

Medium Frequencies in Non-Frontier Economies*

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Abstract

Most countries in the world are not at the technological frontier, yet their economies grow and fluctuate. In this paper we set up a model of endogenous growth with business cycle fluctuations usable to analyze the medium frequency fluctuations in non-frontier countries. The growth mechanism is a Schumpeterian creative destruction framework, which is embedded into a real business cycle dynamic stochastic general equilibrium model, with standard and non-standard features. We allow for multinational firms entering the economy and challenging existing incumbents, and study the tension between their direct positive productivity contribution and their indirect negative contribution through the expected obsolescence of domestic innovators. We calibrate the model and show, via simulations, the potential value added from our prototype model.

JEL classification: O30, O40

Keywords: DSGE and growth; Medium Frequencies; Non-frontier Economies.

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1 Introduction

A novel literature stemming from Comin and Gertler (2006) has started to analyze the theoretical and empirical issues characterizing the possibility of building macroeconomic models in which productivity growth is endogenized in a dynamic stochastic general equilibrium framework (DSGE). This allows to account for a wide range of high- frequencies and medium frequency economic fluctuations previously neglected by real business cycle (RBC) or New Keynesian (NK) models, which focused on short term (usually at the quarterly frequency) fluctuations of the economy around an exogenous productivity deterministic trend. Medium term frequency is encompassing a wide range of frequencies, from two quarters to 50 years, which clearly cannot be accounted by standard DSGE models, unless assuming an abnormally persistent exogenous productivity dynamics. On the other side, endogenous or semi-endogenous growth models, due to their explicitly deterministic and long-run focus, are by construction unable to account for growth effects of temporary fluctuations of the economy, for example due to adverse financial shocks. After the 2007-2009 global financial crisis and the Great Recession, with its decennial slow recovery, this research question has gained high importance, especially for policy institutions willing to stabilize the economy and guarantee medium term growth. Consequently, more and more authors have started to take the challenge of overcoming the complications of medium frequency models integrating DSGE and growth, and therefore combining the non-trivial methodological complexities of each of these two approaches to macroeconomics. Successful models have recently been emerging, such as for example Roeger et al. (2008), Nuño (2011), Guerrón-Quintana and Jinnai (2014), Kung and Schmid (2015), Benigno and Fornaro (2017), Anzoategui et al. (2016), Cozzi et al. (2017), Bolboaca and Fischer (2017), and Bianchi et al. (2018).

These papers mostly focus on advanced closed economies able to push forth the technological frontier. The only exceptions are Roeger et al. (2016) and Cozzi et al. (2017), which allow some degree of technological inflow from abroad, and Bolboaca and Fischer (2017), which studies a closed economy adapting an exogenously evolving technological frontier. However none of them tackles the issue of a small open economy unable to affect the world technological frontier, but undertaking research and development (R&D) to adapt it to its local circumstances. Yet, most of the countries in the world are of this kind, including several European countries.

In this paper we set up the first macroeconomic model able to account for medium frequencies within the context of a non-frontier small open economy. To that purpose we develop a DSGE model with endogenous adoption of an exogenously evolving technological frontier developed abroad. Domestic firms invest in R&D in order to reduce the gap between their sector's productivity and the technological frontier, hoping to appropriate the associated profits by establishing intellectual property rights (IPRs) on it. They will be challenged by future domestic innovators, which leads to a business dynamics typical of the Schumpeterian creative destruction literature stemming from Aghion and Howitt (1992). The mechanism of entry of better firms and exit of technologically obsolete firms emphasized by this literature (recently culminating in the works of Acemoglu et al. (2013)) captures the importance of resource reallocation as an engine of growth, which is instead missed in models of horizontal innovations, stemming from Romer (1990) and culminating with Comin and Gertler (2006), which unrealistically predicts that firm exit is always bad for growth.

Non-frontier open economies, by their nature are always exposed to Schumpeterian competition by foreign origins: firms operating in frontier economies, usually characterized by better knowledge of frontier technologies.¹ This is a point emphasized also by a convincing empirical literature on the effects of foreign direct investment (FDI) of multinational companies (MNCs) on the destination economies: at the micro firm level both negative² and positive effects of MNCs entry on domestic firms³ are found. At the destination country level, Alfaro et al. (2010), and Javorcik (2015) find positive effects of MNC's entry on aggregate productivity, but there is still a lack of completely unambiguous general results.⁴

While theoretical models without an explicit Schumpeterian creative destruction focus are biased in favour of positive effects of MNCs entry, our creative destruction mechanism allows for more flexibility, as effects could overall be positive or negative, and depending on the data used in a calibrated or estimated version of our model, predictions may change. In fact, here we allow for a probability of entry of foreign MNCs transferring the foreign frontier productivity into the sector of the domestic economy in which they enter, but while this technological transfer from abroad is beneficial for the domestic economy's average productivity, it also comes at the expenses of the domestic firms in the sector, which are competed away by the entering MNC. Moreover, this reallocation effect is an additional source of creative destruction penalizing domestic innovators, which have undertaken the R&D investment targeting a partial catch-up with the world technological frontier, and then finding themselves overcome by a top quality foreign firm entering the sector. Hence we are here able to study also how the expectation of a probability of becoming obsolete by potential foreign entry affects the domestic innovator's R&D choice in the first place. While this has been studied in Schumpeterian growth models (such as Chu et al. (2014) and Cozzi and Impullitti (2016)), it has never been cast in a medium frequency framework. Our DSGE model will therefore allow foreign entry probability fluctuations - which may result from foreign business cycles, but also from domestic and foreign policy changes - to be another source of fluctuations of the domestic economy.

Other more standard shocks are source of fluctuations in our stylized economy. These are a temporary productivity shock and a shock to the disutility of labour (Comin and Gertler, 2006), a shock to the stochastic discount factor (Smets and Wouters, 2007), a frontier spillover shock (Nuño, 2011), a shock to the domestic R&D risk premium (Cozzi et al., 2017), and a liquidity premium shock (Anzoategui et al., 2016) to the foreign bonds' demand.

Since we are modelling a small open economy (SOE), we do not assume balanced trade, but we will allow the economy to accumulate net foreign assets and liabilities. This provides a more realistic macroeconomic dynamics, which will also allow a country's debt-elastic interest rate risk premium, along the lines of the seminal contribution by Schmitt-Grohé and Uribe (2003).

¹Broadly intended, inclusive not only of purely engineering blueprints, but also of better management practices, and whatever renders them more productive than local firms.

²As in Aitken and Harrison (1999) evidence on Venezuelan manufacturing plants, whose productivity has been negatively affected by MNCs' entry.

³See Haskel et al. (2007) and Arnold et al. (2011) for evidence of positive spillovers on the productivity of local British and Czech firms.

⁴See Harrison and Rodríguez-Clare (2010).

We calibrate the model using first order moments of data for one of the non-frontier European countries, namely Hungary. The countries from central- and south-eastern Europe are of particular interest because they have entered a catching-up process with western Europe in the mid-1990s and have experienced strong economic growth and productivity gains in the past years, even though the convergence has been slowed down by the global financial crisis. These countries also recorded large FDI inflows in the same period and have a large share of MNCs in the business sector, in Hungary the share being above 50 percent.⁵

The paper is organized as follows: Section 2 provides some motivating facts; Section 3 introduces the main model; Section 4 characterizes the equilibrium of the stationarized economy; Section 5 calibrates the model, while Section 6 discusses the most important dynamic simulations; Section 7 concludes.

2 Motivating Facts

Europe is the top destination in the world for FDI. Together all the countries in Europe attracted almost 40 percent of total world FDI inflows on average between 1995 and 2016, while the 28 member states of the European Union (EU) received between 70 and 98 percent of these flows over time.⁶ In 2016, Europe received about 579 billion dollars worth of FDI flows, being followed by Asia and North America whose FDI inflows amounted to about 487 and 451 billion dollars, respectively.

Among the EU28 countries, Belgium, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Spain, Sweden, and United Kingdom, are the main recipients of FDI inflows as share of total world.⁷ On average, between 1995 and 2016, more than 80 percent of the FDI inflows in the EU28 went to these countries. In contrast, the eleven central- and south-eastern European countries which are EU members, henceforth the CSEE,⁸ attracted about 3 percent of the total world FDI inflows in this period. Poland received almost thirty percent of the inflows, being followed by Czech Republic, Hungary, and Romania, the inward FDI flows to these countries representing slightly more than 70 percent of the group's total.

Nevertheless, there is a growing empirical literature that investigates the effects of international capital flows, in particular of FDI, on output and productivity growth in the CSEE. The reason is that these countries entered a process of catching-up with Western Europe in the mid-1990s after the collapse of the communist regimes in the region and their consequent transition to market economies. In the years that followed the CSEE recorded significant economic growth and productivity gains. As it can be observed in Figure 1, real GDP of the CSEE grew at twice the speed of the EU15⁹ GDP between 1995 and 2016. The higher

⁵See Table 2 from Section 2.

⁶Data source is the United Nations Conference on Trade and Development (UNCTAD).

⁷Each of these ten countries received on average more than one percent of total world FDI between 1995 and 2016.

⁸The eleven CSEE countries which are members of the EU are Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovak Republic, and Slovenia.

⁹The EU15 comprised the following fifteen countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom. These are the EU member countries that joined prior to May 2004. Throughout this paper, the EU15 is used as the representative group of countries for Western Europe.

average growth rate of the CSEE region indicates that there is an economic convergence towards the income levels of the most advanced Western European countries, even though the catching-up process has been slowed down by the global financial crisis.

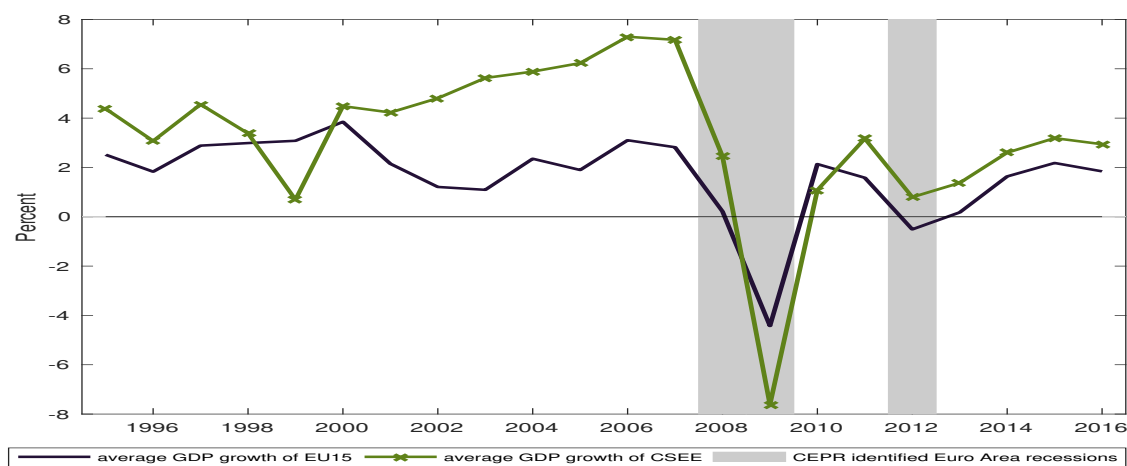


Figure 1: Comparison of GDP growth rates for the sample period 1995-2016. The dark blue line represents the average annual series for the EU15. The green crossed line defines the average annual series for the CSEE. The shaded area marks the CEPR based recession years for the Euro Area.

Source: UNCTAD, authors' computations

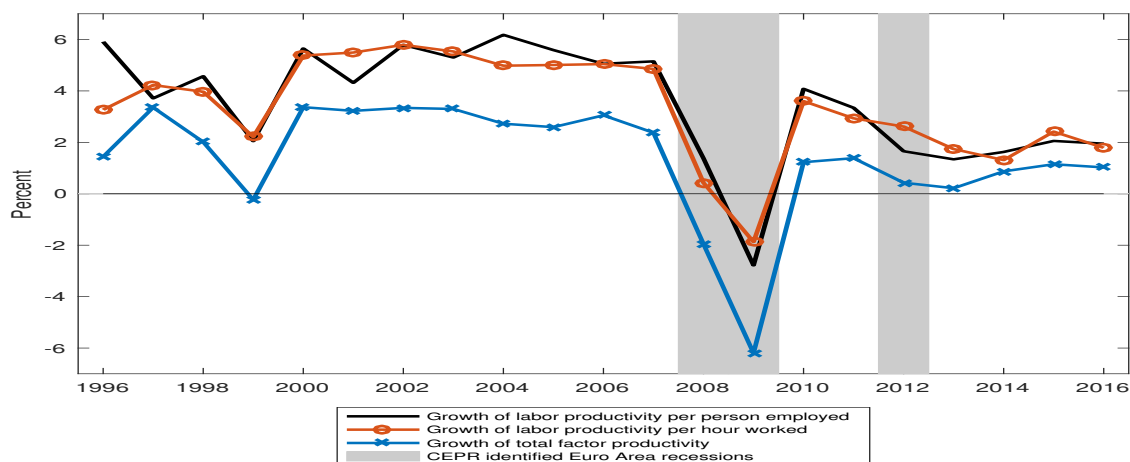


Figure 2: Comparison of measures of annual productivity growth for the sample period 1996-2016. The black line represents the growth rate for labor productivity per person employed. The orange circled line indicates the growth rate for labor productivity per hour worked. The blue crossed line defines the growth rate of TFP. The shaded area marks the CEPR based recession years for the Euro Area.

Source: The Conference Board, authors' computations

One of the main contributors to the economic development of the CSEE region is considered to be productivity, which has experienced a strong growth acceleration in the same period (Georgiev et al., 2017). In Figure 2 we display the growth rates of labor productivity per person employed, labor productivity per hour worked, and total factor productivity

(TFP), respectively.¹⁰ The average annual labor productivity growth was about 3.4% between 1996 and 2016, while TFP growth recorded an average of almost 1.4% in this period.¹¹ Regardless of the productivity measure considered, productivity in the CSEE countries grew on average three times faster than in the EU15.

In Figure 3 it can be observed not only the difference between the productivity growth rates of the two main subgroups of the EU, but also the similarity to the evolution of output growth rates in these two regions which are displayed in Figure 1. Nevertheless, it is important to note that none of the measures of productivity growth presented previously disentangles the effects of the changes in the production technology from those of variations in capacity utilization. Hence, without adjusting TFP for changes in factor utilization, it cannot be said to what extent the fluctuations in productivity, and thus in output, are triggered by technical progress and not by changes in the rate of factor utilization.

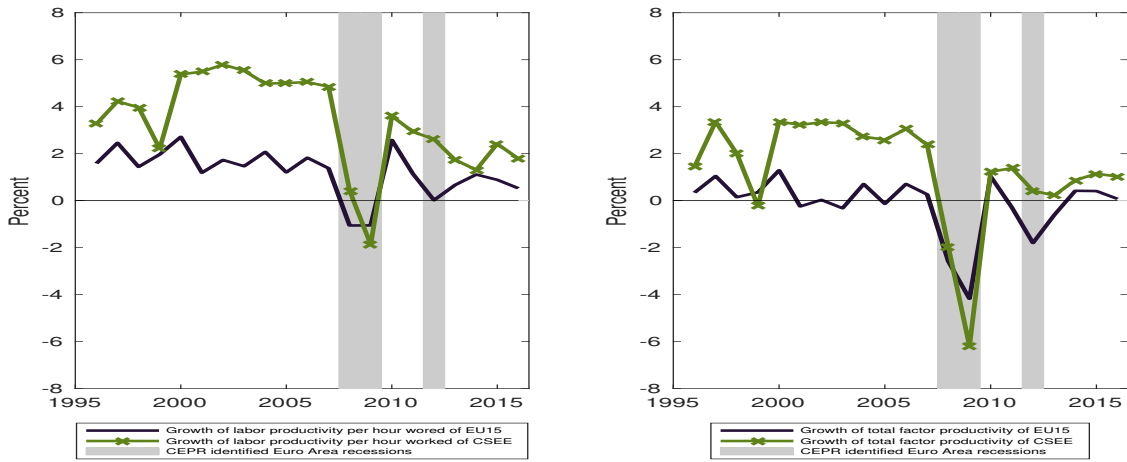


Figure 3: Comparison of productivity growth rates for the sample period 1996-2016. The dark blue line represents the average annual series for the EU15. The green crossed line defines the average annual series for the CSEE. The shaded area marks the CEPR based recession years for the Euro Area.

Source: The Conference Board, authors' computations

To address this issue, Levenko et al. (2017) analyze the contributions to output growth of capital, employment, capacity utilization, and utilization-adjusted TFP growth before, during, and after the global financial crisis using CSEE data for the sample period 1996-2016. Their results indicate that between 1996 and 2016 on average approximately half of GDP growth was determined by capital deepening, about one third by TFP growth, and the remaining one sixth by increased utilization of capital. Based on this analysis, changes in employment did not seem to play an important role in driving GDP growth in this period. Nevertheless, the authors find significant differences across countries and over time. In particular, they show that in the boom period between 2002 and 2007, TFP growth accounted for approximately half of GDP growth, capital deepening for about one third,

¹⁰Data source is the Total Economy Database (TED-1, as of March 2018, and TED-2, as of November 2017) of The Conference Board.

