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OVERVIEW OF THE NEW CALIBRATED DSGE MODEL OF THE ECONOMY OF NORTH MACEDONIA

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ABSTRACT: This paper presents a calibrated DSGE model of the economy of North Macedonia that was developed at the National Bank of the Republic of North Macedonia (NBRNM) within a technical assistance project delivered jointly by the International Monetary Fund (IMF) and the Czech National Bank (CNB). The model structure reflects the specific characteristics of the economy of North Macedonia. Namely, it is a small open economy DSGE model featuring a fixed exchange rate regime functioning in an economy experiencing structural changes over time. The paper provides a detailed overview of the theoretical structure of the model, including optimization problems of economic agents and first-order optimality conditions. A particular emphasis is put on model calibration, as well as on model evaluation, including the analysis of impulse responses, shock decompositions and historical in-sample simulation. Compared to other empirical papers focusing on DSGE models, our approach explicitly includes additional trends and wedges needed to capture non-stationary great ratios as well as the Balassa-Samuelson effect. The model has been developed to complement the existing analytic tools used at the NBRNM for policy analyses and to improve the understanding of the underlying drivers of the business cycle of the domestic economy.

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WORKING PAPERS

Overview of the new calibrated DSGE model for the economy of North Macedonia

Prepared by Tibor Hlédik, Joana Madjoska, Mite Miteski and Jan Vlček[1]

[1] This model was developed in the context of technical assistance of the Czech National Bank (CNB) and the International Monetary Fund (IMF) to the National Bank of the Republic of North Macedonia (NBRNM). The authors would like to thank the members of the NBRNM's DSGE modeling team. The authors would also like to express their gratitude for Stephen Ayerst, Daniel Baksa and Ezequiel R. Cabezon (all IMF) for their comments and suggestions.

Contents

Introduction

Monetary policy decision making at central banks relies increasingly on more advanced, macro-economic models developed for policy analysis and forecasting. DSGE models have become one of the standard tools developed and used by central banks both in advanced and emerging market economies[2]. Following this experience, more and more central banks in emerging markets are extending their toolkits with DSGE models. Due to these ongoing structural changes, it is important to add special technological trends and wedges besides the commonly included total factor productivity in order to bring the model to data. To date, the DSGE approach to policy analysis has become a dominant modeling device for analyzing macroeconomic policy issues used by both practitioners and academics alike.

To keep pace with these trends, the National Bank of the Republic of North Macedonia (NBRNM) embarked upon development of a new calibrated New Keynesian DSGE model reflecting the specific characteristics of the economy of North Macedonia - a small open economy with fixed exchange rate- within the technical assistance project delivered by the CNB/IMF. The aim of this paper is to provide an overview of the structure, calibration, and empirical verification of this new model. It contains many of the standard features of DSGE models, such as monopolistic competition, Calvo sticky prices and wages, habit formation and multilayer goods production to properly capture the dynamics of the business cycle. The model shares several features of the ICD canonical DSGE model, STAMP, which has been used in the ICD TA practice on macroeconomic frameworks with central banks and ministries of finance. See Remo et al. (2023). However, it also encompasses features such as sector specific technology and trends to match Macedonian narratives.

The small open economy DSGE model is intended to be used as an additional analytical tool for policy analysis, alongside the main quarterly projection model (MAKPAM)[3], as it may offer a more coherent, micro-founded theoretical framework for structural analysis and policy guidance at the NBRNM. Namely, unlike the MAKPAM model, which belongs to the class of the so-called gap models, the DSGE model is derived from micro-foundations, meaning that it considers the interdependent behavior of consumers and companies, the technology, and the institutional framework (e.g., budget constraints, market clearing and monetary policy rules). As such, it enables the analysis of the effects of monetary policy on decisions of economic agents via analyzing the effects of various shocks on the economy. Hence, this model represents a useful new tool and reference for extensive research on many policy-relevant topics. At the same time, it improves the story-telling capacity of the Monetary Policy and Research Department of the NBRNM and enriches the monetary policy decision making at the central bank with a new analytic tool. The model, however, is not intended to be used for forecasting; the MAKPAM remains the NBRNM's core forecasting tool.

The paper is structured as follows. Section 2 discusses stylized facts about the Macedonian economy that motivate our modeling choices. Section 3 presents the model specification and Section 4 explains the calibration of the model. Section 5 contains a discussion of model diagnostics. Section 6 concludes.

[2] Some of the central banks that have developed their DSGE models include the Bank of England (COMPASS), ECB (NAWM), FED (SIGMA), Bank of Canada (TOTEM), Riksbank (Ramses II), Czech National Bank (g3+), and National Bank of Romania.

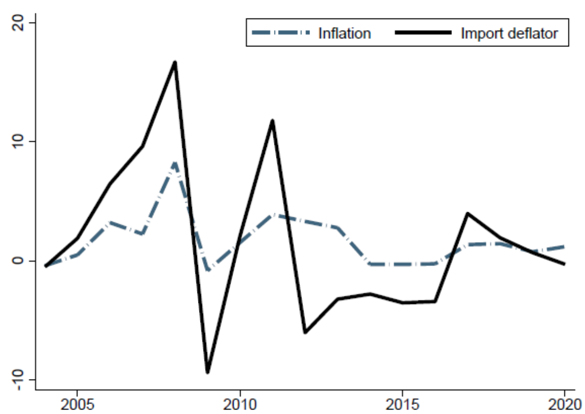
[3] A detailed description of MAKPAM can be found in Hlédik et al. (2016).

Stylized facts of the Economy of North Macedonia

The DSGE model presented in this paper is tailor-made for the narratives of the Macedonian economy, which is a small, open economy with a fixed exchange rate regime that has undergone noticeable structural changes.

The primary objective of the NBRNM is to maintain price stability in the domestic economy. That is achieved by keeping the nominal exchange rate of the domestic currency, the Macedonian denar, against the Deutsche Mark/Euro, stable, since October 1995[4]. This monetary strategy has proved to be quite successful in taming inflation as the average consumer price growth between 1996 and 2020 amounted to only 1.8%, (as opposed to the multi-digit inflation rates registered previously), characterized by a high degree of persistence. Figure 1 displays dynamics of consumer and imported price inflation over time, where it is noticeable that the latter is more volatile in the sample period. Exceptions from the low and stable inflation path are the periods characterized by volatile world prices of the primary commodities, which swiftly feed into consumer domestic prices, a link that is obvious in small and open economies under a peg. Figure 2 depicts the annual growth rate of domestic output. Historically, GDP growth has been positive on average (at around 2.6%), with short-lived episodes of decreased activity during the Global Financial Crisis (GFC) in 2009, the escalation of the domestic political crisis in 2017 and the COVID pandemic in 2020. In fact, contractionary phases of the cycle have shorter duration than expansionary episodes in the economy of North Macedonia, as shown in Miteski and Georgievska (2016). Figure 3 plots the annual growth rates of domestic prices and net wages. A higher growth rate of wage inflation in comparison to price inflation is observed, which is a similar finding to some of the other peer countries, such as Czechia for example (Beneš et al. (2005)), given productivity growth.

Figure 1. Domestic and import prices, y-o-y



[4] Until end-2001 with respect to the Deutsche Mark, from 2002 onwards with respect to the Euro.

Figure 2: Real GDP, y-o-y

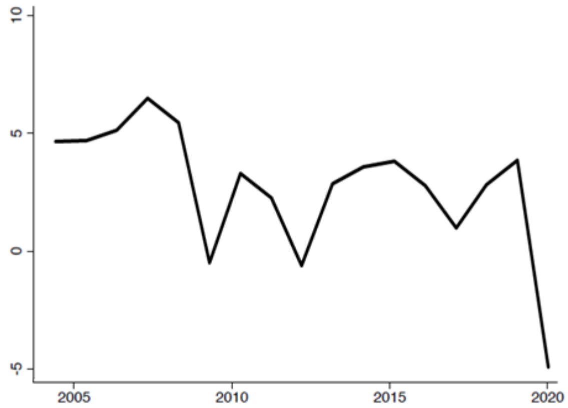
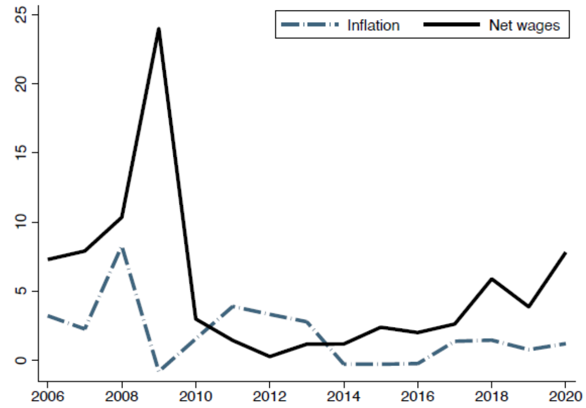


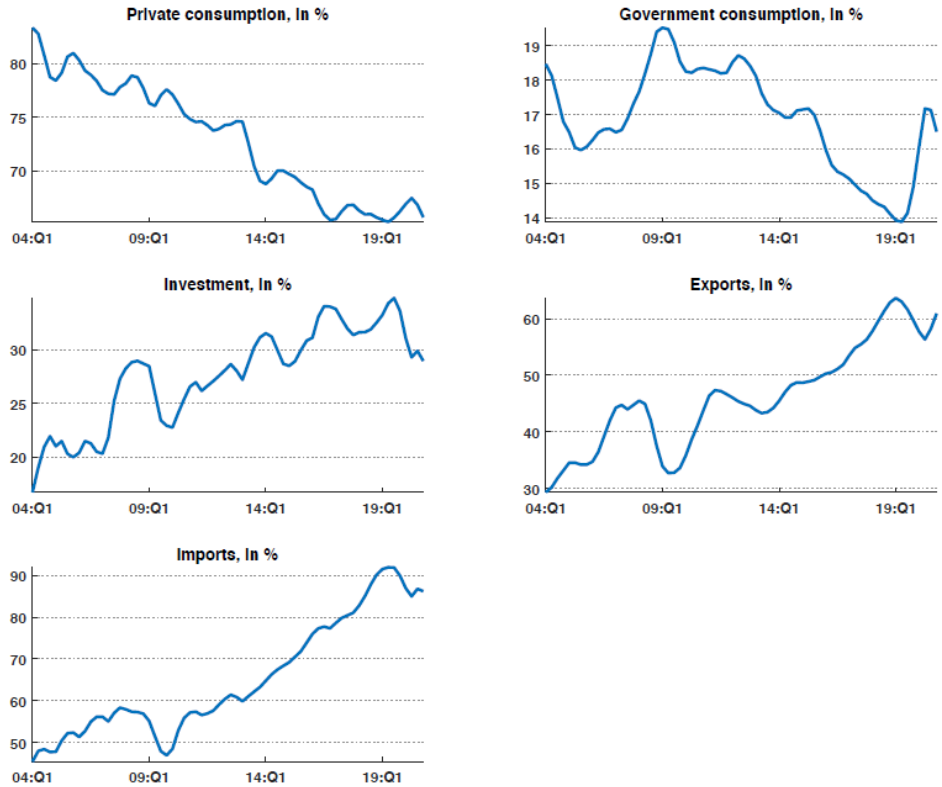
Figure 3: Inflation and net wages, y-o-y



Next, Figure 4 captures the historical evolution of nominal shares of GDP components over time in the Economy of North Macedonia. There is a steady rise in investment, export and import shares in nominal GDP over the sample. The opposite trend is observed for the share of nominal private consumption, which continuously declines. This is an important feature which needs to be properly considered in the modelling process. As it is stated in Andrle (2008), trend-cycle interactions arising from spillovers of permanent shocks to short-run dynamics are increasingly important for emerging market economies. Specifically, sectoral trends need to be included to bring the model to data. Hence, instead of pre- ad-hoc filtering of the data, our approach treats long-run trends within the model structure, which allows for consistent treatment of trends in relative prices and quantities[5]. In this sense, rather than allowing the model to converge to a structural steady state, the focus is placed on the balanced growth path (BGP) specification (see also Andrle et al. (2009)). The BGP is defined such that the nominal expenditure shares in GDP are non-stationary. A common approach in DSGE models introduces only BGP with the differences in real growth rates stemming from changes in relative prices. As a result, nominal shares are assumed to be stationary.

[5] For explicit treatment of these technological sectoral trends, see subsection 3.8.

Figure 4: Nominal expenditure shares



Yet another prominent feature of the North Macedonia is the overall increase in trade openness[6], as reflected by the higher growth rate of trade volumes in comparison to value added. Figure 5 displays the share of imports in value added and Figure 6 shows export and import real growth rates, in combination with the growth of GDP. The figures reveal that there is a continuous rise in trade openness over the years that is inconsistent with constant expenditure shares of GDP in the steady state. Not only do the growth rates of exports and imports exceed the GDP growth, but they also exhibit significant co-movement with each other over the sample. The relatively synchronized import and export growth rates may be explained to a large extent by the relatively high import content of exports. This can be confirmed with the data from input-output tables, according to which the average value of the import share of exports for the years 2005, 2010 and 2015 is 50.9%. This observation is also consistent with the sizeable increase in investment. That is also highly import-intensive, largely explained by the increasing number of export-oriented production facilities combined with the ongoing structural changes in the economy.

