x,t}^{x}\epsilon_t \tag{27}$$

In each period, the foreign sector's market share of the domestic demand for consumption goods ($ms_{x,t}$) is determined by its price competitiveness *vis-à-vis* domestic producers, as follows:

$$ms_{x,t} = \iota_4(1 - e^{(-\bar{p}_t^{C,*,\$}/p_{x,t}^{\$})^{(\iota_5)}}) \tag{28}$$

where $1 > \iota_{4,5} > 0$ are parameters capturing the maximum market share for the foreign sector, which reflects legal barriers, tariffs, local tastes, and preferences that limit the foreign sector's share of the domestic market, and the sensitivity of the foreign sector's market share to price competitiveness, respectively, and $\bar{p}_t^{C,*,\$}$ is the average price level of domestic producers.[20]

Consequently, the real imports demand is given by the market share of the foreign sector multiplied by the real demand of the domestic consumers.[21] In domestic currency, the aggregate import demand is given by equation 29. Since, for simplicity, we assume that the foreign sector (through an importer firm) can always fulfill the domestic sector's demand for imported goods,[22] this value is also equal to the realized nominal imports in domestic currency.

$$IM_t^{D,\$} = IM_t^{\$} = ms_{x,t}p_{x,t}^{\$}\sum_{h=1}^{N^h} C_{h,t}^{D} \tag{29}$$

where $\sum_{h=1}^{N^h} C_{h,t}^{D}$ is the households' real consumption demand.

[18] There is also a limit for the real wage growth desired by firms, which is given by $\hat{w}^{max}$.

[19] For simplicity and focus on the main issues of interest in this article, we abstract from transportation costs.

[20] After $ms_{x,t}$ is set, domestic firms' market shares (equation 16) are rescaled so that the sum of their market shares is equal to $1 - ms_{x,t}$.

[21] As in the closed economy model version, this demand is simply the households' nominal demand divided by the average price level in the market weighted by the sellers' market shares.

[22] In other words, the supply of the imported goods is infinitely elastic at their current price.

### 3.8 Exchange rate dynamics

Given the simplified structure of our open economy model, we follow an exchange rate determination process similar to that in Dosi et al. (2019). Formally, we assume that the exchange rate dynamics depends on the previous period nominal trade balance and on the change in the nominal interest rate differential relative to the international nominal interest rate, as follows:[23]

$$\epsilon_t = \epsilon_{t-1}\left(1 - \lambda_3 \frac{X^{\$}_{t-1} - IM^{\$}_{t-1}}{Y^{\$}_{t-1}} + \lambda_4 \sum_{i=1}^{T^e} \Delta i^{dif}_{t+1-i}\right) \tag{30}$$

where $\lambda_{3,4} \geq 0$ are fixed parameters capturing the sensitivity of the nominal exchange rate to the trade balance and to the interest rate differential respectively, $i^{dif}_t = i_x - i_t$ is the interest rate differential between the foreign and domestic sectors, and $T^e$ is the number of periods that the exchange rate takes to adjust to a change in the interest rate differential.

The real exchange rate is defined as:

$$\epsilon^r_t = \frac{\epsilon_t p^x_{x,t}}{\bar{p}^{C,*,\$}_t} \tag{31}$$

### 3.9 Sequence of events

In each simulation period, the sequence of events is the following:

1. The central bank sets the nominal interest rate;
2. The nominal exchange rate is determined;
3. Consumption goods firms set desired production levels and prices;
4. Exporter firms are selected;
5. Nominal wages are set;
6. Capital goods firm sets the price and the technologies used and embodied in new machines;
7. Credit market opens;
8. Consumption goods firms set investment demand and all firms set labor demand;
9. Labor market opens;
10. Production and R&D activities take place;
11. Unemployment benefits and wages are paid;
12. Households set their nominal consumption demand and the foreign sector sets its demand for domestic goods;
13. Market shares in the domestic and foreign consumption goods markets are determined and consumption takes place;
14. Taxes are paid;
15. New machines are delivered and old machines are scrapped;
16. National accounts and statistics are computed;
17. Exit and entry of consumption goods firms take place.

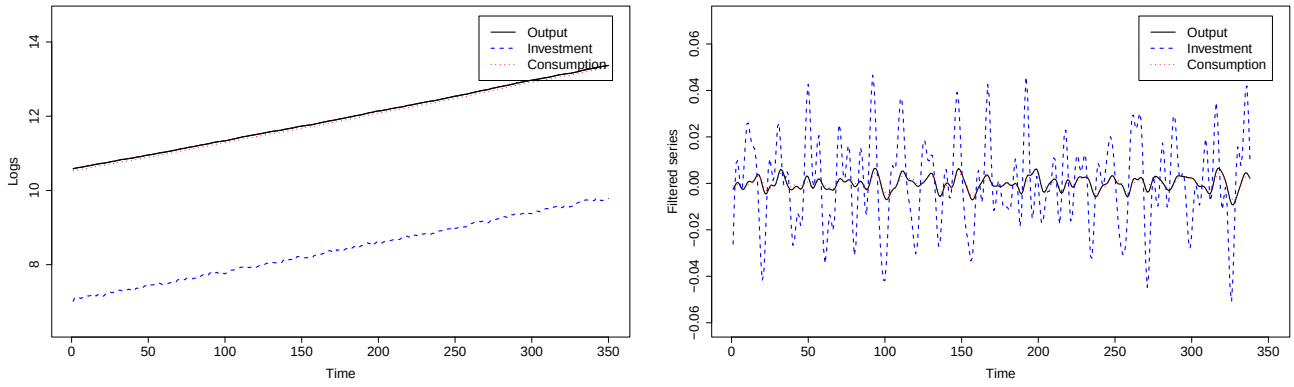
## 4 Model validation

This section analyzes the ability of the model to reproduce key stylized facts reported in the empirical literature. We extend our analysis beyond the stylized facts reported in Rolim et al. (2021) by incorporating stylized facts related to open economy variables and also referring to studies that focus more specifically on developing economies.[24] The model is simulated for 600 periods (250 transient periods and 350 considered periods). This section reports the main average results for the 100 Monte Carlo simulations for the baseline scenario, whose parameters are reported in the Appendix.

We find that domestic output presents a sustained growth pattern with fluctuations (figure 2). With respect to the domestic components of aggregate demand, we find that consumption is less volatile than output and that investment is more volatile than output (Carlin and Soskice, 2014): the standard deviation relative to that of output is equal to 0.783 and 7.919 for consumption and investment respectively. In developing economies, nonetheless, consumption may be more volatile than output, but it is always less volatile than investment (Jacobo and Marengo, 2020), as reproduced in our model.

[23] Arguably, this is a simplification of the dynamics of the nominal exchange rate. Nevertheless, such a simplification allows us to focus on some specific factors affecting the nominal exchange rate that are more aligned with our purpose in this article, while assuming that the other factors remain constant.

[24] In this section we also report a few of the stylized facts that were reproduced by Rolim et al. (2021). Yet, it should be mentioned that the model structure is robust and the stylized facts analyzed in Rolim et al. (2021) are also reproduced in the open economy model outlined in this article. In particular, we highlight the ability of the model in reproducing stylized facts related to the income distribution dynamics, which suggests that it provides an adequate framework for investigating our research question.

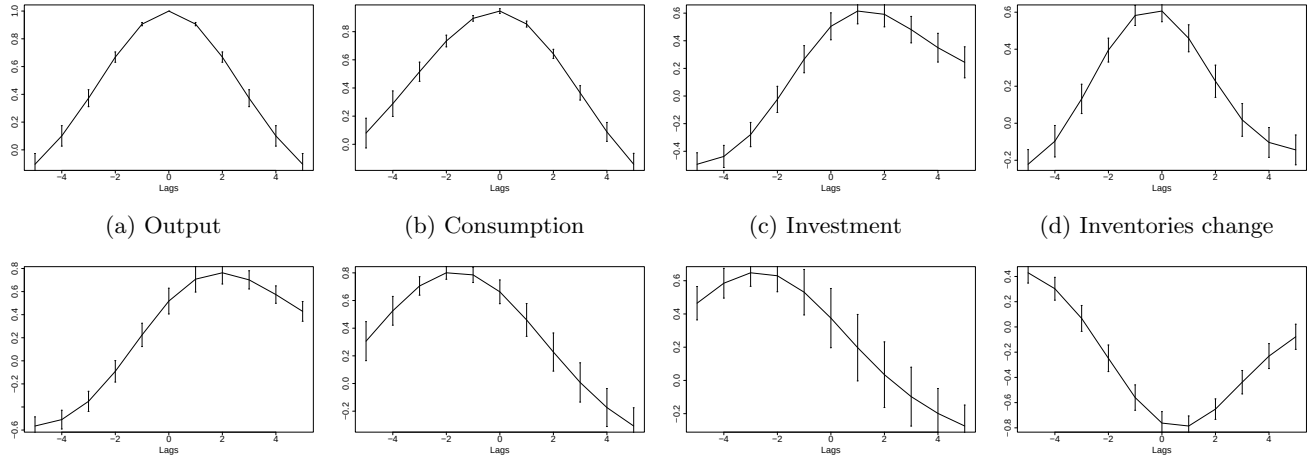



(a) Level (logs) (b) Cycle (Bpf)

**Fig. 2**: Output, consumption, and investment

Note: Series represent average of 100 Monte Carlo runs. All series are taken in logarithm. Bpf: bandpass-filtered (6,32,12). Source: author's own elaboration based on simulation results.

Figure 3 reveals additional information concerning the cyclical components of selected macroeconomic series obtained through the bandpass filter. As reported in Rolim et al. (2021), we find that consumption, investment, change in inventories, and labor productivity are procyclical, while the unemployment rate is countercyclical (Agenor et al., 2000; Toledo, 2008; Stock and Watson, 1999). In addition, we find that real aggregate exports and real aggregate imports are procyclical.[25]




(a) Output (b) Consumption (c) Investment (d) Inventories change

(e) Exports (f) Imports (g) Labor productivity (h) Unemployment rate

**Fig. 3**: Cross-correlations structure for output

Note: Bpf: bandpass-filtered (6,32,12). Output, consumption, investment, change in inventories, average productivity, exports and imports series are all taken in logarithm. Bars are standard deviations of 100 Monte Carlo average cross-correlations. Source: author's own elaboration based on simulation results.

In line with empirical evidence, we find that the real and nominal exchange rates are positively correlated (Agenor et al., 2000), presenting a correlation coefficient of 0.949 (standard deviation equal to 0.03).

At the micro level, the model also reproduces empirical regularities concerning firms' penetration in international markets (table 1). In line with the evidence reported by Bernard et al. (1995, 2003, 2012), we find that only a fraction of the firms are exporters. In addition, these exporter firms are larger and more productive than non-exporting firms. Thus, firms are also heterogeneous with respect to their trade relations with the foreign sector and the model endogenously reproduces a key empirical finding indicating that exporters tend to be more productive than other firms.

[25]It should be noted that these stylized facts are not necessarily observed in all developing economies, since not all of these economies present procyclical real aggregate exports (Jacobo and Marengo, 2020).

**Table 1**: Exporters

| Variable | Average | Standard deviation |
|---|---|---|
| Ratio of exporters (of total consumption goods firms) | 0.335 | 0.022 |
| Size (exporters relative to non-exporters) | 4.252 | 0.503 |
| Productivity (exporters relative to non-exporters) | 1.086 | 0.033 |

Note: Averages across 100 Monte Carlo runs. Source: author's own elaboration based on simulation results.

# 5 Foreign shocks, output, income distribution, and inflation

The aim of this article is to investigate how external shocks affect the economic activity, inflation, and the income distribution of a small, open economy. Income distribution in this artificial economy is determined by a social conflict that presents a multitude of determinants, most of which are likely to be directly or indirectly influenced by external shocks. Indeed, the effect on income distribution largely depends on how external shocks affect the relative strength of the different groups through different channels, which depends on the underlying economic structure. While distributional changes affect the economic activity, the external shocks are also expected to affect output directly through changes in imports and exports. Similarly, changes in output can be a further factor influencing income distribution following an external shock. The changes in the conflict over income distribution also have implications to the inflation dynamics, which is further impacted by changes in the nominal exchange rate and foreign price levels. Thus, the experiments reported below capture this coevolutionary dynamics between income distribution, economic activity, and inflation rates that is already present in the model and is now disturbed by external shocks.