¹¹Using the TFP series from AMECO, we compute an average TFP growth of about 1.7%. However, the cross-correlation between the two series equals 0.97.

while higher employment and capital utilization determined the rest. During the recession between 2008 and 2009, capital stock continued to contribute positively to GDP growth in all countries, but employment, capacity utilization and TFP growth dropped considerably and can be accounted for the decline in GDP growth on average. Lastly, after the global financial crisis economic growth has resumed with capital deepening and increased capital utilization contributing equally to it. However, TFP growth has been low and is considered responsible for slowing down the convergence process.

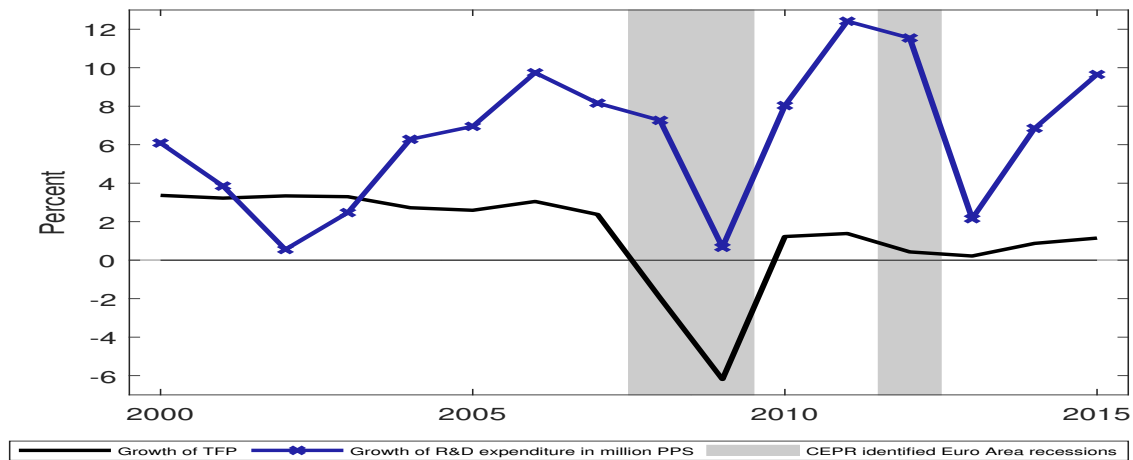


Figure 4: Comparison of growth rates of TFP and R&D expenditure for the sample period 2000-2015. The black line defines the growth rate of TFP in the CSEE. The blue crossed line represents the growth rate of R&D spending in the CSEE. The shaded area marks the CEPR based recession years for the Euro Area.
Source: The Conference Board, Eurostat and UNESCO Institute of Statistics, authors' computations

The findings of Levenko et al. (2017) indicate that technological progress has been the main driver of the strong economic growth in the CSEE region before the Great Recession. However, domestic innovation does not seem to be accountable for this economic performance. The reason is that intramural R&D expenditure in the CSEE region has been significantly lower than in the average EU country between 2000 and 2015. Specifically, the CSEE countries invested on average less than one percent of GDP on R&D projects in this period. In contrast, the average for the whole EU or the EU15 group of countries was about two percent of GDP. The value of the R&D expenditure in the CSEE represented about 5 percent of the total expenditure made in the EU, while per capita expenditure on R&D in the region was about one third of the EU average.¹² One may think that as the CSEE countries were and still are on average lagging behind those in the EU15 in terms of productivity levels, increased investment in domestic innovation in this region may have a higher marginal effect on productivity than in the rest of the EU. Nevertheless, when computing the cross-correlation between the growth rates of TFP and R&D expenditure, we find no evidence in favor of a lead-lag effect.¹³ Moreover, by eyeballing the growth rates of

¹²R&D expenditure is measured in million purchasing power standards (PPS) and PPS per inhabitant at 2005 prices. Data source is Eurostat and UNESCO Institute of Statistics.

¹³We consider lags from 4 to 11 years and find no consistent pattern that could indicate that changes in lagged growth rates of R&D expenses lead to higher productivity growth.

TFP and R&D spending in the CSEE region presented in Figure 4, we observe that in the period prior to the financial crisis, investment in R&D grew fast, which may lead us to the conclusion that the increase in domestic innovation should have triggered an acceleration in productivity growth in the following years. However, the average growth rate of TFP in the CSEE region has been modest during and after the Great Recession.

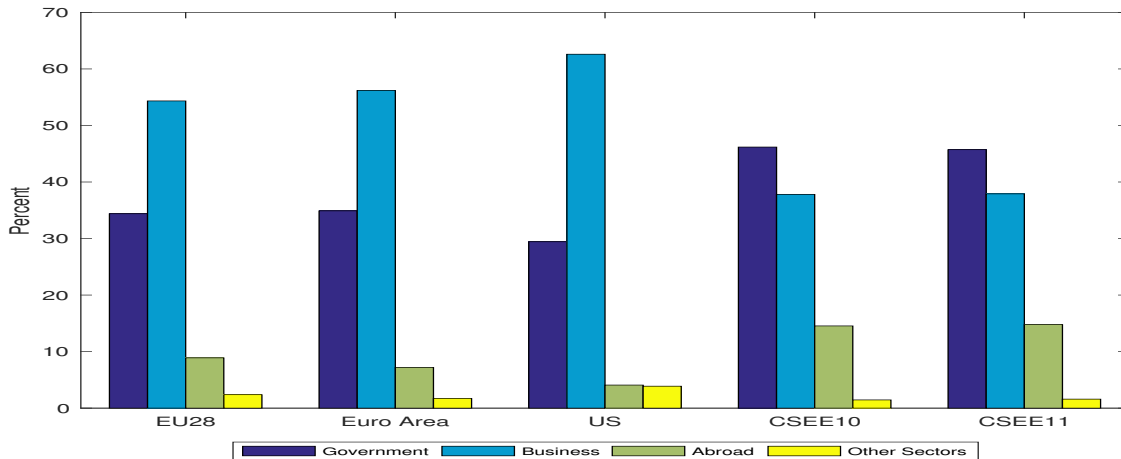


Figure 5: Average intramural R&D expenditure by source of funds for the period 2000-2015. The dark blue bar defines the share of total GERD funded by the government, the light blue bar represents the share funded by the business sector, while the green bar indicates the share of funds provided by foreign private and public institutions. The yellow bar defines the funds provided by other sectors such as higher education and private non-profit. The average values for CSEE11 are for the period 2002-2015, while CSEE10 excludes Croatia from the group of countries but covers the period 2000-2015.

Source: Eurostat, authors' computations

As it can be observed in Figures 5 and 6, a peculiarity of the R&D activity in the CSEE region is that the public sector is a more important funder and performer than in Western Europe and the US. National governments along with the European Commission and other international organizations funded on average more than 50 percent of the R&D projects performed in the CSEE region in the period 2000-2015.¹⁴ Regarding the sectors performing R&D activities, the government and the higher education sector together performed most of the projects on average in the CSEE region. In contrast, in the US and the EU15 group the business sector is the major performer of R&D. This peculiarity of R&D in the CSEE when compared to Western Europe and the US seems to be common among countries with lower GDP per capita. Coccia (2012) shows that countries with higher GDP per capita have private R&D expenditure greater than public R&D expenditure, while the opposite holds true for countries with lower GDP per capita. Moreover, the author finds that labor productivity tends to growth if national private expenditure in R&D exceeds public investment, but has inertia in countries in which R&D expenditure is primarily done by the government sector.

¹⁴Category titled 'Abroad' contains all funds supplied from outside the country of interest by foreign enterprises, foreign governments, EU, and other international organizations. The foreign business sector invests less in domestic R&D projects than the EU and other international organizations. For example, in 2015 foreign enterprises funded about 35 percent of the R&D expenditures allocated to the category 'Abroad.'

These findings are confirmed by Alexa et al. (2014) for the CSEE countries. Their results indicate that business R&D expenditure boosts economic growth, but public R&D is found to play a statistically insignificant role. This can be an explanation for the lack of evidence in favor of a strong contribution of domestic R&D activities to productivity improvements in the CSEE and for the interest in the empirical literature to investigate the role of international capital flows in driving output and productivity growth in this region.

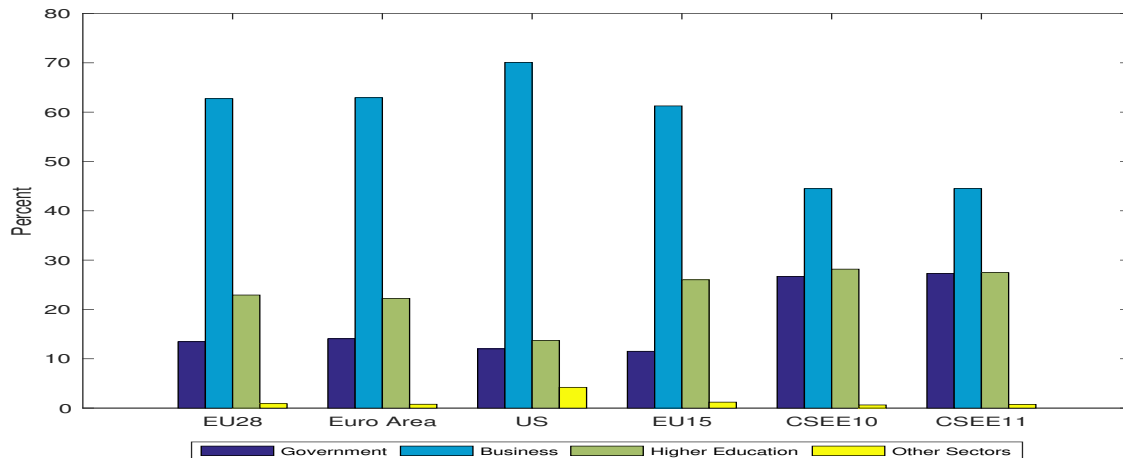


Figure 6: Average intramural R&D expenditure by performer for the period 2000-2015. The dark blue bar defines the share of total GERD performed by the government, the light blue bar represents the share performed by the business sector, while the green bar indicates the share of funds used by the higher education sector. The yellow bar defines the funds used by other sectors such as private non-profit. The average values for CSEE11 are for the period 2002-2015, while for the EU15 are for the period 2004-2015. CSEE10 excludes Croatia from the group of countries and covers the period 2000-2015.

Source: Eurostat, authors' computations

Keller (2004) makes an overview of the literature on international technology diffusion and discusses the various channels for technology diffusion across countries. The author identifies two major channels through which technology can spread internationally. These are international trade and capital flows. Regarding international trade, Keller (2004) reports the findings of various strands of literature which point to an important role for imports in enhancing international technology diffusion. However, Keller (2004) shows that there is less conclusive evidence in the literature in favor of strong effects of exporting activities on learning about foreign technology. For the case of CSEE countries, Alguacil et al. (2015) investigate the role played by foreign technology embodied in capital goods imports from more advanced countries in driving productivity growth in the CSEE region. Using data for ten CSEE countries¹⁵ over the period 1995-2009, the authors find that, when domestic conditions such as domestic R&D activities and human capital are controlled for, foreign capital goods imports are a significant source of productivity growth in the CSEE countries. Moreover, they show that countries with a larger stock of physical and human capital, domestic R&D, and which are closer to the technology frontier absorb faster foreign technology and thus experience stronger productivity growth.

¹⁵Alguacil et al. (2015) consider the group CSEE10 and thus exclude Croatia from the sample.

On what concerns the importance of FDI as a channel for technology diffusion, Keller (2004) reports the different findings of the empirical literature ranging from significantly negative effects to large positive spillovers of FDI on productivity. The conflicting results stem from the differences in methodology, data aggregation level, and chosen sample, among others. The conclusion in this paper is that when more granular (i.e. industry, sector, or firm level) data is employed and methodological problems such as heterogeneity or endogeneity are dealt with by the empirical models, results tend to favor the positive externality of FDI on domestic productivity.¹⁶

The question on whether international capital flows enhance productivity and output growth is even more relevant for the CSEE countries as the catching-up process with Western Europe has coincided with large FDI inflows (Bijsterbosch and Kolasa, 2009). As presented previously, the CSEE region attracted on average about 3 percent of the total world FDI inflows between 1995 and 2016. While this may seem a small share when compared with the 40 percent of world FDI inflows that went to the whole Europe, the importance of FDI flows for the CSEE countries can be better assessed when measured as a share of GDP. Between 1995 and 2016, FDI inflows in the CSEE region averaged 4.3 percent of GDP, ranging from 1.5 percent in Slovenia to 7.9 percent in Bulgaria. In contrast, the world average for the same period was 2.1 percent of GDP. Moreover, the average inflows represented 2.8 percent of GDP in EU28 and 2.7 percent of GDP in the EU15, respectively. As illustrated in Figure 7, regardless of the subperiod considered, FDI inflows to CSEE represented a bigger share of GDP than in all countries or groups of countries considered for comparison. Moreover, the share has increased from one subperiod to the other in the years between 1995 and 2009, but the Great Recession led to a considerable drop in this share for the subperiod 2010-2014. Even though the decrease was more drastic than in the other groups of countries, inward FDI flows still represented a bigger share of GDP in the last sub-period considered in the CSEE region than in the other groups.

The CSEE region stands out from the other groups of countries also when considering the evolution of inward FDI stocks, as presented in Figure 8. Between 1995 and 2016, there was a relatively fast and continuous increase in the CSEE's FDI stocks relative to GDP, as inward FDI stocks rose by 43.7 percentage points in this period. In contrast, the increase was by 30.7 percentage points in the EU15 and 21.2 percentage points in the US. Among the CSEE countries, the strongest increase was registered in Bulgaria, by about 81.4 percentage points, while the smallest was in Slovenia, by slightly more than 20 percentage points. In the period 1995-2016, CSEE's inward FDI stocks represented on average almost 40 percent of GDP, while the shares were about 32.5 percent in the EU15 and 25.3 percent in the world. At the level of 2016 the average inward FDI stock relative to GDP in the CSEE region was 53.1 percent, with inward FDI stocks in Bulgaria and Estonia representing more than 80 percent of GDP and about 30 percent in Slovenia and Lithuania. In comparison, the average inward FDI stock in the EU15 was 44.8 percent of GDP and 34.2 percent in the US.

¹⁶A more recent review of the empirical literature on this topic is provided by Contessi and Weinberger (2009).

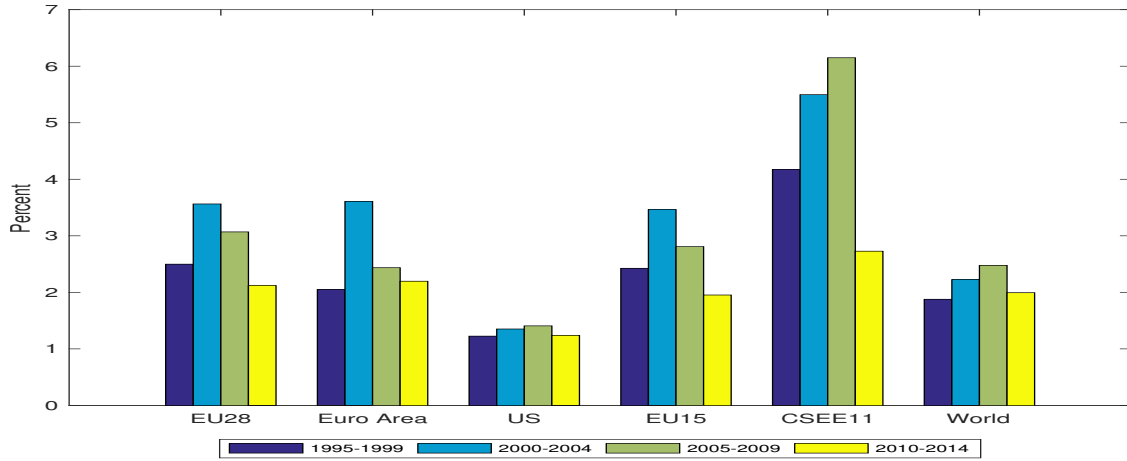


Figure 7: Average inward FDI flows in percentage of GDP for the period 2000-2014.
Source: UNCTAD, authors' computations

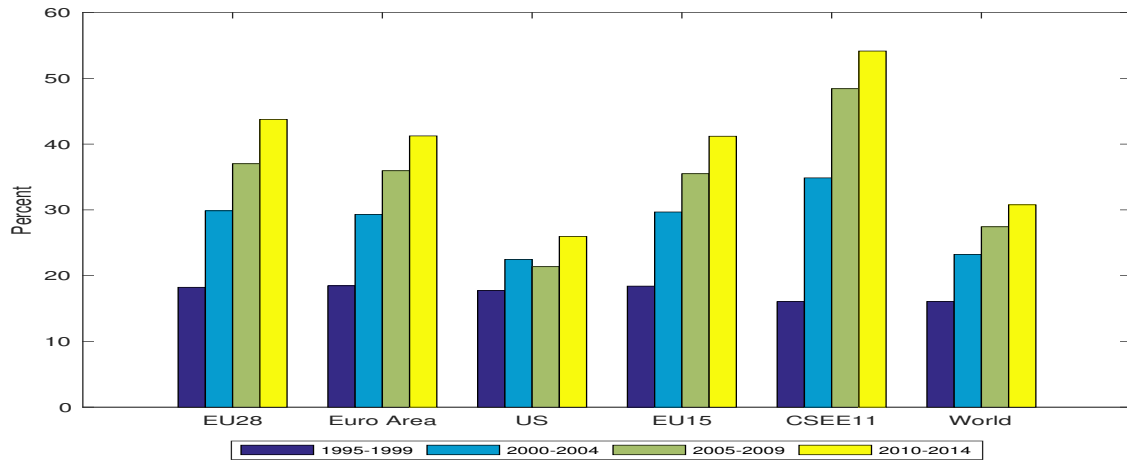


Figure 8: Average inward FDI stocks in percentage of GDP for the period 1995-2014.
Source: UNCTAD, authors' computations

As illustrated in Figure 9, inward FDI flows represented a bigger share of GDP than outward flows in the CSEE region, which indicates that the attractiveness of the CSEE region led to more capital going into the CSEE countries than out of them between 1995 and 2016. Moreover, we find positive cross-correlations between net inward FDI flows and different measures of productivity.¹⁷ This contradicts Gourinchas and Jeanne (2013) who conclude that capital does not flow more to countries that grow faster. The countries in the CSEE region seem to be different than the developing countries considered in the analysis of Gourinchas and Jeanne (2013) as they experienced higher productivity growth and at the

¹⁷We compute the cross-correlation between FDI net inward flows as percentage of GDP and growth of TFP, growth of labor productivity per person employed, or growth of labor productivity per hour worked. The coefficients of correlation vary between 0.32 and 0.58 depending on the productivity measure employed.

same time attracted more capital between 1995 and 2016. While Gourinchas and Jeanne (2013) find that capital has been flowing “upstream” from developing countries to the US, in the case of the CSEE we find that capital moved “downstream” to the poorer CSEE countries, investment coming mostly from the richer EU15 neighbors.