[6] Defined as a common trend in real exports and imports.

Figure 5: Share of imports in value added

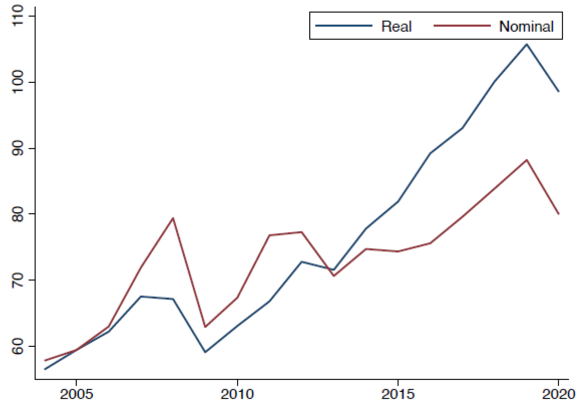
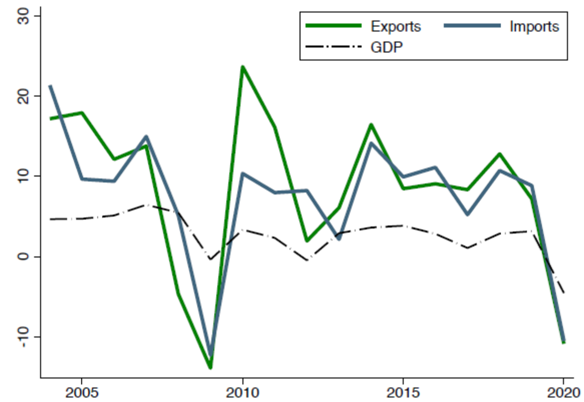


Figure 6: Components growth rates p.a.



These observed trends for exports and imports are far from an isolated phenomenon. They are also observed in many other small open economies such as the Czech Republic, Hungary and Slovakia, converging to their economically advanced counterparts (see Andrle et al. (2009)). Hence, the way the model includes sector-specific technologies to account for trends in the data, makes it possible to apply the Kalman filter to identify these unobserved trends.

Structure of the model

Households

There is a continuum of households in the economy within the unit interval *i* ∈ [0, 1]. Households are owners of factors of production in the economy. They consume all final consumption goods and provide labor and capital to firms.

Households earn wages and receive rental price and dividends from ownership of firms. Also, the government pays some lump sum to households on a previously issued risk-free government bond.

Representative household is optimizing the following utility function:

$$\max_{C_t,L_t,B_t,J_t,K_t} E_t \left\{ \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_t - \chi \bar{C}_{t-1})^{1-\sigma}}{1-\sigma} - \frac{L_t^{1+\psi}}{1+\psi} \right] \right\} \tag{3.1}$$

where C_t is consumption of goods, $\bar{C}_{t-1}$ is past aggregate consumption[7] adjusted for the technological progress[8], L_t is number of hours worked, β is the intertemporal discount factor, σ is relative risk aversion coefficient, ψ is the marginal disutility of labor and χ is the habit persistence parameter.

[7] Terms marked with bar do not appear in the optimality equations due to the assumption of symmetric equilibrium.
[8] The adjustment for the technological progress is necessary to be consistent with the balanced growth path.

We assume external habit formation in the utility function, meaning that households smooth their consumption by looking at the previous level of aggregate consumption.

Household utility maximization is subject to two constraints. The first is the flow budget constraint which equalizes the sum of the nominal expenditures on consumption and investment with the nominal income stream, given in (3.2), and the second one is the law of motion for the capital stock which will be defined later on.

$$B_t + s_t B_t^* + P_t^C C_t + P_t^j J_t = I_{t-1} B_{t-1} + I_{t-1}^* B_{t-1}^* s_t + W_t^h L_t + P_t^k K_{t-1} + \Pi_t \tag{3.2}$$

where B_t is the nominal bonds issued by the government, B_t^* is the nominal bonds issued by the foreign government in foreign currency, I_t^* is the return on this asset, P_t^C is the price level[9], W_t^h is the nominal wage received by households, J_t is real investment, P_t^j is price of investment, K_t is the stock of capital, P_t^k is the rental rate, I_t is the nominal interest rate and Π_t are dividends (firms profits).

The solution to the household optimization problem gives the following first-order conditions related to the household sector decisions:

$$\frac{W_t^h}{P_t^C} = \frac{L_t^{\psi}}{(C_t - \chi C_{t-1})^{-\sigma}} exp(\varepsilon_t^L) \tag{3.3}$$

$$(C_t - \chi C_{t-1})^{-\sigma} exp(\varepsilon_t^C) = (E_t(C_{t+1}) - \chi C_t)^{-\sigma} \beta i_t \frac{P_t^C}{E_t(P_{t+1}^C)} \tag{3.4}$$

i.e.

$$\left(\frac{E_t(C_{t+1}) - \chi C_t}{C_t - \chi C_{t-1} \exp(\varepsilon_t^C)}\right)^{\sigma} = \beta i_t \frac{P_t^C}{E_t(P_{t+1}^C)} \tag{3.5}$$

where $i_t \frac{P_t^C}{E_t(P_{t+1}^C)}$ denotes the real interest rate, ε_t^C is a habit shock and ε_t^L is a labor disutility shock.

On the top of the above equations, there is an uncovered interest rate parity equation, see equation (3.34), as a part of first-order conditions consistent with the fixed exchange rate regime.

Equation (3.3) is the labor supply equation which equalizes the real wage and the marginal rate of substitution between labor (leisure) and consumption. This equation shows the trade-off between working less and consuming more, stating that an increase in consumption, ceteris paribus, is possible only by increasing the amount of labor (i.e. decrease of leisure). Furthermore, it shows that an increase in the real wage translates into higher consumption, without the need to sacrifice leisure. Equation (3.5) is the Euler equation. It represents the intertemporal choice of households between present and future consumption, showing that if real interest rate increases, consumption today becomes more expensive, which leads to a rise in future consumption, ceteris paribus. The expression in (3.5) simply states that the marginal rate of substitution between present and future consumption and the relative price of present consumption in terms of future consumption should be equal in the optimal case.

[9] Approximated by the private consumption deflator.

Wage setting

Households monopolistically supply their labor to domestic intermediate goods producers and are subject to wage stickiness via the Calvo (1983) assumption. In the Calvo framework, a fraction of households $(1-\theta_w)$ can reoptimize its wage in any given period, while the rest of the households, which are not allowed to do so, apply a full backward indexation rule considering the wage inflation in the previous period:

$$W_t^h = W_{t-1}^h w_{t-1} \tag{3.6}$$

This gives rise to a hybrid New-Keynesian Phillips curve for the wage setting in the following form:

$$\triangle \, logw_t = \frac{1}{1+\beta} \triangle \, logw_{t-1} + \frac{\beta}{1+\beta} E_t(\triangle \, logw_{t+1}) + \frac{(1-\theta_w)(1-\beta\theta_w)}{\theta_w(1+\epsilon_w \psi)} log\left(\frac{W_t^h}{W_t}\mu_w\right) + \varepsilon_t^w \tag{3.7}$$

where $(1-\theta_w)$ is probability to change wages, ϵ_w is a parameter affecting the elasticity of substitution among differentiated labor types, μ_w a wage mark-up and ε_t^w is a wage cost-push shock.

Technology for capital accumulation

Households also determine the capital accumulation rate in the economy, as they are the owners of the capital stock.

The stock of capital goods evolves according to the following Cobb-Douglas accumulation function:

$$K_t = K_{t-1}^{1-\delta}\left(\frac{J_t \varepsilon_t^j}{\delta}\right)^{\delta} \tag{3.8}$$

where δ is the rate of depreciation of capital and ε_t^j is an investment specific technology shock. The accumulation technology is a special version of intertemporal adjustment costs, following Kim (2003).

This equation is a special case of a more general CES specification of the following form[10] (see the argument in Andrle et al. (2009)):

$$K_t = \left[\nu(\Delta K^{ss} K_{t-1})^{\frac{\sigma-1}{\sigma}} + (1-\nu)\left(\frac{J_t}{1-\nu}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

where $\nu = (1-\delta)/\Delta J^{ss}$, and ΔJ^{ss} resp. ΔK^{ss} are the steady-state growth rates of investment resp. the capital stock. Setting σ → ∞ results in the standard capital accumulation identity $K_t = J_t + (1-\delta)K_{t-1}$, the parameterization of σ = 1 leads to the Cobb-Douglas specification above.

As mentioned earlier, in addition to the nominal budget constraint, optimization of the household utility function is also subject to the capital accumulation technology. We use the following expression denoted in the literature as Tobin's Q:

[10] The choice of this specific capital accumulation equation was motivated by pragmatic reasons: by its simplicity in terms of implied first order conditions and reasonable investment dynamics captured by in-sample simulation results.

$$Q_t = \frac{P_t^j J_t}{\delta K_t} \tag{3.9}$$

Next, we impose the capital accumulation equation (3.8) expressed in terms of J_t: $J_t = K_t^{\frac{1}{\delta}} K_{t-1}^{\frac{-(1-\delta)}{\delta}} \frac{\delta}{\varepsilon_t^j}$ to the budget constraint (3.2):

$$P_t^C C_t + B_t + s_t B_t^* + P_t^j K_t^{\frac{1}{\delta}} K_{t-1}^{\frac{-(1-\delta)}{\delta}} \frac{\delta}{\varepsilon_t^j} = W_t^h L_t + P_t^k K_{t-1} + I_{t-1} B_{t-1} + I_{t-1}^* B_{t-1}^* s_t + \Pi_t$$

and solve for the first order condition with respect to capital, by using equation (3.9) and the definition that $\frac{E_t(\lambda_{t+1})}{\lambda_t} = \frac{1}{i_t \beta}$ in the process

$$\frac{dL}{dK_t} = -\lambda_t P_t^j \frac{1}{\delta} K_t^{\frac{1}{\delta}-1} K_{t-1}^{\frac{-(1-\delta)}{\delta}} \frac{\delta}{\varepsilon_t^j} - E_t(\lambda_{t+1} \beta P_{t+1}^j K_{t+1}^{\frac{1}{\delta}} \frac{(\delta-1)}{\delta} K_t^{\frac{-1}{\delta}} \frac{\delta}{\varepsilon_{t+1}^j}) + E_t(\lambda_{t+1} \beta P_{t+1}^K) = 0$$

to arrive at the following expression:

$$Q_t = \left(E_t(Q_{t+1})(1-\delta) \frac{E_t(K_{t+1})}{K_t} + E_t(P_{t+1}^k) \right) \frac{1}{i_t} \tag{3.10}$$

From equation (3.9) it is apparent that the firm will invest up until the marginal cost of one additional unit of capital equalizes the shadow price of capital. Equation (3.10) is effectively an investment Euler equation. It shows that the value of current installed capital depends on its future expected value, considering the depreciation rate, the expected rental rate of capital and the interest rate. Note that for simplicity, there are no costs to adjusting the level of investment or capital assumed in the model.

Production sector

The production sector in the economy consists of producers of intermediate goods and producers of final goods.

Intermediate goods producers

Intermediate producers operate in a perfectly competitive environment and have access to constant returns to scale Cobb-Douglas technology. In the production of intermediate goods, they combine domestic intermediate goods and imported goods. Domestic intermediate goods are produced only by using households' labor and capital as inputs.

The production function of the intermediate goods producers is of the form:

$$Y_t = (Y_t^d)^{\alpha} (M_t / a_t^X)^{1-\alpha} \tag{3.11}$$

whereas the separate production technology for domestic intermediate producers is given by:

$$Y_t^d = \varsigma_t (A_t L_t)^{\alpha_2} (K_t)^{1-\alpha_2} \tag{3.12}$$

where ς_t denotes total factor productivity shock, A_t is the labor-augmenting technology, M_t is imported goods, α is the share of domestic intermediate goods in production and α_2 refers to the share of labor in production.

In (3.11) we also include export specific technology a_t^X. It is a proxy for the Balassa-Samuelson effect, driving a wedge between GDP deflator growth and growth of export deflator. The permanent effects of export-specific shocks thus allow for consumption-based real exchange rate appreciation in the long run. Symmetrically, the export specific technology is introduced in the imported goods sector as well. This specification ensures that the net exports to GDP ratio remains stationary over time. For further discussion see Andrle et al. (2009).

Firms' objective is to maximize profit given the costs of inputs. Thus, domestic intermediate goods producers optimize the following utility function, subject to (3.12):

$$\max_{Y_t^d, L_t, K_t} P_t^d Y_t^d - P_t^K K_t - W_t L_t \tag{3.13}$$

with P_t^d being the price of domestic intermediate goods, $P_t^K K_t$ capital services costs and $W_t L_t$ labor costs.

