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Slovene Quarterly Macroeconomic Model: Overview and Properties[1]

Milan Damjanović[1]

Abstract

This paper presents an overview and properties of the new quarterly macroeconomic model for Slovenia (SiQM). By design and structure, the model follows a country version of the ECB-BASE, the workhorse institutional model of the ECB. The model is intended to be used for forecasting purposes within the Eurosystem Broad Macroeconomic Projection Exercises (BMPEs) and to be applied regularly to other policy questions relevant for Banka Slovenije. Given the intended use, Basic Model Elasticities (BMEs), a tool used for updating projections during the BMPE process, appear as a natural benchmark to evaluate the properties of the new model and to validate its future use. The SIQM exhibits properties that are underpinned by theoretical and empirical regularities and are in a quantitative sense comparable to a selected set of benchmarks.

Keywords: Semi-structural model, SIQM, ECB-BASE, Basic Model Elasticities, Broad Macroeconomic Projection Exercise

[1]Opinions and results are the author's own and do not necessarily reflect those of Banka Slovenije or the Eurosystem. Additionally, the model presented in this paper represents an auxiliary toolkit of the forecasting process in the Bank of Slovenia. As such, the results in the paper do not reflect the actual forecasts or official forecasting elasticities of the Bank of Slovenia or Eurosystem as they result from the wider range of models and additional expert judgment.

Acknowledgment

The model presented in this paper is a product of the ECB's Multi-Country Model (ECB-MC) project, under which the ECB's workhorse macroeconomic model for the euro area, the ECB-BASE, has been adjusted and estimated for selected euro area countries. The newly developed macroeconomic model for Slovenia is a result of long-lasting cooperation with the ECB-MC team and benefits heavily from the programming infrastructure, joint discussions and advisory role provided by the ECB colleagues. In this regard, I would like to express immense gratitude to the entire ECB-MC team, including Elena Angelini, Nikola Bokan, Kai Christoffel, Matteo Ciccarelli and Srečko Zimic.

I am additionally grateful to Banka Slovenije colleagues Miha Breznikar, Nika Sosič and Marija Drenkovska, who provided data support and information on price and monetary-financial statistics.

The paper and corresponding model has been reviewed by external referees Elena Angelini (lead economist at the European Central Bank) and Belma Čolaković (chief economist at the Central Bank of Bosnia and Herzegovina), whose comments and suggestions greatly improved the initial version of the work and provided clear guideposts for further development.

Povzetek[2]

Delovni zvezek predstavlja strukturo in dinamične lastnosti makro-ekonometričnega modela Banke Slovenije. Model spada v kategorijo sodobnih semi-strukturnih modelov in predstavlja različico glavnega makroekonomskega modela ECB, *ECB-BASE*, prilagojeno na slovensko gospodarstvo. Z vidika rednih delovnih procesov Banke Slovenije je glavni namen modela nuditi vsebinsko ter kvantitativno podporo pri pripravi makroekonomskih napovedi in pri naslavljanju vprašanj, vezanih na analizo učinkov ekonomskih politik. Glede na predvideno uporabo je v delovnem zvezku primernost dinamičnih lastnosti modela ovrednotena z vidika modelsko simuliranih baznih napovednih elastičnosti (t. i. Basic Model Elasticities), ki predstavljajo orodje za mehanično posodobitev napovedi v procesu projekcij Evrosistema. Simulirane elastičnosti izkazujejo teoretično in empirično smiselne odzive modelskih spremenljivk na izbrane eksogene šoke ter so v kvantitativnem smislu primerljive z elastičnostmi modelov primerljivih centralnih bank v evroobmočju.

[2]Rezultati, predstavljeni v delovnem zvezku odražajo izključno simulacije izbranega modela in tako ne predstavljajo uradnih napovedi ali napovednih elastičnosti Banke Slovenije ali Evrosistema, saj so te oblikovane na podlagi širšega nabora modelov in dodatne ekspertne presoje.

1. Introduction

This paper presents an overview and properties of the new semi-structural quarterly macroeconomic model of the Banka Slovenije, (SiQM). The model represents a country version of the ECB-BASE, Angelini et al. (2019), the workhorse projection model of the ECB, fitted for the Slovene economy. By design and structure, the ECB-BASE and consequently SiQM follow a class of increasingly popular semi-structural institutional models used by other central banks, such as the FRB-US, Brayton and Tinsley (1996), or Bank of Canada's LENS, Gervais and Gosselin (2014). There are several features that make this kind of model particularly appealing in the institutional policy framework: (i) they seek balance between the economic structure and empirical fit, which renders them useful both for shaping the narrative behind policy questions as well as for producing reasonable stand-alone forecasts; (ii) the scope of behavioral and reporting variables commonly matches the representation of the economy consistent with the official statistics, for example the National Accounts System; and (iii) the modular structure allows the inclusion of additional transmission channels in a timely and flexible manner.

The theoretical consistency of this particular class of models is sought via agents' equilibrium planning, commonly in the setting of the New Neoclassical Synthesis as summarized in Goldstein and Khan (1985b). Due to frictions, decision variables are assumed to adjust to their equilibrium only gradually, whereby costs of adjustment are associated with both past and expected changes. Additionally, given the prominent role of the monetary policy and its transmission in the central bank's policy process, this class of models nests a detail account of financial block, which incorporates both risk-free yield curve and lending rates relevant for agents' decision making.

A recent survey of macroeconomic modeling practices, performed within the ECB's Monetary Policy Review in 2021, see Darracq Pariès et al. (2021), showed that semi-structural models commonly take a central role in modeling portfolios of most Eurosystem national central banks, for example Delfi by De Nederlandsche Bank, Dnb (2011), BiQM by Banca di Italia, Bulligan et al. (2017), Mascotte by Bank de France, Brunhes-Lesage (2005), and Deutsche Bundesbank's BbkM, Haertel et al. (2022). The scope and structure of these models is commonly adjusted to align with the reporting framework of the Eurosystem Broad Macroeconomic Projection Exercise (BMPE), which represents the key analytical input into the ECB's policy decision-making. Moreover, modularity of semi-structural models enables national central banks and the ECB to perform forecasts conditional on the harmonized set of euro-area or country-specific assumptions, which relate to external environment, competitiveness, fiscal projections and financial markets. Likewise, the ability to flexibly and quickly adjust model blocks and equations has proven to be a strength rather than a weakness in analyzing various crises scenarios that challenged baseline projections in the past. An example of this kind of agility was offered by the ECB-BASIR model, Angelini et al. (2023), which represents an augmentation of the ECB-BASE model with the epidemiological SIR model that produced projections based on endogenous interaction between epidemiological and macroeconomic developments during the Covid-19 pandemic.

The primary aim of the SiQM model is to provide operational support within the BMPE process and offer analytical input into Banka Slovenije's policy decision making. Given the intended use, the aim of this paper is to scrutinize properties of the SiQM model through the lens of Basic Model Elasticities, which emulate expected responses to revisions in conditioning assumptions used in the BMPE process. subject to the exhibited properties of the model, the paper provides an insight into the main standardized model-based outputs produced for projection purposes and its applied use in addressing specific macroeconomic policy questions.

Beyond this introduction, Section 2 provides a topographical overview of the model, Section 3 discusses key modelling principles, Section 4 provides exemplary illustration of a model block construction, Section 5 analyzes properties of the model, Section 6 demonstrates the model use, while the last section concludes and offers a road-map for future development.

2. Model overview

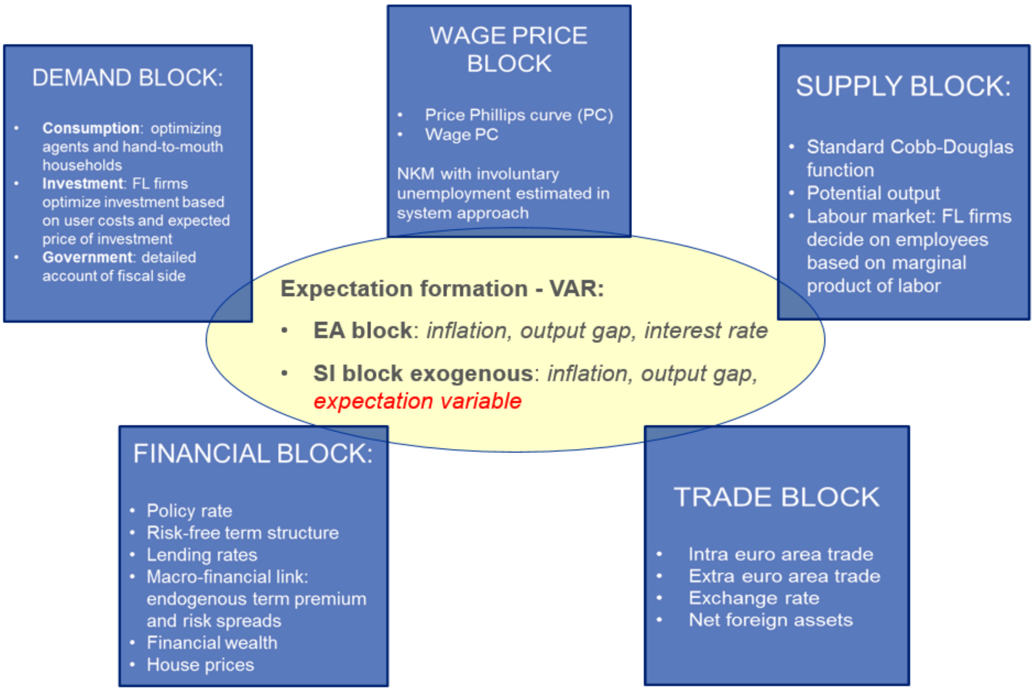
This section provides a topographic view of the structure of the model and it underlying building blocks. In its structure and design, the model pursues several objectives, including representation consistent with the national accounts perspective of the economy, alignment with reporting requirements associated with the ESCB projection process, and embedding transmission mechanisms of various types of macroeconomic shocks relevant for the policy process. In relation to the latter, a special focus is given to the monetary policy transmission via enhanced real-financial linkages nested in the model.

A general schematic representation of the model is provided in Figure 2. The expenditure side of the economy is captured by the demand block, with specific sub-blocks related to household consumption, business and residential investments, fiscal spending, and international trade. The international trade block essentially hinges on foreign demand and competitiveness measures determined within the external block. The supply-side of the economy adopts the Cobb-Douglass representation via the labor market block and a block determining long-term trends associated with the potential output.

The nominal side of the economy is grounded in the wage-price nexus encapsulated by respective price and wage Phillips curves. The core price category attached to the price Phillips curve model is the GDP deflator, which is combined with import prices in order to completes a setting for the HICP block and price deflators of demand aggregates. Real-financial linkages are provided through the financial block, which incorporates the policy rule, the risk-free euro area yield curve, the sovereign yield curve, and financing conditions relevant for spending of households and non-financial corporations. Finally, the gross disposable income side of the economy and net financial worth are completed by property income, wealth and net-foreign asset blocks.

Several blocks in the model are designed around forward-looking agents, whose expectations are formed within the limited information set encapsulated in a representative vector-autoregressive model, the Base VAR. The Base VAR model consists of the euro area part, incorporating euro area real GDP, inflation and short-term interest rate, and the Slovene-specific part, incorporating Slovenian real GDP, inflation and an additional specific variable for which expectations are being formed. The Base VAR model takes a block-exogenous structure, where it is assumed that the euro area variables do not respond to developments in Slovene-specific variables.

Figure 1: Representation of model blocks



The model is estimated in an equation-by-equation manner. The modular structure allows representation of the model to vary depending on the policy needs. At Banka Slovenije, the model is primarily used to support operational work associated with the projection process. Since forecasts within the ESCB Broad Macroeconomic Projection (BMPE) process are conditional on the common set of assumptions for foreign demand, commodity prices, exchange rates, interest rates and fiscal projections provided outside the model. In line with that, the typical representation of the model takes on exogenous foreign, fiscal and monetary-policy rule blocks. This entails that the typical representation of the model used in the projections setting consists of about 90 stochastic equations, 154 identities and 58 exogenous variables.

3. Modelling principles and types of behavior

While a full set of model equations is resorted to Appendix C, the aim of this section is to provide a general characterization of modelling principles adopted in the model. The majority of non-financial variables evolve subject to their theoretical or empirically-based long-term equilibrium targets. However, due to assumed frictions in the economy, the adjustments towards the equilibrium targets occur only gradually. The dynamic behavior of financial variables is grounded in the expectation theory, whereby interest rates of particular maturity are a combination of the short-term risk free rate, its average expected path and a term-premium. Both financial and selected non-financial variables include expectations formation, which is set forth in a limited information setting encapsulated within a VAR model whose dynamic is anchored by targets for inflation and output gaps.

3.1. Equilibrium planning

The macroeconomic structure is in the model provided by theoretical or empirical long-term targets for particular variables.[3] Long-term targets for private consumption and investment stem from the micro-founded optimal behaviors of households and firms, following solutions to the optimization problems set out in Brayton and Tinsley (1996), Brayton et al. (2014), and Laubach and Reifschneider (2003). **Households** choose their optimal consumption subject to their assessment of the lifetime income. The optimal consumption is based on respective propensities to consume out of permanent labor,

[3] The expressions "long-term target", "equilibrium value" and "desired level" are used interchangeably throughout the paper.

transfer, property and wealth incomes. The future income flows are in derivation of permanent incomes discounted with a relatively high rate (25% annual rate) to account for risk-aversion in consumer behavior. Both properties - the different propensities to consume out of respective permanent incomes and the risk preferences - reflect different age cohorts assumed in the original optimization problem and derivation of the total aggregate consumption (see the technical appendix in Angelini et al. (2019)). **Firms** choose optimal investment based on the solution to the standard profit maximization problem, with foundation laid out in Jorgenson (1967). The solution to profit maximization yields the optimal investment level, which is inversely related to user costs of capital. The user cost of capital is in turn expressed as a function of real financing conditions for firms, the depreciation rate of capital and the relative price of the investment good. Given the Cobb–Douglas functional form of the production, the profit maximization is analogously related to total costs minimization, which yields the optimal employment as a function of marginal costs. In this spirit, the actual target employment equation is characterized in terms of the wage gap, trend labor force participation rate and population growth.

Following the theoretical and empirical surveys of Goldstein and Khan (1985a) and Sawyer and Sprinkle (1997), equilibrium **trade flows** are modelled as functions of activity and relative price competitiveness. In particular, long-term real exports are assumed to vary in proportion to foreign demand and the difference between export prices of domestic exporters and competitors' export prices. Conversely, real imports in the long run are expected to align with the import content of GDP and the difference between domestic and import prices. The respective trade deflators in the long run evolve as a weighted sum of domestic prices and competitors' prices. Following Dieppe and Warmedinger (2007), the trade block follows an intra-/extra-euro area breakdown.

Price setting follows the theoretical framework provided in Charsonville et al. (2017), according to which firms under monopolistic competition in optimum set prices as a combination of domestic producing costs and import prices. Specifically, the long-term targets for domestic demand deflators and HICP components are set as a weighted sum of GDP and import deflators, where the GDP deflator is modelled via a New-Keynesian Phillips curve.

The majority of other equilibrium categories are derived on an empirical basis. For example, fiscal spending and revenue targets evolve around their respective average shares of GDP observed in the period between 2014 and 2018, resembling the period of relative stability in terms of spending and absent any considerable fiscal consolidations. Similarly, the real dividends income in the long run is assumed to undertake a constant share of households' gross operating surplus.

3.2. Short-term adjustment towards equilibrium targets

The model assumes a variety of frictions present in the economy that prevent immediate adjustment towards the equilibrium values. The short-term adjustments are therefore gradual and can take two forms: i) traditional error-correction equations, without explicit expectation term, in line with Engle and Granger (1987), or ii) generalized polynomial adjustment costs (hereafter PAC), in line with Tinsley (1993).