With this observed comovement of productivity growth and FDI inflows in the CSEE countries, questions of causality arise. There is an extensive empirical literature on the effect of capital flows and their components, such as FDI, on output and productivity growth. As pointed out previously, the evidence in this literature is mixed, with no conclusive support for either positive or negative impact of capital flows on growth.

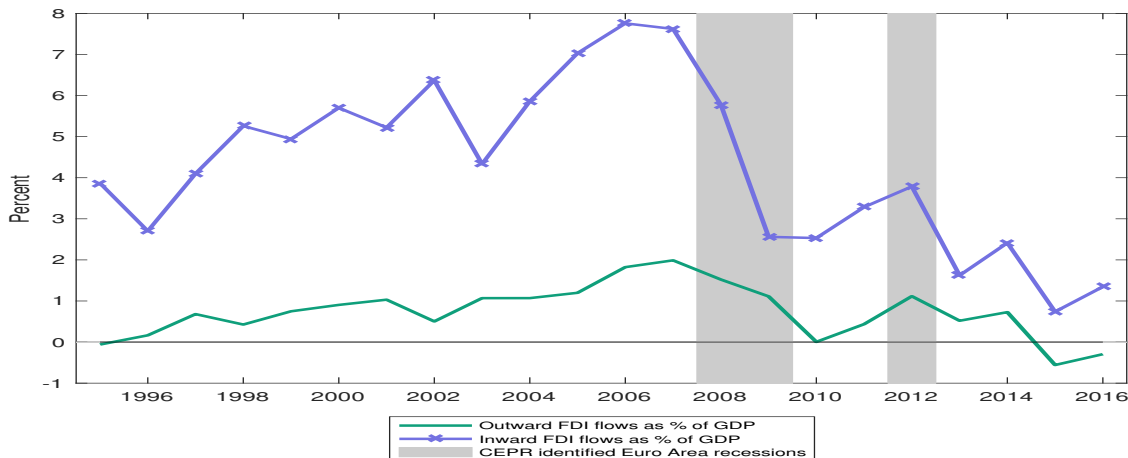


Figure 9: CSEE’s Inward and Outward FDI flows in percentage of GDP for the period 1995-2016.

Source: UNCTAD, authors’ computations

Iamsiraroj and Ulubaşoğlu (2015) review 108 empirical studies using data from around the globe and reporting 880 regression estimates of the effects of FDI on economic growth. The authors find that the distribution of these estimates is such that 43 percent are positive and statistically significant, 26 percent are positive and statistically insignificant, 17 percent are negative and statistically significant, and 14 percent are negative and statistically insignificant.¹⁸ The effect of FDI on productivity growth has been investigated to a lesser extent by the empirical literature. Kose et al. (2009) employ annual cross-country data over the period 1966 to 2005 for 67 advanced and developing countries and find strong evidence that FDI and portfolio equity liabilities boost TFP growth.¹⁹ Bijsterbosch and Kolasa (2009) make an overview of the empirical evidence provided by the literature investigating this relationship in the CSEE countries and, using more recent industry-level data that covers nineteen sectors of eight of the CSEE countries (excluding Croatia, Bulgaria, and Romania) over the period 1995-2005, find that FDI inflows play an important role in driving productivity growth in the CSEE region.

¹⁸See also Almfraji and Almsafir (2014) for a review of the literature on the relationship between FDI and economic growth.

¹⁹See the references in Kose et al. (2009) for a review of the literature on the relationship between FDI and productivity growth using different levels of data aggregation.

On what concerns the MNCs in the CSEE region, using data from Eurostat for foreign-owned companies (FATS dataset) and for all firms (SBS dataset) in the CSEE countries, we can investigate how important the MNCs are for the domestic economy and how they compare with the other local firms.

Table 1: MNCs at the level of 2014. Comparison of country groups

	CSEE	EU15	EU28
Foreign Enterprises - % of total	3.1	3.0	2.9
Foreign penetration based on turnover	38.0	30.2	32.3
Foreign penetration based on production value	38.5	29.9	32.5
Foreign penetration based on value added at factor cost	34.3	26.0	28.6
Relative apparent labour productivity	166.6	161.4	164.3
Relative wage adjusted labour productivity	117.7	121.9	120.0

Source: Eurostat, authors' computations

As it can be observed in Table 1, foreign enterprises represent approximately 3 percent of the total number of firms in all groups. However, the share of foreign control in terms of either turnover, production value, or value added, is different between the groups. Regardless of the measure employed, foreign control is higher in the CSEE than in the EU15. The share of turnover under foreign control is about 38 percent in the CSEE, but slightly more than 30 percent in the EU15. The discrepancy is even higher when comparing the foreign penetration in terms of value added, but highest in terms of production value, the share for the CSEE being 8.6 percentage points higher.

When comparing the performance of foreign versus domestic enterprises in the three groups of countries based on productivity, we observe that labour productivity is larger in foreign firms than in their domestic counterparts regardless of the measure employed or the region considered.²⁰ The greatest disparity in labour productivity between foreign and domestic enterprises, using gross value added per person employed as a proxy, is registered in the CSEE region. However, when considering the wage adjusted labour productivity, measured as gross value added divided by personnel costs, the difference between the productivity in foreign-controlled and domestic firms is largest in the EU15. The reason for this could be the higher wages paid by foreign-controlled companies relative to those paid by the local firms, the gap being larger in the CSEE than in the EU15.

The ratios for individual countries reported in Table 2 show that there is greater variation within the CSEE region than between the groups of countries. Most foreign-controlled enterprises are registered in Latvia, 7.1 percent of the total number of companies, and Romania, 6.5 percent, while the least are in Poland, 0.5 percent of total, and Slovak Republic, 0.8 percent. Interestingly, foreign penetration in terms of either turnover, production value, or

²⁰The labour productivity of domestic firms used in this analysis is in fact the labor productivity of all firms registered in the countries included in each group. However, as foreign firms represent a small share of the total number of firms, they may influence very little the average value of labor productivity. In any case, this would imply a small downward bias of the ratios reported.

value added, in the countries with smaller shares of foreign-controlled enterprises is relatively high, which implies that fewer multinational companies generate a large turnover, production value, or value added. For example, in Poland these three foreign penetration indicators are close to 30 percent and are similar to the respective indicators for Slovenia where the number of foreign companies represents 5.1 percent of the total. Even stronger penetration of few foreign enterprises is observed in the Slovak Republic for which the indicator in terms of production value is about 55 percent.

Table 2: MNCs at the level of 2014. Comparison of individual countries

	Bulgaria	Croatia	Czech Rep.	Estonia	Hungary	Latvia
Foreign Enterprises - % of total	3.5	2.8	1.3	1.2	3.6	7.1
Foreign penetration based on turnover	33.9	29.0	46.7	26.9	52.8	39.3
Foreign penetration based on production value	38.7	28.1	48.4	29.9	57.4	29.1
Foreign penetration based on value added at factor cost	33.0	24.9	42.3	26.4	52.7	31.1
Employees in MNCs - % of total	18.2	:	33.4	23.7	29.9	19.2
Relative apparent labour productivity	203.8	187.3	157.7	116.3	199.0	166.3
Relative wage adjusted labour productivity	124.1	130.8	129.9	97.2	130.0	108.2

	Lithuania	Poland	Romania	Slovak Rep.	Slovenia	CSEE
Foreign Enterprises - % of total	2.1	0.5	6.5	0.8	5.1	3.1
Foreign penetration based on turnover	32.5	29.6	48.1	49.9	29.1	38.0
Foreign penetration based on production value	34.3	27.9	47.3	55.3	26.6	38.5
Foreign penetration based on value added at factor cost	26.5	29.1	43.9	43.4	24.1	34.3
Employees in MNCs - % of total	6.3	:	27.5	:	:	:
Relative apparent labour productivity	137.2	166.0	163.0	170.7	124.9	162.9
Relative wage adjusted labour productivity	109.6	120.0	104.9	126.8	111.6	117.6

Source: Eurostat, authors' computations

3 The Model

In this section, we set up the model of our stylized non-frontier small open economy, which is cast in an infinite horizon in discrete time, $t = 0, 1, 2, \dots$, with all agents having perfectly rational expectations. Growth is given by the evolution of the technological frontier $A_t^{\max}$, whose growth rate fluctuates exogenously around a deterministic trend rate $g_{\text{exo}} > 0$.²¹

3.1 Manufacturing

A unique final good Y_t is produced at time t by perfectly competitive firms, which combine a continuum (normalized to a mass of 1 without loss of generality) of intermediate goods

²¹We discard population growth in this model because population has been shrinking in most of the CSEE countries during the period considered in this paper, population decline being attributed not only to low birth rates but also to large out-migration. As migration can be reverted and the time series are not sufficiently long, it is not advisable to consider the trend observed in the past years as the steady state growth rate of population in these countries.

$i \in [0, 1]$ according to a constant returns to scale (CRS) production function

$$Y_t = \exp(\epsilon_t^{\text{temp}}) \left(\int_0^1 Y_{it}^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}}, \quad (1)$$

with constant elasticity of substitution (CES) $\sigma > 1$, and subject to a temporary disembodied productivity shock ϵ_t^{temp} .

It easily follows that the demand function for each intermediate good is:

$$Y_{it} = Y_t \left(\frac{P_{it}}{P_t} \right)^{-\sigma}, \quad (2)$$

where P_t is the general price index

$$P_t = \left(\int_0^1 P_{it}^{1-\sigma} di \right)^{\frac{1}{1-\sigma}}. \quad (3)$$

Since we will focus on real variables, we normalize the final goods price index to 1.

The intermediate goods are produced under monopolistic competition. Each intermediate good i is produced using capital K_{it-1} and labor l_{it} according to a technology represented by the following Cobb-Douglas production function:

$$Y_{it} = A_{it} (l_{it})^\alpha \left(\frac{K_{it-1}}{A_t} \right)^{1-\alpha}, \quad (4)$$

where α is labor elasticity, A_{it} is sector i 's technological level, and $A_t = \int_0^1 A_{it} di$ denotes aggregate technology. As in Howitt and Aghion (1998), Nuño (2011), and Cozzi et al. (2017), with more sophisticated technologies, production becomes more capital-intensive. It follows that the nominal marginal cost of producing one unit of output is:

$$MC_{it} = \frac{(r_t^K)^{1-\alpha} \left(\frac{W_t}{A_t} \right)^\alpha}{\frac{A_{it}}{A_t} (\alpha)^\alpha (1-\alpha)^{1-\alpha}} \quad (5)$$

where r_t^K and W_t are the real rental cost of capital and real wage. Hence the intermediate good i 's firm profit is:

$$D_{it} = P_{it} Y_{it} - W_t l_{it} - r_t^K K_{it-1} = (P_{it} - MC_{it}) Y_{it}$$

and its unconstrained profit maximizing price is:

$$P_{it} = \frac{\sigma}{\sigma-1} MC_{it},$$

with $\frac{\sigma}{\sigma-1}$ providing the mark-up over marginal costs.

Averaging sector i 's production function

$$Y_{it} = \frac{A_{it}}{A_t} (A_t l_{it})^\alpha (K_{it-1})^{1-\alpha},$$

and integrating over all sectors gives

$$Y_t = \exp(\epsilon_t^{\text{temp}}) (A_t l_t)^\alpha (K_{t-1})^{1-\alpha},$$

which implies a standard growth accounting relationship:

$$g_{Y_t} = \alpha g_{A_t} + (1 - \alpha) g_{K_{t-1}}. \quad (6)$$

Since in the deterministic trend (balanced growth path) growth rates are constant, i.e. $g_{A_t} = g_A = g_{\text{exo}}$, and $g_K = g_Y$, from eq. (6) it follows that

$$g_K = g_Y = g_{\text{exo}},$$

meaning that the trend growth rate of capital and GDP - and therefore that of investment and consumption - are all equal to the deterministic growth rate of frontier productivity. These considerations will be very useful when we recast our model in stationary form, which is useful for numerical simulations.

3.2 Households

In this economy there is a unit continuum of identical households, and generic household $j \in [0, 1]$ maximizes its intertemporally additive utility function

$$U_{jt} = \mathbb{E}_t \left[\sum_{s=0}^{\infty} \exp(\epsilon_{t+s}^{\text{beta}}) \beta^s u(C_{j,t+s}, l_{j,t+s}, B_{j,t+s}) \right],$$

where the discount factor has a constant component $0 < \beta < 1$ and a log-normally distributed stochastic component driven by an exogenous shock ϵ_t^{beta} . Therefore, as in much of the New Keynesian models used for policy (Smets and Wouters, 2007; Roeger et al., 2008), fluctuations in the time preference of households drive fluctuations in consumption and saving.

The period utility $u(C_{jt}, l_{jt}, B_{jt})$ depends on the household's consumption C_{jt} , on foreign bonds holding B_{jt} , and on labor supplied by the household l_{jt} according to

$$\begin{aligned} u(C_{jt}, l_{jt}, B_{jt}) = & \frac{1}{1 - \chi} (C_{jt} - hC_{t-1})^{1-\chi} \\ & - \exp(\epsilon_t^{\text{labour}}) \omega (C_t)^{1-\chi} \frac{(l_{jt} - \tau l_{t-1})^{1+\theta}}{1 + \theta} \\ & + \exp(\epsilon_t^{\text{B}}) \nu B_{jt} (C_t - hC_{t-1})^{-\chi} \end{aligned} \quad (7)$$

with $C_t = \int_0^1 C_{jt} dj$ and $l_t = \int_0^1 l_{jt} dj$. As common in the literature, parameters $h \in (0, 1)$ and $\tau \in (0, 1)$ measure the strength of external habits in consumption and labour respectively, while ω and ν are the relative weight of labor and foreign bonds respectively in the utility function. $\epsilon_t^{\text{labour}}$ is a labor disutility shock standard in the real business cycle literature.

Foreign bonds holding utility shock ϵ_t^B represents a “flight to liquidity” shock,²² similar to the liquidity demand shocks of the closed economy models of Fisher (2015) and Anzoategui et al. (2016). However, our open economy interpretation opens the door to a wider range of interpretations, including a domestic currency crises such as the Asian crisis.

The representative household in each period t receives labour incomes at wage W_t , profits D_{jt} from firms they own, obtain interest $(1 + r_{t-1})$ from foreign bonds B_{jt-1} , and rental rates r_t^K from their capital stock holdings K_{jt-1} , and spend them on consumption C_{jt} , physical capital investment I_{jt} , the share $(1 - Z_t)$ of R&D investment X_{jt} that is not refunded by the government in proportion to the R&D subsidy Z_t , lump-sum taxes T_{jt} , and foreign bonds according to the following budget constraint:

$$C_{jt} + I_{jt} + (1 - Z_t)X_{jt} + B_{jt} + T_{jt} = l_{jt}W_t + D_{jt} + (1 + r_{t-1})B_{jt-1} + r_t^K K_{jt-1}.$$

The household’s law of motion of physical capital is

$$K_{jt} = I_{jt} \left[1 - \eta_I \left(\frac{I_{jt}}{I_{t-1}} \right) \right] + (1 - \delta)K_{jt-1},$$

where $\eta_I \left(\frac{I_{jt}}{I_{t-1}} \right)$ is a quadratic adjustment cost to investment defined as

$$\eta_I = \frac{\gamma_K}{2} \left(\frac{I_{jt}}{I_{t-1}} - \exp(g_I) \right)^2,$$

$\exp(g_I)$ being the growth rate of investment along the balanced growth path.