Intermediate goods producers, using imported goods as an input for their production, optimize the following utility function, subject to (3.11):

$$\max_{M_t} P_t^Y Y_t - P_t^d Y_t^d - P_t^M M_t \tag{3.14}$$

where $P_t^M M_t$ are costs of imported goods.

The solution to the firms' maximization problem results in the following first order conditions for optimal labor, capital and import input demands:

$$\frac{W_t}{P_t^d} = \alpha_2 \frac{Y_t^d}{L_t} \tag{3.15}$$

$$\frac{P_t^K}{P_t^d} = (1 - \alpha_2) \frac{Y_t^d}{K_t} \tag{3.16}$$

$$\frac{P_t^M}{P_t^Y} = (1 - \alpha) \frac{Y_t}{M_t} \tag{3.17}$$

Equations (3.15), (3.16) and (3.17) capture the notion that the real marginal costs of capital, labor and import should be equal to their respective marginal products This implies, for example, that a lower real wage or price of capital would lead to a rise in the demand for labor or capital, until their marginal products do not fall enough to restore the equilibrium.

The demand function for domestic intermediate goods production is given by:

$$\frac{P_t^d}{P_t^Y} = \alpha \frac{Y_t}{Y_t^d} \tag{3.18}$$

Intermediate goods are used in the production of final consumption, investment, export and public goods:

$$Y_t = Y_t^C + Y_t^J + Y_t^X + Y_t^G \tag{3.19}$$

Final goods producers

Final goods are produced by a continuum of i retailer firms by utilizing the goods produced by intermediate producers. We assume that there are four final goods producers: producers of consumption, investment, export, and public spending goods. The sectors are monopolistically competitive. Firms minimize the production costs with respect to the prices of inputs, the demand functions and the Calvo probability of price optimization. They all utilize only the domestic intermediate goods as an input, i.e. they do not include any additional import component in the production of their final goods. This assumption is made to simplify the derivation of the model and can be relaxed at a later stage of the model development.

Final consumption goods producers

Given the assumption of a home bias in the production of final consumption goods, the technology that individual producers use has the following simple form:

$$\int_0^1 C_t(i)di = Y_t^C \tag{3.20}$$

where C_t is the final output of the *i-th* producer and Y_t^C is the intermediate goods output used by the consumption sector.

The objective of final consumption goods producers is to maximize profit. The solution of the profit maximization problem leads to the following demand function for domestic intermediate goods:

$$C_t(i) = \left(\frac{P_t^C(i)}{P_t^C}\right)^{-\epsilon_c} C_t \tag{3.21}$$

Identical to the wage setting process, the price setting of final consumption goods producers is à la Calvo, where $(1-\theta)$ fraction of firms chooses optimal price and θ fraction of firms set prices following price indexation rule under the assumption of full backward indexation i.e indexation taking into account the inflation in the previous period:

$$P_t^C = P_{t-1}^C \pi_{t-1}^C \tag{3.22}$$

The solution to the firms' optimization problem gives rise to the hybrid New Keynesian Phillips curve of the following form:

$$\triangle\, logp_t^c = \frac{1}{1+\beta} \triangle\, logp_{t-1}^c + \frac{\beta}{1+\beta} E_t(\triangle\, logp_{t+1}^c) + \frac{(1-\theta)(1-\beta\theta)}{\theta(1+\beta)} log\left(\frac{P_t^Y}{P_t^C}\mu\right) + \varepsilon_t^{pc} \tag{3.23}$$

where μ is price mark-up, $log\left(\frac{P_t^Y}{P_t^C}\mu\right)$ is real marginal cost and ε_t^{pc} is a price cost-push shock.

Export sector

Export firms also operate in monopolistic competition and use the following technology to produce the export goods:

$$\int_0^1 \mathrm{X}(i)di = Y_t^X a_t^x \qquad (3.24)$$

where Y_t^X are the domestic intermediate goods used in the production of export goods and a_t^x is time-varying export-specific technology that captures the productivity increase in export in excess to real GDP growth. Hence, the inclusion of the export-specific technology allows us to account for the real exchange rate appreciation trend stemming from the economic convergence process in the long run.

The marginal costs of exporters that are consistent with this production technology are:

$$P_t^{X,Y} = \frac{P_t^Y}{a_t^x} \qquad (3.25)$$

The price setting of exporters follows the same Calvo setup as described previously, with the following Phillips curve for export prices:

$$\triangle\, logp_t^x = \frac{1}{1+\beta} \triangle\, logp_{t-1}^x + \frac{\beta}{1+\beta} E_t(\triangle\, logp_{t+1}^x) + \frac{(1-\theta_{p^x})(1-\beta\theta_{p^x})}{\theta_{p^x}(1+\beta)} log\left(\frac{P_t^{X,Y}}{P_t^X}\mu_{p^x}\right) + \varepsilon_t^{px} \qquad (3.26)$$

The demand for domestic export goods from abroad has the standard form:

$$X_t = \alpha^* \left(\frac{P_t^x}{P_t^* S_t}\right)^{-\varepsilon^*} a_t^X Y_t^* exp(\varepsilon_t^x) \qquad (3.27)$$

where α^* is share of exports from MK in EU-28 countries imports, P_t^x is the domestic price of exports, P_t^* is the foreign price, S_t is the nominal exchange rate MKD/EUR, Y_t^* is the foreign demand and ε_t^x is the relative price elasticity of domestic exports. Foreign demand is calculated as a sum of weighted GDP indices of the trading partners that are most important for the economy of North Macedonia, which include Germany, Greece, Italy, the Netherlands, Belgium, Spain, Bulgaria, Slovenia, and Serbia.

Investment goods producers

Analogous to the other sectors, investment goods producers' technology has a simple form:

$$\int_0^1 J_t(i)di = Y_t^J a_t^j \qquad (3.28)$$

where Y_t^J are the domestic intermediate goods used in the production of investment goods and a_t^j is the aggregate investment-specific technology trend.

The price of the investment good is assumed to be the price of the consumption good deflated for the investment-specific technology:

$$P_t^J = \frac{P_t^C}{a_t^j} \qquad (3.29)$$

Investment-specific productivity is important in that it represents one of the determinants of the growth rate of the aggregate technology and thus affects all real variables in the model. This is because investment technology affects the production of domestic intermediate producers through the capital accumulation function.

Public spending goods

All producers of public goods have identical technology for production:

$$\int_0^1 G_t(i)di = Y_t^G a_t^g \tag{3.30}$$

where Y_t^G are the domestic intermediate goods used in the production of public spending goods and a_t^g is the sector-specific technology trend.

Like investment goods, price of public spending goods is assumed to be the price of consumption goods after considering the specific public spending technology:

$$P_t^G = \frac{P_t^C}{a_t^g} \tag{3.31}$$

Import sector

The domestic import sector faces the prices of foreign exporters, and then converts them in domestic currency by using the nominal exchange rate MKD/EUR. This represents the nominal marginal cost of importers:

$$P_t^{M,Y} = S_t P_t^* \tag{3.32}$$

Pricing in the import sector is subject to stickiness in domestic currency. We assume that import price setting follows the same Calvo mechanism as for domestic monopolistically competitive sectors, which leads to the analogous hybrid Phillips curve for importers:

$$\triangle logp_t^m = \frac{1}{1+\beta}\triangle logp_{t-1}^m + \frac{\beta}{1+\beta}E_t(\triangle logp_{t+1}^m) + \frac{(1-\theta_{p^m})(1-\beta\theta_{p^m})}{\theta_{p^m}(1+\beta)}log\left(\frac{P_t^{M,Y}}{P_t^M}\mu_{p^m}\right) + \varepsilon_t^{pm} \tag{3.33}$$

Monetary policy

The central bank implements a fixed exchange rate regime. With a fixed exchange rate and high capital mobility, it is not possible for the domestic interest rate to be different from the foreign interest rate adjusted for the risk premium. In other words, the reaction function of the central bank links the nominal interest rate in the domestic economy with the foreign interest rate and risk premium:

$$i_t = i_t^* + prem_t \tag{3.34}$$

The nominal exchange rate MKD/EUR is modeled as a fixed exchange rate regime allowing for de- or revaluation of the exchange rate, captured by the shock term ε_t^s:

$$S_t = S_{t-1} + \varepsilon_t^s \tag{3.35}$$

Government

It is assumed that the government adjusts its spending to maintain the ratio of nominal public expenditures to the nominal private consumption constant. This is a simplification, since at this stage a detailed modeling of the fiscal sector is not our main focus. However, this assumption is in line with the relatively stable ratio of public to private consumption observed in the data.

$$\frac{P_t^g G_t}{P_t^c C_t} = \left(\frac{P_{t-1}^g G_{t-1}}{P_{t-1}^c C_{t-1}}\right)^{0.5} (ss^{PG2PC})^{0.5} + \varepsilon_t^G \tag{3.36}$$

where ε_t^G is a fiscal policy shock.

On top of the fiscal rule above, the government faces a budget constraint. The government collects taxes and issues debt on one side and repays interest costs on the existing debt and provides lump sum transfers to households.

National accounts

The nominal gross domestic product according to the expenditure-based approach is defined as:

$$Y_t^N = P_t^C C_t + P_t^G G_t + P_t^J J_t + P_t^X X_t - P_t^M M_t \tag{3.37}$$

Net foreign asset position is a function of the previous period stock and the trade balance flows:

$$NFA_t S_t = i_{t-1}^* S_{t-1} NFA_{t-1} + P_t^x X_t - P_t^m M_t \tag{3.38}$$

The share of NFA in nominal exports is given by:

$$NFA_t/PXX_t = \frac{NFA_t S_t}{P_t^x X_t} \tag{3.39}$$

The risk premium is inversely related to the net foreign assets to nominal exports ratio relative to its steady state.

$$prem_t^{nfa} = \left(\frac{NFA_t/PXX_t}{ss^{NFA2PXX}}\right)^{-\epsilon_{nfa}} \tag{3.40}$$

where $-\epsilon_{nfa}$ is risk premium elasticity to NFA position, $ss^{NFA2PXX}$ is the steady-state NFA to nominal exports ratio.

The law of motion for the risk premium is given by:

$$prem_t = \rho_{prem} prem_{t-1} + (1 - \rho_{prem}) prem_t^{nfa} + \varepsilon_t^{prem} \tag{3.41}$$

where ε_t^{prem} is risk premium shock.

Foreign sector

The foreign sector is captured with the following three equations:

Foreign demand

$$\triangle logY_t^* = \rho_{\triangle logY^*} \triangle logY_{t-1}^* + (1-\rho_{\triangle logY^*}) \triangle logz_t + \varepsilon_t^{Y^*} \quad (3.42)$$

Where z is the balanced growth path of domestic economy. Given the structure of the model, it is a function of labor-augmenting technology and investment-specific technology as defined in (3.46) and (3.48) in the next section:

$$\triangle logz_t = \triangle loga_t + \triangle loga_t^j \frac{1-\alpha_2}{\alpha_2}$$

Real variables of the model that do not have sector specific trends are growing by this overall stochastic trend. The same growth is assumed to be experienced by foreign demand.

Foreign inflation

$$\triangle logP_t^* = \rho_{\triangle logP^*} \triangle logp_{t-1}^* + (1-\rho_{\triangle logp^*}) \triangle logp^* + \varepsilon_t^{\pi^*} \quad (3.43)$$

There is a foreign inflation target, Δp*, assumed for foreign prices.

Foreign interest rate

$$i_t^* = \rho_{i^*} i_{t-1}^* + (1-\rho_{i^*})(\frac{1}{\beta} + \sigma \triangle logz_t + \triangle logp_t^* - Wedge_t^I) + \varepsilon_t^{i^*} \quad (3.44)$$

The foreign interest rate is a sum of the natural rate of interest, which equals real growth, and the inflation target. We extend the model equation (3.44) by adding a wedge to interest rates to match the observed data. It enables us to shift down both the foreign and by construction also the domestic nominal interest rates.

Technological processes

The model includes the following technological trends, specified as simple AR(1) processes for growth rates[11]:

$$\varsigma_t = \varepsilon_t^{\varsigma} \quad (3.45)$$

$$\triangle log(a_t) = \rho_a \triangle log(a_{t-1}) + (1-\rho_a) ss^a + \varepsilon_t^a \quad (3.46)$$

$$\triangle log(a_t^g) = \rho_{a^g} \triangle log(a_{t-1}^g) + (1-\rho_{a^g}) ss^{a^g} + \varepsilon_t^{a^g} \quad (3.47)$$

$$\triangle log(a_t^j) = \rho_{a^j} \triangle log(a_{t-1}^j) + (1-\rho_{a^j}) ss^{a^j} + \varepsilon_t^{a^j} \quad (3.48)$$

[11] Total factor productivity is considered to follow a white noise without persistence.

$$\triangle log(a_t^x) = \rho_{a^x} \triangle log(a_{t-1}^x) + (1 - \rho_{a^x}) ss^{a^x} + \varepsilon_t^{a^x} \quad (3.49)$$

$$\triangle log(a_t^o) = \rho_{a^o} \triangle log(a_{t-1}^o) + (1 - \rho_{a^o}) ss^{a^o} + \varepsilon_t^{a^o} \quad (3.50)$$

$$\triangle log(a_t^q) = \rho_{a^q} \triangle log(a_{t-1}^q) + (1 - \rho_{a^q}) ss^{a^q} + \varepsilon_t^{a^q} \quad (3.51)$$

The technological processes specified above are crucial for deriving the balanced growth path - the constant long-run growth rates of all variables - of the model. Furthermore, these trends are necessary to match the data.