We investigate and compare the effect of two types of external shocks with different magnitudes, signs, and durations to analyze how these shocks and their characteristics affect the system. The first experiment consists on applying a temporary shock on the foreign output growth rate, which represents an external demand shock for the domestic economy. The second experiment consists on applying a temporary shock on the foreign price inflation rate, which has implications for the domestic economy's terms of trade.[26] Given the different natures of each type of shock, their impacts on the domestic economy operate through different mechanisms and, thus, lead to different economic and distributional outcomes. All scenarios are compared with the baseline scenario reported in the previous section, in which there are no shocks.

## 5.1 Foreign output growth rate shocks

In our first experiment, we investigate the effect of temporary shocks on the foreign output growth rate on the dynamics of the domestic economy. This experiment intends to capture key mechanisms that operate in an economy when there is a context of higher (or lower) world output growth rates, which can have a direct effect on domestic output through exports. The different scenarios configurations with shocks of different magnitudes, signs, and durations on the foreign output growth rate ($g_x$) are reported in table 2 below. The periods of the shocks refer to the time span after the transient phase (that is, during the considered simulation periods).

**Table 2**: Design of experiments (shocks on $g_x$)

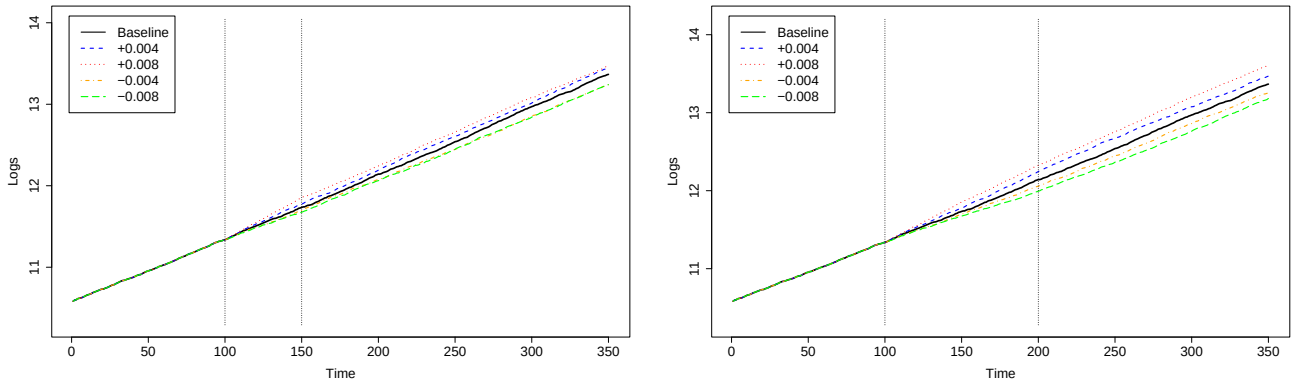
| Experiment | Period | $\Delta g_x$ | | | |
|---|---|---|---|---|---|
| 1 | 50 to 100 | + 0.004 | + 0.008 | - 0.004 | - 0.008 |
| 2 | 50 to 150 | + 0.004 | + 0.008 | - 0.004 | - 0.008 |

Note: Source: authors' own elaboration.

As expected, a positive foreign demand shock is associated with an increase in the domestic output level (figure 4), which is not reverted when the foreign output growth rate returns to the baseline value. Despite the different magnitudes, output levels do not clearly differ between both positive shocks on $g_x$ when they are applied from period 50 to 100. This is related to the behavior of the growth rates during and after the shocks, as discussed in the end of this section (see table 3). Yet, despite not presenting a clear difference between the two shocks of different magnitudes, both of them lead to a higher output growth rate if compared to the baseline scenario, indicating at least a persistent level effect. The negative foreign demand shocks are associated with lower domestic output levels. In this case, the difference between both magnitudes are much clearer when the shock is applied from 50 to 150, with the output level being even lower and more persistently affected when the magnitude of the negative shock is larger.

The foreign demand stimulus also leads to lower unemployment rates (figure 5), which stabilize at different levels after the shock is reverted. Such a decrease in the unemployment rate increases workers' power in the nominal wage bargaining process and increases the number of employed workers, who desired an increase in their

[26] Albeit affecting directly one component of the terms of trade (the foreign price level), such shock also affects indirectly its other components (nominal exchange rate and domestic price inflation) as discussed in the analysis of the experiments.

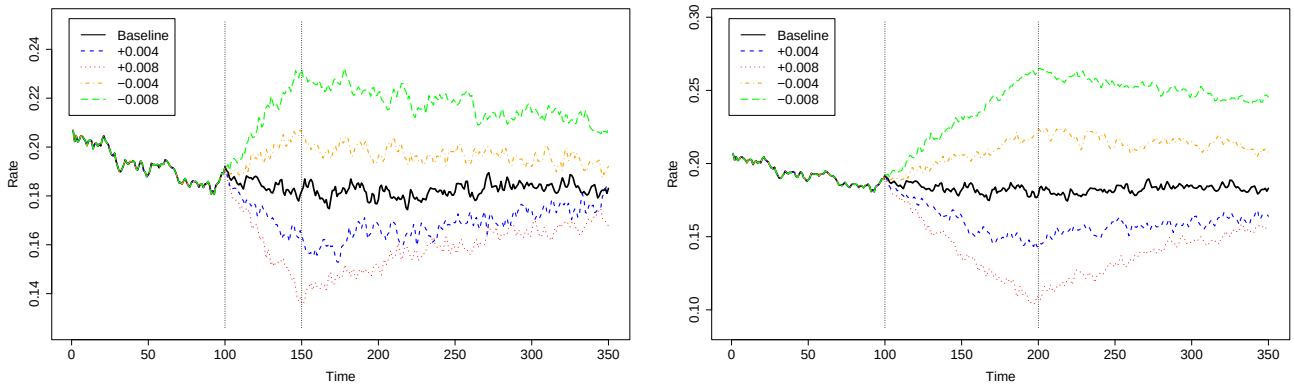



(a) Exp. 1 (b) Exp. 2

**Fig. 4**: Comparison of experiments: output level in logs (shocks on $g_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

real wage. These processes lead to higher nominal wages, which are partially passed-on to prices. Therefore, the inflation rate also tends to be higher when there is an increase in $g_x$ (figure 6). Such increase in the inflation rate triggers a response of the central bank, and higher levels of the nominal interest rate are observed as well (figure 7). In the case of the negative shocks on $g_x$ the response is quite symmetric, with higher unemployment rates and lower inflation and interest rates being observed.

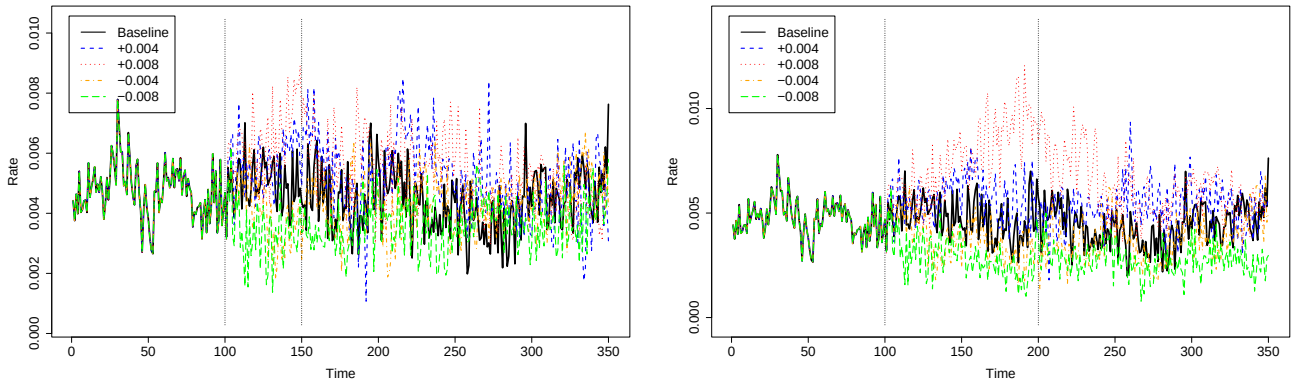



(a) Exp. 1 (b) Exp. 2

**Fig. 5**: Comparison of experiments: unemployment rate (shocks on $g_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

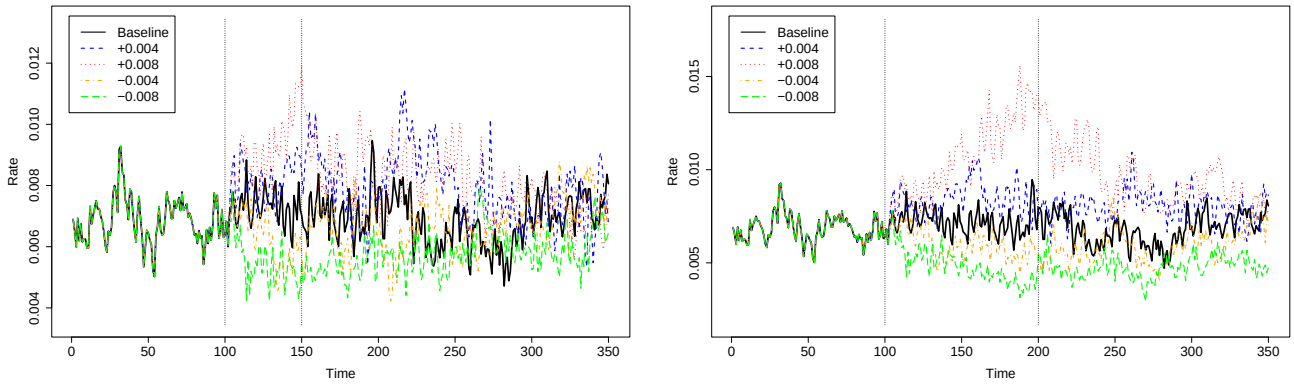
The combination of the foreign demand shock and the resulting higher inflation and interest rates has important implications for how the nominal and the real exchange rates behave (figures 8 and 9 respectively). Since the scenarios with higher values of $g_x$ are those experiencing nominal trade balance surpluses (due to the higher external demand) and higher nominal interest rates, these scenarios present a tendency of nominal exchange rate appreciation. The real exchange rate, which is described by equation 31, tends to decrease due to this nominal exchange rate appreciation, but also due to the higher domestic inflation rate resulting from the positive shock on $g_x$ (in this scenario, the foreign inflation rate is kept constant). Consequently, these scenarios present a lower real exchange rate, which is not reverted after the shock is over. It is interesting to note that the domestic currency appreciation during the period of the shock operates to reduce the increase in export growth, as firms' competitiveness reduces, but this is insufficient to fully compensate the positive shock on exports due to the increase in the foreign demand. Also in this case, the effect of negative shocks is almost symmetric, with negative shocks on $g_x$ leading to higher nominal and real exchange rates.