Notice that our timing convention for stocks, similar to that used in *Dynare* coding, assigns to stock variables the time date when they have been decided. For example, the investment in physical capital available for production in period t is decided at the end of period $t - 1$. Therefore, capital used in production at time t is indicated as K_{jt-1} . Similarly for B_{jt-1} , etc. This makes immediately clear that variables predetermined at time t have been accumulated in $t - 1$.

The household first-order condition with respect to consumption is:

$$\Lambda_{jt} = (C_{jt} - hC_{t-1})^{-\chi}$$

where Λ_t is the Lagrange multiplier associated with the budget constraint.

The Euler Equation is the household first-order condition with respect to the risk free foreign bonds:

$$\exp(\epsilon_t^{\text{beta}}) \exp(\epsilon_t^B) \nu(C_t - hC_{t-1})^{-\chi} - \exp(\epsilon_t^{\text{beta}}) \Lambda_{jt} + \mathbb{E}_t \beta [\exp(\epsilon_{t+1}^{\text{beta}}) \Lambda_{jt+1} (1 + r_t)] = 0.$$

The first order condition with respect to labour equates the marginal rate of substitution between consumption and labour with real wage:

$$\exp(\epsilon_t^{\text{labour}}) \omega(C_t)^{1-\chi} (l_{jt} - \tau l_{t-1})^\theta = W_t \Lambda_{jt}.$$

²²The utility of risk-free bond holding is weighted, with no loss of generality, by the average marginal utility of consumption, as in Anzoategui et al. (2016).

In its optimal capital acquisition choice, each household compares the real price of a unit of physical capital, p_t^K , at the end of period t to the expected present discounted value of the next period rental rate of a unit of capital, r_{t+1}^K , plus the expected discounted value of the undepreciated part of capital remaining, $1 - \delta$, weighted by its new price p_{t+1}^K , according to:

$$\exp(\epsilon_t^{\text{beta}}) p_t^K \Lambda_{jt} = \mathbb{E}_t \beta \exp(\epsilon_{t+1}^{\text{beta}}) \Lambda_{j,t+1} [r_{t+1}^K + p_{t+1}^K (1 - \delta)]$$

Then households optimally choose investment, by equalizing the cost of investment to the price of a unit of capital exclusive of adjustment costs:

$$1 = p_t^K \left[1 - \frac{\gamma_K}{2} \left(\frac{I_{jt}}{I_{t-1}} - \exp(g_I) \right)^2 - \gamma_K \frac{I_{jt}}{I_{t-1}} \left(\frac{I_{jt}}{I_{t-1}} - \exp(g_I) \right) \right].$$

3.3 The R&D Sector

While this stylized model economy is characterizing a non-frontier country, its medium frequencies will be affected by the way endogenous domestic R&D adopts the evolving technological frontier developed abroad. More in detail, we will assume that the world technological frontier, A_t^{max} , evolves exogenously, with fluctuations around a constant trend growth rate g_{exo} , according to:

$$A_t^{\text{max}} = A_{t-1}^{\text{max}} [1 + g_{\text{exo}} \exp(\epsilon_t^{\text{Amax}})],$$

where ϵ_t^{Amax} is a shock process.

3.3.1 Domestic R&D

Domestic innovators use the R&D investment provided by the households to produce a probability of filling the gap between their sectorial productivity, A_{it-1} , and the frontier, A_t^{max} , that is by targeting an intermediate technological level A_{it}^{target} measured by:

$$A_{it}^{\text{target}} \equiv A_{it-1} + \phi_{t-1} (A_t^{\text{max}} - A_{it-1}), \quad (8)$$

with ϕ_t defined by:

$$\phi_t = \phi_0^{\left(1 - \frac{A_t}{A_t^{\text{max}}}\right)}, \quad (9)$$

and parameterized by $0 < \phi_0 < 1$. Equation 9 allows the speed of convergence through domestic R&D to depend on the distance to the frontier of domestic average productivity, which is in line with the empirical findings indicating that countries closer to the frontier converge faster. Notice also in equation (8) that in case of success, the domestic innovator's technology will be dependent on the last period's technological level in the sector. This heterogeneity will reflect itself on marginal costs, prices, and production, implying that more advanced incumbents set the stage for higher productivity by domestic innovators in the sector. Each period there is a domestic entrepreneur able to attempt the innovation, and the success probability of domestic innovation depends on his/her R&D expenditure

(expressed in final goods) X_{it} according to the following innovation probability production function:

$$n_{it} = 1 - \exp \left(- \frac{X_{it} \left[1 - \eta_X \left(\frac{X_{it}}{X_{t-1}} \right) \right]}{\varpi^{RD} A_{it}^{\text{target}}} \right). \quad (10)$$

For symmetry to physical capital investment, we assume that also R&D investment is subject to a quadratic adjustment cost $\eta_X \left(\frac{X_{it}}{X_{t-1}} \right) = \frac{\gamma_{RD}}{2} \left(\frac{X_{it}}{X_{t-1}} - \exp(g_X) \right)^2$. This captures in reduced form the idea that the past size of R&D laboratories sets a standard for the current research laboratory size, with researchers struggling when imposed abrupt changes.

Note also that, unlike Nuño (2011), we set the probability of innovation n_{it} to be always between 0 and 1 and increasing in R&D expenditure X_{it} , but with decreasing marginal product

$$\frac{\partial n_{it}}{\partial X_{it}} = \frac{1 - \eta_X \left(\frac{X_{it}}{X_{t-1}} \right) - \gamma_{RD} \frac{X_{it}}{X_{t-1}} \left(\frac{X_{it}}{X_{t-1}} - \exp(g_X) \right)}{\varpi^{RD} A_{it}^{\text{target}}} \exp \left(- \frac{X_{it} \left[1 - \eta_X \left(\frac{X_{it}}{X_{t-1}} \right) \right]}{\varpi^{RD} A_{it}^{\text{target}}} \right).$$

Our R&D production function (10) also features a degree of R&D difficulty that increases with the technological target, A_{it}^{target} , i.e. more sophisticated technologies are more difficult to achieve. This allows us to avoid the prediction of scale effects in adoption.

Moreover, unlike its linear counterparts used by Nuño (2011), Benigno and Fornaro (2017), and other important studies, the ability of this production function to always guarantee a non-negative and lower than 1 probability of innovation allows a lot of flexibility in the analysis of medium term frequencies in non-frontier economies, and sets a basis for several potentially useful theoretical and empirical exercises, including policy evaluations.

3.3.2 Multinational Firms Entry

However, domestic innovators are not the only ones which can modernize the industries in the country. In fact, we assume that after domestic R&D is spent in sector i , a multinational firm equipped with the frontier technology A_t^{max} can enter the sector with an exogenous probability f_t . Since both domestic and multinational firms operate under constant returns to scale, under the assumption of price competition, the incumbent firm will exit the sector and the newly entering MNC will bring the frontier technology A_t^{max} in that sector.

We remark that we are allowing MNCs to also enter sectors already dominated by a MNC entered in the past: also in that case the newly entering MNC will bring the frontier productivity into the sector. Similarly, domestic innovators can challenge MNC incumbents endowed with past frontier technologies, now overcome by the current frontier. Also in this case, the domestic innovator can scale up their sector's productivity by targeting a better technology A_{it}^{target} determined by equation (8).

The probability of multinational entry f_t can itself fluctuate stochastically according to shock ϵ_t^f :

$$f_t = f \exp(\epsilon_t^f)$$

around its deterministic steady state value $f \in (0, 1)$. From our timing assumption that MNCs enter later in the period after the domestic innovator has attempted the innovation

follows that the productivity in each sector i evolves according to the following intra-period lottery:

$$A_{it} = \begin{cases} A_t^{\max}, & \text{probability } f_t \\ A_{it-1} + \phi_{t-1} (A_t^{\max} - A_{it-1}) \equiv A_{it}^{\text{target}}, & \text{probability } n_{it-1} (1 - f_t) \\ A_{it-1}, & \text{probability } (1 - n_{it-1}) (1 - f_t) \end{cases}$$

With these timing assumptions, the domestic R&D firm's expected profit maximization is expressed by:

$$\max_{X_{it}} n_{it} P_{it}^{\text{Starget}} (1 - f_t) - X_{it} (1 - Z_t) [1 + r_{\text{RDpremium}} + \exp(\epsilon_t^{\text{RD}})],$$

subject to equation (10), where P_t^{Starget} is the nominal stock market value of the firm at the target technology, $r_{\text{RDpremium}}$ is a constant systematic R&D risk premium, and ϵ_t^{RD} an associated zero mean R&D risk premium shock.

The R&D investment first order condition is then:

$$\begin{aligned} P_{it}^{\text{Starget}} (1 - f_t) \exp \left(- \frac{X_{it} \left[1 - \eta_X \left(\frac{X_{it}}{X_{t-1}} \right) \right]}{\varpi^{\text{RD}} A_{it}^{\text{target}}} \right) \\ \frac{\left[1 - \eta_X \left(\frac{X_{it}}{X_{t-1}} \right) - \gamma_{\text{RD}} \frac{X_{it}}{X_{t-1}} \left(\frac{X_{it}}{X_{t-1}} - \exp(g_X) \right) \right]}{\varpi^{\text{RD}} A_{it}^{\text{target}}} \\ = (1 - Z_t) [1 + r_{\text{RDpremium}} + \exp(\epsilon_t^{\text{RD}})]. \end{aligned}$$

Hence:

$$\frac{X_{it} \left(1 - \eta_X \left(\frac{X_{it}}{X_{t-1}} \right) \right)}{\varpi^{\text{RD}} A_{it}^{\text{target}}} = \ln \left(\frac{P_{it}^{\text{Starget}} (1 - f_t) \left[1 - \eta_X \left(\frac{X_{it}}{X_{t-1}} \right) - \gamma_{\text{RD}} \frac{X_{it}}{X_{t-1}} \left(\frac{X_{it}}{X_{t-1}} - \exp(g_X) \right) \right]}{\varpi^{\text{RD}} A_{it}^{\text{target}} (1 - Z_t) [1 + r_{\text{RDpremium}} + \exp(\epsilon_t^{\text{RD}})]} \right). \quad (11)$$

In equilibrium firm values are proportional to their productivity index, which implies that

$$\frac{P_{it}^{\text{Starget}}}{A_{it}^{\text{target}}} = \frac{P_t^S}{A_t^{\text{target}}}, \text{ for all } i \in [0, 1].$$

where P_t^S denotes the value of an average intermediate good monopolist in this economy. Therefore equation (11) becomes

$$\frac{X_t \left(1 - \eta_X \left(\frac{X_{it}}{X_{t-1}} \right) \right)}{\varpi^{\text{RD}} A_t^{\text{target}}} = \ln \left(\frac{P_t^S (1 - f_t) \left[1 - \eta_X \left(\frac{X_{it}}{X_{t-1}} \right) - \gamma_{\text{RD}} \frac{X_t}{X_{t-1}} \left(\frac{X_t}{X_{t-1}} - \exp(g_X) \right) \right]}{\varpi^{\text{RD}} A_t^{\text{target}} (1 - Z_t) [1 + r_{\text{RDpremium}} + \exp(\epsilon_t^{\text{RD}})]} \right).$$

Notice from the term $1 - f_t$ that the risk of a MNC's vanifying the R&D investment of a domestic innovator will discourage domestic R&D investment.

Due to the two sources of creative destruction in our model economy, domestic and MNC innovations, the (average) stock market value of an incumbent intermediate good monopolist

is expressed by the present discounted value of next period's dividends plus the continuation value of this firm scaled down by the lower than 1 probability of its not becoming obsolete due to domestic or foreign competition. Therefore its stock market valuation, after taking into account the household's stochastic discount factor, is:

$$\begin{aligned} & \exp(\epsilon_t^{\text{beta}}) (C_t - hC_{t-1})^{-\chi} \\ &= E_t \left[\exp(\epsilon_{t+1}^{\text{beta}}) \beta (C_{t+1} - hC_t)^{-\chi} \frac{D_{t+1} + P_{t+1}^S (1 - n_{t+1}) (1 - f_{t+1})}{P_t^S} \right] \end{aligned}$$

3.4 Sectorial Dynamics and Productivity Growth

Each sector will alternate the nationality of its leader based on the realization of the innovative entry processes. Therefore we cannot determine the nationality of the incumbent of a sector at a given time. However, since all innovative entry processes are assumed to be independent, we can appeal to the law of large number and use them to study the average frequency of sectorial incumbency changes, which is indeed deterministic. Remembering that multinationals can enter also sectors already dominated by a (potentially obsolete) multinational entered in the past, it follows that MNCs control a subset of the sectors of the economy of mass F_t , which evolves according to this law of motion:

$$F_t = F_{t-1} + (1 - F_{t-1})f_{t-1} - F_{t-1}(1 - f_{t-1})n_{t-1}.$$

By aggregating the domestic innovations and the MNCs innovation over the economy, and using the law of large numbers again, we can conclude that the average domestic technology evolves deterministically according to the following difference equation:

$$\begin{aligned} A_t = & f_{t-1}A_t^{\max} + (1 - f_{t-1}) \{ n_{t-1} [A_{t-1} + \phi_{t-1} (A_t^{\max} - A_{t-1})] + \\ & (1 - n_{t-1})A_{t-1} \}. \end{aligned}$$

3.5 Foreign Assets

This small open economy can free trade its homogeneous final good with the rest of the world at the price of 1. However, we do not restrict this country to always have a balanced trade, but rather allow it to accumulate net foreign assets or liabilities. Since there are various sources of fluctuations in this economy, the possibility of accumulating and decumulating net foreign assets allows its households to smooth consumption by borrowing in bad times and lending in good times. In this section we will then describe the asset and current account dynamics. Net foreign assets are expressed in terms of the household's net stock of foreign bonds, which in the aggregate evolves according to the following equation:

$$B_t = (1 + r_{t-1})B_{t-1} - D_t F_t + T B_t,$$

where $T B_t$ denoted the domestic country's trade balance in period t . Notice that we assume that households can, via a costless financial sector, also issue such bonds to finance their debt: hence, by consolidating all household's positions, country's net foreign liabilities will

be represented by negative values of B_t . The real interest rate on foreign assets or liabilities is

$$r_t = \bar{r} + \psi \left[\exp \left(\frac{\bar{B}}{\bar{Y}} - \frac{B_t}{Y_t} \right) - 1 \right],$$

where $\bar{r}$ is the steady state rest of the world interest rate, and $\psi > 0$ is the sensitivity parameter of the external debt elastic interest rate premium assumed here as in Schmitt-Grohé and Uribe (2003). This allows us to study economic fluctuations of out small open economy using linear approximations in a relatively simple way, under the realistic assumption that if domestic assets are lower than a steady state ratio to GDP $\frac{\bar{B}}{\bar{Y}}$, or domestic liabilities are too high, then the country will have to pay an interest rate risk premium $\psi \left[\exp \left(\frac{\bar{B}}{\bar{Y}} - \frac{B_t}{Y_t} \right) - 1 \right]$.

Trade balance is measured by the difference between the country's production of the final good and its aggregate expenditure in consumption and physical and R&D investment:

$$TB_t = Y_t - C_t - I_t - X_t.$$

The current account is obtained from the trade balance, by adding the incomes from foreign bonds and subtracting the dividends paid to the foreign owned firms (MNCs), that is:

$$CA_t = TB_t - D_t F_t + r_{t-1} B_{t-1}.$$

Notice that if the steady state foreign assets/liabilities are zero, the current account will be zero as well, while the trade balance will be positive and equal to the total dividends, $D_t F_t$, paid to the owners of the multinational firms.

3.6 Government

The government finances a part of the R&D investment performed by domestic innovators. This share of domestic R&D investment, Z_t , fluctuates stochastically according to shock ϵ_t^{RDsub} .

$$Z_t = Z \exp(\epsilon_t^{RDsub})$$

around a deterministic steady state value $Z \in (0, 1)$.

The government raises revenue via lump sum taxes

$$Z_t X_t = T_t,$$

which are collected from households.

3.7 Shocks

As previously mentioned, there are eight exogenous sources of fluctuations in this economy: a temporary TFP shock ϵ_t^{temp} , a shock to the household's discount factor ϵ_t^{beta} , a labour disutility shock $\epsilon_t^{\text{labour}}$, a preference for safe foreign assets shock ϵ_t^B , a domestic R&D investment risk premium shock ϵ_t^{RD} , a MNCs entry rate shock ϵ_t^f , a frontier technology growth rate shock $\epsilon_t^{A^{\text{max}}}$, and a shock to R&D government investment subsidy, ϵ_t^{RDsub} .