Technologies ς_t, denoting a total factor productivity shock and a_t, standing for the log of the labor-augmenting technology (see equations (3.45) and (3.46) above), enter directly into the production function. They are standard ingredients of most DSGE models featuring Cobb-Douglas production functions.

The persistence of technology processes was calibrated to match trends in the data. The approach is identical to the one applied in Andrle et al. (2009). As there are non-stationary nominal shares several sector specific technological trends were needed.

- Government consumption and investment-specific technologies were introduced to capture observed growth rates of real consumption and real investment, that are different from aggregate GDP growth for our sample period.
- Export specific technology, included in equation (3.49), intends to capture the real economic convergence observed in many transition economies, the so-called Balassa-Samuelson effect. This trend quantifies the trend real appreciation of the exchange rate, driven by higher growth rate in exports compared to aggregate GDP.
- Openness technology measures the common trend in exports and imports that cannot be explained solely by the growth rates of aggregate GDP and export specific technology. For instance, both exports and imports tend to grow dynamically when large logistic centers are built close to national borders to supply goods to various countries from those centers. The more such logistic capacities are built, the faster growth in exports and imports is experienced, but without any significant changes in aggregate GDP growth or export specific technology.
- Finally, equation (3.51) quantifies the AR(1) process capturing the change in quality of exported goods. The identification of change in quality is straightforward. Any growth in exports not caused by higher aggregate technology, export specific technology, openness or higher foreign demand is attributed to the changes in quality of exported goods, accompanied with an increase of global market share of domestic exporters.

Calibration

We decided to calibrate the model instead of applying a formal estimation. The reasons for calibration are the usual ones mentioned in the literature: the available time series are relatively short, and the economy of North Macedonia has been undergoing significant structural changes in recent years. That can be seen, among others, from the presence of non-stationary shares of the many great ratios (such as the shares of nominal expenditure side variables in national accounts to GDP in current prices). Furthermore, DSGE models are difficult to estimate due to the presence of expectations and unobserved variables, such as technologies. That said, by calibration we do not mean just setting some plausible parameters of the model, based on an-hoc selection from a pool of values known from the literature. The calibration has been an iterative process. Specifically, we examined the model's properties via diagnostic testing, such as reviewing its impulse response functions, Kalman filter based shocks decompositions and historic in-sample simulations (for results see the next section, focusing on Model diagnostics). Whenever some of these properties were not satisfactory, we recalibrated the model and examined its diagnostic properties as long as the results were satisfactory for policy analysis reflecting country stylized facts. As a useful byproduct, the calibration process contributed to learning, gradually creating ownership of the model by all involved in its development.

We divided the model parameters into two broad groups. First, we list the parameters, included in Table T1 below, responsible for the model's dynamic properties, including the inertia for real and nominal variables. The second group of parameters, reported in Table T2 below, contribute to the model's balanced growth path and big ratios.

Some of the model parameters included in Table T1, can more easily be calibrated than others, as their values can directly be derived from observed data.

- The share of labor in production is set at 0.6. This calibration is close to the sum of compensations to employees and income of individual agricultural producers, both as shares of nominal GDP.
- The share of domestic production in the final production is set at 0.475. This value is broadly in line with input-output tables. Moreover, it provides reasonable decomposition of consumer price dynamics.
- α^*, the share of exports from MK in EU-28 countries imports, is 0.02, a value based on Eurostat statistics.
- The remaining parameters in Table T1 were set to achieve dynamic plausible dynamic properties of the model in terms of impulse response functions and in-sample simulation results. Specifically, the relative risk aversion, σ, has been set to 1, a typical value used in DSGE models. The inertia observed in households' consumption is consistent with a high habit persistence parameter χ, set at 0.85. The marginal disutility of labor, ψ, has been calibrated to 1, the intertemporal (deterministic) discount factor, β = 0.99 which is in line with standards of the literature.
- The Calvo parameters set for the economy of North Macedonia reflect the stylized fact observed in many countries: nominal wages are more rigid than consumer prices. We also observe in the data somewhat higher price rigidity for imports θ_{p^m} = 0.7) compared to exports θ_{p^x} = 0.6). The elasticity of domestic exports w.r.t. foreign demand fits the data the best at 0.5.

Table T1. Dynamic parameters of the model

Variable	Model Parameters	Values
Relative risk aversion	σ	1.00
Habit persistence	χ	0.85
Marginal disutility of labor	ψ	1.00
Intertemporal discount factor	β	0.99
Share of domestic production in final production	α	0.475
Share of labor in production	α_2	0.6
Depreciation rate of capital	δ	0.7
Calvo parameter, consumer-price equation	θ	0.7
Calvo parameter, nominal wage equation	θ_w	0.85
Calvo parameter, export-price equation	θ_{p^x}	0.6
Calvo parameter, import-price equation	θ_{p^m}	0.7

Share of exports from MK in EU-28 countries imports	α^*	0.02
Elasticity of domestic exports w.r.t. foreign demand	ε^*	0.5

The steady-state parameters of the model are included in Table T2. The technological trends were set based on the slopes of trends observed in the data. The same holds for the government- to household consumption ratio ss^{a^g}. The risk premium elasticity linked to the NFA position has been set to 0.15 and the NFA to nominal exports ratio has been determined to obtain plausible households consumption dynamics. As in other DSGE models, wealth effects have strong implications on consumption dynamics also in our case.

Table T2. Steady-state parameters of the model

Variable	Model Parameters	Values
Risk premium elasticity to NFA position	ϵ_{nfa}	0.15
NFA to nominal exports ratio	$ss^{NFA2PXX}$	10.0
Government- to household consumption ratio	ss^{PG2PC}	0.25
Labor augmented technology	ss^{a}	0.5
Government consumption-specific technology	ss^{a^g}	0.475
Investment-specific technology	ss^{a^j}	6
Export-specific technology	ss^{a^x}	0
Openness technology	ss^{a^o}	0.6
Quality improvement technology	ss^{a^q}	0.6

Model diagnostics

Steady-state of key model variables versus data

To get an overview of the model's calibration, we present its most important steady-state characteristics in Table T3a and Table T3b.

Table T3a below includes the steady-state nominal expenditure to nominal GDP shares of the model in comparison with the observed data averages calculated for the full sample and a restricted sample from 2004. The steady-state shares of the model reflect the judgement of the authors regarding the perceived average expenditure shares prevailing on the horizon relevant for the forecast (2-3 years ahead). Specifically private household/government consumption and investment shares are calibrated close to observed averages calculated on the restricted sample from 2004. The higher export share reflects the assumption that the trend growth rate, observed historically in the export share, (see Figure 4) will continue over the forecast horizon. The increase in import share is an implication of the high input share of imports in domestic production.

Table T3a. Y-o-Y growth rate of actual data versus model implied steady-state

Share to nominal GDP	Model	Data (full sample)	Data (from 2004)
Private consumption (*C*)	0.70	0.74	0.73
Investment (*J*)	0.27	0.25	0.27
Government consumption (*G*)	0.17	0.18	0.17
Imports (*M*)	0.63	0.57	0.63
Exports (*X*)	0.78	0.41	0.45

Table T3b below presents the means of the observed series y-o-y growth compared to the model's steady-state. The steady-state of the model is in line with mean y-o-y growth rate for most variables presented in the table. Only the model implied investment deflator steady-state growth is calibrated somewhat higher than in the observed mean growth rate calculated from data. The model with the shortened sample is better able to match the means of the investment, import and export volume series and nearly all deflators than the model using the full history. These results are in line with the view that recent history matters more for the current and future dynamics of macroeconomic variables in economies such as the Macedonian, which have undergone a substantial transformation and structural changes over the years.

Table T3b. Y-o-Y growth rate of actual data versus model implied steady-state

Y-o-Y growth rate	Model	Data (full sample)	Data (from 2004)
Private consumption (*C*)	2.8	2.8	2.3
Investment (*J*)	6.3	6	6.5
Government consumption (*G*)	1.3	1.7	1.9
Imports (*M*)	8.8	6.8	6.9
Exports (*X*)	9.8	7	7.9
Pr. consumption deflator (P_c)	2	2.3	2.1
Investment deflator (P_j)	4.5	2.6	2.9
Gov. consumption deflator (P_g)	3.5	3.7	3.4
Import deflator (P_m)	2	2.1	1.6
Export deflator (P_x)	2	3	2.5
Wages (*W*)	4.8	4.4	4.3

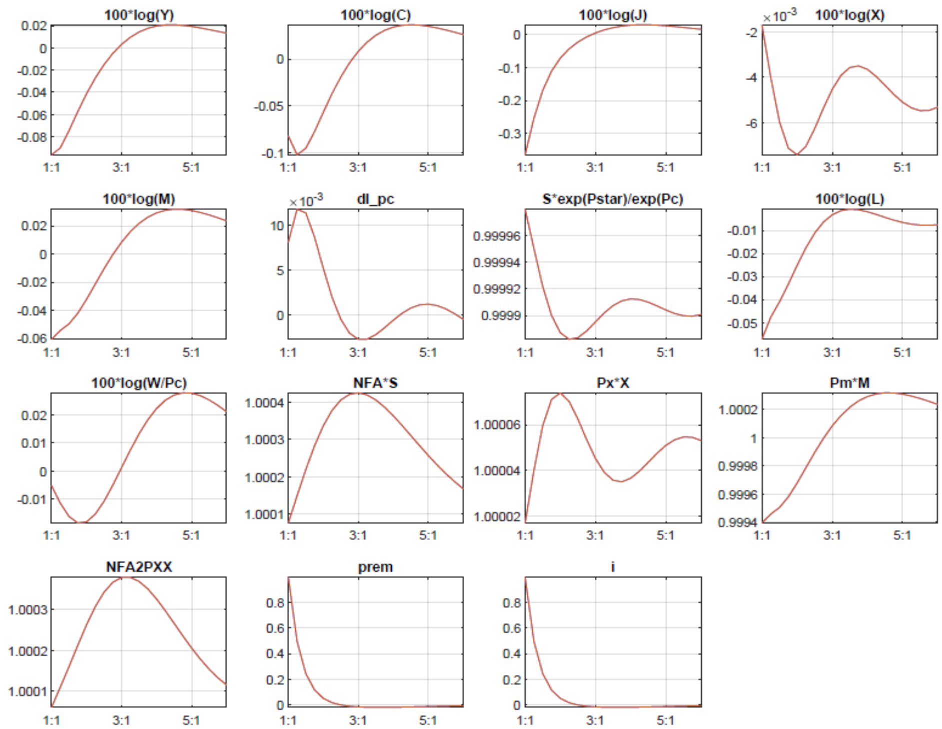
Impulse response functions

This section presents the impulse response analysis based on the calibrated model. Impulse response functions of key macroeconomic variables to exogenous shocks are analyzed. Specifically, the model's dynamic responses to a monetary policy shock, a cost-push shock, a demand-driven shock and a risk premium shock are presented. The figures below show the effect of one standard deviation shock on the variable dynamics over time[12].

Figure 7 depicts the effects of a positive shock to the country risk premium (ε_t^{prem}). Given the fixed exchange rate, domestic interest rate increases immediately and in a one-to-one manner to this shock, henceforth following the dynamics of the risk premium over the entire simulation horizon. The rise in the interest rate negatively affects both domestic consumption and investment, which consequently results in a drop in GDP. In addition, this shock forces firms to cut their demand for labor, which is accompanied by a downward adjustment of real wages. The effects of the rise in the risk premium on domestic prices are negligible. Consequently, we do not observe noticeable changes in the real exchange rate or real exports. Real imports, however, decrease in line with the diminishing domestic demand. As import prices are almost unchanged, nominal imports fall, that improves the trade balance. This induces a rise in NFA expressed in domestic currency, so the NFA share in nominal exports increases as well.