Compared to the traditional error-correction equations, the key generalization embedded in the PAC approach is allowing for explicit consideration of expectations in the short-run dynamics. Specifically, under the PAC approach, the short-term dynamics depends on the proportion of distance closed relative to the desired target value, degree of persistence associated with the growth rates of previous periods, and adjustment related to the expected change of the target. For convenience, the general PAC framework provided in Tinsley (1993) is summarized in a compressed form by the equations below.

The representation is initiated by a function characterizing disutility associated with deviations from the target path and costs that agents face when adjusting their activity towards the desired equilibrium level:

$$C_t = \sum_{i=0}^{\infty} \beta^i \left[(x_{t+i} - x^*_{t+i})^2 + \sum_{k=1}^{m} b_k \left((1-L)^K x_{t+i} \right)^2 \right] \tag{1}$$

where x^* represents a desired level for decision variable x in time t, L is the lag operator, m denotes the lag-polynomial order, and b is a cost elasticity associated with past changes in x. Minimization of the cost function yields the following first order condition (a full algebraic derivation of the condition is provided in the appendix in Tinsley (1993)):

$$(x_t - x^*_t) + \sum_{k=1}^{m} b_K \left[(1-L)(1-\beta F) \right]^k x_t = 0 \tag{2}$$

where $F = L^{-1}$ denotes the lead operator. This expression can be re-written in a compact form in terms of lag and lead polynomials:

$$A(\beta F)A(L)x_t = cx^\star_t \tag{3}$$

where c is a constant and A is a polynomial of order m in lag and lead operators so that $A(L) = 1 + \alpha_1 L + \cdots + \alpha_m L^m$ and $A(\beta F) = 1 + \alpha_1 \beta F + \cdots + \alpha_1 \beta^m F^m$. After rearrangement of terms and algebraic steps provided in Tinsley (1993), generic PAC expression describing short-run adjustment dynamics can be given by:

$$\Delta x_t = a_0 \left(x^*_{t-1} - x_{t-1} \right) + \sum_{k=1}^{m-1} a_k \Delta x_{t-k} + \mathbb{E}_{t-1} \sum_{j=0}^{\infty} d_j \Delta x^*_{t+j} \tag{4}$$

where parameters a are transformations of parameters α in polynomial A and consequently of parameters b and β in cost functions.[4] The transformations imply reciprocity according to which lead parameters are functions of lagged parameters, which allows inclusion of an expectation term and estimation of its effect on the contemporaneous dynamic. In this setting, parameter a_0 relates to the degree of the previous period's distance to the desired level of the decision variable closed in time t, parameter a_k relates to the persistence of past changes in the decision variable, and parameter d_j characterizes adjustment in the decision variable due to expected changes in equilibrium level.

3.3. Financial intermediation

The financial block is built on a premise of the standard expectation hypothesis and no arbitrage condition (Longstaff (2000)), under which a yield of a particular maturity can be perceived as an average of the current and mean expected short rate over the maturity horizon. With this in mind, the financial block is constructed sequentially, whereby in the first step the short-rate is defined via a monetary-policy rule, in the second step a risk-free yield curve is characterized, while in the third step country and credit-risks spreads are added on top of the risk-free curve in order to derive country-specific financing conditions associated with both government and private sectors.

The short-term risk-free rate is determined by the following Taylor rule specification:

$$r^0_t = \rho r^0_{t-1} + (1-\rho)(r^\star + \bar{\pi}_t) + (1-\rho)(\Phi_{\hat{\pi}} \hat{\pi}_t) + \Phi_{\Delta\pi} \Delta\pi_t + \Phi_{\hat{y}} \Delta\hat{y}_t + \epsilon_t \tag{5}$$

where r^0 represents the short-term risk-free rate, $r^\star$ represents a real natural rate, π is inflation, $\hat{\pi}$ is inflation gap, $\bar{\pi}$ denotes long-term inflation expectations, and $\hat{y}$ is output gap.

Following the expectation hypothesis, a risk-free rate of maturity m is expressed as

$$r^m_t = \frac{1}{m} \sum_{z=0}^{m-1} r^0_{t+z} + TP^m_t \tag{6}$$

[4] $a_0 = d_0 = A(1) = 1 + \sum_{j=1}^{m} \alpha_j$ and $a_k = -\sum_{j=k+1}^{m} \alpha_j$ for $k = 1, 2, \ldots, m-1$; $d_j = 1 - A(1)A(\beta) \sum_{i=0}^{j-1} \iota' G^i \iota$ for $j = 1, 2, \ldots \infty$, where matrix G is a function of the discount factor β and ι is a selection vector.

where $\frac{1}{m}\sum_{z=0}^{m-1} r_{t+z}^0$ is an average return from a risk-free asset with underlying short-term yield, r^0, compounded over maturity horizon m, while TP^m represents a term-premium associated with investment in the EA risk-free asset with maturity m. In this vein, the above equation characterizes the euro area risk-free term structure in line with the conventional expectation hypothesis. A country-specific sovereign yield curve is then governed by the respective country-premium added on top of the risk-free term-structure, so that a specific government bond yield, r_i, is expressed as:

$$r_{i,t}^m = r_t^m + CP_t^m \tag{7}$$

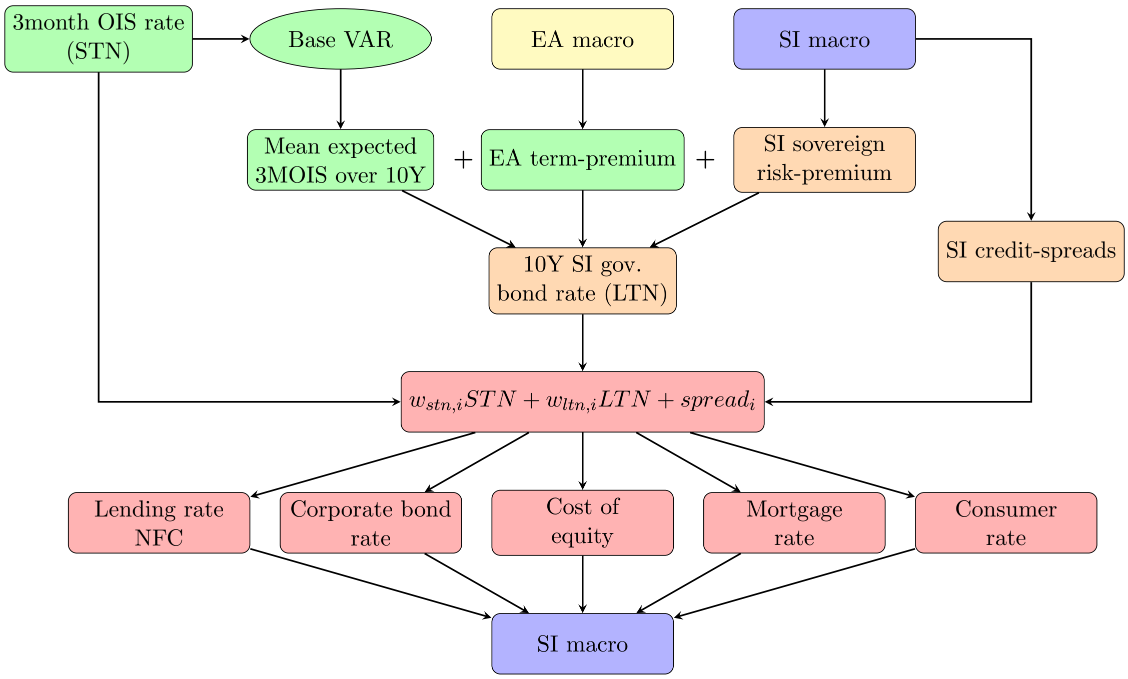
where CP^m is the country-premium related to the Slovene government yield with maturity m. The country-premium reflects a market assessment of government's ability to service its debt and other liabilities. In the model, this assessment is provided on the basis of macroeconomic and fiscal outlooks (see equation C.84). The government bond yield can be perceived as a lower limit for lending rates in a particular country, as it is assumed that no other entity in the country can obtain financing at more favorable conditions than the government. In this respect, lending rates are obtained by adding a specific credit-risk related to a particular lending segment. Specifically, lending rates are defined as a weighted average of the short-term risk-free rate, the long-term government bond rate, and the credit-spread associated with specific lending segment j:

$$LR_{j,t} = \omega_S \times r_t^0 + \omega_L \times r_{i,t}^{10Y} + \zeta_{j,t} \tag{8}$$

where ω_S represents a share of short-term bank lending in a specific segment of the economy, ω_L represents a corresponding share of long-term lending, r_i^{10Y} is a 10-year government bond yield, and ζ_j is a credit-spread associated with specific financing segments, including consumer loans, mortgages, lending to non-financial corporations, corporate bonds and equities.

The country-premium related to government bond rates and credit risks associated with particular lending segments evolve conditionally on expected macroeconomic and fiscal outlooks, enabling an endogenous interaction between the real-side of the economy and financial system. Figure 3.3 provides a schematic representation of the financial intermediation embedded in the model. A more detailed empirical account of the financial block and its estimation are provided in Appendix C.10.

Figure 2: Schematic overview of the financial block



3.4. Expectation formation

As it was outlined in the previous two subsections, expectations are inherently included in modelling of key non-financial and financial variables. The expectations are formed via a specially designed vector-autoregressive model, hereafter denoted as the Base VAR. The Base VAR relates to a system of euro area and Slovene-specific macroeconomic variables, inflation and output gap, and the euro area short-term interest rate. The dynamic of the system is in the long-term anchored by a set of attractors related to target values of euro area and Slovenian inflation and output gap variables and the euro area interest rate. Following this, the Base VAR representation can be written in the following form:

$$\Delta y_t = \beta^0 \left(y_{t-1} - y^*_{t-1} \right) + \sum_{k=1}^{K} \beta^k \Delta y_{t-k} \tag{9}$$

where $y_t = \left[y_t^{EA} \;\; y_t^{SI} \right]'$ is a block exogenous vector containing 3×1 block of euro area inflation, output gap and interest rate, $y_t^{EA} = \left[\pi^{EA} \;\; \hat{y}_t^{EA} \;\; r_{0,t}^{EA} \right]'$, and 2×1 block containing inflation and output gap for Slovenia, $y_t^{SI} = \left[\pi_t^{SI} \;\; \hat{y}_t^{SI} \right]'$. β^0 is a 5×5 matrix indicating the degree of distance closed in a particular period relative to attractors contained in vector y^*, while β^k is a 5×5 lagged coefficient matrix. The lagged coefficient matrix is block-exogenous, reflecting a small-country perspective, where country-specific macro developments in Slovenia are assumed not to affect the euro area economy or policy-rule setting. The dynamic of the Base VAR is anchored by long-term inflation expectations and expected future short-term interest rate, while the output gaps for the euro area and Slovenia are expected to close in the long run. For estimation purposes, long-term inflation expectations are observed in terms of 10-year-ahead Consensus forecasts, while interest rate expectations are derived from the interest rate swap data. In simulations, long-term inflation expectations evolve as a combination of current inflation and the target inflation at 2% (see Appendix C.7), interest rate expectations follow a random walk process, while long-term output gaps are set at zero.

When modelling expectations for a particular variable not explicitly contained in the vector y, the following augmented Base VAR representation is employed:

$$\Delta x_t = \zeta \tilde{\beta}^0 \left(y_{t-1} - y^*_{t-1} \right) + \sum_{k=1}^{K} \zeta \tilde{\beta}^k \Delta \tilde{y}_{t-k} \tag{10}$$

where x is the decision variable for which expectations are formed, $\tilde{y} = [y \;\; x]'$ is a 6×1 matrix of the Base VAR variables and the decision variable x, $\tilde{\beta}^0$ is 6×6 augmented matrix of coefficients indicating the distance closed between variables in y and their attractors, $\tilde{\beta}^k$ is a 6×6 matrix of lagged coefficients, and $\zeta = [0 \;\; 0 \;\; 0 \;\; 0 \;\; 0 \;\; 1]$ is a selection vector. The selection vector is applied in estimation and simulation settings, rendering the Base VAR unaffected by the decision variable outside the initial vector of variables y.

3.5. Country-specific features

Relative to the seminal model for the euro area, the ECB-BASE, the above subsections revealed several modifications to the general structure of the model, its estimation and simulation strategies that account for country-specific features. In terms of the structure and equations, the country-specificity is predominantly limited to the financial block and expectation formation. As highlighted in subsection 3.3, the derivation of the financial block importantly hinges on a country-specific premium that is added on top of the risk-free euro area rates to arrive at government bond yields. Given that government bond yields reflect financing conditions for the government and pricing of its debt issuance, the country-premium evolves as a function of both macroeconomic as well as fiscal developments in the country. In contrast, the macro-financial linkages in the ECB-BASE do not explicitly include fiscal developments, as the euro area yield curve is considered as a benchmark from which the country-premium is derived.

Additional modification of the model structure is reflected in the expectation formation setting. Compared to the ECB-BASE, the so-called Base VAR in the country case is augmented with its key macroeconomic variables. As noted in subsection 3.4, an important feature of the country version of the Base VAR is block exogeneity, which in line with the small country assumptions assumes that Slovenian macroeconomic developments do not affect the euro area block. The exogeneity of the euro area is preserved also in the general model setting, where the policy rule, euro area term-premium and euro area macroeconomic variables remain unresponsive to developments in Slovenian macroeconomic and financial variables. In the simulation settings, the euro area variables therefore either evolve on the basis of their own autonomous dynamics or are provided as an external conditioning set.

The estimation strategy in particular blocks follows closely the seminal ECB-BASE. A slight exception in this regard is the foreign trade block, where explicit intra-EA and extra-EA trade split data is available for individual countries but not for the euro area as a whole. This implies that in the SiQM extra and total trade quantities are explicitly modelled, whereas intra-EA trade quantities are derived as an exact identity rather than an approximation as is the case for the euro area.

4. Illustration of modelling principles: example of the investment block

This section applies the main modelling principles of the SiQM presented in the previous section to the specific example of the investment block. The modelling of the private investment demand is initiated by solving the firm's optimization problem, which provides the economic structure to the block. The solution to the firm's problem represents a desired level of investment to which agents adjust only gradually, whereby frictions are modelled via Polynomial Adjustment Costs (PACs). Additionally, a proportion of agents are assumed not to adhere to the optimization and only respond to changes in current output growth. Estimation of equations is performed individually and in isolation from other blocks. While this approach carries advantages in terms of flexibility and empirical fit, it ignores the cross-equation restrictions, which reduces the structure of the model and means that the estimated parameters can only be interpreted in a reduced form.

4.1. Long-run target investment

The investment behavior is derived from a standard optimization problem, where firms maximize their profits subject to the capital accumulation equation. With respect to the latter, we adopt a time-to-build assumption according to which current investments enter into the capital stock in the next period only. The profit optimization problem can be written as:

$$\max_{\{K_t, I_t\}} \sum_{j=0}^{\infty} \left(\frac{1}{1 + R_{t+j}} \right)^j \{Y_{t+j} - W_{t+j} N_{t+j} - RP_{t+j} I_{t+j}\}$$

subject to

$$K_{t+1} = (1 - \delta) K_t + I_t \tag{11}$$

and

$$Y_t = F(N_t, K_t) = N_t^{\alpha} K_t^{1-\alpha} \tag{12}$$

where Y_t is the output of a firm given by the Cobb-Douglas production function with constant returns to scale and two production inputs, capital K_t and labor N_t, whose costs are given by the relative price of investment good, RP_t, and wages, W_t[5]. The depreciation rate of capital is given by δ.