These exogenous processes are assumed to be independent and to be following an autoregressive process of order 1, described by the following equations:

$$\begin{aligned}
\epsilon_t^{\text{temp}} &= \rho^{\text{temp}} \epsilon_{t-1}^{\text{temp}} + u_t^{\text{temp}}, \\
\epsilon_t^{\text{labour}} &= \rho^{\text{labour}} \epsilon_{t-1}^{\text{labour}} + u_t^{\text{labour}}, \\
\epsilon_t^{\text{beta}} &= \rho^{\text{beta}} \epsilon_{t-1}^{\text{beta}} + u_t^{\text{beta}}, \\
\epsilon_t^B &= \rho^B \epsilon_{t-1}^B + u_t^B, \\
\epsilon_t^{RD} &= \rho^{RD} \epsilon_{t-1}^{RD} + u_t^{RD}, \\
\epsilon_t^f &= \rho^f \epsilon_{t-1}^f + u_t^f, \\
\epsilon_t^{A^{\max}} &= \rho^{A^{\max}} \epsilon_{t-1}^{A^{\max}} + u_t^{A^{\max}}, \text{ and} \\
\epsilon_t^{RDsub} &= \rho^{RDsub} \epsilon_{t-1}^{RDsub} + u_t^{RDsub}.
\end{aligned}$$

4 Competitive Equilibrium

The competitive equilibrium for this model is defined by a set of prices $\{r_t, r_t^k, w_t, p_t^K, p_t^S\}_{t=0}^{\infty}$ and allocations $\{C_t, Y_t, I_t, X_t, B_t, K_t, l_t, D_t, TB_t, CA_t\}_{t=0}^{\infty}$ such that, taking the initial conditions and the stochastic processes for the exogenous variables as given, household's allocation satisfies the optimal choices defined by the first order conditions; firms' allocations maximize profits; all markets clear; and budget constraints hold with equality.

The small open economy we are analyzing is always growing at the trend growth rate of exogenous frontier technology. Therefore in order to solve the model in a way manageable to analyze medium frequencies, we need to stationarize the trending variables. We will denote stationarized variables with lowercase letters. For example, domestic productivity A_t , which eventually grows at the trend rate of $A_t^{\max}$, is stationarized by dividing it by $A_t^{\max}$, obtaining $a_t = \frac{A_t}{A_t^{\max}}$. We proceed similarly for all variables asymptotically growing like A_t , most notably output, consumption, wage rate, investments, physical capital, foreign bonds, trade balance, current account, etc. Finally, variables with no trend, such as the interest rate, the rental rate of capital, and the probability of innovation by incumbents or MNCs, etc. have not been further stationarized. In equations in which variables appear at different dates, it will be necessary to deflate stationarized past variables and inflate stationarized forward-looking variables by the trend growth rate. With all this in mind, the reader can now easily interpret the meaning of the stationarized model equations listed below.

The growth rate of frontier technology is:

$$g_t^{A^{\max}} = g_{\text{exo}} \exp(\epsilon_t^A),$$

The Lagrange multiplier is given by:

$$\lambda_t = [c_t - hc_{t-1} \exp(-g_t^{A^{\max}})]^{-\chi},$$

The Euler Equation is:

$$\exp(\epsilon_t^{\text{beta}}) \lambda_t [1 - \nu \exp(\epsilon_t^B)] = \mathbb{E}_t \beta \exp(\epsilon_{t+1}^{\text{beta}}) \lambda_{t+1} \exp(-g_{t+1}^{A^{\max}}) (1 + r_t)$$

The labour supply equation equating the marginal rate of substitution between consumption and labour with real wage, in stationarized form reads:

$$\omega \exp(\epsilon_t^{\text{labour}}) c_t^{1-\chi} (l_t - \tau l_{t-1})^\theta = \lambda_t w_t$$

The capital accumulation equation is:

$$k_t = i_t \left[1 - \eta_I \left(\frac{i_t}{i_{t-1}} \exp(g_t^{A^{\max}}) \right) \right] + (1 - \delta) k_{t-1} \exp(-g_t^{A^{\max}})$$

The price of capital equation becomes

$$\exp(\epsilon_t^{\text{beta}}) p_t^K \lambda_t = \mathbb{E}_t \beta \exp(\epsilon_{t+1}^{\text{beta}}) \lambda_{t+1} \exp(-g_t^{A^{\max}}) [r_{t+1}^K + p_{t+1}^K (1 - \delta)],$$

while optimal investment choice now implies:

$$1 = p_t^K \left[1 - \frac{\gamma_K}{2} \left(\frac{i_t}{i_{t-1}} \exp(g_t^{A^{\max}}) - \exp(g_I) \right)^2 - \gamma_K \frac{i_t}{i_{t-1}} \exp(g_t^{A^{\max}}) \left(\frac{i_t}{i_{t-1}} \exp(g_t^{A^{\max}}) - \exp(g_I) \right) \right].$$

Aggregate production function:

$$y_t = \exp(\epsilon_t^{\text{temp}}) (a_t)^\alpha (l_t)^\alpha [k_{t-1} \exp(-g_t^{A^{\max}})]^{1-\alpha}$$

Labour demand is obtained from monopolistic competitive firm's profit maximization:

$$l_t = \alpha \left(\frac{\sigma - 1}{\sigma} \right) \frac{y_t}{w_t}.$$

The rental rate of capital is:

$$r_t^K = (1 - \alpha) \frac{\sigma - 1}{\sigma} \frac{y_t}{k_{t-1}} \exp(g_t^{A^{\max}})$$

Stationarized monopolistic dividends equation:

$$d_t = y_t - r_t^K k_{t-1} \exp(-g_t^{A^{\max}}) - w_t l_t$$

Production function of innovation probability:

$$\frac{x_t \left(1 - \eta_X \left(\frac{x_t}{x_{t-1}} \right) \right)}{\varpi^{RD} a_t^{\text{target}}} = \ln \left(\frac{1}{1 - n_t} \right),$$

where

$$\eta_X \left(\frac{x_t}{x_{t-1}} \right) = \frac{\gamma_{RD}}{2} \left(\frac{x_t}{x_{t-1}} \exp(g_t^{A^{\max}}) - \exp(g_X) \right)^2.$$

R&D first order conditions:

$$\begin{aligned} & \frac{x_t \left(1 - \eta_X \left(\frac{x_t}{x_{t-1}} \right) \right)}{\varpi^{RD} a_t^{\text{target}}} \\ &= \ln \left(\frac{p_t^S (1 - f_t) \left[1 - \eta_X \left(\frac{x_t}{x_{t-1}} \right) - \gamma_{RD} \exp(g_t^{A^{\max}}) \frac{x_t}{x_{t-1}} \left(\frac{x_t}{x_{t-1}} \exp(g_t^{A^{\max}}) - \exp(g_X) \right) \right]}{\varpi^{RD} a_t^{\text{target}} (1 - Z_t) [1 + r_{RD}^{\text{premium}} + \exp(\epsilon_t^{\text{RD}})]} \right). \end{aligned}$$

The average manufacturing firm value p^S in stationarized form is obtained from:

$$\exp(\epsilon_t^{\text{beta}})\lambda_t p_t^S = \mathbb{E}_t \exp(\epsilon_{t+1}^{\text{beta}})\beta\lambda_{t+1} [d_{t+1} + p_{t+1}^S (1 - n_{t+1}) (1 - f_{t+1})]$$

Frontier productivity-adjusted average target technology:

$$a_t^{Y\text{target}} = a_{t-1} \exp(-g_t^{A\text{max}}) + \phi [1 - a_{t-1} \exp(-g_t^{A\text{max}})]$$

Law of motion of domestic technology:

$$a_t = f_{t-1} + (1 - f_{t-1}) [n_{t-1} a_t^{Y\text{target}} + (1 - n_{t-1}) a_{t-1} \exp(-g_t^{A\text{max}})]$$

Stationarized net foreign assets equation:

$$b_t = (1 + r_{t-1})b_{t-1} \exp[-(g_t^{A\text{max}})] - d_t F_t + t b_t$$

Trade balance:

$$t b_t = y_t - c_t - i_t - x_t$$

Current account:

$$c a_t = t b_t - d_t F_t + r_{t-1} b_{t-1} \exp[-(g_t^{A\text{max}})]$$

Stationarized domestic real interest rate:

$$r_t = \bar{r} + \psi \left[\exp\left(\frac{\bar{b}}{\bar{y}} - \frac{b_t}{y_t}\right) - 1 \right],$$

Since all variables involved are stationary, the dynamics of the set of sectors dominated by MNCs remains the same at:

$$F_t = F_{t-1} + (1 - F_{t-1})f_{t-1} - F_{t-1}(1 - f_{t-1})n_{t-1}$$

Similarly, the evolution of the share of domestic R&D investment provided by the government $Z_t = Z \exp(\epsilon_t^{RD\text{sub}})$ and that of the probability of multinational entry $f_t = f \exp(\epsilon_t^f)$ remain unchanged.

Exogenous processes:

$$\begin{aligned} \epsilon_t^{\text{temp}} &= \rho^{\text{temp}} \epsilon_{t-1}^{\text{temp}} + u_t^{\text{temp}}, \\ \epsilon_t^{\text{labour}} &= \rho^{\text{labour}} \epsilon_{t-1}^{\text{labour}} + u_t^{\text{labour}}, \\ \epsilon_t^{\text{beta}} &= \rho^{\text{beta}} \epsilon_{t-1}^{\text{beta}} + u_t^{\text{beta}}, \\ \epsilon_t^B &= \rho^B \epsilon_{t-1}^B + u_t^B, \\ \epsilon_t^{RD} &= \rho^{RD} \epsilon_{t-1}^{RD} + u_t^{RD}, \\ \epsilon_t^f &= \rho^f \epsilon_{t-1}^f + u_t^f, \\ \epsilon_t^{A\text{max}} &= \rho^{A\text{max}} \epsilon_{t-1}^{A\text{max}} + u_t^{A\text{max}}, \text{ and} \\ \epsilon_t^{RD\text{sub}} &= \rho^{RD\text{sub}} \epsilon_{t-1}^{RD\text{sub}} + u_t^{RD\text{sub}}. \end{aligned}$$

Therefore we have 23 independent equations for 23 endogenous variables: $c_t, \lambda_t, r_t, l_t, w_t, y_t, a_t, a_t^{\text{target}}, k_t, r_t^K, i_t, p_t^K, d_t, n_t, p_t^S, x_t, b_t, t b_t, c a_t, F_t, f_t, Z_t, g_t^{A\text{max}}$ plus eight shocks $\epsilon_t^{\text{temp}}, \epsilon_t^{\text{labour}}, \epsilon_t^{\text{beta}}, \epsilon_t^B, \epsilon_t^{RD}, \epsilon_t^f, \epsilon_t^{A\text{max}},$ and $\epsilon_t^{RD\text{sub}}$.

5 Calibration

In this section we analyze and run the model for numerical parameters. We solve the model numerically using a first order perturbation method. We use the solution to the linear approximation of the detrended model around its deterministic steady state to find the equilibrium values of variables.

We split the calibrated parameters of the model in two groups. The first group of parameters are reported in Table 3 and are standard in the literature, while those presented in Table 2 are chosen to match some first order moments for Hungary, the country selected for the analysis.²³ The calibration is performed to annual data.

Table 3: Calibrated Standard Parameters

Parameter	Description	Value
g_{exo}	Frontier technology growth rate	0.015
β	Subjective discount factor	0.9524
ν	Relative weight of bonds in the utility function	0.0149
χ	Degree of relative risk aversion	1.05
θ	Inverse Frisch elasticity	1
h	Consumption habit	0.6
τ	Labour habit	0.6
γ_K	Investment adjustment cost	1.5
γ_{RD}	R&D adjustment cost	1.5
ψ	Sensitivity parameter of the external debt elastic interest rate premium	0.035

As illustrated in Table 3, we calibrate the steady state growth rate of the frontier technology to 0.015 in order to match the roughly 1.5 percent annual growth rate of real GDP in the US over the period 2005-2014.²⁴ We then calibrate the gross real interest rate to an annual rate of 5 percent, which we choose to be close to the mean after-tax return on capital during the same period.²⁵ The relative weight of bonds in the utility function, ν is calibrated to 0.0149 such that β equals $1.05^{(-1)}$.

The degree of relative risk aversion is set in the vicinity of 1 since most estimates for this parameter for both developed and developing countries are close to this value.²⁶ The external habit formation parameter for both consumption and labour are set equal to 0.6, a calibration chosen at the lower end of the region between 0.5 and 0.9 in which most estimates for these parameters usually lie in the macroeconomic literature in order to impose a mild habit persistence. Similarly, we set γ_K and γ_{RD} , the capital and R&D investment adjustment costs parameters, equal to 1.5, a value which is close to the one used for calibration in

²³We have also performed the analysis for Czech Republic, the results being qualitatively very similar.

²⁴We use data for real GDP at constant national prices (2011=1) from Penn World Table, version 9.0 (Feenstra et al., 2015), to compute an average of 1.49 percent over 2005-2014.

²⁵As reported in Gomme et al. (2015), the return to capital was about 6 percent in 2005, it fell below 5 percent during the Great Recession, but rebounded afterwards to almost 7 percent in 2014.

²⁶For details on the estimation of the degree of relative risk aversion see Chetty (2006) and Gandelman and Hernandez-Murillo (2015).

Jaimovich and Rebelo (2009). This calibration also aims to impose moderate costs to the adjustment of investment levels with the purpose of not having the strength of the real rigidities dictating the results of the model. We further calibrate steady state hours worked equal to 1. Moreover, we calibrate θ , the inverse Frisch labor supply elasticity, to 1.²⁷

The sensitivity parameter of the external debt elastic interest rate premium, ψ , is calibrated to 0.035, following Cozzi and Davenport (2017).²⁸

Table 4: Calibrated Country Specific Parameters

Parameter	Description	Value for Hungary
σ	CES elasticity of substitution	7
α	Labour elasticity of output	0.60
δ	Capital depreciation rate	0.04
ϖ^{RD}	R&D difficulty parameter	2.5
ϕ	Domestic R&D target parameter	0.0036
f	MNCs entry rate	0.0102
ω	Labour disutility	4.4
$r_{RD\text{premium}}$	R&D risk premium	0.0106

As displayed in Table 4, the CES elasticity of substitution is set equal to 7, which implies that the price markup of the monopolists is 1.17. While there are no estimates available for Hungary we are considering in this analysis and for the chosen time span, we found a large pool of estimates for various European countries or group of countries. However, the values vary considerably depending on the data and methodology employed. One of the most popular approaches in the recent literature is the cost-based method of De Loecker and Warzynski (2012),²⁹ which was used by De Loecker and Eeckhout (2017) and De Loecker and Eeckhout (2018) for computing weighted aggregate average price markups for the entire world economy, as well as for individual countries and regions. Using a sample that contains the financial statements of over 70,000 firms in 134 countries starting from 1980, De Loecker and Eeckhout (2018) find that the average global markup increased from close to 1.1 in 1980 to around 1.6 in 2016. While the authors do not report the average values for Hungary, in an illustration of the change in markup between 1980 and 2016, the country is located in the group that registered a decrease to no change in markup. This finding motivates our choice for a calibration of the CES elasticity of substitution which gives an average markup for Hungary that is close to the global and European average in 1980.

Regarding parameter α , we choose the calibration based on the average value of the share of labour compensation in GDP at current national prices over 2005-2014.³⁰ While the value for this parameter is smaller than the usual calibration of 2/3, it must be considered that

²⁷Since estimates of the Frisch elasticity vary depending on the data and approach used for the estimation, with more recent estimates based on macro data indicating that the estimate is in the interval 1 to 2 (for details see Fiorito and Zanella (2012), Keane and Rogerson (2012)), or below 1 in the micro literature, we choose a value of 1 as a compromise between these findings.

²⁸See Cozzi and Davenport (2017) for references to papers which estimate this parameter.

²⁹De Loecker and Warzynski (2012) adapted the method of Hall (1988) that was originally employed for the analysis of aggregate data to applications using micro data.

³⁰Data is contained in the Penn World Table, version 9.0 (Feenstra et al., 2015).

this calibration in macroeconomic models is usually made for the US and using an average for a much longer timespan. Nonetheless, as discussed in Karabarbounis and Neiman (2013), the decline of the labor share has been registered in the majority of countries and industries since the 1980s, the main reason being a decrease in the relative price of investment goods that induced firms to shift away from labor and toward capital.

For the depreciation rate, δ , we set a value of 0.04, which implies an annual rate of depreciation of capital equal to 4 percent. This value of δ is the average depreciation rate of the capital stock for the period from 2005 to 2014 in Hungary.³¹ We set ω , the labor disutility parameter, equal to 4.4, such that the steady state share of consumption in output is about 74%, which is the average share for the period 1995-2015 based on data from the World Bank.

To calibrate the steady state value for the success probability of domestic innovation, n , we start from the benchmark of 0.1 used for the US which implies an average diffusion of a new technology of 10 years (Comin and Gertler, 2006), but we adjust this value depending on the technology capability of the country of interest relative to the US.³² Using the sub-indices computed by Radosevic and Yoruk (2015) for technology capability in 42 countries, we obtain a scale of 0.1 for Hungary. This scaling is an indicator of how poorly countries in the CSEE region perform on this dimension when compared to the US.

Using data from Eurostat on the value added at factor cost in million euro by all firms in a country and only by MNCs, we calibrate the steady state share of sectors dominated by multinationals equal to the average share of MNCs in the economy based on value added for the period 2008-2015. Hence, the steady state value of variable F is 0.51 for Hungary. Plugging the steady state values for F and n in the equation defining the dynamics of the set of sectors dominated by MNCs, we obtain that the long-term probability of MNCs entry, f is about 1 percent per year.