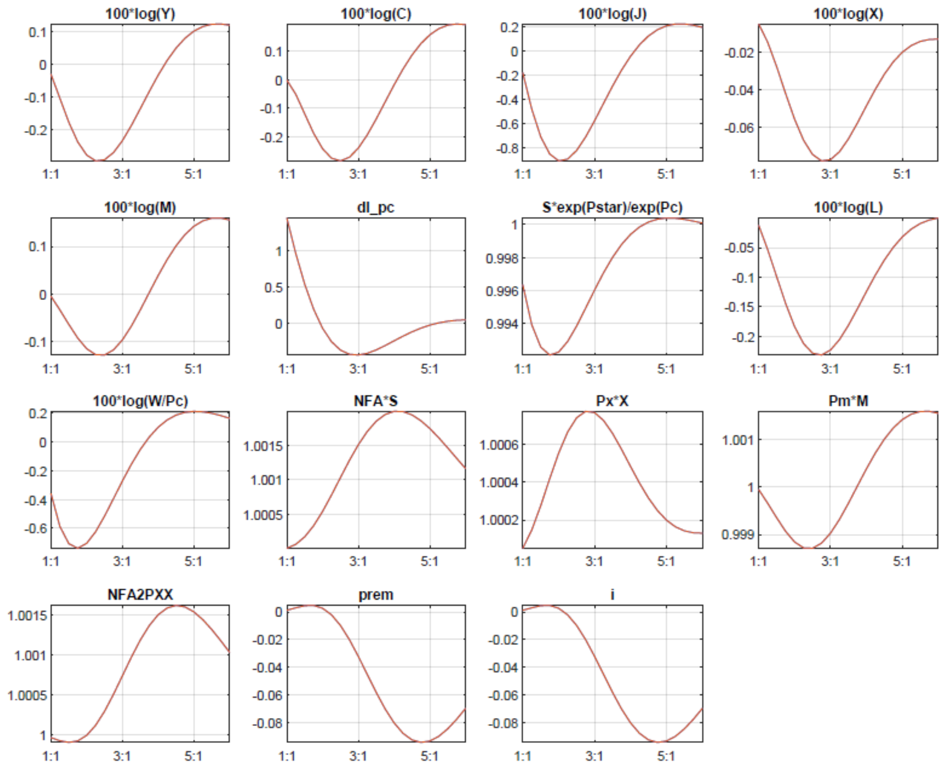
[12] The results are broadly in line with the ones obtained with the main macroeconomic projection model of the central bank (MAKPAM), as shown in Hlédik et al. (2016).

Figure 7: IRFs to the risk premium shock



Impulse response functions to a positive shock to the domestic inflation rate (ε_t^{pc}) are presented in Figure 8. Given the monetary policy rule, under a fixed exchange rate regime the central bank does not react directly to the unexpected rise in inflation with monetary tightening. The jump in inflation curbs real consumption and investment, as real disposable income falls and prices of investment goods increase. As a result, output falls. Firms cut their demand for labor, whereas higher inflation causes real wages to decrease as well. Firms' real marginal cost declines on impact, which in turn helps in mitigating inflationary pressures thereafter. Initially, nominal exchange rate stability implies unchanged exports, imports and NFA. However, that in turn leads to a decrease in imports and appreciation of the real exchange rate. Higher domestic prices deteriorate price competitiveness and as a result the volume of exports falls. The fall in export demand additionally erodes imports demand. The trade balance improves, which implies accumulation of NFA and an increase of the NFA to exports ratio over time. Therefore, we observe a decline in the risk premium, and consequently a fall in the interest rate.

Figure 8: IRFs to the cost push-shock



Next, we discuss the impulse responses to a positive shock to the foreign demand ($\varepsilon_i^{Y^*}$), as depicted in Figure 9. Higher foreign demand increases real exports that in turn results in higher output. Growing demand pressures in the domestic economy push inflation up that, ceteris paribus, results in an appreciation of the real exchange rate. Higher aggregate demand also triggers an immediate increase in the demand for labor, thus leading to higher real wages, which however adjust with a certain delay. Since export demand and investment go up, imports increase as well. Consequently, the trade balance improves, in an environment of more pronounced rise in exports than in imports. Hence, we observe accumulation of NFA in domestic currency. However, the smaller rise in NFA compared to nominal exports implies a worsening NFA-to-exports ratio. The resulting higher risk premium translates one-to-one into an increase of the domestic interest rate. Higher interest rates lower consumption on impact. After some time, consumption starts to increase on the back of the persistent rise in the real wages and falling real interest rates.

Figure 9: IRFs to foreign demand shock

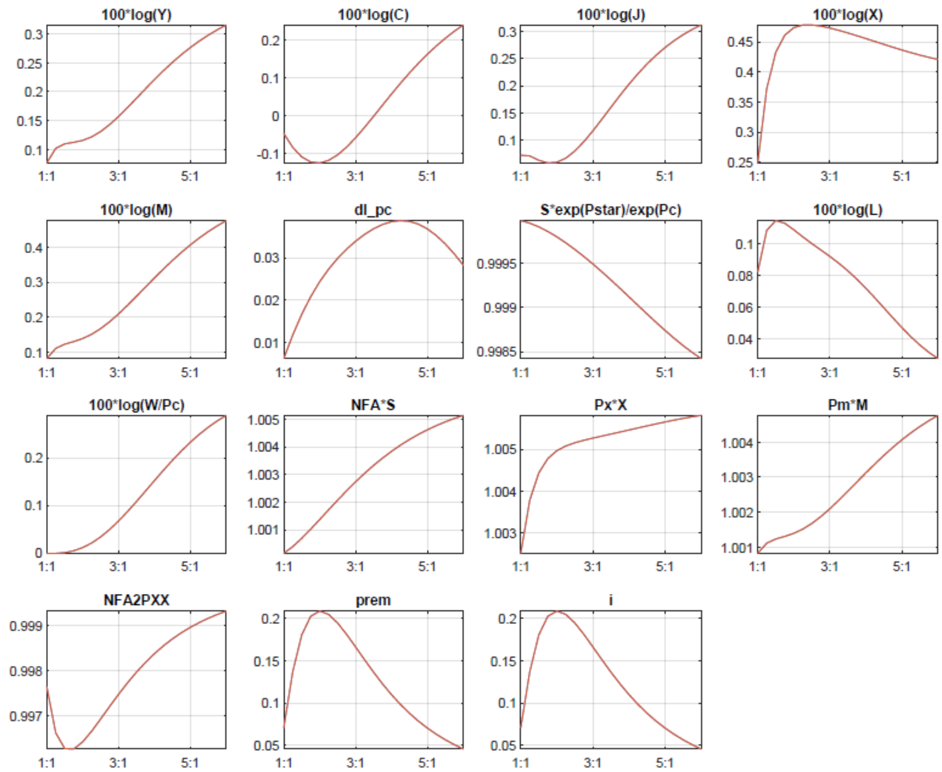
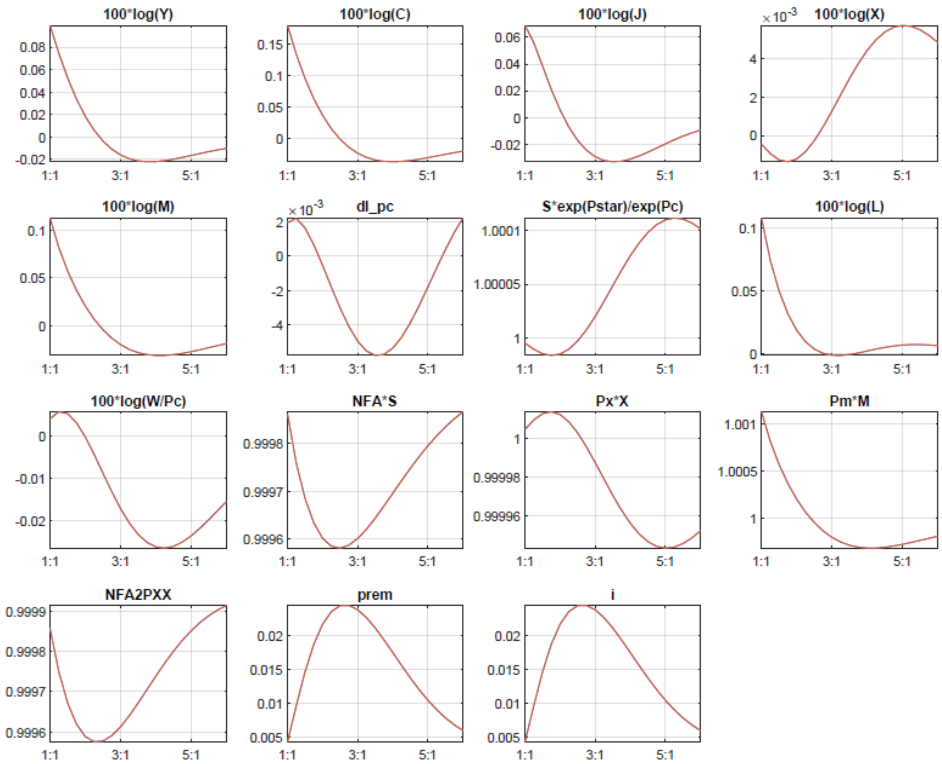


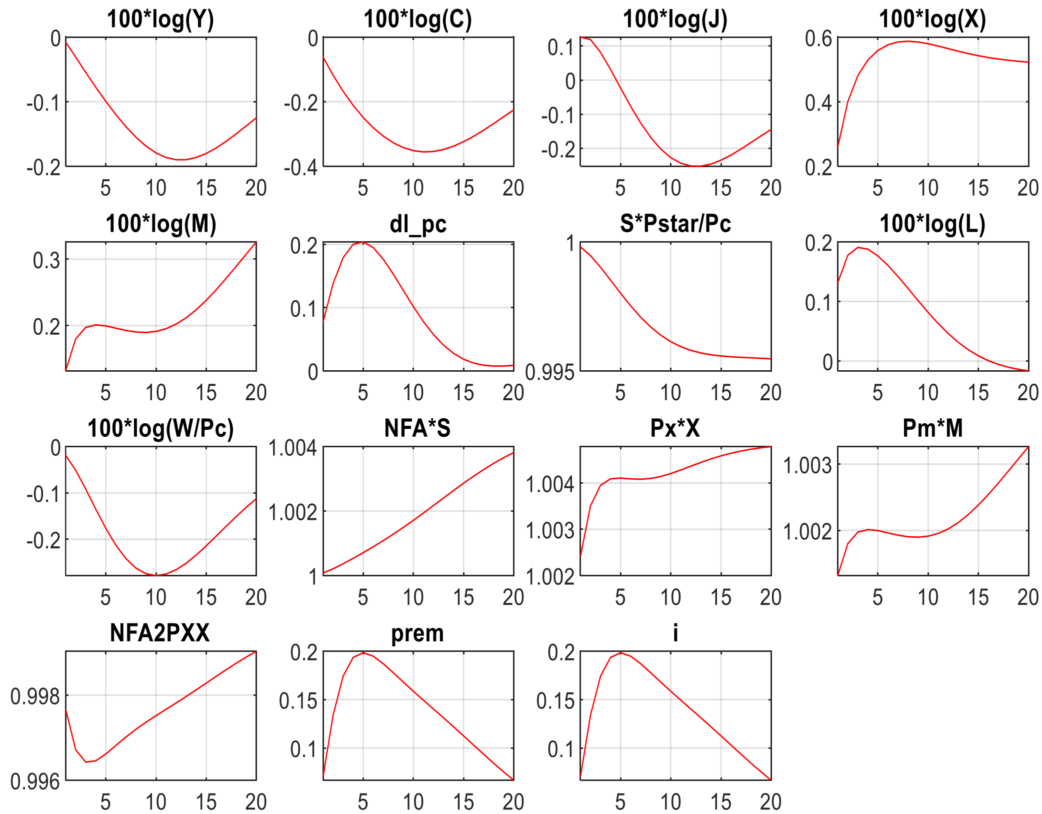
Figure 10 presents the effects of a positive shock to consumption habits (ε_t^C). This is a standard domestic demand shock, where prices and output both respond positively. In the short term, consumption increases, leading to higher demand for goods and encouraging firms to invest more to meet the change in demand. As a result, production increases, which causes GDP to increase as well. Due to the higher demand, firms increase their demand for labor, which puts upward pressure on real wages, leading to a marginal rise of domestic prices. On impact, competitiveness and exports are not affected significantly since the real exchange rate remains basically unchanged. However, the rise in domestic demand positively affects imports, due to the high import content of consumption and investment goods. This entails a worsening of the NFA position of the country as well as of the NFA to exports ratio, which leads to an increase in the risk premium, and consequently of the interest rate. As a result of this, consumption and investment start to go down, and the economy gradually returns toward equilibrium.

Figure 10: IRFs to habit shock



On top of structural shocks, there are shocks to technologies. Technologies and corresponding shocks are needed to match the trends in the actual data. Figure 11 presents a shock to export specific technology. The reaction of the model to this shock is included due to its importance in matching real exchange rate appreciation. An increase in export-specific technology results in a real exchange rate appreciation given the model structure. This is caused by higher domestic inflation while import prices remain unchanged in domestic as well as in foreign currency. Higher domestic prices reduce the real wage and as a result consumption slows down. An improvement in nominal exports reduces the NFA share and thus it implies a higher risk premium. The reaction in the policy interest reflects the change in the premium.

Figure 11: IRFs to export specific technology shock



Shock decomposition

Another tool that is regularly used to evaluate the properties of DSGE models is the historical shock decomposition analysis. The purpose of this analysis is to express the growth rate of selected variables in terms of weighted contributions of different types of shocks over the entire sample used. In that way, we can obtain insights into the importance of all shocks entering the model, organized into groups reflecting shock characteristics. Shock decompositions are important inputs during forecast rounds as they help identifying those shocks that shape actual data and contribute to the change of the forecast the most. Specifically, we grouped the model shocks into demand shocks (labor, export, private consumption, investment, government consumption), supply shocks (inflation, wages, export and import prices), productivity shocks (aggregate technology, export-specific technology, investment-specific technology, investment prices-specific technology, government-specific technology, openness technology and total factor productivity), monetary policy shocks (domestic interest rate and risk premium) and foreign shocks (foreign demand, prices and interest rate). An additional analysis, focusing on the autocorrelation and cross correlation properties of the identified structural shocks, is included in Annex 1.