The solution to the first-order condition of the optimization problem yields an expression for the user costs of capital, UC, which can be expressed in terms of investment costs, determined by the depreciation rate and financing cost for business investments, R_{t+1}^{ib}, and net capital gains given by the relative price growth:

$$(1 - \alpha) \frac{Y_{t+1}}{K_{t+1}} = RP_t \left\{ R_{t+1}^{ib} + \delta - (1 - \delta) \left(\frac{RP_{t+1} - RP_t}{RP_t} \right) \right\} \equiv UC_{t+1} \tag{13}$$

From the optimal condition in 13, we can derive an expression for the target capital stock as:

$$K_t^* = \frac{S_t^K Y_t}{UC_t} \tag{14}$$

where S_t^K denotes the capital to output share. While constant in the optimization problem, this ratio is allowed to be time-varying in the empirical implementation, in line with the trend that it exhibits in the data.[6]

Using (14) and the law of motion for capital, we can then derive the target for

[5]To ease the description and without loss of generality, the technology progress term has been dropped from the production function.

[6]In particular, the capital to output share, s_t, is an HP filtered series of the ratio: $(IB_t/Y_t(\frac{\bar{Y}_t - \bar{Y}_{t-1}}{\bar{Y}_{t-1}} + \delta))UC_t$, where $\bar{Y}_t$ is a measure of potential output

business investment:

$$IB_t^* = \left(G_{t+1}^{K^*} + \delta\right) K_t^* \tag{15}$$

where IB^* denotes the target for business investment and $G_{t+1}^{K^\star}$ is the growth rate of the (target) capital stock, which is approximated by the real GDP growth.

Combining equations (14) and (15), we can rewrite the target for business investment in terms of output and the user costs of capital:

$$IB_t^* = \left(G_{t+1}^{K^*} + \delta\right) \frac{S_t^K Y_t}{UC_t} \tag{16}$$

4.2. Short-run investment dynamics

Frictions associated with the target investment are modelled using the PAC approach. In the short run, not all agents adjust their investment behavior according to a polynomial cost, as some agents base their decisions solely on the basis of the current state of the economy. The behavior of the latter enters the short-run specification in an additive way and can be interpreted as the accelerator effect of output growth on investment growth. It can be shown that the short-run investment dynamics (in logs) is given by the following equation:

$$\Delta ib_t = \left(1 - \theta^{ib}\right) \left(a_0^{ib} \left(ib_{t-1}^* - ib_{t-1}\right) + \sum_{k=1}^{m-1} a_k^{ib} \Delta ib_{t-k} + \mathbb{E}_{t-1} \sum_{j=0}^{\infty} d_j^{ib} \Delta ib_{t+j}^* \right) + \theta^{ib} \Delta y_{t-1} + \epsilon_t^{ib} \tag{17}$$

where ib_t is the log of business investment, a_0^{ib} is the mean reversion parameter associated with previous period deviations from the target investment, a_k^{ib} is an autoregressive coefficient associated with k quarters lagged business investment, and d_j reflects the effect of today's adjustment of investment decisions due to expected changes in the investment target given by $\mathbb{E}_{t-1}\Delta ib_{t+j}$. Finally θ^{ib} represents the share of output accelerated investment growth, which refers to investment demand associated with non-optimizing agents.

4.3. Estimation and empirical specification

The estimation of the system described above hinges on appropriate construction of unobserved series for user costs of capital and subsequently target investment. In line with the solution to the optimization problem, the series related to user costs of capital is in the estimation sample derived from respective input series for relative investment prices, financing costs for business investment and the depreciation rate. Relative investment prices are expressed as a ratio between investment deflator and GDP deflator, both observed within the national accounts data. The financing cost, R^{ib}_{t+1}, is a constructed series and is defined as a composite average of the real lending rate for non-financial corporations (NFC), real corporate bond yields and real cost of equity, with weights for each particular rate resembling the structure of liabilities of the NFC sector in the sector accounts statistics. Finally, the depreciation rate, δ, is in the sample implicitly derived from the constructed series of stock of capital and observed time series of investment and is for the calculation of the user costs averaged over the available time span.[7] For estimation purposes, the share of non-optimizing agents has been set at 0.5, following the ECB-BASE specification.[8]

In simulation, the long-term target for investments evolves in line with model dynamics and behavioral equations for deflators and lending rates, while the depreciation rate is kept constant and consistent with the average value in the sample. The estimated parameters of the equation associated with short-run investment dynamics point towards rather sluggish adjustment of business investment to its optimal target. Namely, roughly two-thirds of past dynamics is carried over into the current period, while on average approximately 8% of past deviation from the target investment is corrected within a quarter.

5. Model properties under the lens of projection elasticities

Since the model is intended to be regularly used within the policy process, which among other things entails Banka Slovenije's participation in the Eurosystem's broad macroeconomic projection exercises (BMPE), the so-called Basic Model Elasticities (BMEs) can be perceived as a natural benchmark for evaluating the model's properties and suitability. The BMEs are a quantitative tool used by the ECB and ESCB National Central Banks to provide timely updates of projections (see ECB (2016)) and reflect impacts on reporting variables implied by revisions in a harmonized set of external, financial and fiscal assumptions.

The evaluation of BMEs is conducted in a specific setting that emulates the particular environment of the BMPE process and may differ from a standard approach commonly

[7] The depreciation rate is implied as $mean(1 - \frac{K_t - IB_{t-1}}{K_{t-1}})$, where K represents derived series for stock of capital and IB relates to observed series of business investment.

[8] Alternative calibrations of the share of cash-flow constrained agents have been tested but led to non-significant changes in the dynamic behavior.

adopted for producing impulse response functions. In particular, given that the technical assumptions are provided outside of modelling apparatus of national central banks within the ESCB, all model simulations are performed with exogenous fiscal, foreign and risk-free rate variables. This implicitly entails an additive nature of technical assumptions, whereby the total impact of assumptions can be obtained by summing individual BMEs. Moreover, since BMEs are used for updating projections by taking into account revisions in technical assumptions over the entire projection horizon, responses refer to shocks that reflect persistent deviations from their respective baselines. Finally, to take into account potential non-linearities in forecasts associated with specific initial conditions, simulations in the BME settings are conducted from the latest available data point rather then the model's steady state. Key differences between BMEs, used in the Eurosystem projections setting, and the conventional impulse responses are summarized in the table below.

Table 1: Comparison between Basic Model Elasticities and structural impulse response functions

Basic Model Elasticities	*Structural impulse response function*
Persistent shock	One-off shock
Shocks observed as deviations from the baseline conditional path	Identified structural shock
Simulations out of a sample point	Simulations out of the steady-state
Exogenous policy response	Endogenous policy response
Additive perspective	System/General-equilibrium perspective

Note: *Properties of Basic Model Elasticities are drawn from ECB (2016). Structural impulse response functions are characterized based on Ramey (2016) and Ajevskis (2019).*

The following subsections present SiQM responses to selected BME shocks over the 12 quarters horizon, reflecting a forecast horizon considered in the Eurosystem projections. Besides qualitative explanation of transmission channels, the responses produced by the SiQM are in quantitative terms bench-marked against publicly available BMEs of other selected national central banks in the Eurosystem for which the BMEs are publicly available. In particular, the quantitative comparisons are made against the BMEs derived from workhorse models of the Deutsche Bundesbank (Haertel et al. (2022)), herewith *BbkM*, Bank de France (Aldama and Ouvrard (2020)), herewith (*FRB-BdF*), and Banco d'Italia (Bulligan et al. (2017)), herewith *BiQM*, and are summarized in Table

A.2, Appendix A.

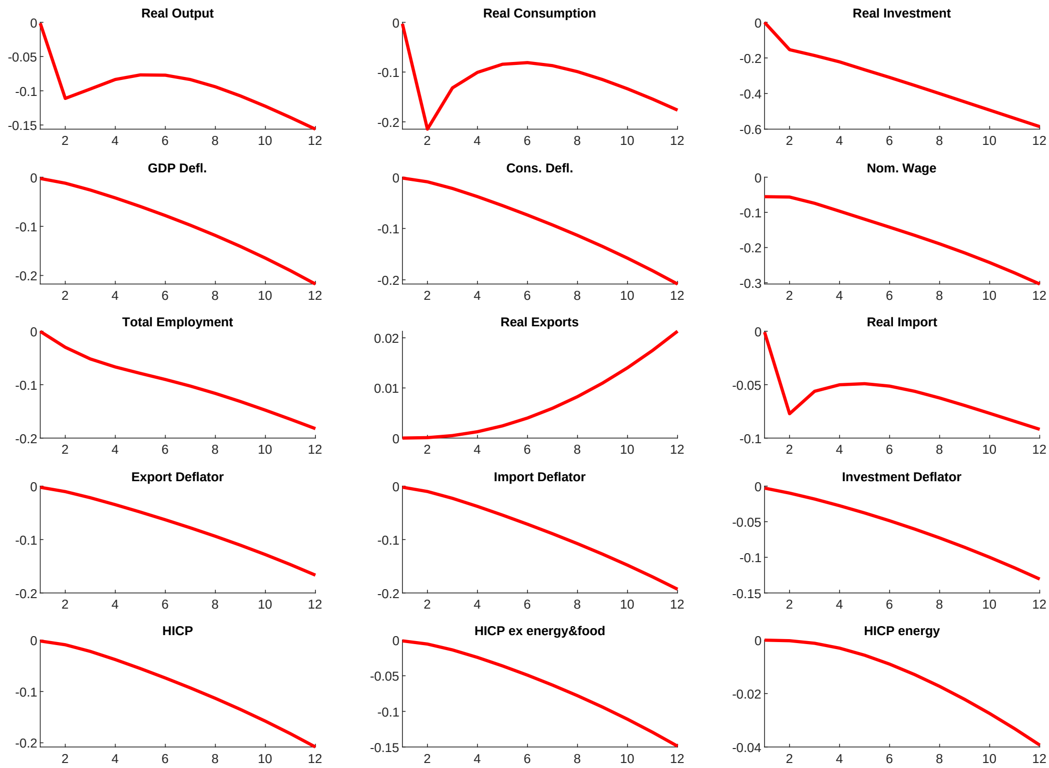
5.1. Short-term Nominal Rate

Figure 5.1 shows impulse responses to a sustained 100 b.p. increase in the EA short-term nominal rate (STN). The transmission of the STN shock operates via two channels, *financial inter-mediation* and *expectations*. In the case of the financial channel, the STN directly affects individual block-specific lending rates. The size of transmission for particular lending rates corresponds to empirical weights associated with short-term liabilities of households and firms. Increased lending rates negatively impact the aggregate demand through the interest-sensitive part of household consumption and elevated user costs of capital and subsequently lower investment target for firms. The drop in aggregate demand leads to a negative output gap, which is passed to lower prices via the Phillips curve relation.

Nevertheless, the nominal side of the economy is predominantly affected through the expectations channel. Namely, the increase in STN leads to an expected decrease in one-period-ahead inflation, which is directly reflected in the forward-looking parts of price and wage Phillips curves. On the real side, the expectation channel operates in a more ambiguous way, which can be attributed to varying responses of different components of the expected permanent households income. While expected permanent labor income responds negatively to the increase in STN shock, expected transfer and property incomes display a positive correlation to STN in the medium term. The increase in expected transfer income could be interpreted in light of a counter-cyclical fiscal policy response to a standard demand shock, while the reaction of expected property income depends on the net financial asset position of the household sector. Nevertheless, the overall expected target consumption response remains negative throughout, and target investment decreases in line with the conventional wisdom, producing an overall net negative impact of the expectation channel on the real side.

In quantitative terms, the responses are comparable to the BMEs of the selected benchmark institutions (see Appendix A). The alignment is closest with the FRB-BdF model, which falls into the same class of semi-structural models inspired by the FRB-US model. In both cases, SiQM and FRB-BdF, the cumulative loss in real GDP from a sustained increase in short-term nominal rate amounts to roughly 0.15%. On the nominal side, SiQM suggests a slightly stronger response, with cumulative 0.2% drop in HICP level instead of 0.1% in the case of FRB-BdF. The effects of a sustained 100 b.p. increase in the short-term interest rate are lowest for the BbkM, with the accumulated drop in real GDP amounting to roughly 0.1% and a broadly muted response of the nominal side. Conversely, BMEs derived from the BiQM model reflect the largest responses, with responses compared to the SiQM roughly three times higher on the real side and roughly two times stronger for prices.

Figure 3: Short-term interest rate shock (100 b.p.)

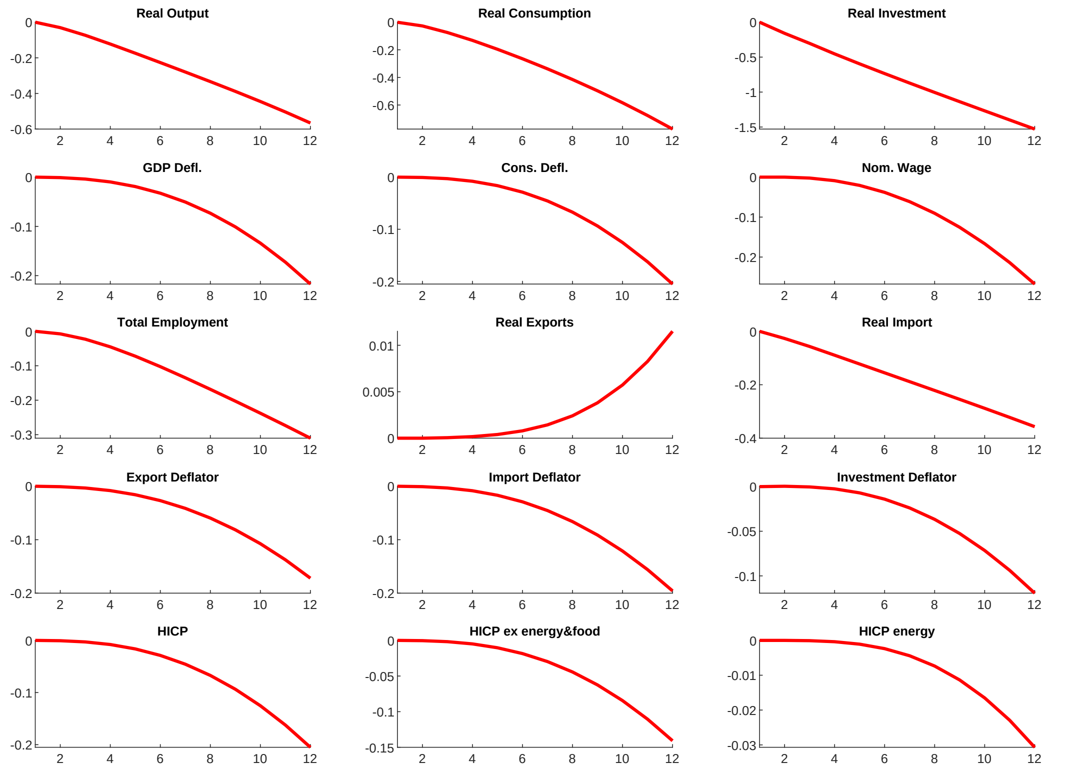


Note: Horizontal axis represents quarters after the initial shock. All variables are expressed as percentage deviations from the baseline levels.

5.2. Long-term Nominal Rate

Figure 5.2 shows impulse responses to a sustained 100 b.p. increase in the EA long-term nominal rate (LTN). In contrast to the STN shock, the transmission of LTN shock remains limited to the financial channel only. Nevertheless, since in the composition of lending rates for Slovenia empirical weights associated with duration of liabilities skew significantly towards the long-term risk-free rate, the overall effect on the real side is stronger than in the case of the STN shock. Among the aggregate demand components, real investments display the strongest interest rate sensitivity. In the absence of an expectation channel and with stronger reaction of the economic slack, the response of the nominal side remains broadly comparable to the STN shock in quantitative terms.