(a) Exp. 1 (b) Exp. 2

**Fig. 6**: Comparison of experiments: inflation rate (shocks on $g_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

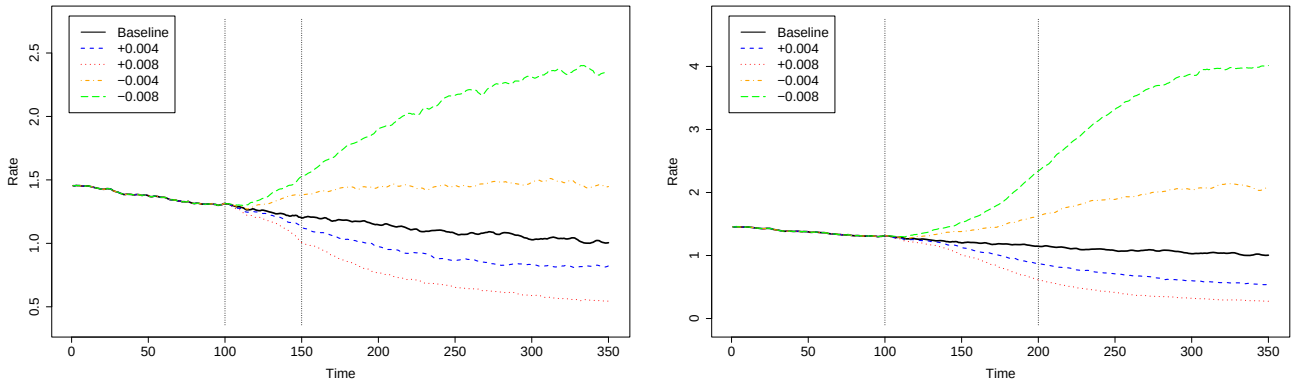



(a) Exp. 1 (b) Exp. 2

**Fig. 7**: Comparison of experiments: nominal interest rate (shocks on $g_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

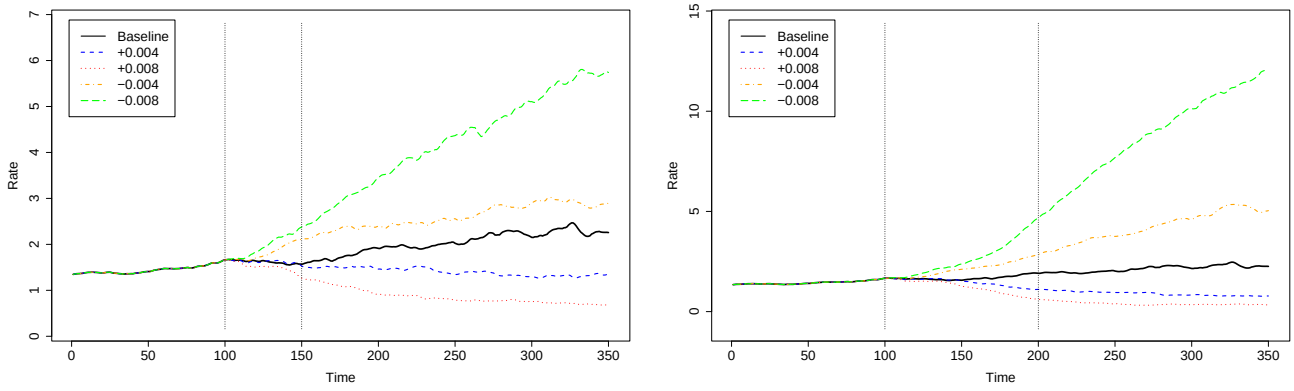
Income distribution is significantly affected by positive shocks on $g_x$ (figures 10 and 11). Indeed, positive shocks on $g_x$ are associated with a higher wage share and lower Gini index, especially after the shock is reverted. As previously discussed, there are several factors that affect the relative strengths of capitalists and workers in the model and explain the observed dynamics of the income distribution. Considering first the dynamics of the functional income distribution, a key factor is how workers' bargaining power evolve. Indeed, by stimulating economic activity and leading to a lower unemployment rate, positive shocks on $g_x$ increase workers' bargaining power, which translates into stronger nominal wage adjustments. These adjustments pressure downwards firms' mark-up due to an increase in unit labor costs. Yet, there are other channels through which the foreign sector affects prices and mark-up rates in this economy. While profits are positively affected by the export growth stimulated by the higher foreign output growth rates, which leads to a positive adjustment in the mark-up rate used to calculate export prices, there are other factors that exert a negative effect and lead to a lower mark-up rate. Indeed, despite the increase in the mark-up rate for export prices, such prices are negatively affected by the currency appreciation, which reduces the value in domestic currency of one of its components (the foreign price level) in an *ex-post* manner. In net terms, this effect may compensate the first effect. With respect to prices of domestic goods, since the domestic currency real appreciation leads to an increase in the foreign sector's market share of the domestic market, firms react by decreasing the mark-up rate set on domestic prices. Thus, the functional income distribution results from the complex interaction between all of these determinants, and overall there is a positive association between positive shocks on $g_x$ and the wage share. The dynamics of the functional income distribution has direct implications for the personal income distribution, since a higher wage share represents a higher average




(a) Exp. 1 (b) Exp. 2

**Fig. 8**: Comparison of experiments: nominal exchange rate (shocks on $g_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.




(a) Exp. 1 (b) Exp. 2

**Fig. 9**: Comparison of experiments: real exchange rates (shocks on $g_x$)

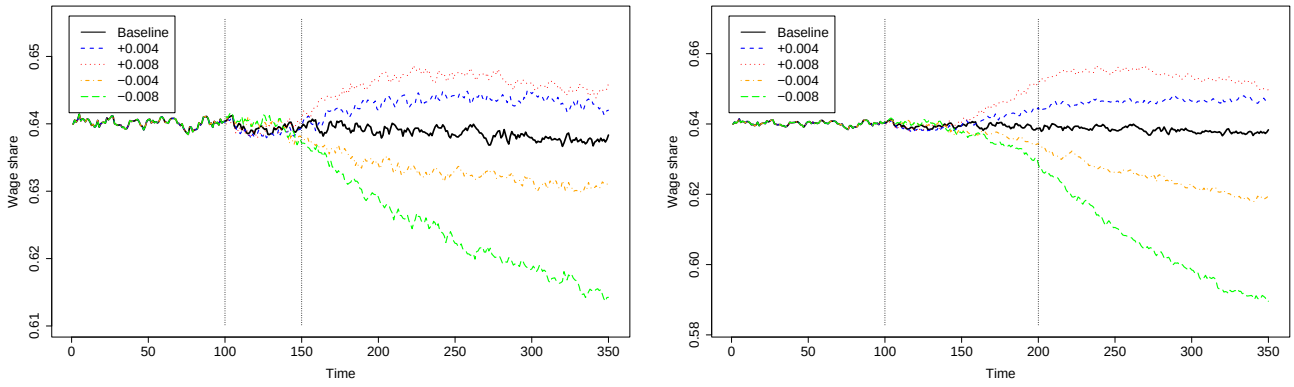
Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

income to classes that tend to earn a lower income and whose income is more equally distributed (Daudey and García-Peñalosa, 2007; Wolff and Zacharias, 2013).

The negative shocks on $g_x$ lead to an increase in income inequality. Such effect on income inequality is also the combination of two factors associated to the social conflict over income distribution: while the lower $g_x$ leads to an increase in unemployment, which leads to higher mark-up rates through the behavior of production costs, it is also associated with lower inflation rates, which increase firms' international competitiveness and leads to further increases in the mark-up rate. Thus, in an open economy firms take advantage of low workers' bargaining power also through the improvement in their international competitiveness: not only wage increases are lower, which allows firms to adjust upward their mark-up rates, but also the lower growth rate of prices (given that costs are growing less) improve firms' position in the foreign market and allow them to further increase their mark-up rates.

Overall, the magnitude, sign and duration of the shocks are important for the dynamics of our variables and their long-run behavior (when $g_x$ has returned to the baseline value).[27] In order to better understand each scenario, table 3 reports the average values of key variables for the periods during and after the shocks on $g_x$ and compares them with the average values observed for the baseline scenario. With respect to the positive shocks on $g_x$, it is possible to observe that the domestic output growth rate increases during the period of the shock, and that such increase relative to the baseline is the larger, the larger the shock on $g_x$ is. Yet, in the period after the shock the growth rates are not always statistically different from the baseline, indicating only a persistent level effect

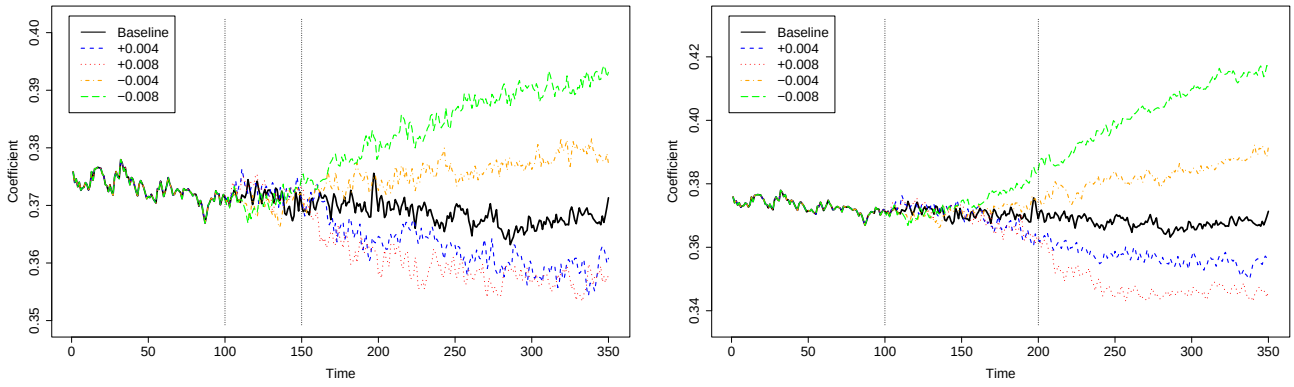
[27] In the following analysis and in the remaining of this article, we adopt a significance level of 10%.




(a) Exp. 1 (b) Exp. 2

**Fig. 10**: Comparison of experiments: wage share (shocks on $g_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.




(a) Exp. 1 (b) Exp. 2

**Fig. 11**: Comparison of experiments: income Gini coefficient (shocks on $g_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

on output in two cases (+0.008 shock from 50 to 100 and +0.004 shock from 50 to 150). On the other hand, distributional changes tend to be statistically significant and persist in the long run in all cases: positive shocks on $g_x$ are associated with higher wage shares and lower income Gini coefficients, and the differences relative to the baseline scenario increase with the magnitude and duration of the shock. These effects are not statistically significant during the period of the shock, probably because they take longer to be completed, but are significant in the period after the shock. The only exception is the +0.004 shock from 50 to 100 for the wage share, which is not statistically different from the baseline. Given the loss in price competitiveness associated with the real exchange rate appreciation, in the period after the shock the market share of domestic firms of the foreign market (market share exports) tends to be lower than in the baseline scenario, while the market share of the foreign sector of the domestic market (market share imports) is higher. This means that, when the shock is over, the export dynamics is negatively affected by the loss in price competitiveness, since the demand effect is no longer present. As a result, there is a reduction in the share of exports in output when the shock is over. Thus, while the effect on output growth rates is clear during the shock, its persistence in the long run depends on the interaction between domestic consumption and international competitiveness. Indeed, a more equal income distribution tends to be associated with more domestic consumption (given that lower classes tend to consume more out of their income) and more loss in price competitiveness (as higher workers' bargaining power is associated with higher inflation rates). If the former effect compensates the latter effect on exports and imports, a higher output growth rate can be sustained in the long run. Yet, when the former effect is not enough to compensate the latter effect, the average output growth rate can be lower.

The dynamics generated by the negative shocks on $g_x$ tends to go on the opposite direction. In this case, the output growth rates are statistically smaller than the baseline scenario only during the shocks, while the worsening in income distribution is statistically significant even after the shock for most cases. Since the worsening in income distribution results from a reduction in workers' bargaining power due to the increase in unemployment rates following the negative shocks on $g_x$, there is also a lower inflation rate, which leads to an increase in firms' international competitiveness. Yet, such improvement in firms' international competitiveness is insufficient to compensate the negative effect of the worsening in income distribution and stimulate higher output growth rates.

In sum, the analysis of the positive and negative shocks on $g_x$ highlights the importance of the interaction between domestic and foreign demands for the output dynamics and, consequently, the interaction between income distribution and international price competitiveness. In the short run, shocks on $g_x$ tend to be positively related with the output growth rate, since they alter the exports dynamics, which can stimulate (or hamper) output growth. In the long run, when the shock is over, there is a statistically significant difference in income distribution (shocks on $g_x$ are negatively related to inequality) and in the domestic firms' price competitiveness, since output growth tends to be followed by nominal wage negotiations that lead to higher inflation rates. Thus, the long-run dynamics of the economy depends on the interaction between income distribution and price competitiveness effects. Indeed, a lower price competitiveness is not a factor that necessarily inhibits economic growth in the long run, as it may be associated with more domestic consumption due to the improvement in income distribution. Nonetheless, this is not guaranteed for all cases, since price competitiveness may exert a dominant role in specific scenarios, as discussed above.