As illustrated in Figure 11, the dynamic properties of investment are largely driven by demand shocks throughout the sample. In fact, demand shocks are the main driving forces behind the fluctuation of investment. Supply and productivity shocks have become increasingly relevant in the recent period, but their effects are offsetting each other. On the other hand, from Figure 12 it is apparent that supply shocks are more relevant for private consumption, contributing negatively to households' consumption growth until 2012. The contribution becomes positive afterwards. The drop in consumption and investment during the first year of the global pandemic is driven largely by demand shocks, supply chain restrictions worldwide and the overall loss of investor and consumer confidence, which is consistent with the observed trends at that time.

Figure 11: Historical decomposition of investment growth (y-o-y in % and contributions in pp)

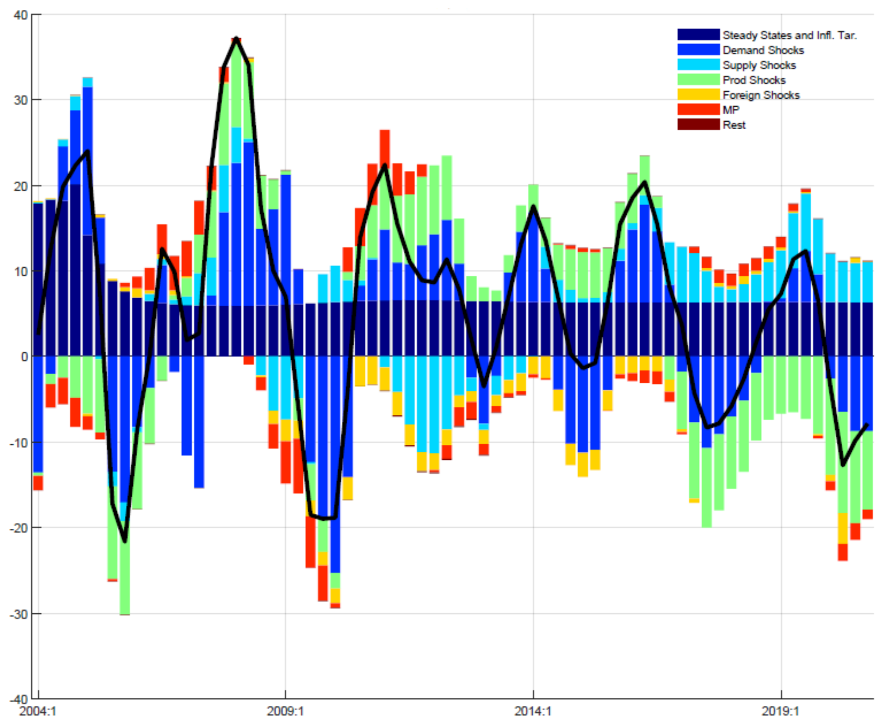


Figure 12: Historical decomposition of consumption growth (y-o-y in % and contributions in pp)

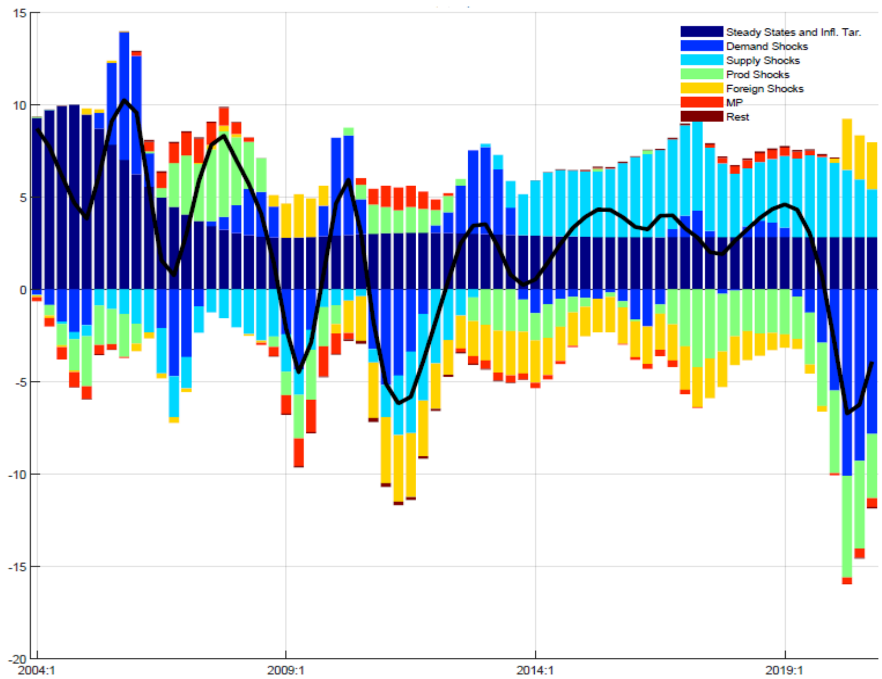


Figure 13 shows that the most important shocks driving the dynamics of real exports over the sample are demand-and foreign shocks, corresponding closely with developments as they occurred during specific periods (for example the 2008 and 2020 crises). The largest drop in the export growth is observed at the time of the global financial crisis and it is mostly explained by negative demand shocks, whereas the second to largest drop is recorded at the time of the global pandemic, largely stemming from the negative foreign shocks. As for real imports, (see Figure 14), apart from demand shocks, productivity and supply shocks are the main drivers of imports growth over the sample.

Figure 13: Historical decomposition of exports growth (y-o-y in % and contributions in pp)

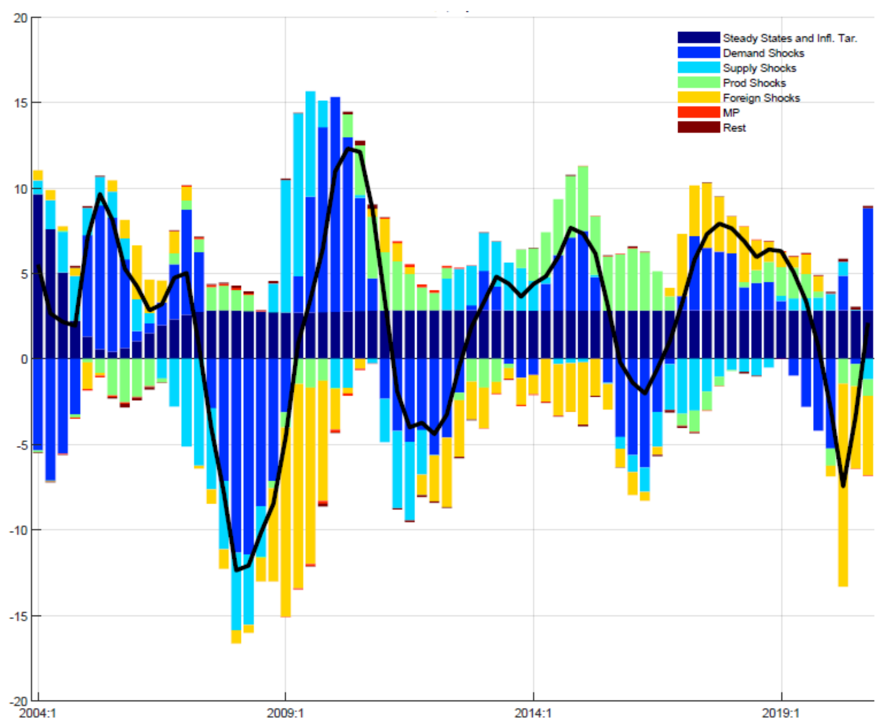
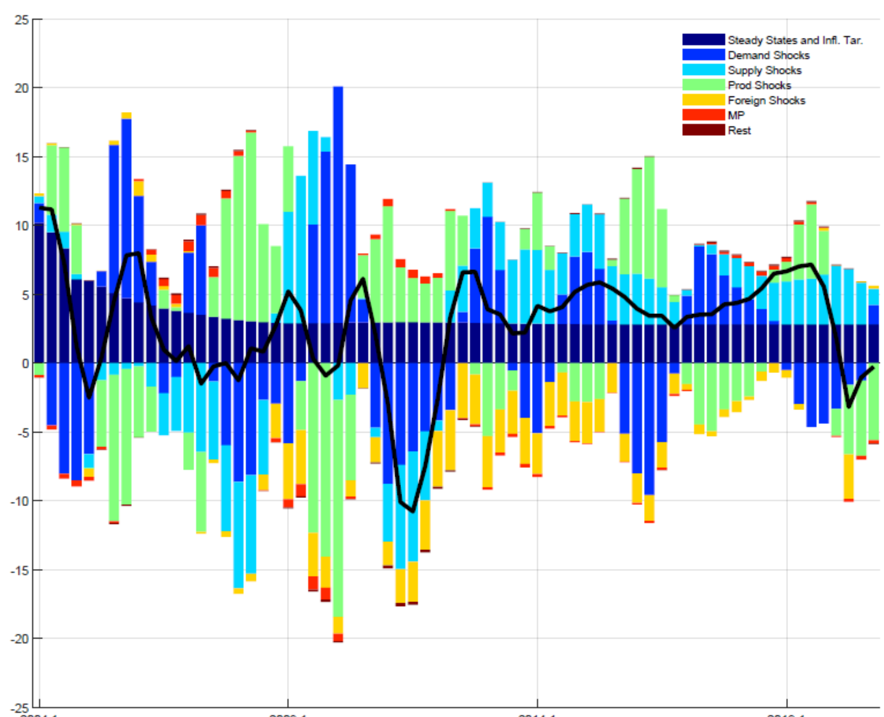


Figure 14: Historical decomposition of imports growth (y-o-y in % and contributions in pp)



When it comes to domestic prices, productivity shocks and supply shocks are the main drivers of the dynamics of the consumption deflator over the sample, as depicted in Figure 15. Moreover, it appears that demand shocks have a very limited contribution to the evolution of domestic inflation, which is in line with the findings of the study of Copaciu et al. (2021) for the economy of North Macedonia. Interestingly, foreign shocks exerted a positive influence on domestic inflation up to 2010, with their contribution becoming systematically negative until 2019 and largely diminishing in the period after. Regarding the domestic interest rate, as expected, its movement is explained by the foreign interest rate and determinants of the risk premium. The latter is determined by the external position of North Macedonia, that is influenced by supply and productivity shocks. Moreover, the difference can also reflect different information sets available in successive forecast rounds compared to the known history used by the shock decompositions included in this paper. (Figure 16).

Figure 15: Historical decomposition of consumption deflator (y-o-y in % and contributions in pp)

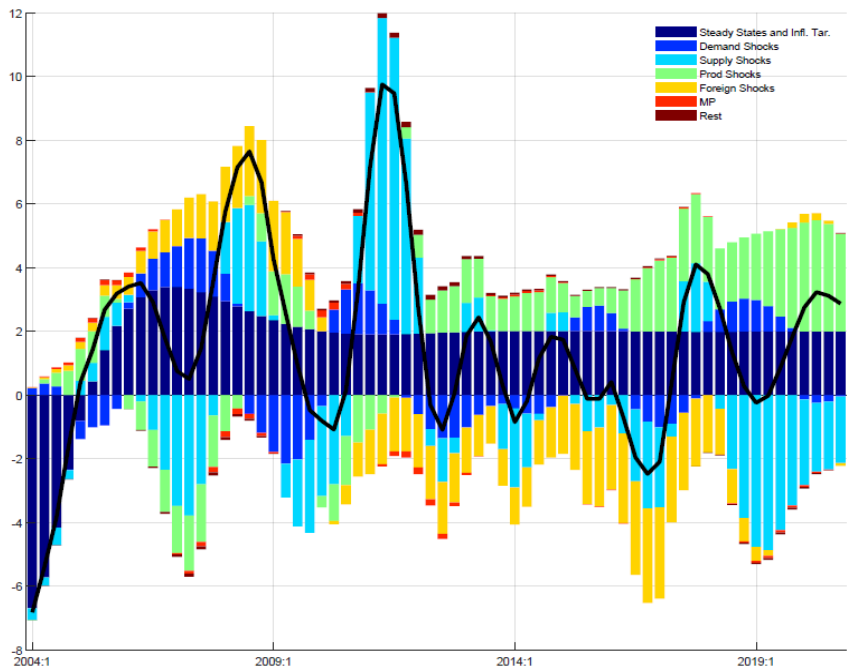
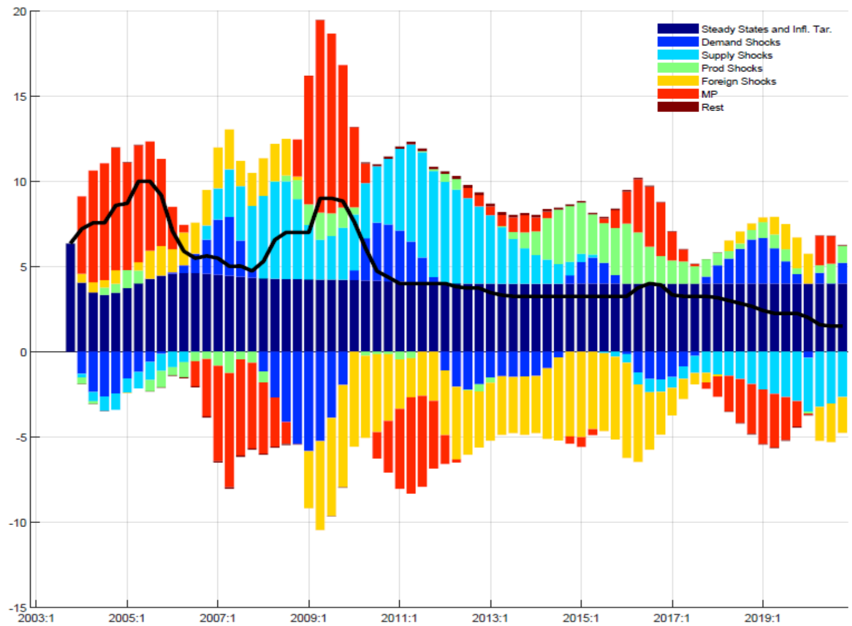