Figure 4: Long-term interest rate shock (100 b.p.)



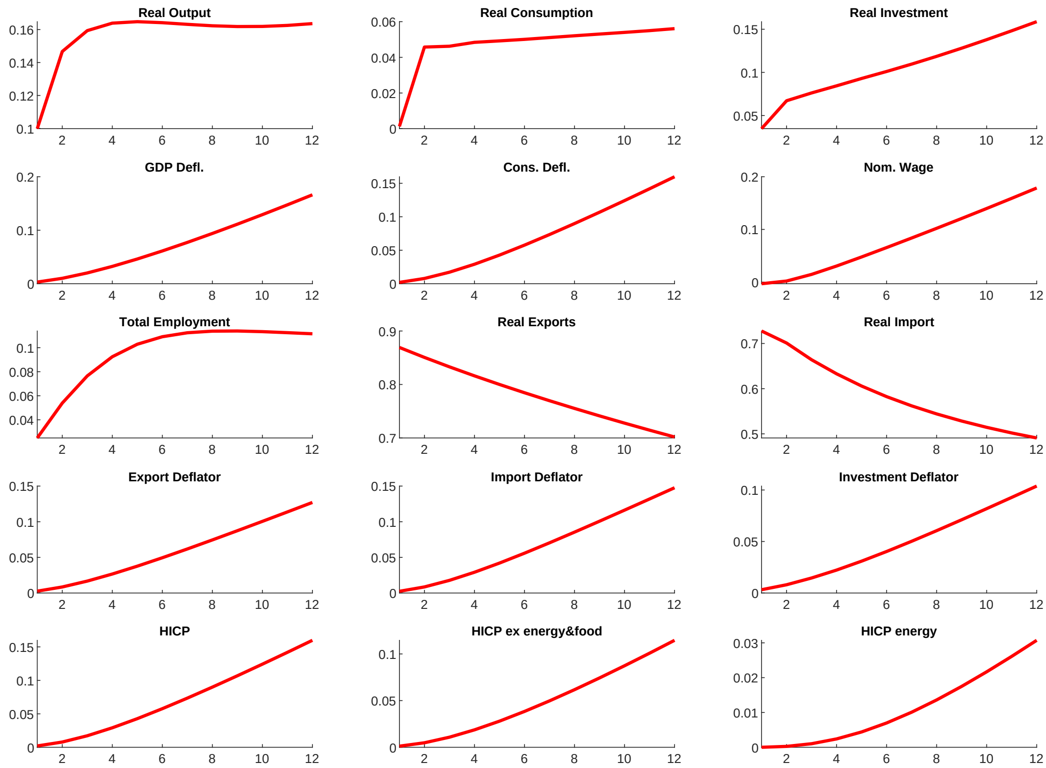
Note: Horizontal axis represents quarters after the initial shock. All variables are expressed as percentage deviations from the baseline levels.

5.3. World Demand

Figure 5.3 presents responses to a permanent 1% increase in foreign demand. The overall transmission can be broadly summarized by net trade and output acceleration effects. The impact of persistently increased world demand on real exports is immediate and near complete. Moreover, as the impact on domestic and export prices remains limited, exports stay permanently elevated relative to the baseline throughout the horizon. The permanently increased export activity affects positively the aggregate demand and opens up the output gap. The net trade effect and its impact on output in the second round of the transmission produce positive responses of other demand components. The investment demand is mainly affected through an output accelerator effect, while the increase in household consumption is induced via reaction of non-optimizing consumers and expected increases in transfer and labor incomes on the back of the current positive output gap. Finally, real imports increase in parallel to other demand components via corresponding import content shares.

In quantitative terms, the responses fall within the range set forth by BMEs derived from the benchmark models provided in Appendix A. The sustained 1% increase in foreign demand leads to roughly 0.16% higher real GDP after three years, compared to 0.28% for BbkM at the higher end and 0.14% for BiQM at the lower end of the range. The cumulative effect on prices amounts to 0.16% and is slightly lower than for the FRB-BdF and higher than the price effect recorded in the BiQM and BbkM.

Figure 5: World demand shock (1%)



Note: Horizontal axis represents quarters after the initial shock. All variables are expressed as percentage deviations from the baseline levels.

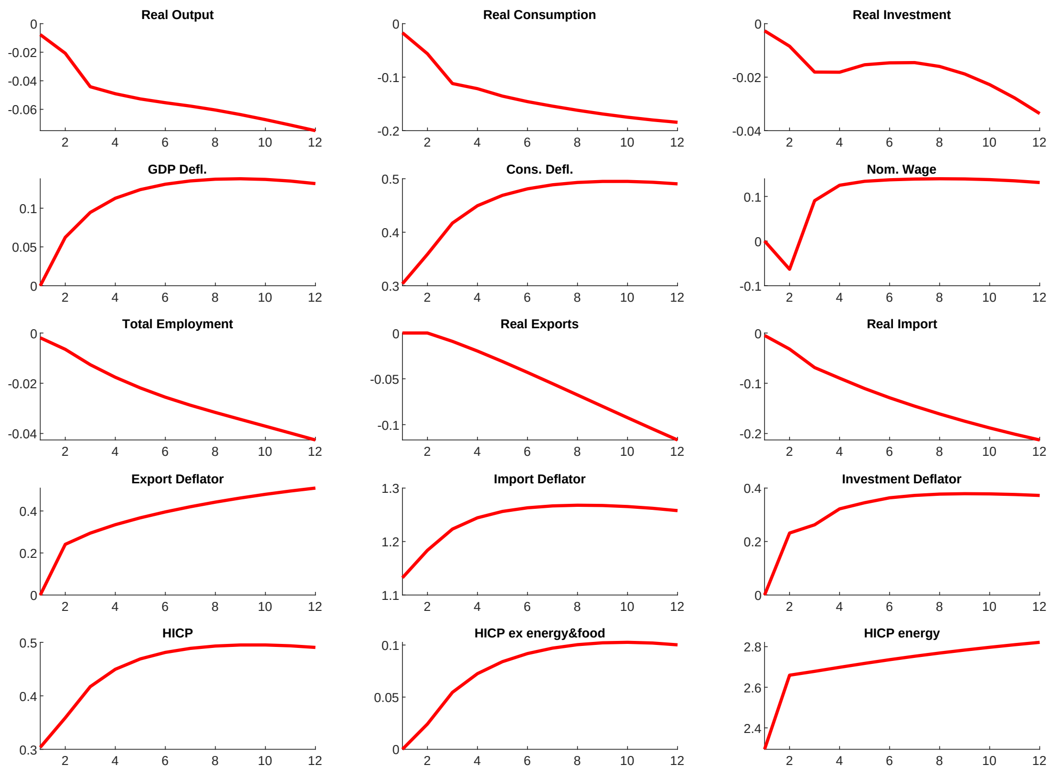
5.4. Oil Price

Figure 5.4 presents responses to a permanent 10% increase in oil prices. The increase in oil prices translates into import prices via oil content of imports, which for Slovenia is calibrated at roughly 11% given the historical average. The increase in import prices is in parallel proportionally translated to consumption and export prices via corresponding import content shares. Given the absence of domestic oil production, the effect on the GDP deflator appears indirectly in terms of the second round effects via indexation to lagged energy price growth. Higher production prices in turn translate into higher nominal wages, which with unchanged productivity leads to a gradual decrease in employment.

Higher consumption prices and decreased employment reduce real disposable income of households and consequently their consumption. The impact of net trade remains roughly neutral throughout the horizon. The reason for the relatively similar dynamics of imports and exports, despite stronger pass-through of oil prices to the import deflator, lies in relative price principles. In other words, relative import prices are reflecting the difference between the import deflator and domestic prices, while relative export prices reflect the difference between the export deflator and competitors' export prices. Since foreign competitors' prices are unchanged in the BME setting, while domestic prices increase proportionally to import prices, the relative price increase is broadly similar for both exports and imports. Likewise, the SiQM responses suggest a roughly unchanged investment demand. The rationale for this can be sought in nominal rigidities. Namely, in the BME setting, the risk-free yield curve remains unchanged, which is consistent with the conventional wisdom of non-responsiveness of monetary policy to supply shocks. Therefore, constant nominal rates in combination with increasing domestic prices implies lower real rates, which produces an offsetting effect to the negative impact of aggregate demand on investment.

In quantitative terms, the pass-through of higher oil prices to consumer prices stands at the higher end of the range set out by BMEs of benchmark models in Appendix A, while the effect on the real side in the case of the SiQM is the smallest among the compared models. This relatively weak nominal-real linkage in part follows the explanation for muted real investment response provided above.

Figure 6: Oil price shock (10%)

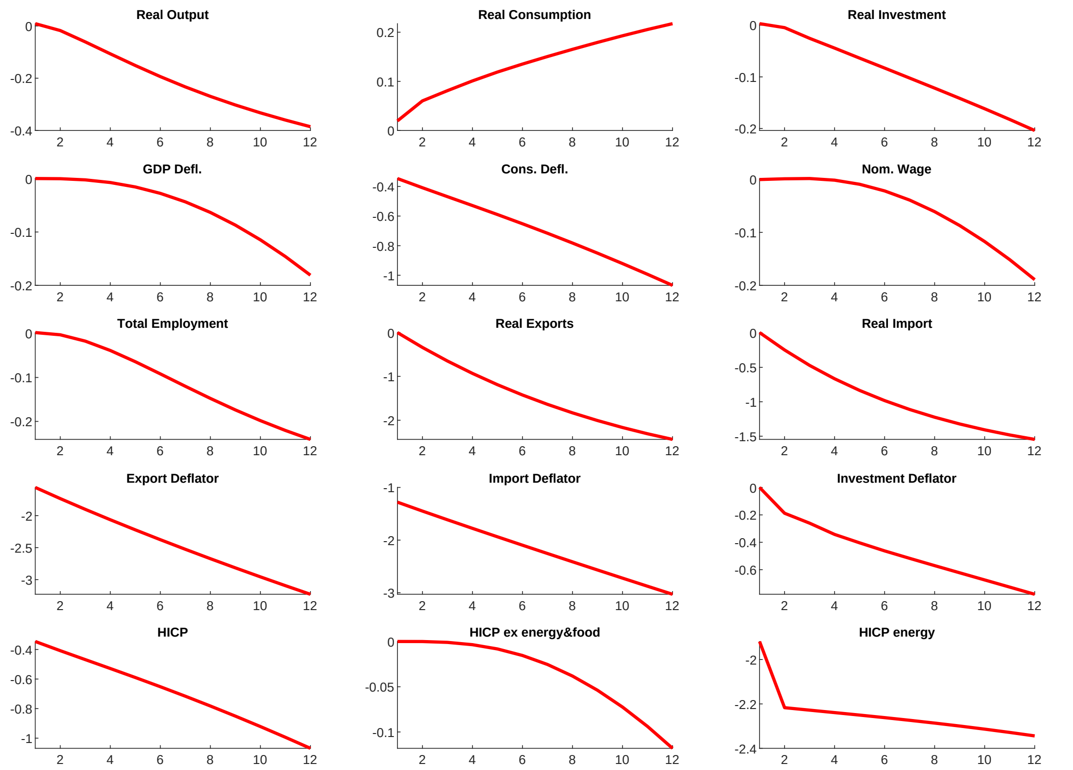


Note: Horizontal axis represents quarters after the initial shock. All variables are expressed as percentage deviations from the baseline levels.

5.5. Exchange Rate

Figure 5.4 presents responses to a 10% appreciation of the euro nominal effective exchange rate excluding USD. The primary channel of the transmission refers to price competitiveness, where export products of domestic producers are becoming more expensive relative to competitors as a consequence of denomination of competitors export prices. Exports gradually adjust to the long-run level implied by the new relative prices ratio. The relative price effect operates in the opposite way in the case of imports, though, imports still decrease proportionally with exports in line with the import content of exports. Nevertheless, the effect on exports remains relatively stronger, implying a negative net trade effect, which translates into roughly 0.6% lower GDP at the end of the horizon.

Figure 7: Exchange rate shock (10%)



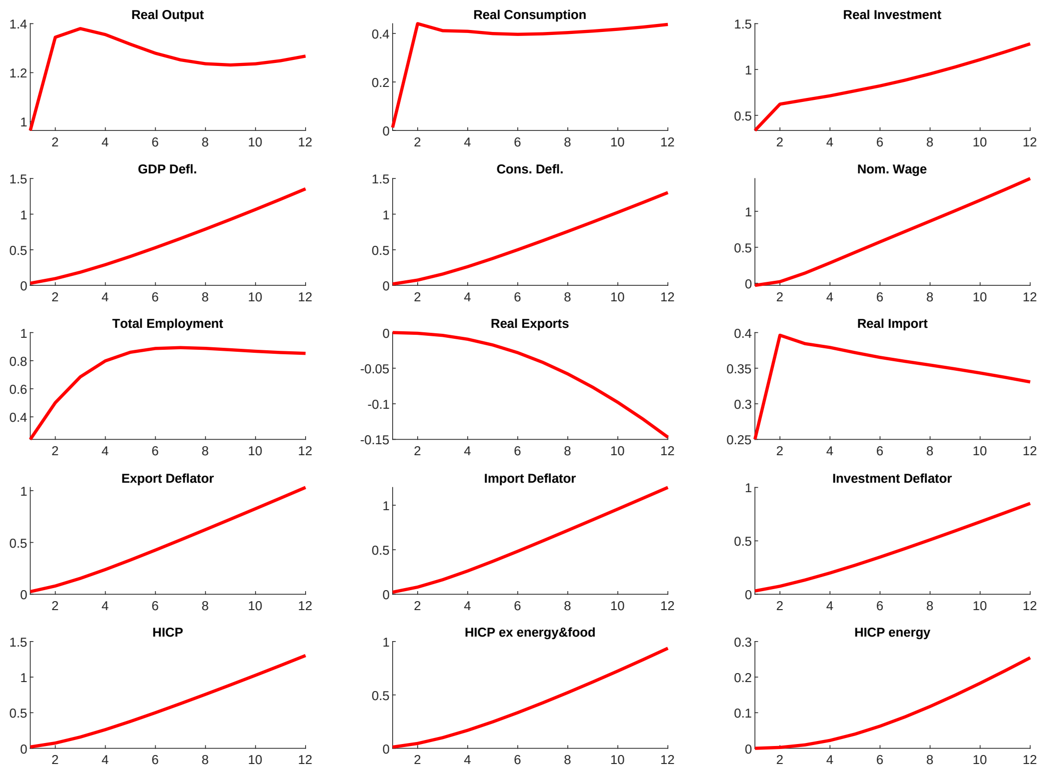
Note: Horizontal axis represents quarters after the initial shock. All variables are expressed as percentage deviations from the baseline levels.

5.6. Government Spending

Figure 5.6 presents responses to a permanent increase in government spending of 1% of GDP. The fiscal expansion implies an increase in aggregate demand, leading to an increase in employment. As output increases, target investment increases, which is further amplified by the accelerator effect of output on short-term investment dynamics. Disposable income increases due to higher wages and employment, producing a positive effect on private consumption. As the potential output remains unchanged, the increase in aggregate demand implies that the output gap is widening, which leads to upward pressures on prices and wages.

Quantitatively, the presented responses point towards relatively strong fiscal multipliers ingrained in the SiQM as effects on real GDP and prices are the strongest among the compared benchmark models (see Appendix A).