**Table 3**: Summary statistics for shocks on $g_x$

| Exp. 1 (Shock period: 50 to 100) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Period | Total | During | | | | | | | | After | | | | | | | |
| Scenario | Baseline | +0.004 | | +0.008 | | -0.004 | | -0.008 | | +0.004 | | +0.008 | | -0.004 | | -0.008 | |
| Variable | Average | Ratio | p-val | Ratio | p-val | Ratio | p-val | Ratio | p-val | Ratio | p-val | Ratio | p-val | Ratio | p-val | Ratio | p-val |
| Output growth rate | 0.0077 | 1.0622 | 0.1282 | 1.2616 | 0.0000 | 0.8936 | 0.0146 | 0.8430 | 0.0001 | 1.0454 | 0.1016 | 1.0142 | 0.6036 | 0.9764 | 0.3716 | 0.9957 | 0.8637 |
| Unemployment rate | 0.1856 | 0.9349 | 0.0220 | 0.8762 | 0.0000 | 1.0595 | 0.0463 | 1.1333 | 0.0000 | 0.9069 | 0.0003 | 0.8535 | 0.0000 | 1.0603 | 0.0250 | 1.1729 | 0.0000 |
| Inflation rate | 0.0046 | 1.2189 | 0.0060 | 1.3837 | 0.0000 | 0.8915 | 0.1397 | 0.7431 | 0.0002 | 1.1078 | 0.0486 | 1.1481 | 0.0045 | 0.9565 | 0.4194 | 0.7957 | 0.0001 |
| Interest rate | 0.0069 | 1.1618 | 0.0062 | 1.3022 | 0.0000 | 0.9177 | 0.0931 | 0.8014 | 0.0000 | 1.1416 | 0.0003 | 1.1646 | 0.0000 | 0.9669 | 0.3584 | 0.8358 | 0.0000 |
| Wage share | 0.6392 | 0.9995 | 0.9229 | 1.0003 | 0.9535 | 1.0009 | 0.8549 | 1.0012 | 0.8050 | 1.0060 | 0.2158 | 1.0105 | 0.0133 | 0.9903 | 0.0953 | 0.9760 | 0.0004 |
| Income Gini | 0.3701 | 1.0065 | 0.4879 | 1.0066 | 0.4897 | 1.0004 | 0.9644 | 1.0020 | 0.8315 | 0.9798 | 0.0416 | 0.9717 | 0.0018 | 1.0157 | 0.1569 | 1.0402 | 0.0013 |
| Market share exports | 0.0023 | 1.0029 | 0.9725 | 0.9833 | 0.8406 | 1.0545 | 0.5176 | 1.0947 | 0.2672 | 0.8181 | 0.0407 | 0.7183 | 0.0011 | 1.0427 | 0.6400 | 1.2052 | 0.0298 |
| Market share imports | 0.2234 | 0.9942 | 0.9124 | 1.0041 | 0.9388 | 0.9761 | 0.6574 | 0.9593 | 0.4537 | 1.0723 | 0.1687 | 1.1233 | 0.0139 | 0.9574 | 0.4551 | 0.8572 | 0.0192 |
| Domestic consumption share of output | 0.8017 | 0.9832 | 0.0374 | 0.9750 | 0.0025 | 1.0004 | 0.9603 | 1.0085 | 0.2628 | 1.0231 | 0.0101 | 1.0247 | 0.0066 | 1.0157 | 0.0687 | 1.0170 | 0.0399 |
| Exports share of output | 0.1435 | 1.0960 | 0.0268 | 1.1395 | 0.0016 | 0.9978 | 0.9576 | 0.9503 | 0.2200 | 0.8759 | 0.0102 | 0.8707 | 0.0082 | 0.9108 | 0.0546 | 0.8973 | 0.0209 |
| Imports share of output | 0.2522 | 0.9769 | 0.7201 | 0.9826 | 0.7862 | 0.9715 | 0.6635 | 0.9590 | 0.5327 | 1.1161 | 0.0768 | 1.1761 | 0.0056 | 0.9807 | 0.7807 | 0.8753 | 0.0863 |
| Exp. 2 (Shock period: 50 to 150) | | | | | | | | | | | | | | | | | |
| Period | Total | During | | | | | | | | After | | | | | | | |
| Scenario | Baseline | +0.004 | | +0.008 | | -0.004 | | -0.008 | | +0.004 | | +0.008 | | -0.004 | | -0.008 | |
| Variable | Average | Ratio | p-val | Ratio | p-val | Ratio | p-val | Ratio | p-val | Ratio | p-val | Ratio | p-val | Ratio | p-val | Ratio | p-val |
| Output growth rate | 0.0077 | 1.1125 | 0.0017 | 1.2103 | 0.0000 | 0.9197 | 0.0155 | 0.8268 | 0.0000 | 1.0259 | 0.3818 | 1.0682 | 0.0349 | 1.0113 | 0.6827 | 1.0107 | 0.7021 |
| Unemployment rate | 0.1856 | 0.8728 | 0.0000 | 0.7658 | 0.0000 | 1.0988 | 0.0009 | 1.2309 | 0.0000 | 0.8494 | 0.0000 | 0.7409 | 0.0000 | 1.1581 | 0.0000 | 1.3568 | 0.0000 |
| Inflation rate | 0.0046 | 1.2380 | 0.0003 | 1.6437 | 0.0000 | 0.8194 | 0.0024 | 0.6399 | 0.0000 | 1.1531 | 0.0087 | 1.3585 | 0.0000 | 0.8120 | 0.0008 | 0.6003 | 0.0000 |
| Interest rate | 0.0069 | 1.2072 | 0.0000 | 1.5375 | 0.0000 | 0.8728 | 0.0012 | 0.7069 | 0.0000 | 1.1563 | 0.0002 | 1.3820 | 0.0000 | 0.8589 | 0.0001 | 0.6901 | 0.0000 |
| Wage share | 0.6392 | 1.0020 | 0.6829 | 1.0053 | 0.2640 | 0.9984 | 0.7518 | 0.9968 | 0.5399 | 1.0112 | 0.0108 | 1.0228 | 0.0000 | 0.9777 | 0.0023 | 0.9474 | 0.0000 |
| Income Gini | 0.3701 | 0.9996 | 0.9669 | 0.9989 | 0.9110 | 1.0032 | 0.7435 | 1.0106 | 0.2904 | 0.9646 | 0.0002 | 0.9403 | 0.0000 | 1.0338 | 0.0131 | 1.0888 | 0.0000 |
| Market share exports | 0.0023 | 0.9423 | 0.4909 | 0.8759 | 0.1335 | 1.0836 | 0.3367 | 1.1582 | 0.0718 | 0.6978 | 0.0004 | 0.4605 | 0.0000 | 1.1632 | 0.0812 | 1.4457 | 0.0000 |
| Market share imports | 0.2234 | 1.0233 | 0.6561 | 1.0543 | 0.2879 | 0.9648 | 0.5222 | 0.9214 | 0.1606 | 1.1389 | 0.0048 | 1.2508 | 0.0000 | 0.8897 | 0.0665 | 0.7129 | 0.0000 |
| Domestic consumption share of output | 0.8017 | 0.9849 | 0.0723 | 0.9758 | 0.0053 | 1.0093 | 0.2309 | 1.0229 | 0.0023 | 1.0291 | 0.0015 | 1.0485 | 0.0000 | 1.0229 | 0.0074 | 1.0304 | 0.0001 |
| Exports share of output | 0.1435 | 1.0875 | 0.0521 | 1.1398 | 0.0027 | 0.9454 | 0.1907 | 0.8647 | 0.0008 | 0.8471 | 0.0020 | 0.7448 | 0.0000 | 0.8656 | 0.0034 | 0.8133 | 0.0000 |
| Imports share of output | 0.2522 | 1.0147 | 0.8185 | 1.0419 | 0.5042 | 0.9710 | 0.6640 | 0.9315 | 0.3119 | 1.1959 | 0.0018 | 1.3434 | 0.0000 | 0.9139 | 0.2327 | 0.7273 | 0.0003 |

Note: Averages across 100 Monte Carlo runs for each scenario. Ratios with respect to baseline scenario. Source: author's own elaboration based on simulation results.

## 5.2 Foreign inflation rate shocks

The second experiment concerns a shock on the foreign price inflation rate, which is expected to affect the domestic economy's terms of trade. The experiment is constructed by applying temporary shocks to the foreign inflation rate. The different scenarios are reported in table 4 below.

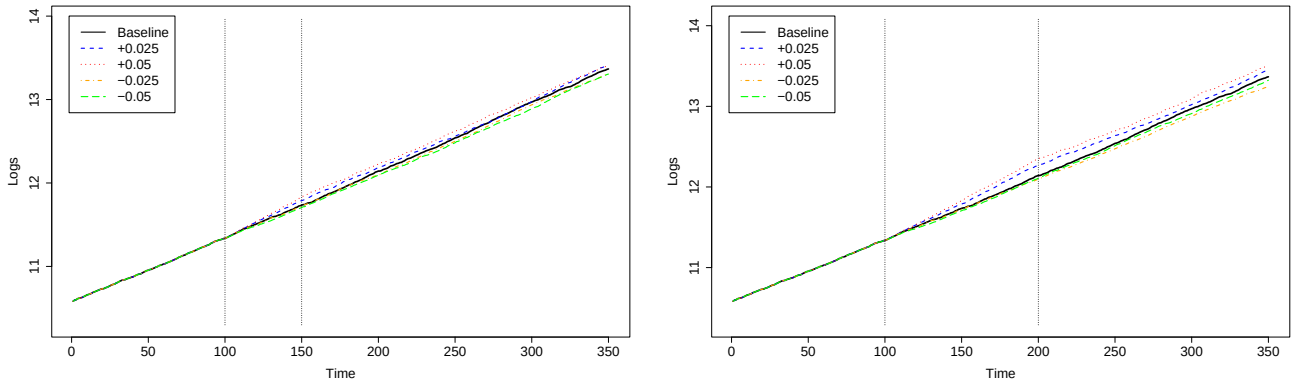
**Table 4**: Design of experiments (shocks on $\hat{p}_x$)

| Experiment | Period | $\Delta\hat{p}_x$ | | | |
|---|---|---|---|---|---|
| 3 | 50 to 100 | + 0.025 | + 0.05 | - 0.025 | - 0.05 |
| 4 | 50 to 150 | + 0.025 | + 0.05 | - 0.025 | - 0.05 |

Note: Source: authors' own elaboration.

As expected, an increase in the foreign price inflation rate leads to higher output rates in the domestic economy. This is due to the gain in price competitiveness by domestic firms when the foreign price level grows at a higher rate, thus leading to higher aggregate exports. In the case of the negative shocks, however, we do not necessarily observe a lower output level (as explored in the end of this section).