Figure 16: Historical decomposition of domestic interest rate



Historical simulations

To evaluate the model's forecasting properties of the domestic economy, historical (in-sample) simulations are produced as a usual verification point. The model simulations are generated at every point of time of the historic sample, assuming the knowledge of all model parameters and exogenous variables (external variables and technological trends). Figure 17 displays the in-sample simulations for the growth rates and nominal shares for selected model variables, namely for the GDP components, inflation, and the domestic interest rate. The figure depicts the 8-quarter ahead model forecasts. The simulated period is 2005q1 - 2021q1. For this model evaluation, the initial state of the economy is rolling from 2005q1 until 2020q4.

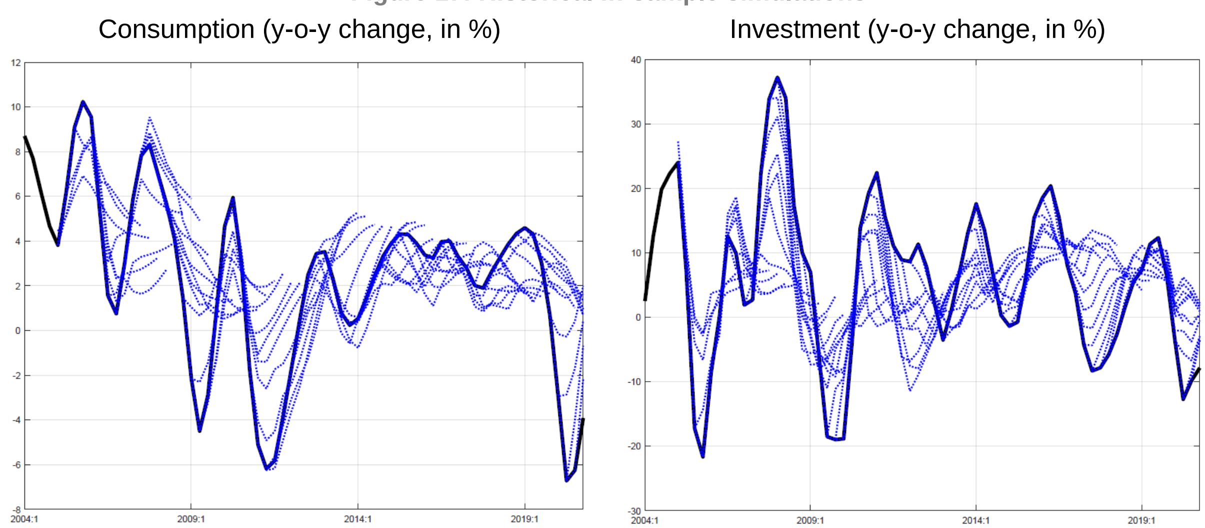
In terms of GDP components, the model forecasts follow the direction of private consumption growth most of the time quite well, although during the periods of falling growth rates the simulation results predict less pronounced decline. Regarding investment, the model undershoots its growth rate for most of the time until 2017. After it starts to predict higher than actual growth rates. These results are not surprising given the observed volatility of investment in the sample and paired with frequent data revisions. The results for exports growth indicate that the model gets the initial direction of exports in the first half of the sample frequently right but predicts the turning point earlier than happens in historic data. For the second half of the sample, it underestimates exports most of the time. The imports perform well during the periods of largest volatility in the data (the Great Financial Crisis and the pandemic). During in-between periods the model underestimates imports, which is obviously a result of underestimating domestic demand and export components in model simulations. Regarding inflation measured in terms of the consumption deflator, the model's in-sample simulation results are close to the observed data, with some overshooting in the run up to the global financial crisis (2009-2010 period) and a lower inflation rate thereafter[13]. The simulation

[13] Except for the last several quarters, when the model overshoots again.

results of the domestic interest rate indicate the need for higher interest rates prior to the Global Economic Crisis and their faster fall afterwards. The very different path for short term rates is partially reflecting the fact that the model simulations are produced based on the knowledge of all exogenous variables, including foreign variables, while the depth of the crisis became evident gradually. Also, the size of the risk premium, largely influencing the path for the policy rate, might have been viewed by the policymakers differently than quantified in the model[14]. In the more recent period, the difference between the predicted and the actual policy rate starts to gradually decrease after 2013, whereas the model forecasts go into negative territory with the start of the global pandemic in 2020. Finally, nominal shares of consumption and exports as observed in the data are well captured except the consumption share at the end of the sample. The higher than observed share of consumption on GDP at the end of the sample is given by the steady-state calibration of the model. The steady-state calibration reflects the staff opinion about dynamics of variables and shares in the long-run. The good fit of actual shares by the model simulations suggests that model forecasts for real growth rates and deflators are matching historical data well.

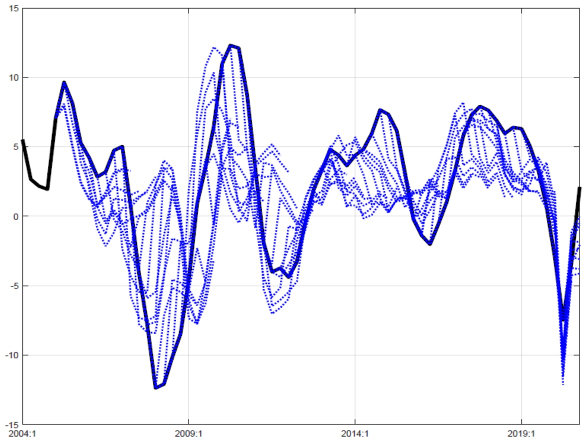
In general, it can be said that the model in-sample forecasts appear not to deviate greatly from actual outcomes and that some of the turning points are generally captured. However, the model is not intended to be used for forecasting exercises at this stage, and further improvements of the model are planned in the future.

Figure 17: Historical in-sample simulations

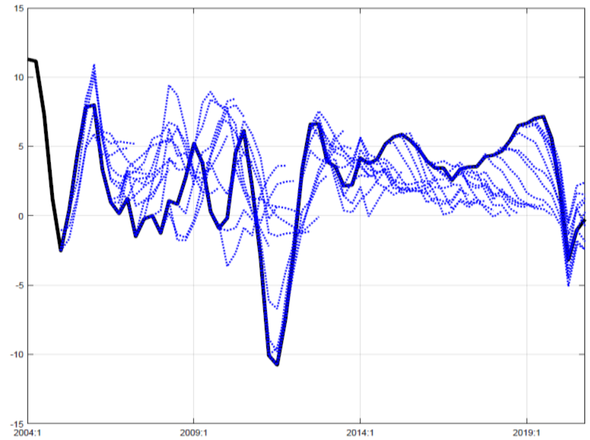


[14] Similar in-sample simulation results of the domestic interest rate are obtained with the main macroeconomic projection model of the National bank (MAKPAM), as shown in Hlédik et al. (2016).

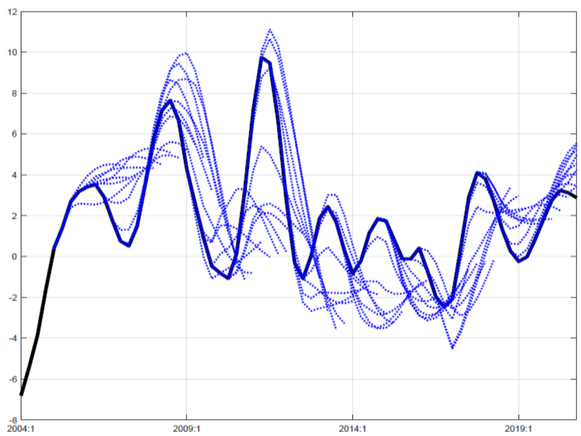
Exports (y-o-y change, in %)



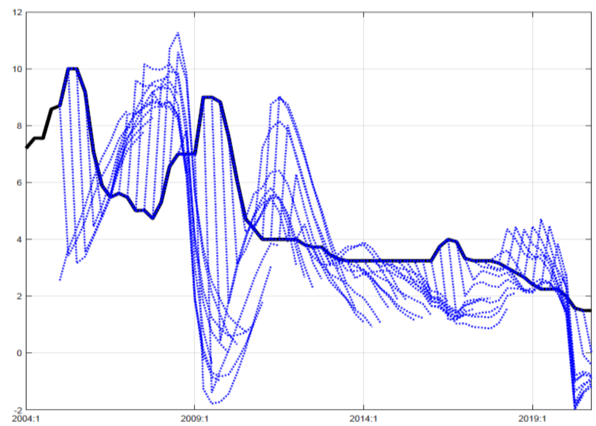
Imports (y-o-y change, in %)



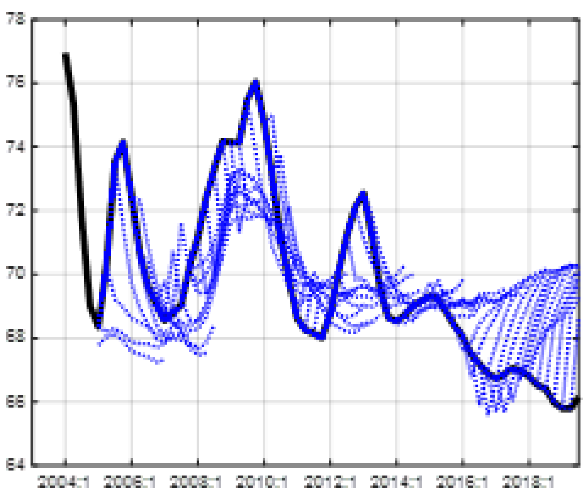
Consumption deflator(y-o-y change, in %)



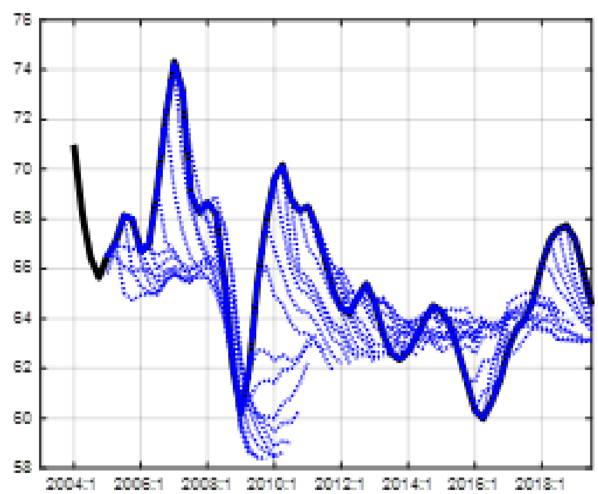
Domestic interest rate (level, in %)



Nom. consumption on nom. GDP (share in %)



Nom. exports on nom. GDP (share in %)



Conclusion

DSGE models are state of the art tools in applied macroeconomics, and hence they are becoming common in policy analysis and forecasting in many central banks in developed countries. The NBRNM decided to include a similar analytic tool in its suite of models. This paper provides an overview of this newly developed DSGE model calibrated to the economic characteristics of North Macedonia. It contains the key features of standard New-Keynesian DSGE models, whilst it reflects the main specifics of the economy of North Macedonia: a small open economy, with a fixed exchange rate regime. An important feature of the model is an explicit treatment of sectoral trends, enhancing the quantification of the ongoing structural economic changes in North Macedonia. The model will be used as a complementary analytical tool for policy analysis at the NBRNM alongside the main model used for macroeconomic forecasts (MAKPAM). It is expected to improve the story-telling capacity of the Monetary Policy and Research Department of the NBRNM and sharpen its understanding of the main drivers of the dynamics of the domestic economy. A particular emphasis is put in the paper on the model calibration and evaluation, including the analysis of impulse responses, shock decompositions and historical in-sample simulations.