Figure 8: Government spending shock (1% GDP)

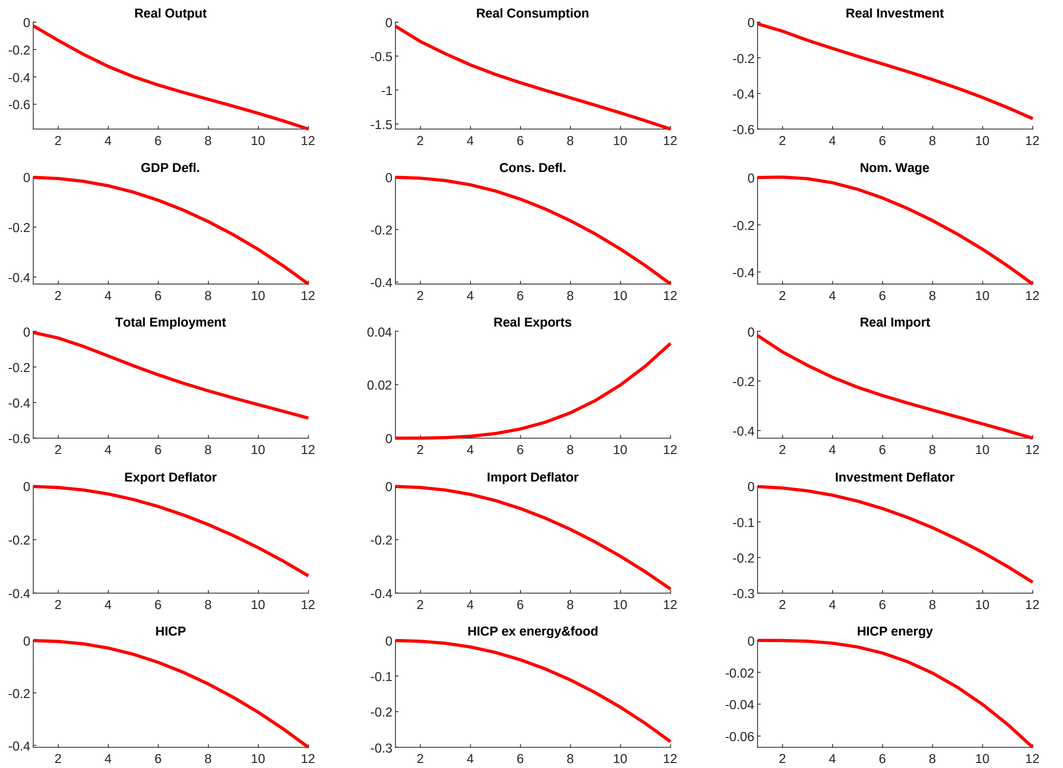


Note: Horizontal axis represents quarters after the initial shock. All variables are expressed as percentage deviations from the baseline levels.

5.7. Direct Taxes

Figure 5.7 presents responses to a permanent increase in direct taxes of 1% of GDP. Direct taxes reduce the disposable income balances of households, which in turn translates to lower consumption and subsequently output. Increased direct taxes likewise imply a higher user cost of capital, which translates into lower investment. The reduced aggregate demand and total output in turn initiate additional indirect effects via hand-to-mouth consumers on the household side and via the output accelerator effect on the investment side. In the medium term, reduced aggregate demand produces negative effects on prices, with the pass-through amounting to roughly 50% after four-year period.

Figure 9: Direct taxes shock (1% GDP)

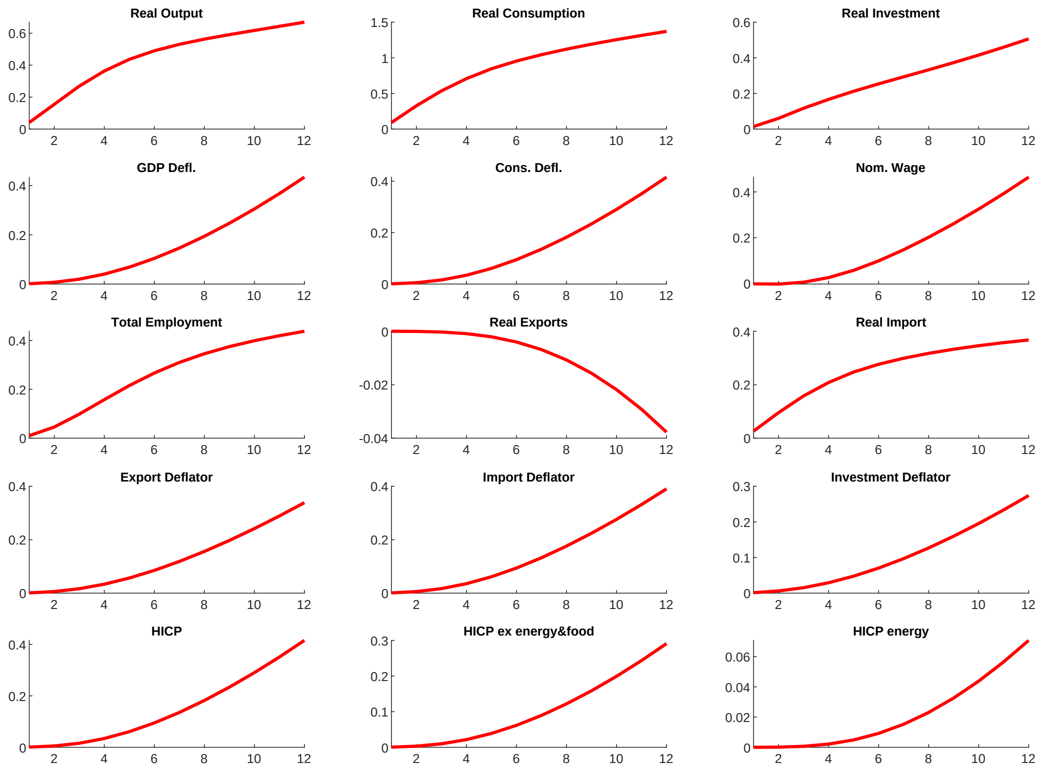


Note: Horizontal axis represents quarters after the initial shock. All variables are expressed as percentage deviations from the baseline levels.

5.8. Social transfers

Figure 5.8 presents responses to a sustained increase in government transfers of 1% of GDP. Permanently increased social transfers affect directly consumption of hand-to-mouth consumers, who respond instantaneously to changes in labor and transfer incomes. The overall effect on aggregate consumption is in the second period additionally amplified through adjustment of optimizing to a new target consumption, increased on the back of higher permanent incomes. Higher aggregate consumption is translated into higher aggregate output, which in turn supports higher investments and employment demand. Higher employment in the second round produces pro-cyclical effects on consumption through increased labor income. As the potential output remains unresponsive to the demand shock, the output gap widens, which is reflected in increasing price levels through real-nominal linkages.

Figure 10: Government transfer shock (1% GDP)



Note: Horizontal axis represents quarters after the initial shock. All variables are expressed as percentage deviations from the baseline levels.

6. Model use and application in the policy process

The properties of the model presented in the previous section provide a solid basis for various model applications to support the policy process of the Bank of Slovenia. This section demonstrates current practices and use of the model in the projection process and in addressing specific policy questions via counterfactual analyses. The exercises performed in this section are exemplary and do not reflect actual Bank of Slovenia's projection or published policy exercises.

6.1. Use of the model in the projection process

The SiQM provides several outputs integral in supporting preparation of the macroeconomic projections of the Banka Slovenije. Its primary use relates to evaluation of revisions in conditioning assumptions associated with the Eurosystem Broad Macroeconomic Projection Exercise. The evaluated ***impact of assumptions*** directly reflects the Basic

Model Elasticities presented in the previous section. Additionally, the model is used to evaluate the ***impact of data***, where the evaluation of data impact relates either to the new statistical releases (e.g. national accounts) or revisions to past data. Evaluating the impact of data through the model allows simultaneous consideration of the statistical carry-over effect, i.e. the effect that a change in the level of a particular variable has on its projected annual growth in the next year and the effect of data realization on the within-year growth by accounting for impact on the projected quarterly growth profile[9].

Combining the impact of data with the impact of assumptions can then serve as a mechanical ***projection update*** of an initial projection profile. The projection update serves multiple purposes in building the final projections, in particular: i) it contributes to shaping the final economic narrative from the perspective of quantification and interpretation of conditioning inputs to projections (i.e. data and technical assumptions); ii) it provides initial point and updated projection profiles for experts preparing forecasts for particular areas of the economy; iii) it derives the quantification of implicit judgment as a difference between the actual and model-based mechanical updates; and iv) it disciplines the bottom-up projections by verifying their consistency from the perspective of the theoretical and statistical structure ingrained in the model.

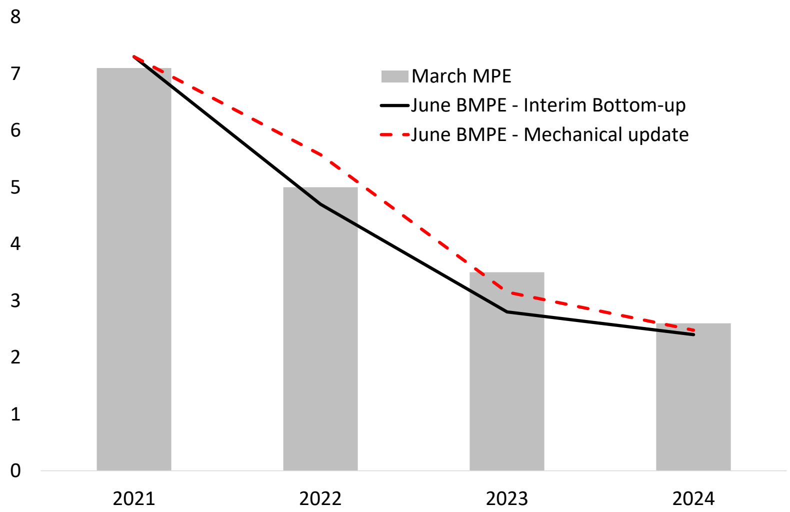
The mechanical outputs highlighted above are performed in the following steps:

1. Perform the model inversion (solve for model residuals) based on the last available projections.
2. Evaluate the impact of new assumptions by comparing projections in step 1 with the simulation over the projection horizon conditional on new assumptions, residuals from step 1 and old historical data up to the start of the projection horizon.
3. Evaluate the impact of data by comparing projections in step 1 with the simulation over the projection horizon using old assumptions, residuals from step 1 and new data up to the start of the projection horizon.
4. Simulate a mechanical projection update using residuals from step 1, new assumptions and new data up to the start of the projection horizon.
5. Derive implicit forecast judgment as a difference between new projections and the mechanical update provided in step 4.

[9]For definitions of the carry-over effect and within-year growth effects, see Tödter (2010).

Figure 11: Model-based projection outputs

(a) Projections of annual GDP growth (%)



(b) Decomposition of revision in projection (in p.p.)

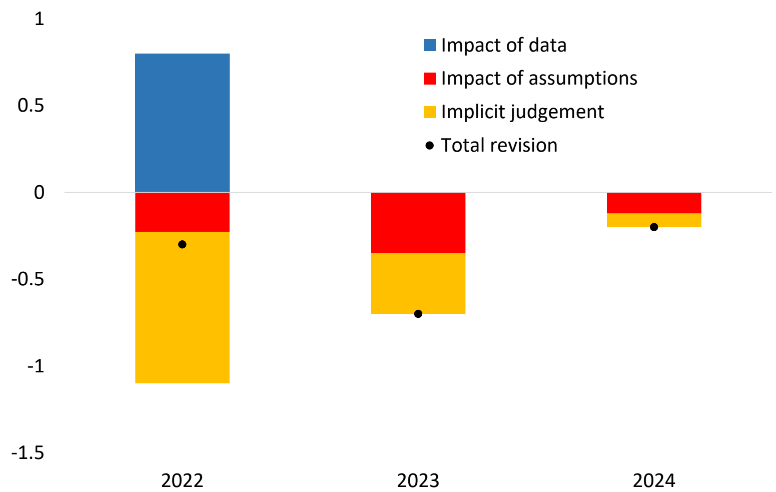


Figure 6.1 shows exemplary model-based outputs in the projection exercise obtained from the simulations described above. The upper panel shows a mechanical update of the initial projection (in our example March 2022 MPE), based on the revision in 2021Q4 data in the size of 1.2 p.p., and revisions in assumptions implying a permanent drop in foreign demand, increase in import prices and deterioration in financing conditions. The bottom panel decomposes the revision between new projections (in our example

June 2022 BMPE) and initial projections (i.e. March 2022 MPE) on the impact of assumptions, data and implicit judgment. The latter is evaluated as the difference between the mechanical update and the new projection. Conditional on ingrained model properties, the expert judgment applied in the new projections amounts to roughly 0.9 p.p. in order to cover the distance between the model-based update and the final projection.

6.2. Solving for a pre-specified counterfactual

Aside from the standardized and mechanical outputs associated with the projection process, the SiQM is regularly used to address specific policy questions and various counterfactual analysis. The model offers a convenient way of solving for specific residuals consistent with a preset counterfactual scenarios. To illustrate the concept, the model is applied to the following policy question:

Q: Given a particular inflation projection, what would be a required adjustment in wage growth that would align inflation with the policy target of 2%?

For the purpose of this exercise, the baseline projection inflation is expected to fall short of its target by roughly 0.3 p.p. in the second half of the projection horizon, as shown in Figure 6.2. The annual wage growth consistent with the given baseline inflation projection would correspond to roughly 2.6% on average over the second half of the horizon. To find a counterfactual wage growth needed to bring inflation at par with its target the following steps are performed:

1. Exogenize the HICP variable and set its growth path consistent with 2% inflation.
2. Restrict the model to a single solution by endogenizing the residual in wage growth equation.
3. Bootstrap past residuals of the wage growth equations around the baseline projection to assess the plausibility of the scenario.

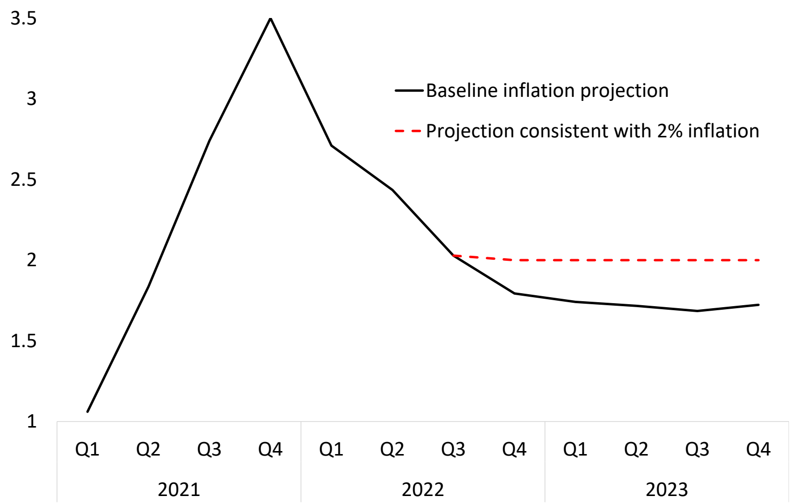
The exogenization of the HICP variable in step 1 implies a model with more equations than endogenous variables. In this kind of setting, the model does not have a single solution, as there would exist a multitude of combinations of shocks consistent with the pre-determined inflation path. Step 2 therefore plays a crucial role, as it restricts the solution through endogenous response of the wage growth residual. Step 3 is performed for benchmarking the counterfactual response from the perspective of historical realizations.