The positive stimulus on domestic demand leads to a temporary decrease in unemployment rates (figure 13), which nonetheless return to the previous value when the foreign inflation rate returns to the baseline value. Similarly to the previous case, there is an increase in domestic inflation rates following the external shock (figure

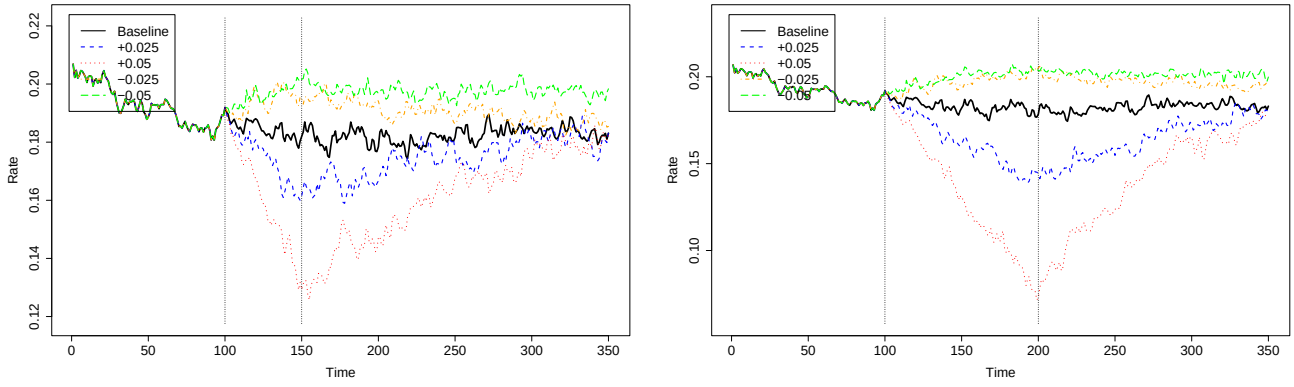



(a) Exp. 3 (b) Exp. 4

**Fig. 12**: Comparison of experiments: output level in logs (shocks on $\hat{p}_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

14), but there are two mechanisms operating in the same direction in this case. On the one hand, the increase in the foreign inflation rate leads to some imported inflation, since there is a pass-through from the foreign inflation to the domestic inflation through the imported goods. On the other hand, the lower unemployment rate means that workers have more bargaining power, achieving larger nominal wage adjustments in their negotiations with firms and inducing higher inflation rates of domestic goods as well. Actually, even the desired wage by workers is affected by the higher foreign inflation rate, since they are concerned with their total consumption goods basket, which includes imported goods. Thus, the imported inflationary pressures have an effect on nominal wage negotiations and domestic inflation rates also through the desired wage by workers. Indeed, foreign inflation rates exert a direct (or exogenous) impact on the domestic inflation through imported goods and an indirect (or endogenous) impact that is mediated by the perceived inflation rate by the domestic agents and by the changes in the dynamics of the social conflict. The higher inflation rates once again trigger a response by the central bank, so the scenarios with a higher $\hat{p}_x$ are associated with higher nominal interest rates (figure 15).



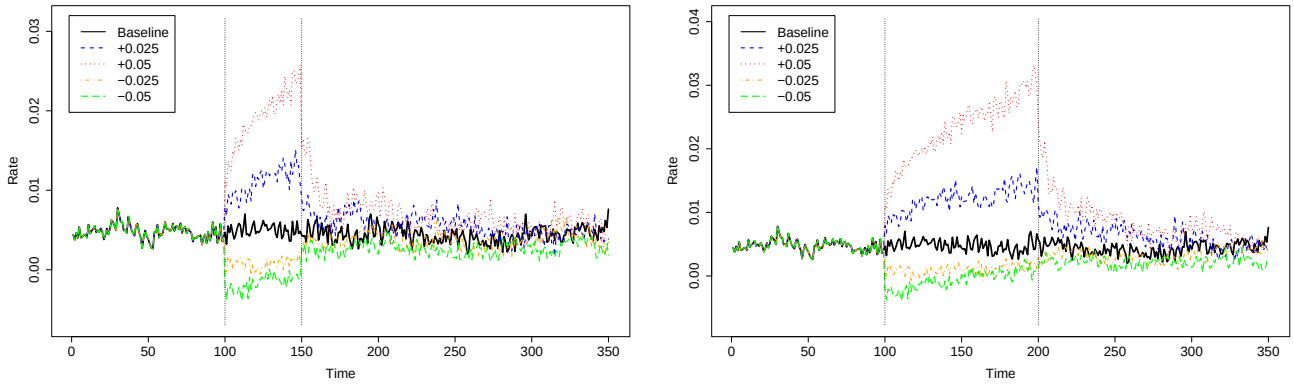

(a) Exp. 3 (b) Exp. 4

**Fig. 13**: Comparison of experiments: unemployment rate (shocks on $\hat{p}_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

In the case of the negative shocks on $\hat{p}_x$, the effect of $\hat{p}_x$ on the desired wage is not as expressive as in the case of positive shocks on $\hat{p}_x$ due to the existence of downward nominal wage rigidity. This rigidity may also explain this why output does not fall in a symmetrical way, since it helps to keep wages at the same level, and thus sustain aggregate demand. Thus, the predominant factor driving down the inflation rate in this case is the foreign price level through imported goods. Due to the weaker strength of the other mechanisms, the effect of shocks of the same magnitude and different signs on $\hat{p}_x$ is asymmetric, which explains why inflation rates decrease less in case of

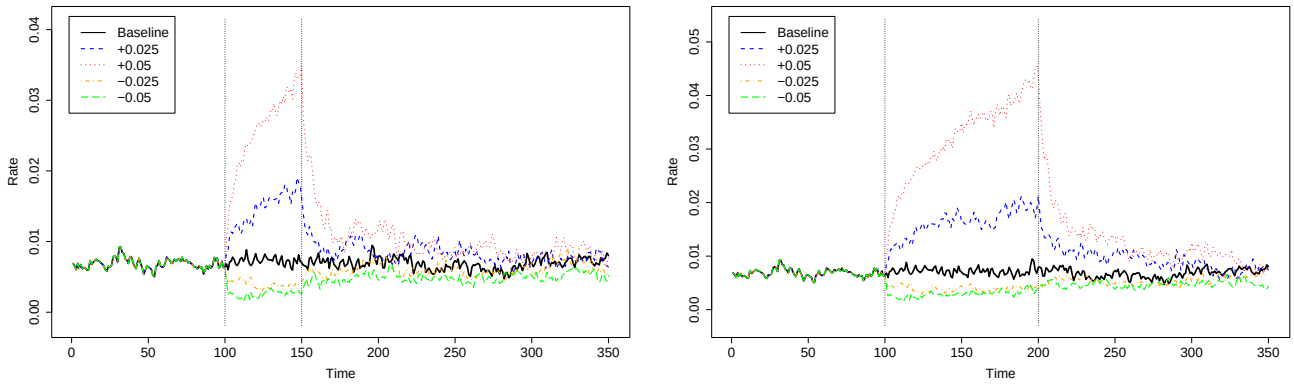
negative shocks than they increase when there is a positive shock. Another implication of this is that when there is a negative shock the decrease in the nominal interest rate is of a smaller magnitude.




(a) Exp. 3 (b) Exp. 4

**Fig. 14**: Comparison of experiments: inflation rate (shocks on $\hat{p}_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

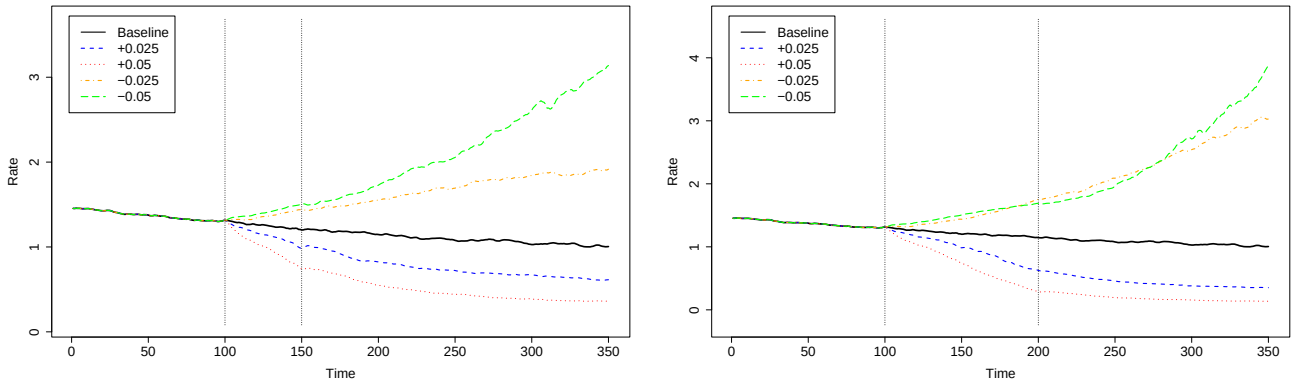



(a) Exp. 3 (b) Exp. 4

**Fig. 15**: Comparison of experiments: nominal interest rate (shocks on $\hat{p}_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

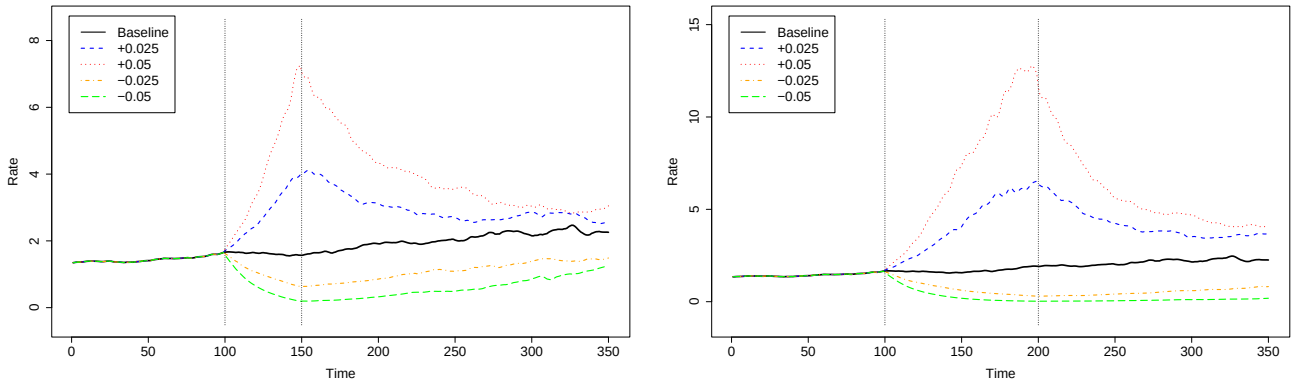
The dynamics of the nominal and real exchange rates, reported in figures 16 and 17 respectively, shows that they are affected in opposite directions by a shock to $\hat{p}_x$. The nominal exchange rate tends to appreciate when there is a positive shock to $\hat{p}_x$ due to the trade surplus and the higher nominal interest rate (similarly to what occurred after a shock in $g_x$). Yet, such a decrease in the nominal exchange rate is not enough to offset the strong effect of higher foreign prices on the real exchange rate, which increases with higher levels of $\hat{p}_x$. Thus, despite the nominal appreciation of the domestic currency and the increase in the domestic inflation rate, the domestic economy becomes more competitive relative to the foreign sector. Given that such increase in the real exchange rate during the shock results from the effect of $\hat{p}_x$ more than compensating the nominal exchange rate appreciation and the increase in domestic prices, this compensation is no longer observed in the period after the shock and the real exchange rate stabilizes. Nevertheless, there remains a tendency of nominal exchange rate appreciation, since the level of the real exchange rate determines the dynamics of imports and exports. In the case of negative shocks on $\hat{p}_x$, the opposite occurs and the nominal exchange rate increases due to the decrease in the trade surplus and the lower nominal interest rate, while the real exchange rate decreases due to the predominant effect of a lower $\hat{p}_x$.




(a) Exp. 3 (b) Exp. 4

**Fig. 16**: Comparison of experiments: nominal exchange rate (shocks on $\hat{p}_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.