We calibrate the fraction of the domestic productivity gap filled by domestic innovators, ϕ , to 0.0036, which is the average reduction of the domestic productivity gap for the CSEE group of countries between 2005 and 2014.³³

³¹The average annual depreciation rate of the capital stock is retrieved from the Penn World Table, version 9.0 (Feenstra et al., 2015).

³²We use the technology capability component of the first dimension, i.e. intensity of technology upgrading by types, of the composite technology upgrading index developed by Radosevic and Yoruk (2015) and Radosevic and Yoruk (2016). The intensity of technology upgrading by types dimension contains three components: production capability, technology capability and R&D capability. While there are no clear boundaries between the three components, some differences can be highlighted. For example, the production capability is more about producing efficiently and generating incremental innovations through improvements in products and processes. Technology capability differs in the sense that it performs advanced development by adapting prototypes for use in manufacturing, while R&D focuses on exploratory development which implies the invention of new prototypes (Radosevic and Yoruk, 2018).

³³We use the TFP level at current PPPs (USA=1) from the Penn World Table, version 9.0 (Feenstra et al., 2015), which is an indicator of the distance to the productivity frontier in each country. We compute the year-on-year change in TFP for each country and report an average for the CSEE group of countries for the period 2005-2014. This value defines the overall catching-up of domestic productivity in the CSEE and not only the part determined by domestic innovation in a particular country, but we choose this calibration as the overall effect is also influenced by the success probability of domestic innovation, n . Hence, the overall effect is small and this is in line with the findings of empirical studies which do not attribute a considerable role to domestic innovation in driving productivity growth.

We use data from Eurostat to calibrate the steady state value of R&D expenditure, X , as a share of output³⁴ and the R&D subsidy.³⁵ We further calibrate the R&D difficulty parameter and the R&D risk premium in order to match these moments.

We compute the steady state value of the endogenous variables in stationarized form, and shock our model with the structural shocks. This allows to visually examine the dynamic general equilibrium effects of exogenous shocks in a non-frontier economy, from which medium term frequencies can be examined in a relatively intuitive way.

We have eight structural shocks in our economy, five of which (ϵ_t^{temp} , $\epsilon_t^{\text{labour}}$, ϵ_t^{beta} , ϵ_t^{RD} , and ϵ_t^{RDsub}) are of domestic origin, and three of which (ϵ_t^f , $\epsilon_t^{A^{\max}}$, and ϵ_t^B) are of foreign origin. We describe the general equilibrium effects of each of them in isolation, by studying the impulse response function plots with the response of the stationarized endogenous variables, expressed in deviation from the steady state value, to a standard deviation change of the white noise shock. We here report the most salient simulations, under the assumption that the shocks have 20% autocorrelation, implying that the shocks fade away after approximately five years, and one standard deviation. However we have tried several robustness checks and IRFs do not change qualitatively.

6 Results

6.1 Variance Decomposition

As it can be observed in Table 5, the variance decomposition of the stationary variables to the various shocks of our model attributes a strong effect to the temporary productivity shock, which is usual in RBC models with mild or no real rigidities. Among the other seven shocks, the discount factor shock and the labour supply shock follow the temporary productivity shock in a ranking of importance. In particular, the discount factor shock explains half of the variation in consumption and almost one third of the variation in investment in either capital or R&D. This is an expected result as the discount factor shock induces substitution of current consumption with investment by making consumers more patient. The frontier technology shock and the MNCs entry shock have strongest effect on the measures of productivity, explaining about 50 percent of the variance of average productivity. The labour supply shock contributes to some variation in almost all variables, but the biggest share of variance it explains is of labour and wage. The R&D risk premium shock and R&D subsidy shock lead to some variation in R&D investment, MNCs share of the economy, and stock market value, while the liquidity demand shock explains very little of variables' volatility.

6.2 Impulse responses to temporary shocks

We further present the impulse response functions to the various shocks introduced in this model. We describe the general equilibrium effects of each shock in isolation, by studying

³⁴The series we use is total GERD as percentage of GDP, which we further average over the period 2005-2015. We find that the average R&D expenditure is 1.15 percent of GDP in Hungary.

³⁵We use the share of R&D performed by the business sector that is funded by the government and compute the average between 2005 and 2015. The average share is 13.2 percent in Hungary.

Table 5: Variance Decomposition

	Frontier Technology	MNCs Entry	Temporary Productivity	Discount Factor	Labour Supply	Liquidity Demand	R&D Premium	R&D Subsidy
Output	0.61	0.50	92.18	2.99	3.70	0.00	0.01	0.00
Consumption	1.10	0.72	65.99	26.93	5.23	0.01	0.02	0.00
Capital Investment	0.45	0.86	69.24	22.57	6.83	0.03	0.02	0.00
R&D Investment	0.12	0.06	62.57	22.87	5.55	0.00	8.07	0.75
MNCs	0.05	0.36	64.48	23.73	5.70	0.00	5.19	0.49
Average Productivity	49.22	50.56	0.14	0.05	0.01	0.00	0.01	0.00
Wage	0.81	0.62	91.42	4.46	2.69	0.00	0.00	0.00
Labour	0.00	0.02	31.69	30.96	37.26	0.02	0.04	0.00
Real interest rate	0.01	0.01	83.68	12.14	4.15	0.01	0.00	0.00
Stock Market Index	2.99	3.09	65.45	18.43	5.80	0.11	3.78	0.35
Foreign Bonds	0.30	0.28	71.12	24.68	3.57	0.03	0.01	0.00
Trade Balance	0.01	0.02	81.48	15.67	2.78	0.01	0.02	0.00
Current Account	0.00	0.01	80.96	16.23	2.79	0.01	0.00	0.00

the impulse response function plots with the response of each endogenous variable expressed in proportional deviation from its steady state value to a one standard deviation change of the shock for a horizon of 60 years.

One important observation from analyzing the impulse response functions obtained from our model is that temporary shocks can cast a long shadow on the economy. An interesting and very powerful shock, which is at the core of the contribution of this paper, is the positive shock ϵ_t^f to the probability, f_t , of MNCs inflow into the country. As a response to this temporary shock, the set of sectors dominated by MNCs increases for a long time, as illustrated in Figure 10. The resulting increased flow of frontier technology into the domestic economy is reflected in the positive medium term effects on productivity, output, consumption, and capital investment, with resulting dynamics displayed in Figures 10 and 11. Notice that this happens despite the drop in domestic R&D, discouraged by the increased probability of creative destruction for domestic innovators. Hence, in this case we can say that stronger MNCs entry, while discouraging domestic innovation, brings about an overall growth process in the country lasting far longer than the initial shock. The previous simulations shall not instill the wrong impression that a higher fraction of MNCs is always leading to an economic boom. One example is the situation when the increase in the share of MNCs in the economy is the symptom of a problem specific to domestic R&D, which has decreased the probability of a domestic innovator's capturing the market. This may be caused by an increase in the domestic R&D risk premium triggered by a positive ϵ_t^{RD} shock. This shock leads to an increase in the fraction of sectors controlled by MNCs as illustrated in Figure 12, but the rest of the economy behaves differently than in response to the shock to the probability of MNCs entry. As observed in Figure 13, output drops for about ten years. Moreover, we observe that the increase in the R&D risk premium makes investment shy away from R&D and go to consumption, physical capital investment, and foreign bonds accumulation. While this partially supports output recovery, it is not enough to counterbalance a subdued medium-term performance of TFP.

Interestingly, the reduction in creative destruction will increase the stock market value of incumbents, which can stay longer in their market. This may look like a bullying stock market to a superficial eye, while instead being the sign of a slowing TFP. The distortion against

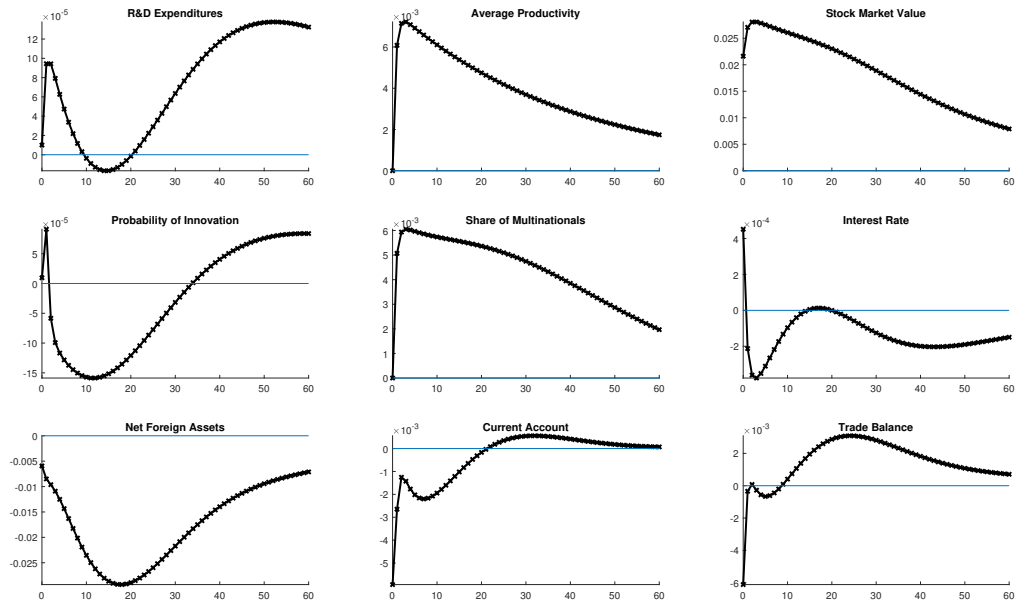


Figure 10: Impulse responses to the MNCs probability of entry shock.

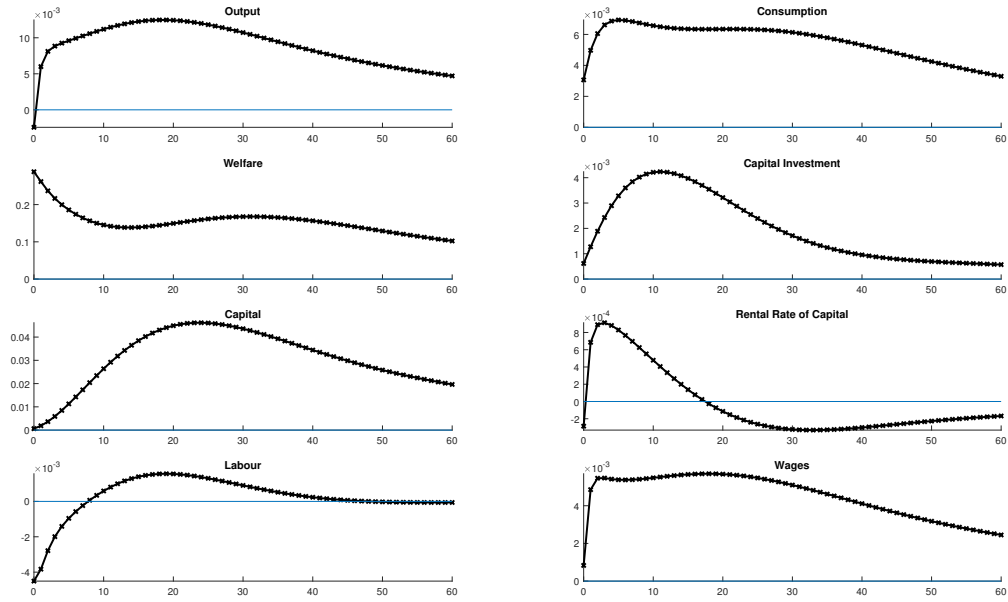


Figure 11: Impulse responses to the MNCs probability of entry shock.

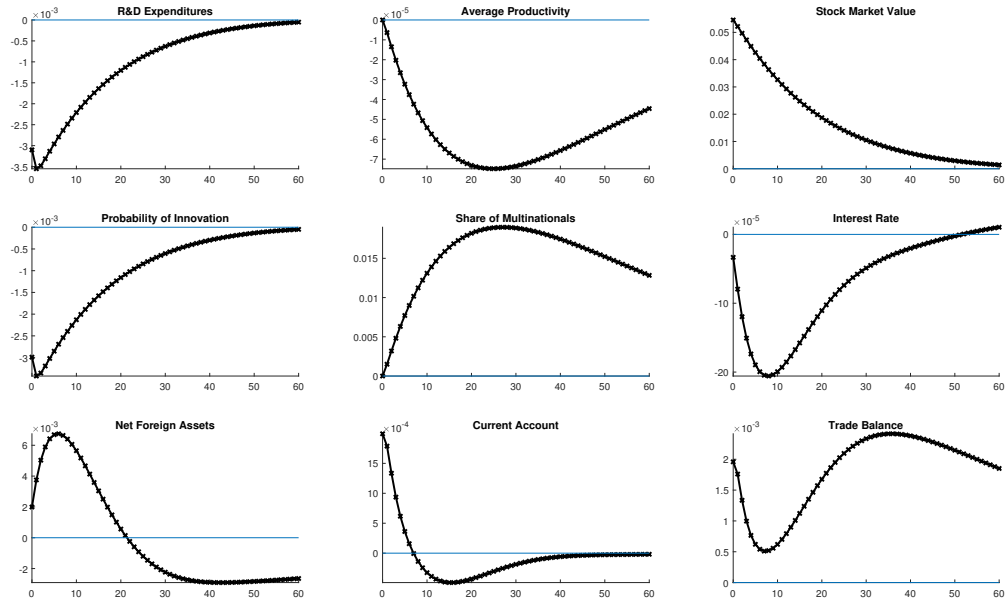


Figure 12: Impulse responses to the domestic R&D investment risk premium shock.

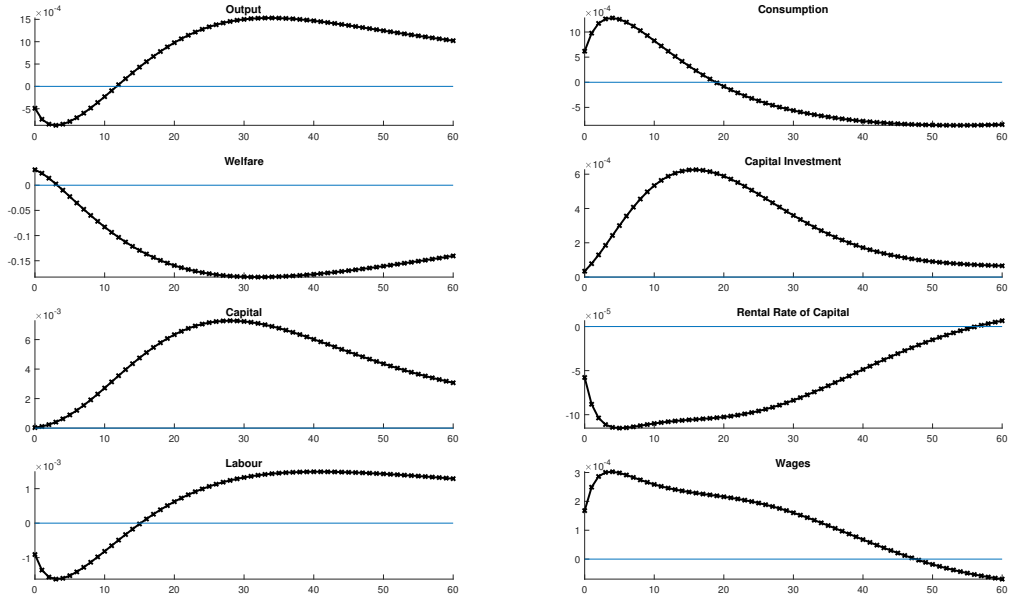


Figure 13: Impulse responses to the domestic R&D investment risk premium shock.

R&D investment, by stimulating physical capital accumulation, partially alleviates the effects on output and on workers wages, whose marginal productivity initially increases. However, labour conditions will deteriorate in the future, when the endogenous productivity slowdown will be translated on their wages. Without an analysis of the medium term productivity dynamics as shown in these figures, the economy's performance would not look that bad. Therefore, we interpret our result as a word of warning - especially important for policy makers and trade union leaders interested in the medium run frequency consequences of innovation and productivity growth - to carefully interpret the available data in light of our theory, because quite often variables such as the R&D risk premium are not directly observed in the basic national statistics. This also suggests a warning to financial analysts that a booming stock market is not necessarily the sign of a good future, but it may reflect a slower innovative dynamics and Schumpeterian creative destruction, with consequent medium term competitiveness losses by the domestic economy as a whole.