In our particular example, the model suggests that, on average, roughly 0.9 p.p. acceleration in projected wage growth would be required for an increase in inflation by

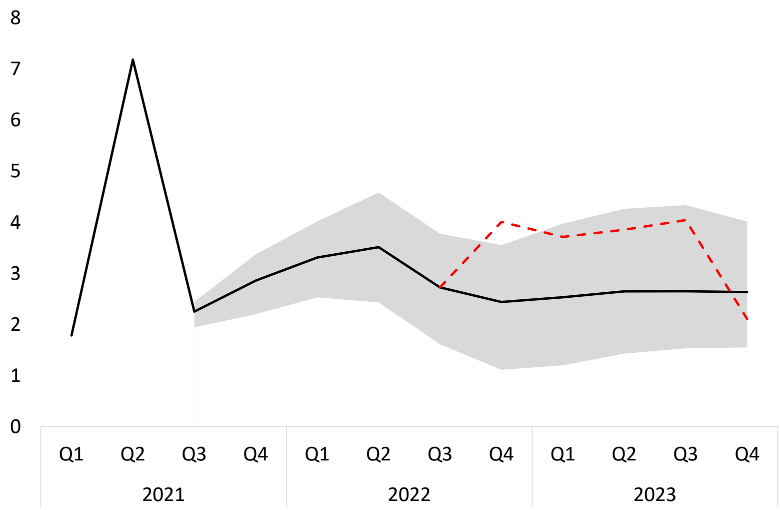
0.3 p.p., which would entail at least 2% inflation over the entire projection horizon. This kind of acceleration would imply on average a 3.5% wage growth in the given horizon, which would fall within the historical bands derived by step 3 in the above procedure.

Figure 12: Wage-price pass-through simulation

(a) Projections of annual HICP inflation (%)



(b) Projections of annual wage growth (%)



7. Conclusion and way forward

The paper presented an overview and properties of the Slovene Quarterly Macroeconomic Model. In its design and structure, the model represents a country version of the ECB's workhorse model, the ECB-BASE. The model is intended to take the central role in the projection and policy modelling process of Banka Slovenije. To this end, the model was scrutinized through the lens of Basic Model Elasticities (BMEs), which are commonly used to evaluate the impact of revisions in a harmonized set of conditional assumptions in the BMPE process. The model produces key BME responses that resemble theoretically and empirically supported transmissions for various demand and supply shocks. Moreover, the BMEs produced by the model are in a quantitative sense comparable to responses produced by models of other NCBs selected as benchmarks.

The theoretically and empirically consistent properties validate the use of the model in projection and policy processes. Nevertheless, further development of the model is warranted along several dimensions. The infrastructure and properties of the model ought to be further fine-tuned to allow for the production of accurate and reliable standalone forecasts, that is, autonomous out-of-sample forecasts beyond technical updates of projections based on the evaluation of revisions in technical assumptions. In parallel, the model should be updated with new BMEs in line with the developing needs recognized within the Eurosystem projection process. In the context of the energy crisis, a topical example of this could entail incorporation of BMEs related to gas and electricity prices that could better support inflation forecasts.

Furthermore, the model is planned to be enhanced with additional blocks or augmentation of existing ones to better serve the national perspective and policy domain of Banka Slovenije. In particular, in the medium term, a banking sector block is planned to be included to add financial stability and macroprudential features to the model. Likewise, the fiscal block should be further equipped with well-defined policy rules to allow for enhanced endogenous policy modelling and at the same time better account for sovereign risks. Finally, further work is planned in the direction of providing more informed policy narrative and considerations, which would benefit from enhanced identification possibilities and improved structural coherence across blocks.

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Appendix A. BME comparison across NCB models

Table A.2 provides comparison to BMEs reported by models of Bank de France (FRB-BdF), Banca d'Italia (BiQM), and Deutsche Bundesbank (BbkM), based on Aldama and Ouvrard (2020), Bulligan et al., 2017, and Haertel et al. (2022).

Table A.2: BME comparison across NCB models

	Sustained 100b.p. increase in STN					
	Real GDP			Consumer Prices		
	Y1	Y2	Y3	Y1	Y2	Y3
SiQM	-0.09	-0.11	-0.17	-0.04	-0.12	-0.21
FRB-BdF	-0.02	-0.09	-0.14	0.00	-0.04	-0.11
BiQM	-0.09	-0.37	-0.45	-0.07	-0.23	-0.43
BbkM	-0.02	-0.07	-0.10	0.00	0.00	-0.01
	Sustained 1% increase in foreign demand					
	Real GDP			Consumer Prices		
	Y1	Y2	Y3	Y1	Y2	Y3
SiQM	0.16	0.16	0.16	0.03	0.09	0.16
FRB-BdF	0.14	0.20	0.21	0.03	0.10	0.17
BiQM	0.09	0.11	0.14	0.00	0.02	0.04
BbkM	0.10	0.25	0.28	0.00	0.03	0.07
	Sustained 10% increase in oil prices					
	Real GDP			Consumer Prices		
	Y1	Y2	Y3	Y1	Y2	Y3
SiQM	-0.05	-0.06	-0.07	0.44	0.49	0.49
FRB-BdF	-0.04	-0.14	-0.19	0.24	0.22	0.17
BiQM	-0.09	-0.25	-0.34	0.22	0.35	0.39
BbkM	-0.04	-0.10	-0.13	0.19	0.33	0.38
	Sustained increase (1% GDP) in government spending					
	Real GDP			Consumer Prices		
	Y1	Y2	Y3	Y1	Y2	Y3
SiQM	1.37	1.28	1.30	0.26	0.76	1.31
FRB-BdF	0.97	1.02	0.92	0.19	0.60	0.94
BiQM	0.92	1.07	1.17	0.05	0.32	0.68
BbkM	1.03	1.15	1.11	0.01	0.10	0.29

Note: All responses are expressed as % deviations from baseline.

Appendix B. Solution to a Firm's Optimization Problem

The target capital demand can be derived from a constrained profit maximization problem of an economic agent. Let us postulate a generic production function $F(N,K)$ with the two arguments denoting labor and capital respectively. Firms' objective is maximization of profits, which are driven by the relative price of investments and real wages W.

What is important is the timing assumption related to the capital law of motion. Namely, instead of assuming that investments are reflected in the capital stock within the same period, we adopt the time-to-build assumption according to which investments are projected onto capital in the next period. Considering the time-to-build assumption and its effect on capital accumulation, the profit maximization problem is given by:

$$\max_{\{K_t,I_t\}} \sum_{j=0}^{\infty} \left(\frac{1}{1+R_{t+j}}\right)^j \{Y_{t+j} - W_{t+j}N_{t+j} - RP_{t+j}I_{t+j}\}$$

s.t.

$$K_{t+j} = (1-\delta)K_{t+j-1} + I_{t+j-1} \tag{B.1}$$

and

$$Y_t = F(N_t, K_t) \tag{B.2}$$

Let λ_t denote the L-multiplier[10] on the evolution of capital, so that we can write the maximization problem as:

$$\begin{aligned}\mathcal{L} \;=\; & \max_{\{K_{t+1},I_t\}} \sum_{j=0}^{\infty} \left(\frac{1}{1+R_{t+j}}\right)^j \{F(N_{t+j}, K_{t+j}) - W_{t+j}N_{t+j} - RP_{t+j}I_{t+j} \\ & \qquad + \lambda_{t+j}\left[I_{t+j} + (1-\delta)K_{t+j} - K_{t+j+1}\right]\}\end{aligned}$$

$$\frac{\partial\mathcal{L}}{\partial K_{t+1}} = \frac{1}{1+R_{t+1}}F^{'}(N_{t+1}, K_{t+1}) - \left(\frac{1}{1+R_t}\right)^0 \lambda_t + \lambda_{t+1}(1-\delta)\frac{1}{1+R_{t+1}} \tag{B.3}$$

$$\frac{\partial\mathcal{L}}{\partial I_t} = R_t - \lambda_t \tag{B.4}$$

[10] In this setting λ can be interpreted as the marginal effect of increased assets on profits and consequently market valuation of a firm, which offers a proxy for the Tobin's Q ratio.

Rearranging the FOC for capital

$$F^{'}(N_{t+1}, K_{t+1}) - (1 + R_{t+1})\lambda_t + \lambda_{t+1}(1-\delta) = 0$$

$$\begin{aligned}
F^{'}(N_{t+1}, K_{t+1}) &= RP_t(1 + R_{t+1}) - RP_{t+1}(1-\delta) \\
&= RP_t\left[1 + R_{t+1} - (1-\delta)\frac{RP_{t+1}}{RP_t}\right] \\
&= RP_t\left[1 + R_{t+1} - (1-\delta) - (1-\delta)\left(\frac{RP_{t+1} - RP_t}{RP_t}\right)\right]
\end{aligned}$$

Under the assumption of constant returns to scales in the Cobb-Douglas production function we get:

$$(1-\alpha)\frac{Y_{t+1}}{K_{t+1}} = RP_t\left\{R_{t+1} + \delta - (1-\delta)\left(\frac{RP_{t+1} - RP_t}{RP_t}\right)\right\} \equiv u_{t+1} \qquad \text{(B.5)}$$

where the right hand side represents the user cost of capital denoted by u.

Appendix C. Model equations and estimates

The following subsections present estimated equations of individual model blocks. The notation follows a convention where small capitalization reflects log transformations, long-term target counterparts of variables are superscripted by "$\star$", "$^-$" represents trend categories, while " $\hat{}$ " stands for gap categories. The standard errors of parameters are reported below the coefficient values. Missing standard errors underneath coefficient values indicate calibration of a particular parameter.

Appendix C.1. Household consumption

Long-run equation: The long-run behavior of households stems from to the lifetime utility optimization, subject to the resource constraint outlined in Laubach and Reifschneider (2003). The solution to the optimization problem yields the equilibrium consumption, $c^\star$, expressed as a function of permanent labor, transfer and property incomes and wealth:[11]

$$c_t^\star = \underset{(0.23)}{0.12} + \underset{(0.07)}{0.57} pyl_t + \underset{(0.05)}{0.27} pyt_t + \underset{(0.04)}{0.03} pyp_t + \underset{(0.06)}{0.14} wth_t + \varepsilon_t^{c^\star} \tag{C.1}$$

$\bar{R}2 = 0.87$ estimation sample = 2000Q1:2018Q4

$c^\star$ - long-run target consumption
pyl - permanent labour income
pyt - permanent transfer income
pyp - permanent property income
wth - wealth

Short-run equation: In the short-run, household consumption adjusts to the long-term target according to Polynomial Adjustment Costs (PAC). The generic PAC representation is augmented with the term reflecting elasticity of households to financing conditions associated with consumer loans. Additionally, the aggregate short-term consumption is formed as a weighted average of consumption related to optimizing agents (following PAC) and rule-of-thumb agents, whose consumption dynamic is entirely a function of changes in current disposable income:

[11] The construction of permanent income variables used in estimation is detailed in Angelini et al. (2019), Appendix B.1

$$\Delta c_t = \underset{(0.03)}{0.95}\left(\underset{(0.13)}{0.55}(c^\star_{t-1} - c_{t-1}) - \underset{(0.16)}{0.10}\Delta c_{t-1} - 0.001\Delta r^c_t + E_{t-1}\sum_{j=0}^{\infty} d_j \Delta c^\star_{t+j}\right) \quad \text{(C.2)}$$
$$+ (1 - 0.95)(\Delta yl_t + \Delta yt_t) + \varepsilon^c_t$$

$\bar{R}2 = 0.47$ estimation sample = 2008Q1:2018Q4

c - household consumption
r^c - real consumer rate
yl - labor income
yt - transfer income

Appendix C.2. Business Investment

Long-run equation: The long-run target investment is given by the solution to the firm's optimization problem and is characterized by the optimal growth rate of capital, desired capital-to-output ratio and user costs of capital:

$$IB^\star_t = (G^{K^*}_{t+1} + \delta)\frac{S^K_t Y_t}{UC_t} \quad \text{(C.3)}$$

$IB^\star$ - target real business investment
G^{K^*} - optimal growth rate of capital approximated by real GDP growth
δ - constant depreciation rate set at 1.3%
UC - user costs of capital
Y - real GDP
S - desired capital-to-output ratio defined by the trend ratio: $IB_t/Y_t(\frac{Y_t - \bar{Y}_{t-1}}{\bar{Y}_{t-1}} + \delta)$, where IB represents observed real business investment and $\bar{Y}$ stands for real potential output.

The user costs of capital determining the long-run investment demand are expressed as a relation between costs of investment, characterized by depreciation of capital and real financing costs of investment, and capital gains, given by a change in relative investment price:

$$UC_t = RP_{t-1}\left\{R_t^{ib} + \delta - (1-\delta)(\frac{RP_t - RP_{t-1}}{RP_{t-1}})\right\} \quad (C.4)$$

RP - relative price of investment good provided as a ratio between investment and GDP deflators
R^{ib} - real financing costs for business investment constructed as a composite of bank lending rate for non-financial corporations, corporate bond rate and cost of equity.

Short-run equation: In the short run, real business investment evolves as a weighted average of PAC-related adjustment towards the target investment and output accelerated investment dynamic:

$$\Delta ib_t = 0.5\left(\underset{(0.09)}{0.08}(ib^{\star}_{t-1} - ib_{t-1}) - \underset{(0.26)}{0.64}\Delta ib_{t-1} + E_{t-1}\sum_{j=0}^{\infty} d_j \Delta ib^{\star}_{t+j}\right) + 0.5\Delta y_t + \varepsilon_t^{ib} \quad (C.5)$$

$\bar{R}2 = 0.29$ estimation sample = 2009Q4:2018Q4

ib - log real business investment
y - log real GDP

Appendix C.3. Residential Investment

Long-run equation: The target residential investment takes the Cobb-Douglas functional form comprised of user costs of housing capital and relative price of housing investment:

$$IH_t^{\star} = \alpha^H Y_t (UC_t^H)^{\beta_1^h} (RP_t^H)^{\beta_2^H} \quad (C.6)$$

$IH^{\star}$ - target residential investment
Y - real GDP
UC^{H} - user cost of housing capital
RP^{H} - relative house price given by a ratio between residential property price and residential investment deflator
β_1^h,β_2^H - Cobb-Douglas elasticities

The log-linearized empirical specification of the target residential investment is provided by:

$$ih_t^{\star} = \underset{(0.35)}{-1.98} + y_t - \underset{(0.01)}{0.07} + \underset{(0.02)}{0.98} - \underset{(0.00002)}{0.01} T + + \varepsilon_t^{ih^{\star}} \tag{C.7}$$

$\bar{R}2 = 0.87$ estimation sample = 2007Q3:2018Q4

The log of user cost of housing capital follows closely the theory-based counterpart, described in the previous subsection, and takes the following empirical form:

$$uc_t^H = \delta^H + r_t^{NFC} - E_{t-1}\left(\Delta rp_t^H\right) \tag{C.8}$$

uc^H - log user cost of housing capital
δ^H - constant depreciation rate of housing capital set at 0.4%
r^{NFC} - bank lending rate for non-financial corporate sector
$E_{t-1}\left(\Delta rp_t^H\right)$ - is a staggered process defined as $0.875{*}E_{t-2}\left(\Delta rp_{t-1}^H\right){+}0.125{*}(100diff(rp_t^H))$

Short-run equation: The adjustment towards the target residential investment is provided by the following estimated PAC process:

$$\begin{aligned}\Delta ih_t =& \underset{(0.05)}{0.02}\left(ih_{t-1}^{\star} - ih_{t-1}\right) + \underset{(0.14)}{0.20}\Delta ih_{t-1} + \underset{(0.11)}{0.10}\Delta ih_{t-2} + \underset{(0.13)}{0.48}\Delta ih_{t-3} \\ &+ E_{t-1}\sum_{j=0}^{\infty} d_j \Delta ih_{t+j}^{\star} + \varepsilon_t^{ih}\end{aligned} \tag{C.9}$$

$\bar{R}2 = 0.48$ estimation sample = 2010Q1:2018Q4

Appendix C.4. International Trade

The construction of the trade block considers an intra-/extra-euro area trade split, in line with Dieppe and Warmedinger (2007). Specifically, behavioral equations describe the total trade and extra-EA trade volumes, while the intra-EA trade components are derived as an identity. The long-run trade volumes are modelled as functions of demand and relative price components, following the framework of Goldstein and Khan (1985a). In the short-run, the adjustment to long-run volumes is provided within the traditional (i.e. non-PAC) error-correction setting.