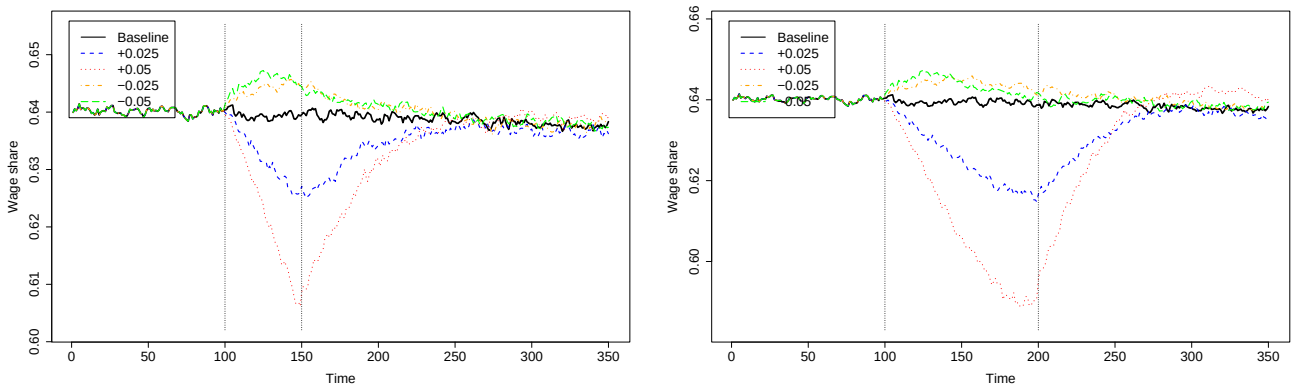

(a) Exp. 3 (b) Exp. 4

**Fig. 17**: Comparison of experiments: real exchange rates (shocks on $\hat{p}_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

In terms of income distribution, the effect of a shock on the foreign inflation rate is markedly different from that in the previous experiment. Indeed, a positive shock on $\hat{p}_x$ is associated with a lower wage share and a higher income Gini coefficient, as reported in figures 18 and 19 respectively. As mentioned, the decrease in unemployment rates benefits workers and improves their bargaining power, leading to higher nominal wages. Nevertheless, firms also benefit from their better position *vis-à-vis* foreign competitors, which allows them to adjust the mark-up rates upward. In this coevolutionary dynamics, firms' mark-ups are negatively affected by the nominal wage adjustments, but positively (and more significantly) affected by the increase in their international competitiveness. An additional effect of the higher real exchange rate is to increase exporters' revenue (and profits) in domestic currency, which is the direct effect emphasized by Rossi and Galbraith (2016). As in the previous case, the dynamics in the functional income distribution has implications for the personal income distribution, so there is a higher income Gini coefficient following the positive shocks on $\hat{p}_x$. In the case of negative shocks on $\hat{p}_x$, the effects are, once again, much milder. The dynamics of the wage share results from factors that tend to benefit firms (the weaker growth in unit costs due to the lower foreign price inflation) and that tend to benefit workers (the loss of international competitiveness and the real exchange rate appreciation). These factors seem to partially compensate each other, but the situation is somewhat more favorable to workers: there a small increase in the wage share and a slight decrease in the income Gini coefficient.

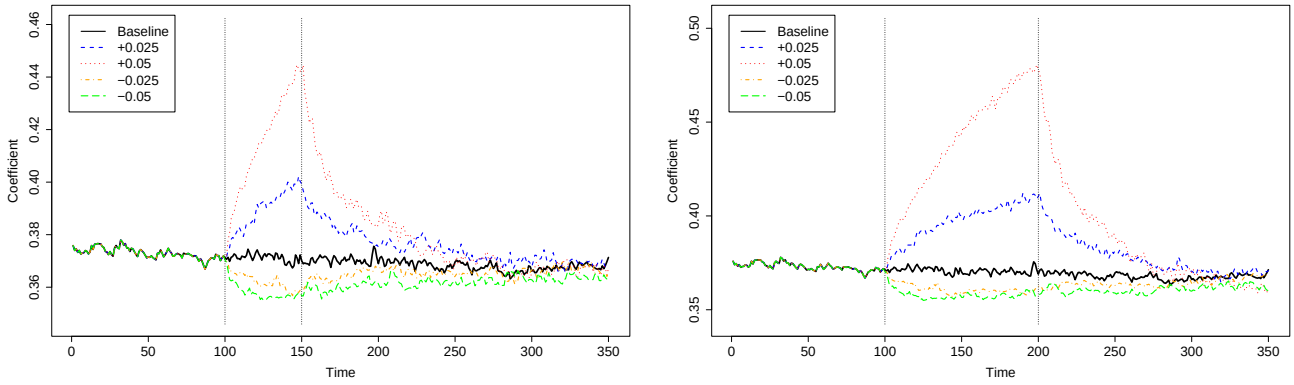
Table 5 provides additional information concerning the effects of the shocks on our variables of interest during and after the shocks. When there is a positive shock on $\hat{p}_x$, there is an increase in the output growth rate during the period of the shock, since the improvement in terms of trade lead to an increase in exports, which grow as a




(a) Exp. 3 (b) Exp. 4

**Fig. 18**: Comparison of experiments: wage share (shocks on $\hat{p}_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.




(a) Exp. 3 (b) Exp. 4

**Fig. 19**: Comparison of experiments: income Gini coefficient (shocks on $\hat{p}_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

share of output. Since a price shock has a more direct effect on income distribution than a demand shock,[28] the changes on income distribution are already significant during the period of the shock, and an increase in inequality is observed. This change in income inequality persists in the long run (after the shock) in some cases, and so do the changes in exports and imports market shares, reflecting a lasting gain in international competitiveness that results from the level effect on the real exchange rate, as previously discussed. Nevertheless, output growth rates return to the baseline value (more precisely, are not statistically different from it). In most cases, this results from exports not being an output growth driver any longer, since export growth during the shock was stimulated by a gain in international competitiveness. When $\hat{p}_x$ returns to the baseline value, exports can no longer stimulate higher growth rates. However, differently from the previous case, now there is no improvement in the income distribution, preventing domestic consumption from becoming a stimulus for economic growth. Indeed, exports continue to represent a larger share of output and domestic consumption continues to represent a smaller share of output. Thus, when the growth stimulus represented by the gains in terms of trade is over, it is not replaced by any domestic component.

In the case of the negative shocks $\hat{p}_x$, lower output growth rates are obtained during the shocks in most cases, but they are not different from the baseline scenario in the periods after the shock. The loss in international price competitiveness leads to a reduction in domestic firms' market share of the foreign sector and an increase

[28] In the case of the demand shock, analyzed in the previous section, the distributional changes operated through the wage bargaining process and through the dynamics of the nominal exchange rate. In the case of a price shock, there is a direct and immediate effect on the numerator of the real exchange rate, which has implications for the exporters' revenues in domestic currency and, consequently, for their profits.

**Table 5**: Summary statistics for shocks on $\hat{p}_x$

| Exp. 3 (Shock period: 50 to 100) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Period | Total | During | | | | | | | | After | | | | | | | |
| Scenario | Baseline | +0.025 | | +0.05 | | -0.025 | | -0.05 | | +0.025 | | +0.05 | | -0.025 | | -0.05 | |
| Variable | Average | Ratio | p-val | Ratio | p-val | Ratio | p-val | Ratio | p-val | Ratio | p-val | Ratio | p-val | Ratio | p-val | Ratio | p-val |
| Output growth rate | 0.0077 | 1.1233 | 0.0022 | 1.2010 | 0.0000 | 0.9536 | 0.2513 | 0.8798 | 0.0102 | 1.0267 | 0.3138 | 1.0066 | 0.7985 | 0.9922 | 0.7779 | 1.0016 | 0.9508 |
| Unemployment rate | 0.1856 | 0.9439 | 0.0549 | 0.8678 | 0.0000 | 1.0443 | 0.1087 | 1.0549 | 0.0325 | 0.9414 | 0.0318 | 0.8695 | 0.0000 | 1.0253 | 0.3157 | 1.0655 | 0.0062 |
| Inflation rate | 0.0046 | 2.4109 | 0.0000 | 4.1946 | 0.0000 | 0.1703 | 0.0000 | -0.3594 | 0.0000 | 1.1980 | 0.0003 | 1.4670 | 0.0000 | 0.8205 | 0.0009 | 0.5867 | 0.0000 |
| Interest rate | 0.0069 | 2.0887 | 0.0000 | 3.6728 | 0.0000 | 0.5744 | 0.0000 | 0.3863 | 0.0000 | 1.2031 | 0.0000 | 1.4613 | 0.0000 | 0.8849 | 0.0010 | 0.7108 | 0.0000 |
| Wage share | 0.6392 | 0.9891 | 0.0857 | 0.9753 | 0.0018 | 1.0072 | 0.0772 | 1.0094 | 0.0121 | 0.9934 | 0.3115 | 0.9911 | 0.2419 | 1.0008 | 0.8552 | 1.0010 | 0.7889 |
| Income Gini | 0.3701 | 1.0509 | 0.0000 | 1.1190 | 0.0000 | 0.9791 | 0.0107 | 0.9678 | 0.0000 | 1.0134 | 0.2695 | 1.0226 | 0.0977 | 0.9875 | 0.1664 | 0.9780 | 0.0049 |
| Market share exports | 0.0023 | 1.1971 | 0.0183 | 1.3071 | 0.0002 | 0.8599 | 0.0914 | 0.6873 | 0.0001 | 1.1348 | 0.1362 | 1.2548 | 0.0051 | 0.6995 | 0.0007 | 0.4512 | 0.0000 |
| Market share imports | 0.2234 | 0.8851 | 0.0377 | 0.8032 | 0.0005 | 1.0766 | 0.1284 | 1.1585 | 0.0006 | 0.8928 | 0.0610 | 0.8258 | 0.0028 | 1.1288 | 0.0119 | 1.2285 | 0.0000 |
| Domestic consumption share of output | 0.8017 | 0.9613 | 0.0000 | 0.9402 | 0.0000 | 1.0263 | 0.0012 | 1.0585 | 0.0000 | 0.9850 | 0.0711 | 0.9676 | 0.0001 | 1.0610 | 0.0000 | 1.1061 | 0.0000 |
| Exports share of output | 0.1435 | 1.2140 | 0.0000 | 1.3332 | 0.0000 | 0.8559 | 0.0009 | 0.6803 | 0.0000 | 1.0844 | 0.0587 | 1.1835 | 0.0000 | 0.6636 | 0.0000 | 0.4130 | 0.0000 |
| Imports share of output | 0.2522 | 0.8357 | 0.0114 | 0.7320 | 0.0000 | 1.1130 | 0.0735 | 1.2437 | 0.0000 | 0.8795 | 0.0782 | 0.7926 | 0.0024 | 1.2229 | 0.0007 | 1.3869 | 0.0000 |
| Exp. 4 (Shock period: 50 to 150) | | | | | | | | | | | | | | | | | |
| Period | Total | During | | | | | | | | After | | | | | | | |
| Scenario | Baseline | +0.025 | | +0.05 | | -0.025 | | -0.05 | | +0.025 | | +0.05 | | -0.025 | | -0.05 | |
| Variable | Average | Ratio | p-val | Ratio | p-val | Ratio | p-val | Ratio | p-val | Ratio | p-val | Ratio | p-val | Ratio | p-val | Ratio | p-val |
| Output growth rate | 0.0077 | 1.1540 | 0.0000 | 1.2312 | 0 | 0.9226 | 0.0328 | 0.9119 | 0.0171 | 1.0173 | 0.5434 | 1.0081 | 0.7633 | 0.9533 | 0.1223 | 1.0117 | 0.7131 |
| Unemployment rate | 0.1856 | 0.8808 | 0.0000 | 0.7130 | 0 | 1.0604 | 0.0194 | 1.0736 | 0.0009 | 0.8840 | 0.0001 | 0.7564 | 0.0000 | 1.0618 | 0.0082 | 1.0874 | 0.0000 |
| Inflation rate | 0.0046 | 2.6353 | 0.0000 | 5.0634 | 0 | 0.2220 | 0.0000 | -0.1310 | 0.0000 | 1.3668 | 0.0000 | 1.8430 | 0.0000 | 0.7110 | 0.0000 | 0.4851 | 0.0000 |
| Interest rate | 0.0069 | 2.3223 | 0.0000 | 4.5850 | 0 | 0.5709 | 0.0000 | 0.4320 | 0.0000 | 1.3680 | 0.0000 | 1.8317 | 0.0000 | 0.7977 | 0.0000 | 0.6906 | 0.0000 |
| Wage share | 0.6392 | 0.9791 | 0.0085 | 0.9533 | 0 | 1.0072 | 0.0541 | 1.0069 | 0.0524 | 0.9901 | 0.2146 | 0.9895 | 0.2672 | 1.0011 | 0.7697 | 1.0000 | 0.9914 |
| Income Gini | 0.3701 | 1.0723 | 0.0000 | 1.1862 | 0 | 0.9758 | 0.0019 | 0.9671 | 0.0000 | 1.0213 | 0.1336 | 1.0401 | 0.0127 | 0.9842 | 0.0476 | 0.9751 | 0.0009 |
| Market share exports | 0.0023 | 1.2942 | 0.0005 | 1.4425 | 0 | 0.7048 | 0.0003 | 0.4522 | 0.0000 | 1.2654 | 0.0031 | 1.4499 | 0.0000 | 0.4766 | 0.0000 | 0.1222 | 0.0000 |
| Market share imports | 0.2234 | 0.8120 | 0.0008 | 0.6856 | 0 | 1.1414 | 0.0030 | 1.2386 | 0.0000 | 0.8209 | 0.0023 | 0.7076 | 0.0000 | 1.2159 | 0.0000 | 1.3274 | 0.0000 |
| Domestic consumption share of output | 0.8017 | 0.9476 | 0.0000 | 0.9219 | 0 | 1.0569 | 0.0000 | 1.1020 | 0.0000 | 0.9664 | 0.0000 | 0.9468 | 0.0000 | 1.1027 | 0.0000 | 1.1630 | 0.0000 |
| Exports share of output | 0.1435 | 1.2906 | 0.0000 | 1.4406 | 0 | 0.6861 | 0.0000 | 0.4374 | 0.0000 | 1.1893 | 0.0000 | 1.3032 | 0.0000 | 0.4327 | 0.0000 | 0.0966 | 0.0000 |
| Imports share of output | 0.2522 | 0.7492 | 0.0001 | 0.5994 | 0 | 1.2235 | 0.0003 | 1.3937 | 0.0000 | 0.7855 | 0.0018 | 0.6522 | 0.0000 | 1.3717 | 0.0000 | 1.5807 | 0.0000 |