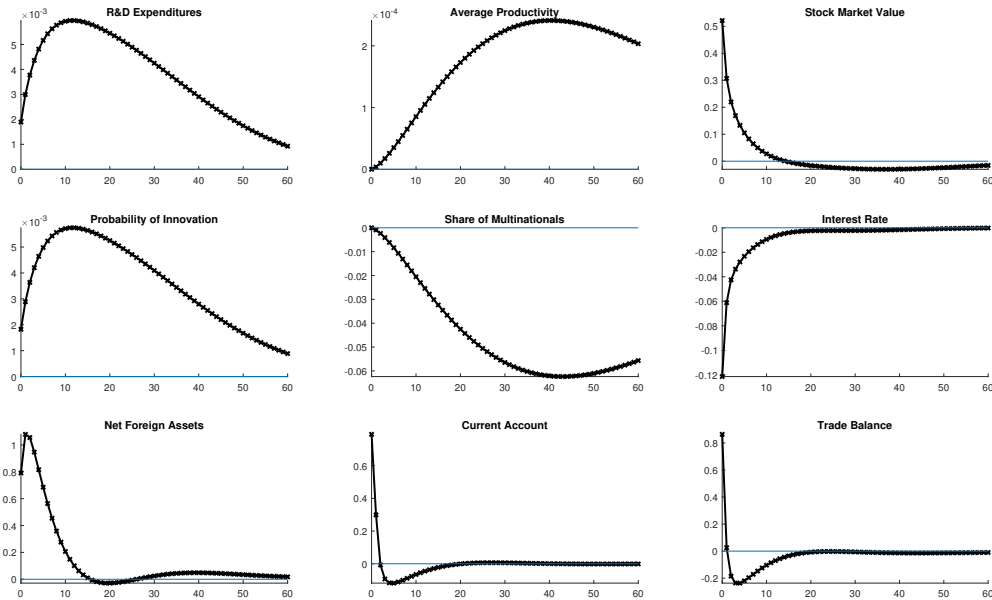


Figure 14: Impulse responses to the temporary productivity shock.

More straightforward to interpret are the effects of a temporary shock to disembodied productivity, ϵ_t^{temp} , which generates more resources for consumption, but also for physical capital and R&D investment, and this way may have positive medium-term effects on embodied productivity, spreading a positive light far beyond its short term impulse, as recorded in the simulations shown in Figures 14 and 15. Interestingly, the effect on the number of sector dominated by MNCs is negative, because of the more intense activities and innovation successes of the domestic R&D firms. As before, we learn from this exercise that a decline in cumulated MNCs penetration is sometimes at odd with a simplistic interpretation of the country's becoming more closed to foreign inflow, but rather could be the natural effect

of the domestic firms becoming more innovative and competitive within an equally open competitive arena.

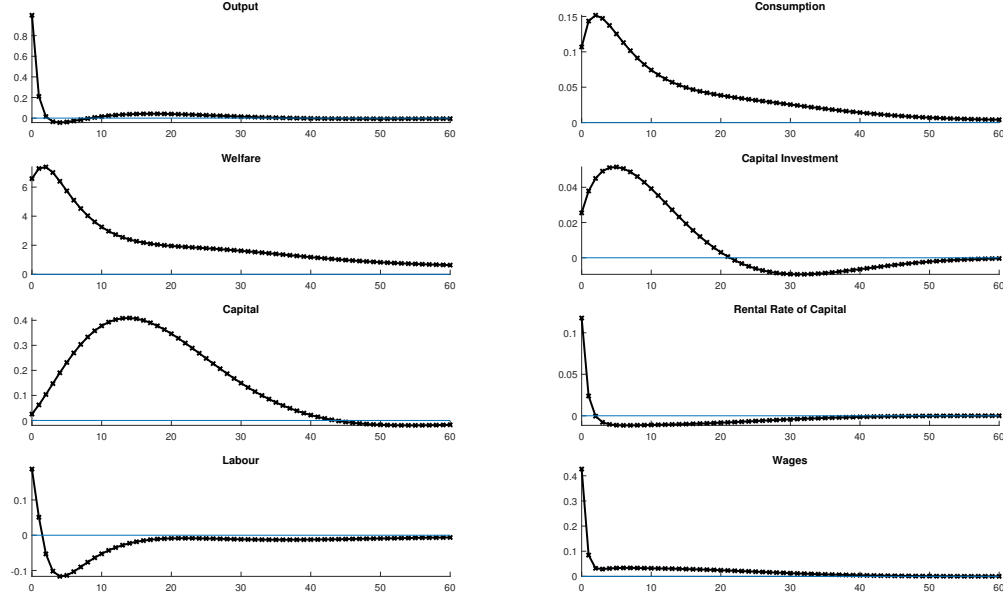


Figure 15: Impulse responses to the temporary productivity shock.

Interesting is also to illustrate the medium run response of the economy of a temporary shock to the representative household's discount factor, as shown in Figures 16 and 17. The takeaway from these figures is that the discount factor shock renders families temporarily more impatient, and less willing to sacrifice consumption to finance all forms of investment - be they in physical capital, R&D, or foreign bonds - nor to work in order to accumulate more assets. The result is a temporary increase in consumption, wages, and leisure, that will be later repaid in terms of less assets accumulation and less productivity growth, with consequently lower wages and consumption. The medium term drag on capital accumulation and output is exacerbated by the slower productivity dynamics resulting from the endogenous R&D transmission channel. During this medium term, we also see an increase in the fraction of sectors dominated by MNCs in the economy. Nevertheless, this is the result of poorer domestic innovative dynamism: the catch-up with frontier technology is lower despite the higher presence of advanced MNCs in the market.

In Figures 18 and 19 we show the dynamic effects of a classical RBC shock, namely the increase in the disutility of labour. A contraction in labour supply, as usual, generates a reduction in employment, a rise in salaries, an output contraction, with resulting decrease in consumption and all forms of investment. However, due to our R&D transmission channel, our model predicts a long lasting negative effect on the productivity dynamics. Also in this case, the reader can see a slight but persistent increase in the MNCs' prevalence in the economy. Therefore the considerations and words of warning previously done also apply for

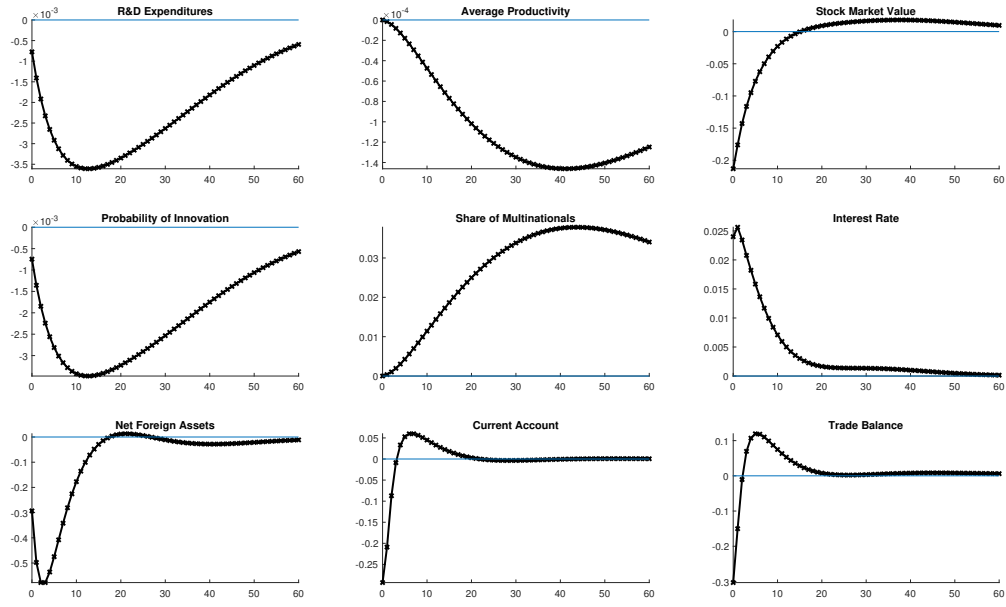


Figure 16: Impulse responses to the discount factor shock.

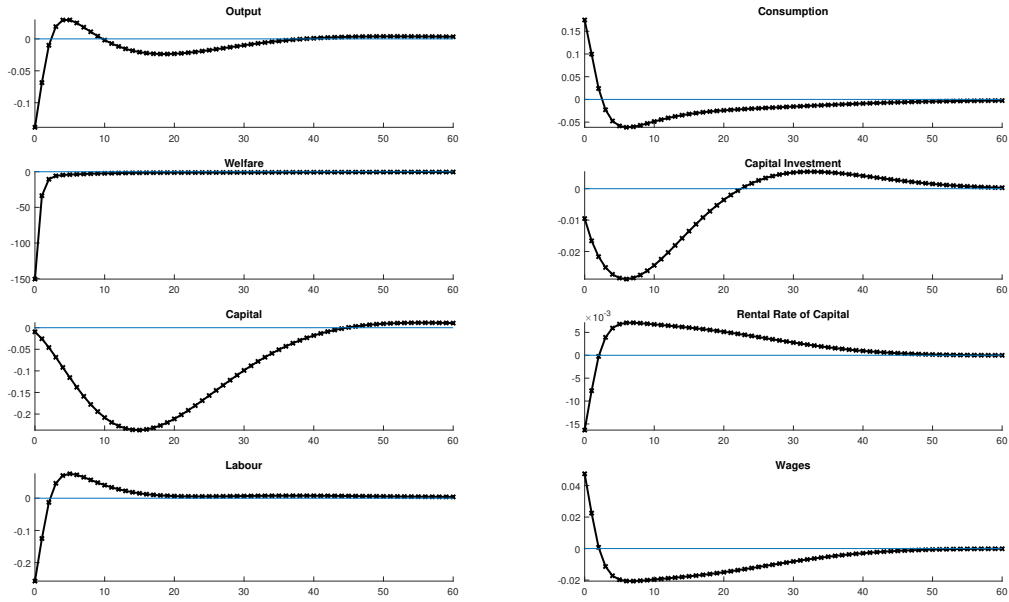


Figure 17: Impulse responses to the discount factor shock.

this case.

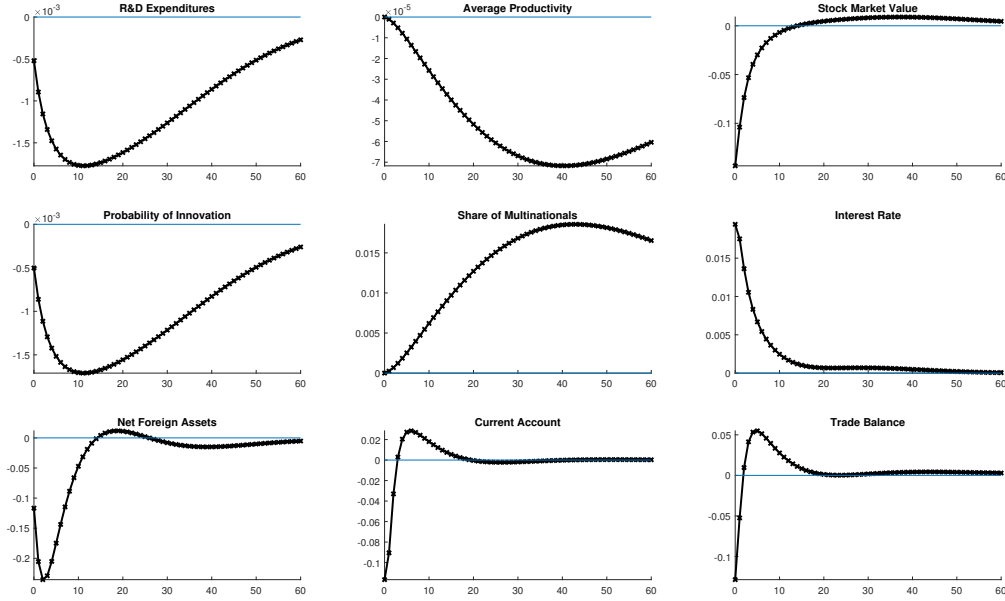


Figure 18: Impulse responses to the labour disutility shock.

Another valuable exercise is the analysis of the medium run response of the economy to a R&D subsidy shock. By introducing this shock in the model, we let the government temporarily raise the share of the R&D investment that it finances and hence to tax more the representative household for this period. As displayed in Figures 20 and 21, the overall R&D investment increases even though the household reduces her consumption and investment in both capital and R&D in order to pay the higher taxes. The household also increases labour supply which along with higher productivity leads to an increase in output for slightly more than ten years. However, the decrease in capital investment and share of sectors dominated by MNCs has stronger negative effects on economic activity, with output decreasing in the medium run.

The flight to liquidity shock has smaller effects on the economy, as illustrated in Figures 22 and 23. This shock leads to a temporary stronger appetite for assets holding, which translates into an increase in net foreign assets, but a reduction in consumption and investment. Households not only reduce spending on anything else than foreign bonds, but also increase labour, these being the contributors to the output increase observed for a short time in response to the flight to liquidity shock. The reduction in investment leads to lower capital accumulation and a reduction in average productivity, which cannot be compensated by the small increase in the share of sector dominated by MNCs, thus leading to a subsequent drop in output. The effects on most variables fade away after about twenty years, while those that are more persistent are also very small.

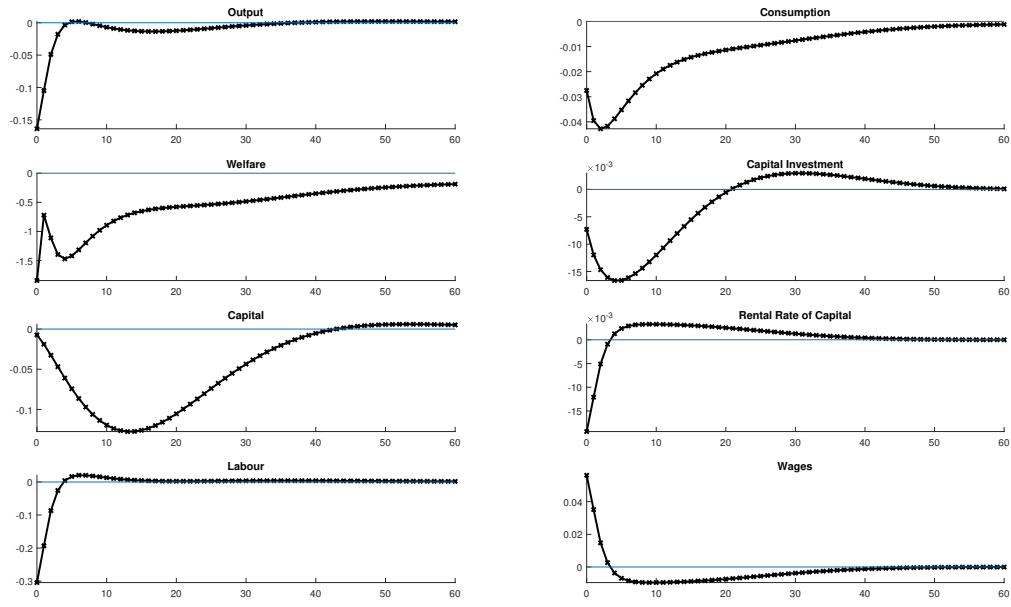


Figure 19: Impulse responses to the labour disutility shock.

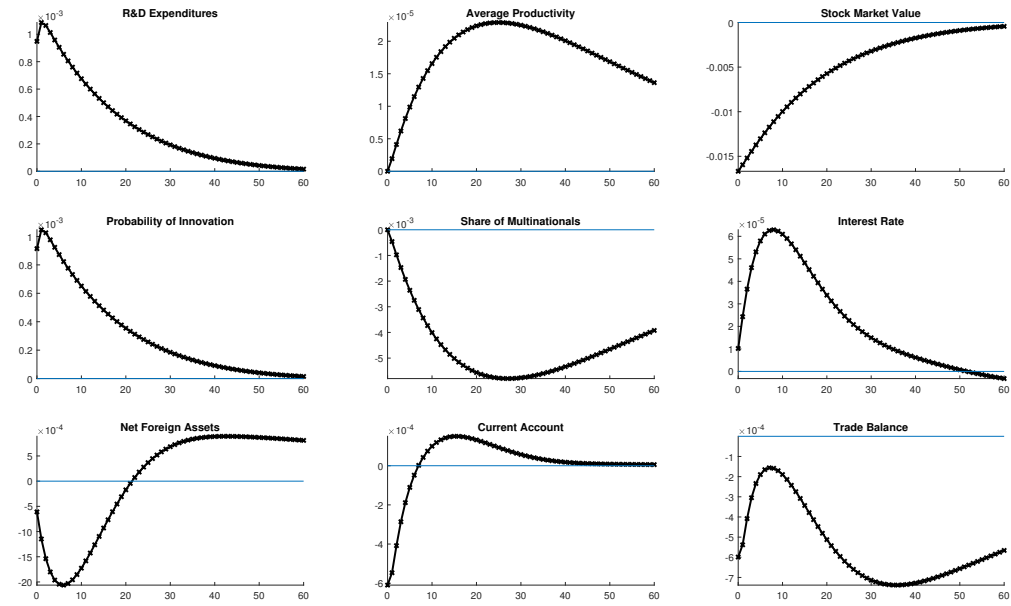


Figure 20: Impulse responses to the R&D subsidy shock.