Total exports

Long-run equation:

$$xtr_t^{\star} = -\underset{(0.017)}{2.86} + wdr_t - \underset{(0.47)}{0.59}(xtd_t - cxd_t) + \varepsilon_t^{xtr^{\star}} \tag{C.10}$$

$\bar{R}2 = 0.92$ estimation sample = 2003Q1:2018Q4

$xtr^{\star}$ - long-run total exports
wdr - world demand (total)
xtd - total export deflator
cxd - competitors' export prices weighted by shares of export partners

Short-run equation:

$$\Delta xtr_t = -\underset{(0.037)}{0.061}(xtr_{t-1} - xtr_{t-1}^{\star}) + \underset{(0.10)}{0.854}\Delta wdr_t + \varepsilon_t^{xtr} \tag{C.11}$$

$\bar{R}2 = 0.64$ estimation sample = 2003Q2:2018Q4

xtr - total exports

Total imports

Long-run equation:

$$mtr^{\star}_t = \underset{(0.145)}{0.039} + wer_t - \underset{(0.144)}{0.092}(mtd_t - yed_t) + \varepsilon^{mtr^{\star}}_t \tag{C.12}$$

$\bar{R}2 = 0.95$ estimation sample = 2003Q1:2018Q4

$mtr^{\star}$ - long-run total import
wer - sum of import contents of GDP sub-components
mtd - total import deflator
yed - GDP deflator

Short-run equation:

$$\Delta mtr_t = -\underset{(0.05)}{0.163}(mtr_{t-1} - mtr^{\star}_{t-1}) + \underset{(0.109)}{1.257}\Delta wer_t + \varepsilon^{mtr}_t \tag{C.13}$$

$\bar{R}2 = 0.76$ estimation sample = 2003Q2:2018Q4

mtr - total import

Extra-EA exports

Long-run equation:

$$xxr^{\star}_t = -\underset{(0.008)}{3.62} + wdrex_t - \underset{(0.197)}{0.389}(xxd_t - cxd_t) + \underset{(0.000)}{0.001}T + \varepsilon^{xtr^{\star}}_t \tag{C.14}$$

$\bar{R}2 = 0.84$ estimation sample = 2003Q1:2018Q4

$xxr^{\star}$ - long-run extra EA exports
$wdrex$ - extra EA world demand (total)
xxd - extra EA export deflator
cxd - competitors' export prices weighted by shares of export partners

Short-run equation:

$$\Delta xxr_t = -\underset{(0.002)}{0.001}(xxr_{t-1} - xxr^{\star}_{t-1}) + \underset{(0.715)}{0.806}\Delta wdrex_t + \underset{(0.971)}{1.109}\Delta eenx_t + \varepsilon^{xtr}_t \qquad \text{(C.15)}$$

$\bar{R}2 = 0.16$ estimation sample = 2010Q1:2018Q4

xxr - extra-EA exports
wdrex - extra-EA world demand
eenx - Euro nominal effective exchange rate

Extra-EA imports

Long-run equation:

$$mxr^{\star}_t = \underset{(0.019)}{0.073} + werex_t - (mxd_t - yed_t) + \underset{(0.000)}{0.005}T + \varepsilon^{mxr^{\star}}_t \qquad \text{(C.16)}$$

$\bar{R}2 = 0.90$ estimation sample = 2003Q1:2018Q4

$mxr^{\star}$ - long-run extra-EA imports
werex - sum of extra-EA import contents of GDP sub-components
mxd - extra-EA import deflator
yed - GDP deflator

Short-run equation:

$$\Delta mxr_t = -\underset{(0.041)}{0.025}(mxr_{t-1} - mxr^{\star}_{t-1}) + \underset{(0.443)}{1.688}\Delta werex_t + \underset{(0.998)}{1.961}\Delta eenx_t + \varepsilon^{mxr}_t \qquad \text{(C.17)}$$

$\bar{R}2 = 0.40$ estimation sample = 2003Q2:2018Q4

mxr - extra-EA imports

Total export deflator

Long-run equation:

$$xtd^{\star}_t = \underset{(0.007)}{0.035} + cxd_t + \underset{(0.049)}{0.407}(yed_t - cxd_t) + \underset{(0.000)}{0.066}(med_t - cxd_t) - \underset{0.000}{0.000}T + \varepsilon^{xtd^{\star}}_t \quad \text{(C.18)}$$

$\bar{R}2 = 0.97$ estimation sample = 2003Q1:2018Q4

$xtd^{\star}$ - long-run total export deflator
med - energy deflator

Short-run equation:

$$\begin{aligned}\Delta xtd_t = &- \underset{(0.011)}{0.012}(xtd_{t-1} - xtd^{\star}_{t-1}) + \underset{(0.060)}{0.305}(\Delta cxd_t - \Delta yed_t) \\ &+ \underset{(0.006)}{0.007}(\Delta med_{t-1} - \Delta yed_{t-1}) + \Delta yed_t + \varepsilon^{xtd}_t\end{aligned} \quad \text{(C.19)}$$

$\bar{R}2 = 0.42$ estimation sample = 2003Q2:2018Q4

xtd - total export deflator

Total import deflator

Long-run equation:

$$mtd^{\star}_t = \underset{(0.005)}{0.032} + cmd_t + \underset{(0.059)}{0.245}(yed_t - cmd_t) + 0.095(med_t - cmd_t) - \underset{0.000}{0.0004}T + \varepsilon^{mtd^{\star}}_t \quad \text{(C.20)}$$

$\bar{R}2 = 0.96$ estimation sample = 2003Q1:2018Q4

$mtd^{\star}$ - long-run total import deflator
cmd - competitors' export prices weighted by shares of import partners

Short-run equation:

$$\Delta mtd_t = -\underset{(0.089)}{0.103}(mtd_{t-1} - mtd^{\star}_{t-1}) + 0.091(\Delta med_t - \Delta yed_t) + \underset{(0.106)}{0.528}(\Delta cmd_t - \Delta yed_t) + \Delta yed_t + \varepsilon^{mtd}_t \tag{C.21}$$

$\bar{R}2 = 0.51$ estimation sample = 2003Q2:2018Q4

mtd - total import deflator

Extra-EA export deflator

Long-run equation:

$$xxd^{\star}_t = \underset{(0.004)}{0.077} + cxdex_t + \underset{(0.047)}{0.761}(yed_t - cxdex_t) - \underset{0.000}{0.002}T + \varepsilon^{xxd^{\star}}_t \tag{C.22}$$

$\bar{R}2 = 0.87$ estimation sample = 2003Q1:2018Q4

$xxd^{\star}$ - long-run extra-EA export deflator
$cxdex$ - competitors' export prices weighted by shares of extra-EA partners

Short-run equation:

$$\Delta xxd_t = -\underset{(0.097)}{0.149}(xxd_{t-1} - xxd^{\star}_{t-1}) + \underset{(0.066)}{0.281}(\Delta cxdex_t - \Delta yed_t) + \Delta yed_t + \varepsilon^{xxd}_t \tag{C.23}$$

$\bar{R}2 = 0.20$ estimation sample = 2003Q2:2018Q4

xxd - extra-EA export deflator

Extra-EA import deflator

Long-run equation:

$$mxd_t^{\star} = \underset{(0.008)}{0.109} + cmdex_t + \underset{(0.845)}{0.908}(yed_t - cmdex_t) + \underset{(0.000)}{0.048}(med_t - cmdex_t) - \underset{(0.000)}{0.002}T + \varepsilon_t^{mxd^{\star}} \tag{C.24}$$

$\bar{R}2 = 0.96$ estimation sample = 2003Q1:2018Q4

$mxd^{\star}$ - long-run extra-EA import deflator
$cmdex$ - competitors' export prices weighted by shares of extra-EA import partners

Short-run equation:

$$\begin{aligned}\Delta mxd_t = &- \underset{(0.016)}{0.040}(mxd_{t-1} - mxd_{t-1}^{\star}) + \underset{(0.015)}{0.011}(\Delta med_t - \Delta yed_t) \\ &+ \underset{(0.072)}{0.439}(\Delta cmdex_t - \Delta yed_t) + \Delta yed_t + \varepsilon_t^{mxd}\end{aligned} \tag{C.25}$$

$\bar{R}2 = 0.52$ estimation sample = 2003Q2:2018Q4

mxd - extra-EA import deflator

Nominal identities

$$XTN = XTR * XTD \tag{C.26}$$

$$MTN = MTR * MTD \tag{C.27}$$

$$XXN = XXR * XXD \tag{C.28}$$

$$MXN = MXR * MXD \tag{C.29}$$

Intra-EA identities

$$XNR = XTR - XXR \tag{C.30}$$

$$MNR = MTR - MXR \tag{C.31}$$

$$XNN = XTN - XXN \tag{C.32}$$

$$MNN = MTN - MXN \tag{C.33}$$

Energy deflator

$$MED = 0.6POU - 0.4POC \tag{C.34}$$

POU - Price of oil
POC - Price of non-oil commodities

$$mtdx_t = (mtd_t - 0.9(med_t - exr_t))/(1 - 0.9) \tag{C.35}$$

$mtdx$ - log import deflator excluding energy
exr - log dollar-euro exchange rate

Appendix C.5. Government

Revenue Side: Particular types of government revenues are in the model constructed by relating implicit revenue rate τ (e.g. implicit tax or social contribution rate) to its relevant tax base (e.g. private and government spending):

$$REV_{i,t} = \tau_{i,t} TAX\_BASE_{i,t} \tag{C.36}$$

A specific implicit revenue rates, τ_i, is in the model assumed to be a function of deviations from its trend value, τ_i^T, and output gap as a measure of business cycle state. For all implicit revenue rates, their trend values are assumed to evolve according to the following generic process:

$$\tau_{i,t}^T = 0.9\tau_{i,t-1}^T + 0.1\tau_i^\star \tag{C.37}$$

where $\tau_i^\star$ is the target implicit rate taken as an average implicit rate observed during the 2014-2018 period. The specific period is considered a reference for a long-term fiscal policy goal due to its relative stability with no sizable expansion or consolidation episodes. The estimated equations for specific implicit revenue rates are provided below:

Indirect taxes - implicit rate

$$\begin{aligned} R\_TIN_t =& T\_R\_TIN_t - \underset{(0.110)}{0.201}(R\_TIN_{t-1} - T\_R\_TIN_{t-1}) \\ & - \underset{(0.111)}{0.392}(R\_TIN_{t-2} - T\_R\_TIN_{t-2}) + \underset{(0.000)}{0.002}\hat{Y}_t + \varepsilon_t^{tin} \end{aligned} \tag{C.38}$$

$\bar{R}2 = 0.49$ estimation sample = 2002Q1:2020Q1

R_TIN - implicit rate related to indirect taxes
T_R_TIN - trend implicit rate related to indirect taxes
$\hat{Y}$ - output gap

Direct taxes paid by households - implicit rate

$$\begin{aligned} R\_DTN_t^{HH} =& T\_R\_DTN_t^{HH} - \underset{(0.118)}{0.541}(R\_DTN_{t-1}^{HH} - T\_R\_DTN_{t-1}^{HH}) \\ & - \underset{(0.117)}{0.026}(R\_DTN_{t-2}^{HH} - T\_R\_DTN_{t-2}^{HH}) + \underset{(0.000)}{0.0004}\hat{Y}_t + \varepsilon_t^{dtnhh} \end{aligned} \tag{C.39}$$

$\bar{R}2 = 0.37$ estimation sample = 2002Q1:2020Q1

R_DTN^{HH} - implicit rate related to direct taxes paid by households
$T\_R\_DTN^{HH}$ - trend implicit rate related to direct taxes paid by households

Direct taxes paid by employers - implicit rate

$$\begin{aligned} R\_DTN_t^{BU} =& T\_R\_DTN_t^{BU} - \underset{(0.118)}{0.053}(R\_DTN_{t-1}^{BU} - T\_R\_DTN_{t-1}^{BU}) \\ & - \underset{(0.119)}{0.335}(R\_DTN_{t-2}^{BU} - T\_R\_DTN_{t-2}^{BU}) + \underset{(0.000)}{0.001}\hat{Y}_t + \varepsilon_t^{dtnbu} \end{aligned} \tag{C.40}$$

$\bar{R}2 = 0.69$ estimation sample = 2002Q1:2020Q1

$R\_DTN_t^{BU}$ - implicit rate related to direct taxes paid by employers
$T\_R\_DTN_t^{BU}$ - trend implicit rate related to direct taxes paid by employers

Social contributions paid by households - implicit rate

$$\begin{aligned} R\_SCN_t^{HH} =& T\_R\_SCN_t^{HH} - \underset{(0.131)}{0.514}(R\_SCN_{t-1}^{HH} - T\_R\_SCN_{t-1}^{HH}) \\ &- \underset{(0.128)}{0.269}(R\_SCN_{t-2}^{HH} - T\_R\_SCN_{t-2}^{HH}) + \underset{(0.000)}{0.0008}\hat{Y}_t + \varepsilon_t^{scnhh} \end{aligned} \tag{C.41}$$

$\bar{R}2 = 0.62$ estimation sample = 2005Q3:2020Q1

R_SCN^{HH} - implicit rate related to social contributions paid by households
$T\_R\_SCN^{HH}$ - trend implicit rate related to social contributions paid by households

Social contributions paid by employers - implicit rate

$$\begin{aligned} R\_SCN_t^{BU} =& T\_R\_SCN_t^{BU} - \underset{(0.131)}{0.316}(R\_SCN_{t-1}^{BU} - T\_R\_SCN_{t-1}^{BU}) \\ &- \underset{(0.132)}{0.23}(R\_SCN_{t-2}^{BU} - T\_R\_SCN_{t-2}^{BU}) + \underset{(0.000)}{0.0000}\hat{Y}_t + \varepsilon_t^{scnbu} \end{aligned} \tag{C.42}$$

$\bar{R}2 = 0.36$ estimation sample = 2005Q3:2020Q1

R_SCN^{BU} - implicit rate related to social contributions paid by employers
$T\_R\_SCN^{BU}$ - trend implicit rate related to social contributions paid by employers

Spending Side: Similar to revenue categories, government expenditures are assumed to evolve around their trends, which are in turn anchored by target expenditure.

Concretely, the generic process for particular trend expenditures, g_i^T, is described as:

$$\delta g_{i,t}^T = 0.1(g_{i,t-1}^\star - gi, t - 1^T) + \frac{1}{4}\sum_{k=0}^{3} \Delta y_{t-k}^\star \tag{C.43}$$

where $g_i^\star$ is target expenditure represented as a constant share of potential output, $s_g * y^\star$. The share s_g is taken as an average expenditure relative to the potential output in the period between 2014 and 2018, analogously to the revenue side. Given the described process for trend expenditures, the equations below provide the model behavior of the government-spending side.