Note: Averages across 100 Monte Carlo runs for each scenario. Ratios with respect to baseline scenario. Source: author's own elaboration based on simulation results.

in the foreign sector's market share of the domestic sector even after the shocks. Yet, the negative effects of the increase in the share of imports and decrease in the share of exports in total output is somewhat attenuated by the slight increase in the wage share (only significant during the shock) and decrease in the income Gini coefficient (significant after the shock in most cases), which allow domestic consumption to compensate the negative effect of the weaker exporting dynamics.

## 5.3 Summary of the main findings

The previous sections discussed the effects of two types of foreign shocks that alter the international trade dynamics of the domestic economy. While we find that positive shocks on the foreign output growth rate and on the foreign inflation rate exert a positive (and in most cases temporary) effect on the domestic output growth rate and a persistent effect on its level, the distributive implications of each type of shock differ considerably, with more equality following the positive shocks on the foreign output growth rate and more inequality following the positive shocks on the foreign inflation rate. Table 6 summarizes the key mechanisms driving the results in each case.

**Table 6**: Summary of main results

| Type of shock | Output growth | Unemployment rate | Inflation rate | Nominal exchange rate | Real exchange rate | Wage share | Gini coefficient |
|---|---|---|---|---|---|---|---|
| $\Delta g_x > 0$ | + | - | + | - | - | + | - |
| $\Delta \hat{p}_x > 0$ | + | - | + | - | + | - | + |

Note: + indicates that the variable increases in comparison to the baseline scenario (either during or after the shock) and - indicates that the variable decreases in comparison to the baseline scenario (either during or after the shock). Source: authors' own elaboration.

Both types of shocks lead to an increase in the output growth rate (which is temporary in most cases), triggering a decrease in the unemployment rate. Also a higher inflation rate follows in both cases, which is related to the lower unemployment rate that tends to favor workers in the wage bargaining process and to increase the growth rate of nominal wages. Yet, in the case of the shock on the foreign output growth rate the increase in domestic prices is somewhat attenuated by the decrease in the nominal exchange rate, which reduces the growth rate of imported goods prices in domestic currency, while in the case of the shock on the foreign inflation rate the increase in domestic prices is reinforced by the strong increase in the growth rate of imported goods prices in domestic currency (captured by the increase in the real exchange rate). Thus, the nature of the inflationary processes triggered by the foreign shocks differ considerably depending on the type of shock.

The dynamics of the nominal and real exchange rates is key to understanding the differences in the distributive implications of each scenario. Since both scenarios are associated with an increase in employment, which induces higher growth rates of nominal costs and lower mark-up rates (equation 14) and an increase in exports growth, which increases the exporter firms' mark-up rates (equation 17), the key differences between them are related to the dynamics of the real exchange rate. Indeed, the nominal exchange rate appreciation (determined by the trade balance surplus and the increase in nominal interest rates) obtained in both cases is associated with a real exchange rate appreciation when there is a shock in the foreign output growth rate (due to a combination of the lower nominal exchange rate and the increase of the domestic price inflation in comparison with the foreign price inflation) and with a real exchange rate depreciation when there is a shock on the foreign inflation rate (since the increase of the foreign inflation rate relative to the domestic inflation rate compensates the decrease of the nominal

exchange rate). The currency real appreciation in the former case means that domestic firms face more competition in the domestic and foreign markets and that exporters' revenue per good in domestic currency reduces,[29] thus leading to a higher wage share and a lower income Gini. On the other hand, the currency real depreciation in the latter case has the opposite effect and the increase in the domestic firms' competitiveness relative to the foreign sector and the increase in the exporters' revenues induce a worsening in the income distribution.

The duration (or persistence) of the macroeconomic and distributive effects of the shocks is also strongly dependent on the type of shock. Indeed, since the shocks on the foreign inflation rates have a strong and immediate effect on the exporters' revenue, the differences in income distribution are statistically significant already during the period when the shock is applied. On the other hand, the distributive implications of the shocks on the foreign output growth rate operate through less automatic mechanisms, and thus take longer to lead to statistically significant differences. Yet, in the former case the differences are not always statistically significant after the period of the shock is over, and the unemployment rates quickly rise back to the baseline level. In the latter case, the duration of the effect on the income distribution is considerably longer, with a slower convergence of the unemployment rates back to the baseline level. As already mentioned, the key mechanism explaining this dynamics is the fact that the improvement in income distribution after the shocks to the foreign output growth rate induce a replacement of foreign demand by domestic consumption when the shock is over, which is not the case when there is a shock to the foreign inflation rate. This improvement in aggregate demand is likely to also exert a feedback effect on income distribution through the lower unemployment rates, thus contributing to the persistence of the effect on distribution (in particular for the wage share).

These results indicate that gains in international competitiveness are not enough to induce higher output growth rates in the long run if they are accompanied by a worsening in the income distribution. Nevertheless, a similar remark applies to the scenarios in which more equality is obtained, since it is not guaranteed that the higher output growth rate persists after the period of the shock, although this is a valid possibility. Thus, while the shift towards more equality may help to sustain higher output growth rates because domestic consumption replaces exports when the shock is over, the loss in international competitiveness may play a countervailing role. In sum, the interplay between income distribution and international competitiveness, which mirrors the interplay between domestic and foreign demands, is key to the relation between output growth and income distribution arising from the foreign shocks. It also indicates that the real exchange rate may have different relations with output depending on the dynamics of income distribution.

# 6 Conclusions

This article compared the effects of two shocks that frequently affect open economies. In general, external shocks on open economies are analyzed through their effects on the output dynamics of the domestic economy or, as in the more recent literature, on income distribution. By dealing simultaneously with these two dimensions and relating them to the inflation dynamics, we also explore how income distribution can be one of the many mechanisms through which external shocks affect the macroeconomic dynamics of open economies.

Our results indicate that both positive demand and price shocks have a positive effect on the domestic output level and growth rates since they stimulate exports. They are also associated with higher inflation rates, but while in both cases the lower unemployment rate is a factor inducing higher inflation rates (as it strengthens the distributive conflict), in the second case there is also an important imported inflation component. In this sense, the model is able to capture two important factors driving inflation rates in open economies.

The distributive implications of these shocks differ considerably. In the case of a demand shock, the increase in economic activity and the nominal and real currency appreciations tend to favor the lower classes and more equality in the functional and personal income distribution is achieved. This contributes to a shift in demand towards domestic demand as lower classes present a higher propensity to consume, which contributes to sustaining the output levels even when the period of higher foreign output growth rates ends. A price shock, by having a direct effect on the real exchange rate, stimulates domestic output through the gain in international competitiveness for domestic firms. While this leads to lower unemployment rates and a nominal exchange rate appreciation, the interplay between these factors tends to benefit firms and high-income groups relatively more. Consequently, in this case the functional and personal income distribution are more unequal. Thus, when the shock in the foreign inflation rate is over, these economies do not have this positive stimulus from domestic consumption.

In sum, our results contribute to the understanding of the diversity of results from the empirical literature concerned with the effects of international trade on income distribution. The comparison between the experiments indicates that the type of external shock that leads to increases in exports and/or decreases in imports matters for how income distribution will be affected. Moreover, the results indicate that also the relation between the real exchange rate and the output dynamics depends on the source of shock driving the changes in the former, with income distribution being an important factor explaining their relationship. This also suggests that economic policy

[29] Exporters follow the pricing to market strategy and thus there is a price component that is determined by the foreign price level and the nominal exchange rate (equation 18).

ought to be carefully designed by considering the complex relationship between these important macroeconomic variables.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## References


Agenor PR, McDermott CJ, Prasad ES (2000) Macroeconomic Fluctuations in Developing Countries: Some Stylized Facts. The World Bank Economic Review 14(2):251–285

Aucremanne L, Druant M (2005) Price-Setting Behaviour in Belgium: What Can Be Learned from an Ad Hoc Survey ? SSRN Electronic Journal

Baltar CT, Rolim LN (2018) Desigualdade e vulnerabilidade no mundo do trabalho. In: Krein J, Gimenez D, dos Santos A (eds.) Dimensões críticas da reforma trabalhista no Brasil, Curt Nimuendajú, Campinas, SP, pp. 243–274

Berman N, Martin P, Mayer T (2012) How do Different Exporters React to Exchange Rate Changes? The Quarterly Journal of Economics 127(1):437–492

Bernard AB, Eaton J, Jensen JB, Kortum S (2003) Plants and Productivity in International Trade. The American Economic Review 93(4):94

Bernard AB, Jensen JB, Lawrence RZ (1995) Exporters, Jobs, and Wages in U.S. Manufacturing: 1976-1987. Brookings Papers on Economic Activity Microeconomics 1995:67–119

Bernard AB, Jensen JB, Redding SJ, Schott PK (2012) The Empirics of Firm Heterogeneity and International Trade. Annual Review of Economics 4(1):283–313

Bertola G, Dabusinskas A, Hoeberichts M, Izquierdo M, Kwapil C, Montornès J, Radowski D (2012) Price, wage and employment response to shocks: Evidence from the WDN survey. Labour Economics 19(5):783–791

Bewley TF (2007) Insights gained from conversations with labor market decision makers. European Central Bank Working Paper Series 776

Blecker R (1989) International Competition, Income Distribution and Economic Growth. Cambridge Journal of Economics 13(3):395–412

Bobeica E, Jarocinski M (2019) Missing Disinflation and Missing Inflation: A VAR Perspective. International Journal of Central Banking 15(1):34

Borio CEV, Filardo AJ (2007) Globalisation and Inflation: New Cross-Country Evidence on the Global Determinants of Domestic Inflation. BIS Working Papers 227

Busato MI, Possas ML (2016) Restrição externa e crescimento simulando um modelo multissetorial aberto. Economia e Sociedade 25(2):279–313

Caiani A, Catullo E, Gallegati M (2018) The effects of fiscal targets in a monetary union: A Multi-Country Agent-Based Stock Flow Consistent model. Industrial and Corporate Change 27(6):1123–1154

Caiani A, Catullo E, Gallegati M (2019) The effects of alternative wage regimes in a monetary union: A multi-country agent based-stock flow consistent model. Journal of Economic Behavior & Organization 162:389–416

Cardaci A, Saraceno F (2019) Inequality and imbalances: A monetary union agent-based model. Journal of Evolutionary Economics 29(3):853–890