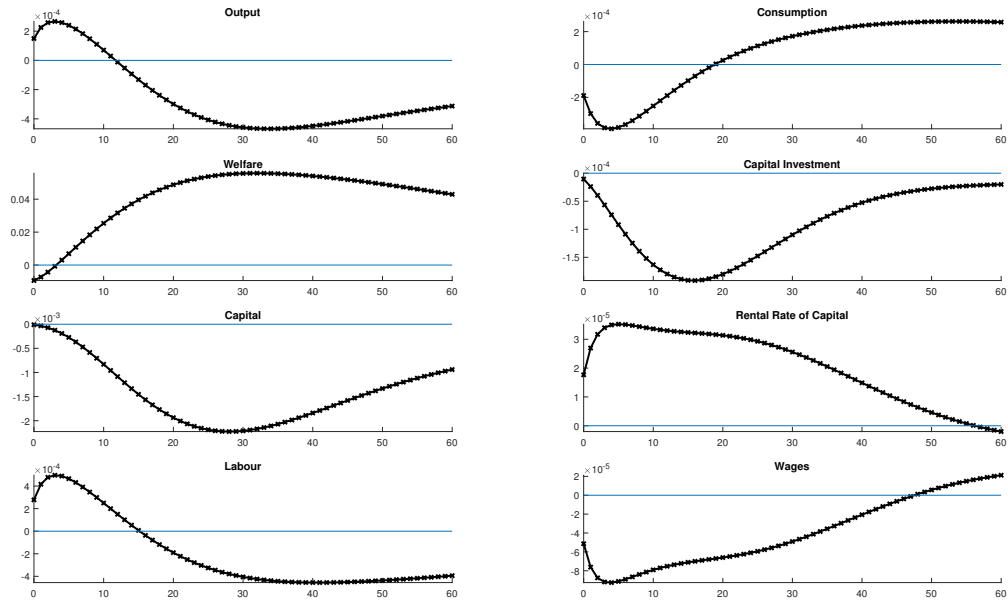


Figure 21: Impulse responses to the R&D subsidy shock.

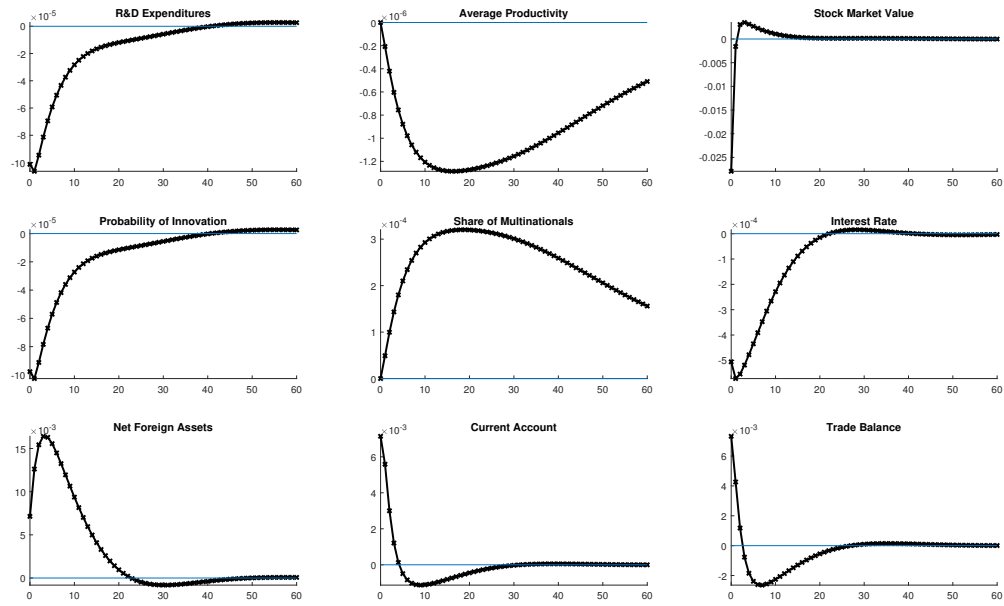


Figure 22: Impulse responses to the flight to liquidity shock.

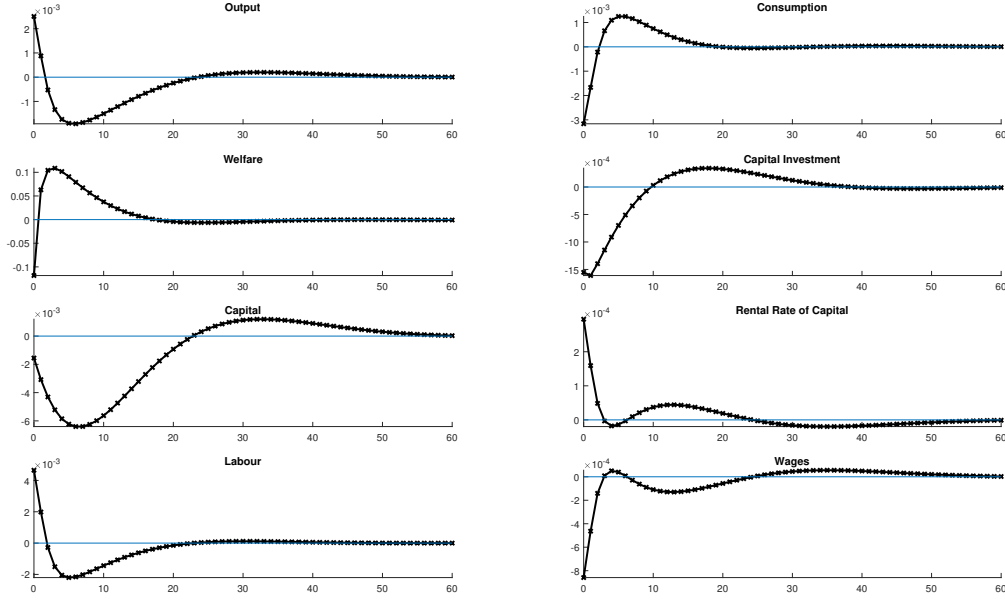


Figure 23: Impulse responses to the flight to liquidity shock.

6.3 Impulse responses to permanent shocks

In this section we investigate the extreme case in which the government bans MNCs from entering the country. The global financial crisis and the European debt crisis signaled the potential costs of FDI to the governments of countries in the CSEE region, with some deciding to take actions against the MNCs that were exploiting domestic markets (e.g. banking, retail, utilities) and possibly repatriating realised profits (Galgóczy and Drahokoupil, 2017). Our exercise is motivated by the measures taken by the post-2010 Hungarian government to negatively discriminate against the foreign dominated economic sectors engaged in non-tradable services, which reduced MNCs entry in the financial sector and utilities (Hunya, 2017).

We model the measures taken by the government to block MNCs' entry into the country as a permanent negative one standard deviation white noise shock to the probability of MNCs entry, assuming that $\rho^f = 1$:

$$\epsilon_t^f = \rho^f \epsilon_{t-1}^f - u_t^f.$$

The results displayed in Figures 24 and 25 indicate that the reduction in MNCs entry leads to an increase in domestic R&D as it decreases the probability of creative destruction for domestic innovators by reducing the foreign competition on the market. However, the increase in R&D expenditures and hence in innovation probability is not big enough to compensate for the negative effects that the reduction of MNCs share of the economy has for the domestic economy. The share of MNCs in the domestic economy is shrinking over

time as the shock on the probability of MNCs entry is permanent and economic activity deteriorates at the same time. We observe that after 60 years the effects of the shock are still present, with output, consumption, capital investment, productivity, and labour continuing to decrease regardless of the R&D efforts. These impulse response functions confirm the empirical findings that domestic R&D activities in non-frontier CSEE countries do not lead to considerable productivity improvements and hence cannot substitute international capital flows in driving productivity growth.

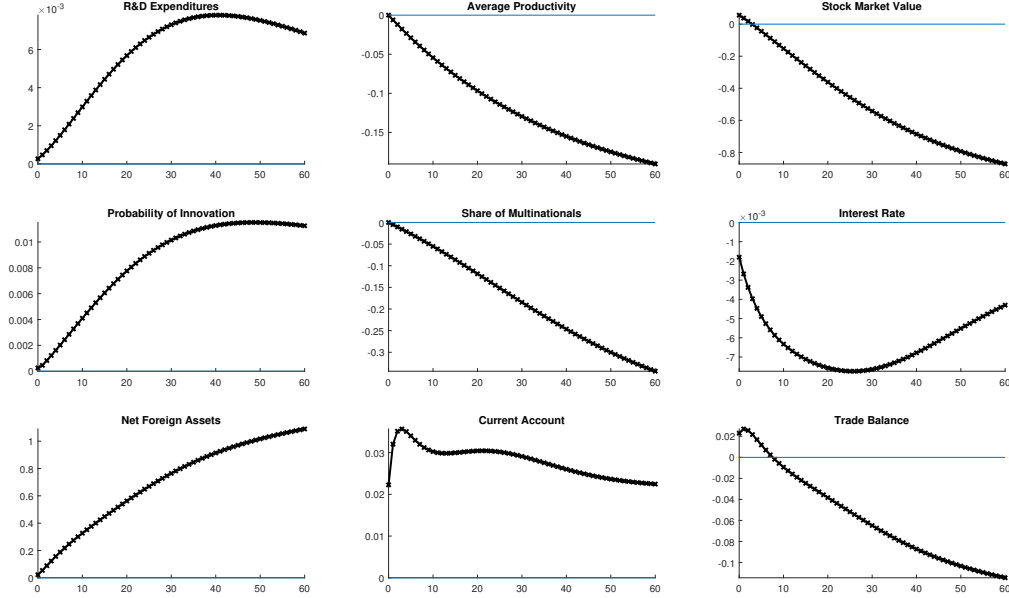


Figure 24: Impulse responses to the permanent MNCs probability of entry shock.

Instead of discriminating against MNCs entry, the government could try to improve the competitiveness of domestic innovators by, for example, increasing permanently the share of R&D which it finances. We model this measure of the government as a permanent positive one standard deviation white noise shock to the R&D subsidy by assuming that $\rho^{RDsub} = 1$:

$$\epsilon_t^{RDsub} = \rho^{RDsub} \epsilon_{t-1}^{RDsub} + u_t^{RDsub}.$$

This way the government permanently raises the share of the R&D expenditures that it finances, but also permanently increases the taxes it collects from households. As illustrated in Figure 26 and similar to the results obtained for the temporary R&D subsidy shock, R&D expenditures increase leading to an increase in the probability of innovation and average productivity. There is a medium-run increase in average productivity even though the share of sectors dominated by MNCs decreases. In Figure 27 it can be observed that labour, capital investment, and output also increase for several years after the permanent shock hits the economy, but the effects are negative in the medium-run. Only consumption, which is reduced initially, increases in the medium-run.

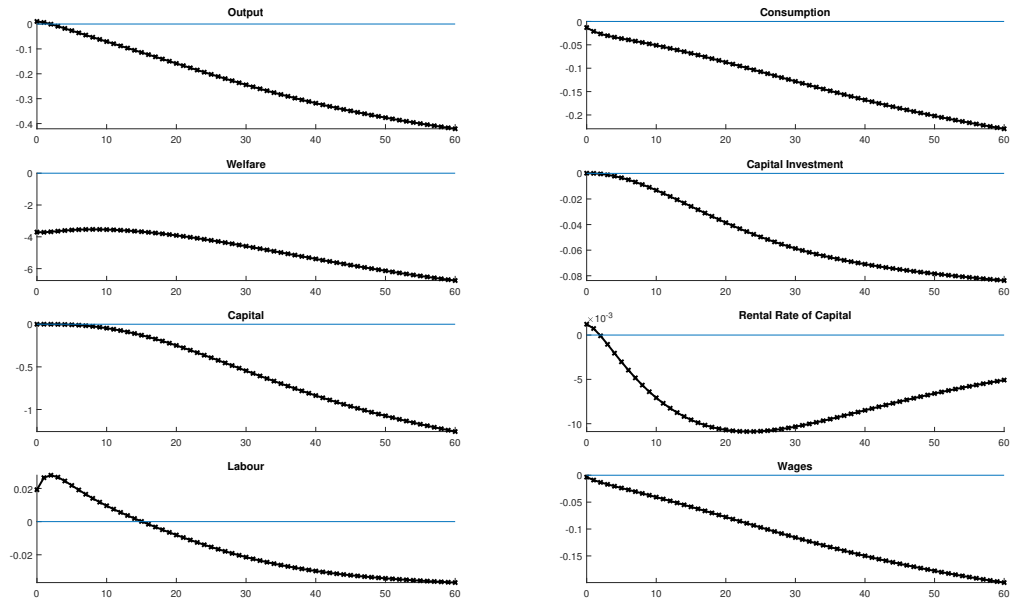


Figure 25: Impulse responses to the permanent MNCs probability of entry shock.

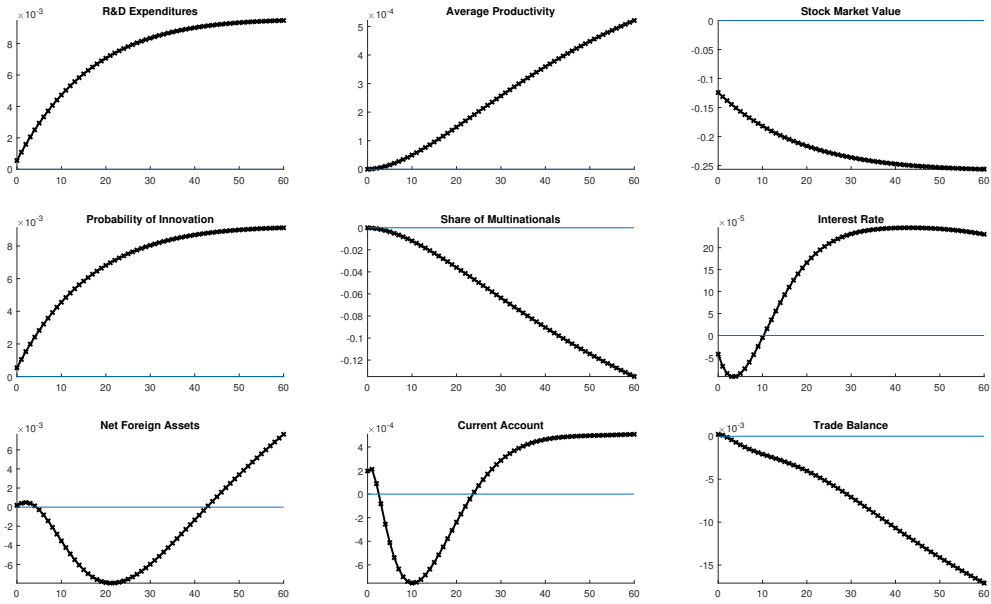


Figure 26: Impulse responses to the permanent R&D subsidy shock.

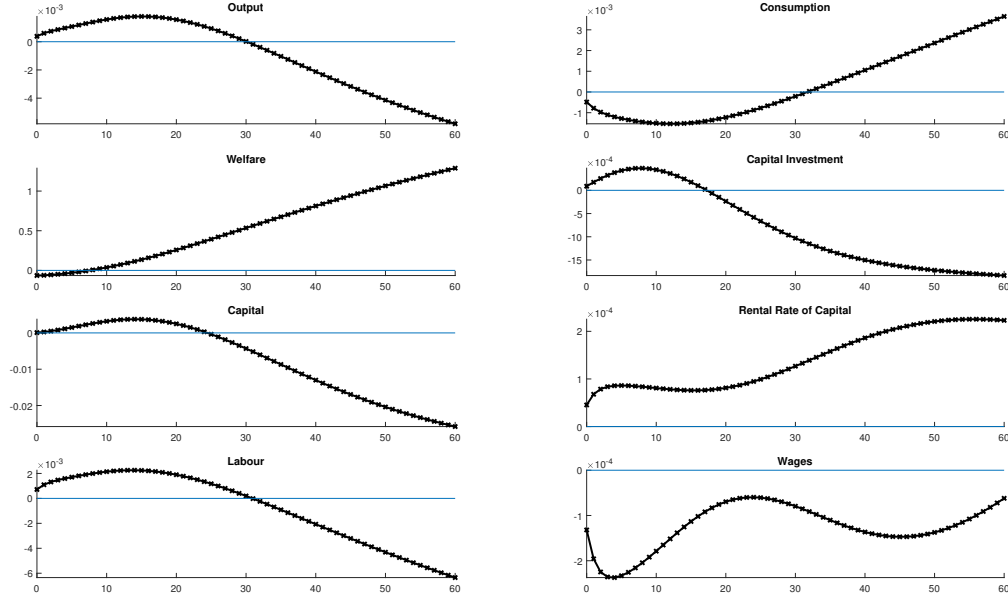


Figure 27: Impulse responses to the permanent R&D subsidy shock.

While both permanent shocks lead to a reduction in the share of sectors dominated by MNCs and an increase in domestic innovation, the effects of the R&D subsidy shock are slightly more positive. Hence, the policy advice would be for governments to focus more on improving the technological capability of domestic firms such that they can become more competitive in the catching up process with the technology frontier and less on banning foreign enterprises from the country.

7 Concluding Remarks

In this paper we have introduced a Schumpeterian creative destruction model of the productivity dynamics of a generic non-frontier small open economy in dynamic stochastic general equilibrium. The integration of Schumpeterian growth and DSGE is not straightforward, but it opens the door to a more rigorous and complete analysis of medium frequency effects of shocks in non-frontier countries, than previously achievable only by DSGE or Schumpeterian growth models taken in isolation.

The proposed model is a prototype, and therefore it purposefully abstracted from several important additional features that would increase the realism of the model and allow for reliable estimation and policy evaluations, but that would also introduce complexity to a level that would render the exposition much less transparent. However, our setting could be extended in a relatively straightforward way in important directions. Most notably are two. One is the explicit introduction of a more complex government policy block, which would allow the simulation of government policies. Another is the introduction of sticky prices and

wages, which would increase the realism of the model and allow for Bayesian estimation of all its parameters. These are certainly the directions for our next future research.

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