When it comes to the dynamic properties of the model, the results from the impulse response analysis are found to be intuitive, considering the monetary regime in place. We observe that an unexpected rise in domestic inflation results in a slowdown of the domestic economy, but at the same time it leads to an improvement in the NFA position of the country. As a result, the country's risk premium declines, resulting in a decrease in nominal interest rates, that in turn helps to recover the economy thereafter. A positive shock to the interest rate, which is de facto a risk premium shock, exhibits also intuitive dynamics. The NFA position improves, which drives private consumption down as well as investment, and hence imports. Not surprisingly for a small and open economy with a fixed exchange rate, this shock has negligible effects on inflation, implying a rather weak monetary policy transmission through the interest rate channel. The positive shock to the foreign demand leads to a worsening of the NFA to exports ratio, due to the more pronounced increase in exports as denominator, which is followed by a rise in the risk premium and the policy rate[15].

We also referred to the historical shock decomposition analysis to evaluate the importance of structural shocks for the observed dynamics of the key macroeconomic variables. The results suggest that demand side shocks are the main driving force of the growth rate of investment in our sample period. This result is in contrast with the identification of shocks driving consumption growth, for which supply shocks are more relevant. In the external sector, exports are mainly explained by demand- and foreign shocks. Demand, productivity, and supply shocks appear to be the main drivers of imports demand. In line with other studies focusing on the economy of North Macedonia, we found that productivity and supply shocks, in combination with external related shocks, drive the evolution of inflation over the sample period, with a very limited contribution from demand shocks. Regarding the policy rate, its path is mainly determined by the foreign policy rate and supply and productivity shocks.

The results from the historical in-sample show that the predictions generally follow the dynamics of actual outcomes and that some of the turning points are captured well. At the same time, there is room to improve the forecasting properties of the model further, especially for some selected expenditure items of the

[15] This is different from the current main policy model (MAKPAM), where additional components of foreign exchange flows, not only the exports and imports, are considered in the policy reaction function.

national accounts. However, the intended use of the model at this stage is in policy analysis as opposed to regular forecasting.

To conclude, it is expected that the new DSGE model developed for the NBRNM will provide grounds for improved policy analysis. The new tool should help to make appropriate monetary policy decisions that, in turn, should contribute to an efficient delivery of the NBRNM’s mandate to maintain price stability. The model is planned to be extended to a more sophisticated specification and structure in the future, such as for the incorporation of a simple financial sector, including additional frictions and including of some other country specific features. The modeling approach based on the explicit treatment of sectoral trends applied in this paper could potentially be used in emerging market economies experiencing ongoing structural changes.

Annex 1

Analysis of structural shocks

This annex describes analysis of identified structural shocks. This analysis provides an additional view and assessment of the model calibration on the top of impulse responses, in-sample simulations, and the historical decomposition to shocks.

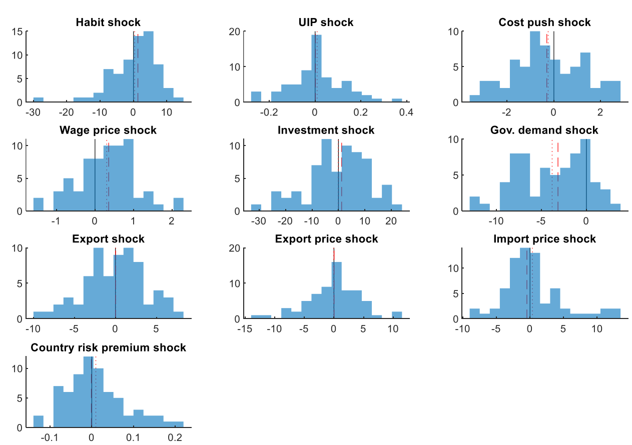
The identified structural shocks are expected to fulfill several properties that are the signs of appropriate model calibration. First, the shocks should exhibit a zero mean and no autocorrelation. Second, the cross-correlation among the shocks should be zero. A non-zero mean between shock would indicate a need for amendment of model steady state. An autocorrelation of shocks would imply that the actual data exhibits a higher persistence than the model. Finally, a non-zero cross-correlation of shocks indicates that there are differences between model implied second moments and the actual data moments.

In an ideal case of perfect calibration shocks fulfil the above-mentioned criteria. However, there are several caveats. First, the above-criteria are suitable for assessing how well the model matches historical data - the “historical fit” of the data by the model - as opposed to the model forecasting performance. Hence, there might be a trade-off between “historical fit” of the model and its forecasting capabilities. Second, the cross-correlation analysis does not provide guidance on whether model parameters or stochastic properties of the model should be adjusted. The main reason is that both parameters and standard deviation of model shocks determine the second moments of model variables. Third, proper statistical tests need to be applied to determine whether the above-mentioned measures are statistically different from zero and at which level of statistical significance.

The analysis is conducted only for shocks which are structural in their nature. Therefore, shocks to technologies and foreign shocks are excluded from the analysis. Furthermore, only structural shocks directly linked to observed variables are selected.

Figure A.1: Histogram of structural shocks

Note: The dotted vertical red line denotes the sample mean and the dashed line the sample median



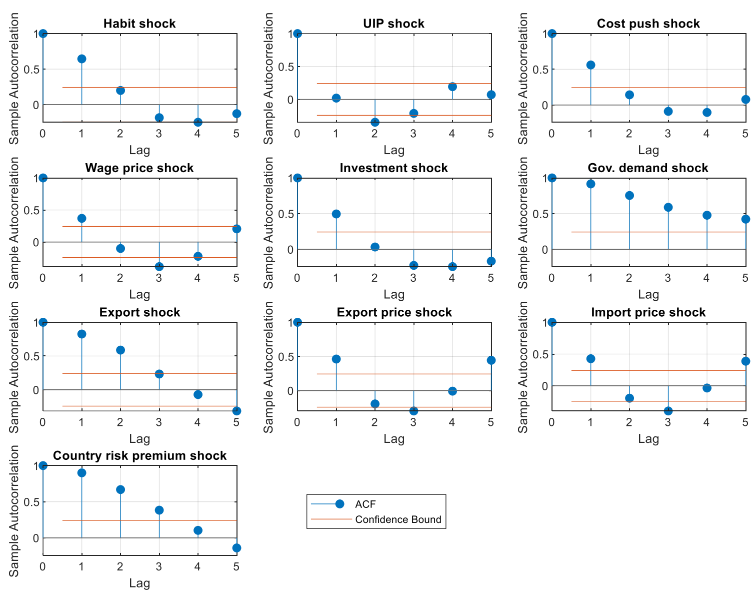
Source: Authors’ computations

Sample mean and median of structural shock are close to zero, Figure A.1, implying that there is no bias in structural equations describing the actual data. This is the case for all shocks except for government demand shock. However, the government demand shock (fiscal policy shock) is a shock in fiscal rule. The fiscal rule assumes that the government adjusts spending to achieve some targeted level of inflation and thus it is a simplified quantification of fiscal spending.

Most shocks exhibit first order autocorrelation, Figure A.2. It would suggest that there might be needed to raise persistence of real variables as exports, investment, and household consumption. Also, nominal variables as export, import, and consumption good prices and the country risk premium might be more persistent given first order autocorrelation. Thus, this analysis suggests a potential direction of further amendments of model calibration, but the model's forecasting performance needs to be cross-checked at the same time. The government demand shock (the fiscal shock) experience significant autocorrelation, which suggests that the fiscal rule is not matching the data well.

Figure A.2: Sample autocorrelation function of structural shocks

Note: The red line denotes 95 percent confidence band



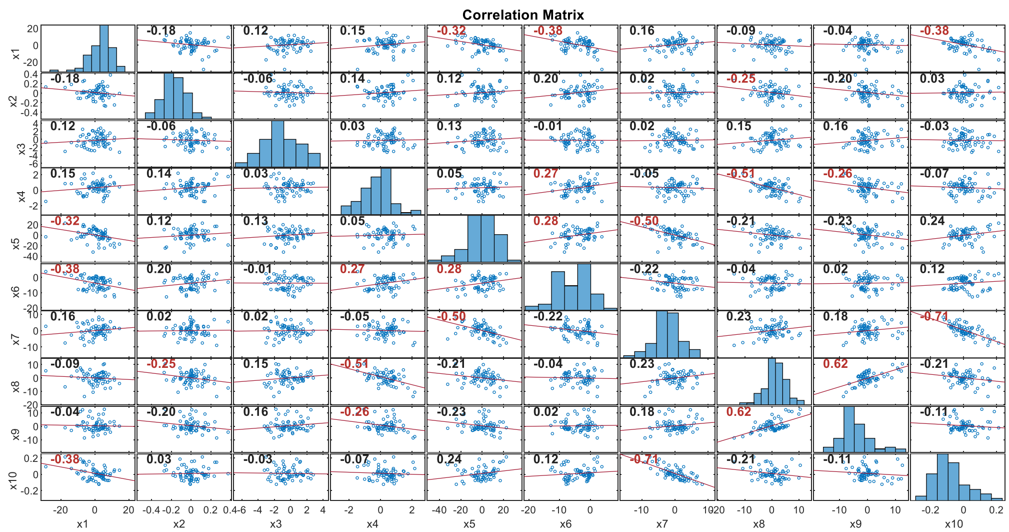
Source: Authors' computations

Some sample cross-correlations among structural shocks are statistically significant, as captured by Figure A3. This suggests that some model implied correlations among variables differ from the correlations implied by the data. The highest cross-correlation in absolute terms is between the export shock and the country risk premium. As the correlation between shocks is negative, the model implied correlation between these variables is higher than in the data. On the contrary, the cross correlation between export and import prices is positive and thus the model implied correlation is lower than the correlation between export and import price growth in the actual data.

The correlations bootstrapped from the actual data and their comparison with the model implied correlations is depicted by Figure A4. The figure shows that the cross correlation between the premium (prem) and real export growth (Δx)[16] is negative in the data while the model implied is slightly positive. On the contrary, the cross correlation between import (Δpm) and export price (Δpx) growth in the actual data is high, close to 0.9 at the mean. However, the model implied correlation is about 0.4.

Figure A.3: Sample cross-correlation of structural shocks

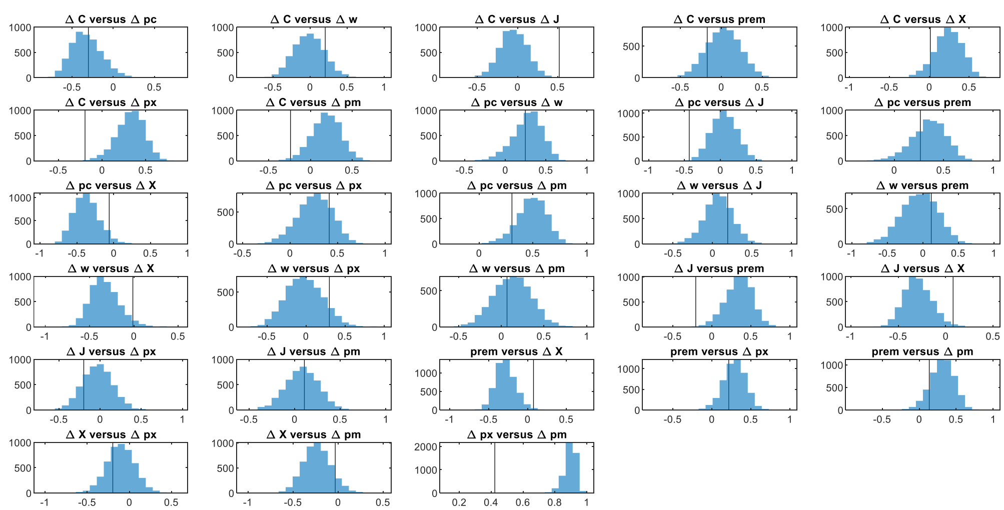
Note: x1 – habit shock, x2 – UIP shock, x3 – cost push shock, x4 – wage price shock, x5 – investment shock, x6 -- gov. demand shock, x7 -- export shock, x8 – export price shock, x9 – Import price shock, x10 – country risk premium shock
Statistically significant correlations with 5 percent risk are in red based on the p-value test.



Source: Authors' computations

Figure A.4: Data cross-correlation versus model implied correlations

Note: Blue bars depict distributions bootstrapped from actual data. The vertical black line is the model implied correlation.



Source: Authors' computations

[16] The fifth row and the fourth column.

The analysis included into this annex implies that the model calibration produces some cross correlations among variables that differ from the correlations observed in historic data. As mentioned above, the calibration has been done to focus on the model forecasting properties, verified via in-sample simulation results, so matching historic correlations was not a priority. Nevertheless, the results presented above could be used by the forecasting team in the future, when the model forecasting properties will be reassessed, and a potential recalibration of the model considered. Moreover, a future extension of the model, including a more detailed modeling of foreign exchange reserves, more detailed fiscal accounts, including a more representative fiscal rule, could mitigate some of the issues related to the identified cross correlation between some variables.

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