Carlin W, Soskice D (2014) Macroeconomics: Institutions, Instability, and the Financial System. Oxford University Press, Oxford, UK

Carlsson M, Skans ON (2012) Evaluating Microfoundations for Aggregate Price Rigidities: Evidence from Matched Firm-Level Data on Product Prices and Unit Labor Cost. American Economic Review 102(4):1571–1595

Cornia GA (2014) Income Inequality in Latin America: Recent Decline and Prospects for Its Further Reduction, vol. 149 of ECLAC - Macroeconomics of Development Series. UNU-WIDER

Cullen ZB, Li S, Perez-Truglia R (2022) What's my employee worth? The effects of salary benchmarking. NBER Working Paper Series 30570

Daudey E, García-Peñalosa C (2007) The personal and the factor distributions of income in a cross-section of countries. The Journal of Development Studies 43(5):812–829

Dawid H, Harting P, Neugart M (2014) Economic convergence: Policy implications from a heterogeneous agent model. Journal of Economic Dynamics and Control 44:54–80

Deissenberg C, van der Hoog S, Dawid H (2008) EURACE: A massively parallel agent-based model of the European economy. Applied Mathematics and Computation 204(2):541–552

Dickens WT, Goette L, Holden S, Messina J, Turunen J, Ward ME (2007) How Wages Change: Micro Evidence from the International Wage Flexibility Project. Journal of Economic Perspectives 21(2):195–214

Dorn F, Fuest C, Potrafke N (2017) Globalization and Income Inequality Revisited. European Economy Discussion Paper 56

Dosi G, Fagiolo G, Roventini A (2010) Schumpeter meeting Keynes: A policy-friendly model of endogenous growth and business cycles. Journal of Economic Dynamics and Control 34(9):1748–1767

Dosi G, Roventini A, Russo E (2019) Endogenous growth and global divergence in a multi-country agent-based model. Journal of Economic Dynamics and Control 101:101–129

Dweck E (2006) Uma análise da interação micro-macro com base em um modelo dinâmico multissetorial de simulação Ph.D. Dissertation, Federal University of Rio de Janeiro

Dweck E, Vianna MT, Barbosa AdC (2020) Discussing the role of fiscal policy in a demand-led agent-based growth model. EconomiA 21(2):185–208

Fabiani S, Druant M, Hernando I, Kwapil C, Landau B, Loupias C, Martins F, Matha T, Sabbatini R, Stahl H, Stokman A (2006) What Firms' Surveys Tell Us about Price-Setting Behavior in the Euro Area. International Journal of Central Banking 2(3):3–47

FitzGerald EVK (1996) The New Trade Regime, Macroeconomic Behaviour and Income Distribution in Latin America, Palgrave Macmillan UK, London, pp. 29–52

Galuscak K, Keeney M, Nicolitsas D, Smets F, Strzelecki P, Vodopivec M (2012) The determination of wages of newly hired employees: Survey evidence on internal versus external factors. Labour Economics 19(5):802–812

Goldberg PK, Pavcnik N (2007) Distributional Effects of Globalization in Developing Countries. Journal of Economic Literature XLV:39–82

Jacobo AD, Marengo A (2020) Are the Business Cycles of Argentina and Brazil Different? New Features and Stylized Facts. Paradigma económico 12(2):5–38

Krugman P (1986) Pricing to Market when the Exchange Rate Changes. NBER Working Paper Series 1926

Krugman P, Taylor L (1978) Contractionary effects of devaluation. Journal of International Economics 8:445–456

Milanovic B (2005) Can We Discern the Effect of Globalization on Income Distribution? Evidence from Household Surveys. The World Bank Economic Review 19(1):21–44

Mohun S (2016) Class structure and the US personal income distribution, 1918-2012. Metroeconomica 67(2):334–363

Nelson RR, Winter SG (1982) An Evolutionary Theory of Economic Change. Belknap Press, Cambridge, MA

Petrović M, Ozel B, Teglio A, Raberto M, Cincotti S (2017) Eurace Open: An agent-based multi-country model. Working Paper Series of the Economics Department of the Universitat Jaume I, Castellón (Spain) 2017/09

Possas ML, Dweck E (2004) A Multisectoral Micro-Macrodynamic Model. EconomiA 5(3):1–43

Ribeiro RS, McCombie JS, Lima GT (2020) Does real exchange rate undervaluation really promote economic growth? Structural Change and Economic Dynamics 52:408–417

Ribeiro RSM, McCombie JSL, Lima GT (2017) Some unpleasant currency-devaluation arithmetic in a post Keynesian macromodel. Journal of Post Keynesian Economics 40(2):145–167

Rodrik D (1997) Has Globalization Gone Too Far? Institute of International Economics, Washington D.C

Rodrik D (2021) A primer on trade and inequality. NBER Working Paper Series 29507:1–12

Rogoff K (1996) The Purchasing Power Parity Puzzle. Journal of Economic Literature 34(2):647–668

Rolim LN, Baltar CT, Lima GT (2021) Income Distribution, Productivity Growth and Workers' Bargaining Power in an Agent-Based Macroeconomic Model. Department of Economics, FEA-USP Working Paper 2021–27

Rossi D, Galbraith J (2016) Exchange Rates and Industrial Wage Inequality in Open Economies. UTIP Working Paper 71:1–23

Rowthorn RE (1977) Conflict, inflation and money. Cambridge Journal of Economics 1:215–239

Sánchez-Ancochea D (2021) The surprising reduction of inequality during a commodity boom: What do we learn from Latin America? Journal of Economic Policy Reform 24(2):95–118

Silverberg G, Dosi G, Orsenigo L (1988) Innovation, Diversity and Diffusion: A Self-Organisation Model. The Economic Journal 98(393):1032–1054

Stock JH, Watson MW (1999) Business Cycle Fluctuations in US Macroeconomic Time Series. In: Taylor J, Woodford M (eds.) Handbook of Macroeconomics, Elsevier, Amsterdam, vol. 1A, pp. 3–64

Stolper WF, Samuelson PA (1941) Protection and Real Wages. The Review of Economic Studies 9(1):58–73

Storm S (2022) Inflation in the Time of Corona and War. Institute for New Economic Thinking Working Papers 185

Toledo M (2008) Understanding Business Cycles in Latin America. Manuscript

Warmedinger T (2004) Import prices and pricing-to-market effects in the euro area. European Central Bank Working Paper Series 299

Wolff EN, Zacharias A (2013) Class structure and economic inequality. Cambridge Journal of Economics 37(6):1381–1406

# Appendix

The parameters used in the baseline scenario are reported below:

**Table 7**: Parameters and initial values in baseline scenario

| Symbol | Description | Value |
|---|---|---|
| $\alpha, \beta$ | Beta distribution parameters (innovation) | (3, 3) |
| $\gamma_1$ | sensitivity of desired wage by employed workers to output growth rate | 1 |
| $\gamma_2$ | sensitivity of desired wage by unemployed workers to periods of unemployment | 0.01 |
| $\gamma_3$ | sensitivity of firms' desired wage to change in unemployment rate | 0.5 |
| $\gamma_4$ | adjustment in offered wage in case of unfilled job positions | 0.1 |
| $\delta$ | fraction of the average capital stock of the established firms for entrant firms' desired investment | 0.5 |
| $\zeta$ | search capability (K firm) | 0.034 |
| $\vartheta$ | employees turnover share | 0.05 |
| $\lambda_1$ | interest rate smoothing parameter | 0.5 |
| $\lambda_2$ | interest rate sensitivity to inflation gap | 0.5 |
| $\lambda_3$ | exchange rate sensitivity to trade balance | 0.15 |
| $\lambda_4$ | exchange rate sensitivity to change in the interest rate differential | 2 |
| $\mu_{c,0}$ | initial mark-up rate (C firms) | 0.8 |
| $\mu^{min}$ | minimum mark-up rate (C firms) | 0.1 |
| $\mu_k$ | mark-up rate (K firm) | 0.6 |
| $\nu_1$ | sensitivity of mark-up rate to market share (C firms) | 0.04 |
| $\nu_2$ | mark-up deviation persistence (C firms) | 0.99 |
| $\nu_3$ | sensitivity of mark-up rate to unit costs (C firms) | 0.1 |
| $\nu_4$ | sensitivity of market share to competitiveness (C firms) | 1 |
| $\nu_5$ | sensitivity of mark-up rate to exports growth (C firms) | 0.2 |
| $\rho_1$ | number of capitalists per firm | 1 |
| $\rho_2$ | proportion of revenue to R&D (K firms) | 0.15 |
| $\rho_3$ | managers per direct workers in (K firms) | 0.24 |
| $\rho_4$ | indirect workers per direct worker (C firms) | 0.24 |
| $\rho_5$ | indirect workers per direct worker at full capacity production (C firms) | 0.1 |
| $\tau$ | tax rate on income | 0.15 |
| $\tau^i$ | tax rate on interest on deposits | 0.15 |
| $\iota_1$ | sensitivity of probability of exporting to domestic market share | 100 |
| $\iota_2$ | maximum domestic firms' market share of foreign market | 8e-05 |
| $\iota_3$ | sensitivity domestic firms' market share of foreign market to price competitiveness | 0.8 |
| $\iota_4$ | maximum foreign sector's market share of the domestic market | 0.3 |
| $\iota_5$ | sensitivity foreign sector's market share of the domestic market to price competitiveness | 0.8 |
| $\phi$ | sensitivity of surveyed wage weight in bargaining to employment rate | 0.9 |
| $b$ | payback rule threshold | 3 |
| $c_1$ | real consumption persistence | 0.8 |
| $c_2^{dir,ind,cap}$ | propensity to consume out of income (direct workers, indirect workers, capitalists) | (0.95, 0.85, 0.75) |

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| Symbol | Description | Value |
|---|---|---|
| $c_3$ | propensity to consume out of deposits | 0.001 |
| $c_x$ | foreign sector's propensity to consume | 0.8 |
| $g_x$ | foreign sector's real output growth rate | 0.008 |
| $h$ | sensitivity of productivity to unfilled demand for managers and supervisors | 1 |
| $i_0$ | initial base interest rate | 0.01 |
| $i_{min}$ | minimum base interest rate | 1e-07 |
| $i_x$ | foreign sector's interest rate | 0.005 |
| $k$ | pricing to market parameter | 0.1 |
| $L_g^{dir,ind}$ | workers hired as public servants | (287, 116) |
| $ms^{min}$ | minimum market share to stay in the market (C firms) | 0.0005 |
| $ms^{exp}$ | minimum market share for accessing foreign market (exporters) | 0.005 |
| $N^c$ | number of consumption goods firms | 200 |
| $N^{dir,ind,cap}$ | number of direct workers, indirect workers, and capitalists | (1754, 707, 201) |
| $n^{IN}$ | desired share of inventories | 0.1 |
| $n^{s,dir,ind}$ | proportion of workers in survey | (0.15, 0.3) |
| $n^w$ | number of hiring rounds per open position | 1.5 |
| $\hat{p}^T$ | inflation rate target | 0.005 |
| $\hat{p}_x$ | foreign sector's inflation rate | 0.005 |
| $Q_{c,0}^{fc}$ | initial full capacity production (C firms) | 80 |
| $Q_m^{fc}$ | machines production at full capacity | 2.5 |
| $R$ | maximum interest payments to cash flow ratio | 0.4 |
| $s$ | sensitivity of probability of on-the-job search to difference in wages | 5 |
| $T^c$ | number of periods before a new firm can exit the market | 5 |
| $T^e$ | number of periods in the exchange rate adjustment to a change in the interest rate differential | 4 |
| $T^k$ | machines lifetime | 20 |
| $T^p$ | number of periods in average inflation (inflation targeting regime) | 1 |
| $T^u$ | number of periods of unemployment benefit | 4 |
| $u^d$ | desired capacity utilization level | 0.8 |
| $w_0^{min,\$}$ | initial minimum wage | 1 |
| $v$ | expansion investment adjustment speed | 0.5 |
| $\hat{w}^{max}$ | maximum desired wage real growth rate | 0.1 |
| $x$ | Beta distribution support parameter | 0.15 |

Source: authors' own elaboration.