Government purchases

$$\begin{aligned}\Delta gpur_t =& \Delta gpur_t^T - \underset{(0.180)}{0.890}(gpur_{t-1} - gpur_{t-1}^T) - \underset{(0.167)}{0.215}(\Delta gpur_{t-1} - \Delta gpur_{t-1}^T) \\ & - \underset{(0.110)}{0.249}(\Delta gpur_{t-2} - \Delta gpur_{t-2}^T) + \varepsilon_t^{pur}\end{aligned} \tag{C.44}$$

$\bar{R}2 = 0.94$ estimation sample = 1999Q4:2020Q1

$gpur$ - government purchases
$gpur^T$ - trend government purchases

$gcer$ - government wages
$gcer^T$ - trend government wages

Government wages

$$\begin{aligned}\Delta gcer_t =& \Delta gcer_t^T - \underset{(0.223)}{1.958}(gcer_{t-1} - gcer_{t-1}^T) + \underset{(0.173)}{0.589}(\Delta gcer_{t-1} - \Delta gcer_{t-1}^T) \\ & + \underset{(0.101)}{0.393}(\Delta gcer_{t-2} - \Delta gcer_{t-2}^T) + \varepsilon_t^{gcer}\end{aligned} \tag{C.45}$$

$\bar{R}2 = 0.89$ estimation sample = 1999Q4:2020Q1

$gcer$ - government wages
$gcer^T$ - trend government wages

Other government consumption
Other government consumption is calibrated and follows the smooth process described below:

$$GRCR_t = 0.125(GRCR_{t-1} + GRCR_{t-2} + GRCR_{t-3}) + 0.5 * GRCR_t^T + \varepsilon_t^{grcr} \quad \text{(C.46)}$$

The **total government consumption** (GCR) is then defined as the sum of the endogenous expenditure components defined above:

$$GCR_t = GPUR_t + GCER_t + GRCR_t \quad \text{(C.47)}$$

Beyond government consumption, the remainder of the total fiscal expenditures is composed of government investment, social benefits, government subsidies and interest rate expenditures.

Government investment

$$\begin{aligned}\Delta gitr_t =& \Delta gitr_t^T - \underset{(0.120)}{0.413}(gitr_{t-1} - gitr_{t-1}^T) - \underset{(0.133)}{0.214}(\Delta gitr_{t-1} - \Delta gitr_{t-1}^T) \\ &+ \underset{(0.118)}{0.095}(\Delta gitr_{t-2} - \Delta gitr_{t-2}^T) + \varepsilon_t^{gitr}\end{aligned} \quad \text{(C.48)}$$

$\bar{R}2 = 0.41$ estimation sample = 1999Q4:2020Q1

$gitr$ - government investment
$gitr^T$ - trend government investment

The deflator of government investment is assumed to mean revert around the weighted average of GDP and import deflator:

$$\Delta gitd_t = -\underset{(0.041)}{0.03}(gitd_{t-1} - (1 - 0.16)yed_{t-1} - 0.16mtd_t) + \varepsilon_t^{gitd} \quad \text{(C.49)}$$

$\bar{R}2 = 0.99$ estimation sample = 1999Q2:2020Q1

Social benefits in cash

$$\begin{aligned}\Delta gsbcn_t =& \Delta gsbcn_t^T - \underset{(0.210)}{1.315}(gsbcn_{t-1} - gsbcn_{t-1}^T) + \underset{(0.171)}{0.176}(\Delta gsbcn_{t-1} - \Delta gsbcn_{t-1}^T)\\ &+ \underset{(0.112)}{0.195}(\Delta gsbcn_{t-2} - \Delta gsbcn_{t-2}^T) + \varepsilon_t^{gsbcn}\end{aligned} \tag{C.50}$$

$\bar{R}2 = 0.97$ estimation sample = 1999Q4:2020Q1

$gsbcn$ - social benefits in cash
$gsbcn^T$ - trend social benefits in cash

Government subsidies

$$\begin{aligned}\Delta gsin_t =& \Delta gsin_t^T - \underset{(0.215)}{1.211}(gsin_{t-1} - gsin_{t-1}^T) + \underset{(0.165)}{0.196}(\Delta gsin_{t-1} - \Delta gsin_{t-1}^T)\\ &- \underset{(0.117)}{0.023}(\Delta gsin_{t-2} - \Delta gsin_{t-2}^T) + \varepsilon_t^{sin}\end{aligned} \tag{C.51}$$

$\bar{R}2 = 0.41$ estimation sample = 1999Q4:2020Q1

$gsin$ - government subsidies
$gsin^T$ - trend government subsidies

Nominal interest payable

$$\begin{aligned}GIPN_t =& 0.94(0.01\frac{GIPN_{t-1}}{DBN_{t-2}}DBN_{t-1})\\ &+ \alpha_{ipn}DBN_{t-1}(0.01\frac{GIPN_{t-1}}{DBN_{t-2}} + AIR_t) + \varepsilon_t^{gipn}\end{aligned} \tag{C.52}$$

$GIPN$ - interest rate payable
$GIPN^T$ - trend interest rate payable
DBN - nominal government debt
α_{ipn} - average share maturing within a given quarter

AIR - average of long-term soverign rate and short-term nominal rate

The **total nominal government expenditures**, TEN, are then given by:

$$TEN_t = GCON_t + GITN_t + GSBCN_t + GSIN_t + GIPN_t \tag{C.53}$$

where $GCON$ and $GITN$ represent nominal government consumption and investment, using respectively private consumption deflator (specified in C.65) and government investment deflator (specified in C.49).

Appendix C.6. Labor Market

The labor market block is centered around employment dynamics, which derives from the firm's optimization problem set up in Appendix B. Solving for the firm's optimal labor demand yields the following first order condition:

$$(1-\alpha)\frac{Y}{N}MC = W \tag{C.54}$$

α - Cobb-Douglas elasticity of substitution
Y - production output
MC - denotes the Lagrange multiplier related to technology constraint
W - denotes wages

The optimal condition provided above is in the model empirically approximated by:

$$n_t^{\star} = -0.15\hat{w}_t + n_t^T \tag{C.55}$$

where $\hat{w}$ denotes wage gap (specified in wage block) and n^T represents trend employment, which is modelled as:

$$N_t^T = LFP_t^T * WAP_t * (1 - U_t^t) \tag{C.56}$$

where WAP represents working age population, while LFP^T and U^T are trend labor-participation and unemployment rates, whose processes are specified as random walks with drifts.

The adjustment towards target employment is gradual and follows the PAC process:

$$\Delta n_t = \underset{(0.010)}{0.03}\,(n^{\star}_{t-1} - n_{t-1}) + \underset{(0.114)}{0.72}\,\Delta n_{t-1} + \underset{(0.025)}{0.08}\,\Delta \hat{y}_t + E_{t-1} \sum_{j=0}^{\infty} d_j \Delta n^{\star}_{t+j} + \varepsilon^n_t \tag{C.57}$$

$\bar{R}2 = 0.86$ estimation sample = 2008Q1:2018Q4

Appendix C.7. Wage-price-output_gap nexus

The core domestic price measure in the model is the GDP deflator, which is modelled via the following New-Keynesian Phillips Curve specification:

$$\pi_t = (\underset{(0.08)}{0.39}\,\pi_{t-1} + \underset{(0.02)}{0.12}\,(\hat{w}_t + 0.44\hat{y}_t) + \underset{(0.07)}{0.63}\,E\pi_{t+1} + (1 - \underset{(0.07)}{0.63})(1 - \underset{(0.08)}{0.39})\bar{\pi}_t)/ (1 + \underset{(0.07)}{0.63} \times \underset{(0.08)}{0.39}) + \varepsilon^{\pi}_t \tag{C.58}$$

π - annual GDP deflator inflation
$\hat{w}$ - wage gap
$\hat{y}$ - output gap
π_{t+1} - VAR-based one-period-ahead inflation prediction
$\bar{\pi}$ - long-term inflation expectations

The inflation dynamics specified above is in the long term attracted by long-term inflation expectations, which evolve as a combination of inflation in the previous period and the central bank's target, $\pi^{\star}$:

$$\bar{\pi}_t = 0.75\bar{\pi}_{t-1} + 0.25 * (0.4\pi_{t-1} + 0.6\pi^{\star}) \tag{C.59}$$

Similar to the price inflation, the wage dynamics takes the following New-Keynesian

Phillips Curve specification:

$$\hat{w}_t = (0.3\hat{w}_{t-1} + \underset{(0.043)}{0.41} E\hat{w}_{t+1} - \underset{(0.045)}{0.39} \times (1 + \underset{(0.043)}{0.41})\hat{\pi}_t + \underset{(0.045)}{0.39} \hat{\pi}_{t-1})/(1 + \underset{(0.045)}{0.39} \times \underset{(0.043)}{0.41}) - \underset{(0.045)}{0.39} \hat{u}_{t-1} + \varepsilon_t^{\hat{w}} \tag{C.60}$$

$\hat{w}$ - real wage gap
$\hat{w}_{t+1}$ - VAR-based one-period-ahead wage gap forecast
$\hat{\pi}$ - inflation gap characterized with respect to the 2% inflation target
$\hat{u}$ - VAR-based one-period-ahead inflation prediction

The Phillips curve specifications for price and wage inflations essentially hinge on gap categories associated with output, unemployment and wage inflation. The following describes the corresponding trend categories of these variables. Starting with the output, its potential stems from the Cobb-Douglas production function and takes the following form:

$$\bar{y}_t = \bar{a}_t + 0.33skr_t + (1 - 0.33)n_t^T + \varepsilon_t^{\bar{Y}} \tag{C.61}$$

$\bar{a}$ - log trend total factor productivity
skr - log real aggregate capital stock
n^T - trend employment

While trend employment is defined in Appendix C.6 of this appendix, trend total factor productivity is assumed to grow at a quarterly rate of 0.3% in line with the calibration set forth in Angelini et al. (2019):

$$\bar{A}_t = 1.012^{\frac{1}{4}} \bar{A}_{t-1} \tag{C.62}$$

The real stock of capital follows a standard law of motion:

$$SKR_t = (1-\delta)SKR_{t-1} + ITR_t \tag{C.63}$$

δ - capital depreciation rate set at 1.3%
ITR - aggregate real investment

Finally, the wage gap is characterized around the long-run real wage trend that evolves in line with the potential output and trend employment:

$$w_t^T = -0.5 + \bar{y}_t - n_t^T \tag{C.64}$$

Appendix C.8. Demand deflators

Deflators related to particular demand components are modelled within a classical error-correction framework. In the long-run, deflators are expected to move in line with the weighted average of domestic and import prices, whereby weights are calibrated based on the import-content of a particular demand component. The short-run dynamics is characterized by the mean reversion process associated with the long-run target and dynamic homogeneity associated with the GDP deflator inflation described by the Phillips curve in the previous subsection of this appendix.

Household consumption deflator

Long-run equation:

$$pcd_t^{\star} = -\underset{(0.006)}{0.04} + (1-0.32)yed_t + 0.32mtd_t + \underset{(0.000)}{0.000}T - \underset{(0.004)}{0.009}D + \varepsilon_t^{pcd^{\star}} \tag{C.65}$$

$\bar{R}2 = 0.99$ estimation sample = 2000Q1:2018Q4

$pcd^{\star}$ - long-run private consumption deflator
yed - gdp deflator
mtd - total import deflator

d - shift dummy taking value of 1 in period 2008Q4-2018Q4

Short-run equation:

$$\begin{aligned}\Delta pcd_t = &- \underset{(0.078)}{0.25}\,(pcd_{t-1} - pcd^{\star}_{t-1}) + \underset{(0.114)}{0.43}\,\Delta yed_t + \underset{(0.435)}{0.05}\,\Delta mtd_t \\ &+ (1 - \underset{(0.114)}{0.43} - \underset{(0.435)}{0.05})yed_{t-1} + \varepsilon^{pcd}_t\end{aligned} \tag{C.66}$$

$\bar{R}2 = 0.50$ estimation sample = 2000Q3:2018Q4

Business investment deflator

Long-run equation:

$$ibd^{\star}_t = - \underset{(0.020)}{0.01} + (1 - 0.39)yed_t + 0.39mtd_t + \underset{(0.000)}{0.000}T - \underset{(0.008)}{0.007}d + \varepsilon^{ibd^{\star}}_t \tag{C.67}$$

$\bar{R}2 = 0.97$ estimation sample = 2000Q1:2018Q4

$ibd^{\star}$ - long-run business investment deflator
yed - gdp deflator
mtd - total import deflator
d - d - shift dummy taking value of 1 in period 2008Q4-2018Q4

Short-run equation:

$$\begin{aligned}\Delta ibd_t = &- \underset{(0.134)}{0.54}\,(ibd_{t-1} - ibd^{\star}_{t-1}) + \underset{(0.29)}{1.55}\,\Delta yed_t - \underset{(0.109)}{0.21}\,\Delta ibd_{t-1} \\ &+ (1 - \underset{(0.29)}{1.55} - \underset{(0.109)}{0.21})yed_{t-1} + \varepsilon^{ibd}_t\end{aligned} \tag{C.68}$$

$\bar{R}2 = 0.48$ estimation sample = 2000Q3:2018Q4

Residential investment deflator

Long-run equation:

$$ihd_t^{\star} = -\underset{(0.011)}{0.36} + (1 - 0.39)yed_t + 0.39mtd_t + \underset{(0.000)}{0.003}T - \underset{(0.008)}{0.004}d + \varepsilon_t^{ihd^{\star}} \tag{C.69}$$

$\bar{R}2 = 0.99$ estimation sample = 2000Q1:2018Q4

$ihd^{\star}$ - long-run residential investment deflator
yed - gdp deflator
mtd - total import deflator
d - d - shift dummy taking value of 1 in period 2008Q4-2018Q4

Short-run equation:

$$\begin{aligned}\Delta ihd_t = &- \underset{(0.036)}{0.06}(ihd_{t-1} - ihd_{t-1}^{\star}) + \underset{(0.149)}{0.14}\Delta yed_t + \underset{(0.049)}{0.27}\Delta mtd_t \\ &+ \underset{(0.105)}{0.36}\Delta ihd_{t-1} + (1 - \underset{(0.29)}{1.55} - \underset{(0.109)}{0.21})yed_{t-1} + \varepsilon_t^{ihd}\end{aligned} \tag{C.70}$$

$\bar{R}2 = 0.46$ estimation sample = 2000Q3:2018Q4

Appendix C.9. HICP block

In the model, the primary real-nominal interaction is established through demand deflators. While the HICP block follows similar modelling principles as laid out for demand deflators, it nevertheless serves for reporting purposes only and does not propagate into other model blocks. The HICP block is built in the bottom-up fashion by specifying first respective dynamics for HICP energy and HICP excluding energy. The headline HICP is then constructed as a weighted sum of HICP energy and HICP excluding energy, where weights are calibrated on the basis of the energy content of private consumption.

HICP energy

Long-run equation:

$$heg^{\star}_t = -\underset{(0.010)}{0.41} + \underset{(0.004)}{0.27}\, med_t + \underset{(0.000)}{0.007}T - \underset{(0.022)}{0.05}\, D + \varepsilon^{heg^{\star}}_t \quad \text{(C.71)}$$

$\bar{R}2 = 0.93$ estimation sample = 2000Q1:2018Q4

$heg^{\star}$ - long-run HICP energy
med - euro denominated energy deflator

Short-run equation:

$$\Delta heg_t = -\underset{(0.021)}{0.02}\,(heg_{t-1} - heg^{\star}_{t-1}) + \underset{(0.016)}{0.18}\,(\Delta med_t - \bar{\pi}_t) + \underset{(0.016)}{0.18}\,(\Delta med_{t-1} - \bar{\pi}_{t-1}) + \varepsilon^{heg}_t \quad \text{(C.72)}$$

$\bar{R}2 = 0.79$ estimation sample = 2007Q4:2018Q4

HICP excluding energy

Long-run equation:

$$hex^{\star}_t = \underset{(0.002)}{0.14} + 0.78 yed_t + 0.22 hif_t - \underset{(0.000)}{0.000}T - \underset{(0.004)}{0.007}D + \varepsilon^{hex^{\star}}_t \quad \text{(C.73)}$$

$\bar{R}2 = 0.99$ estimation sample = 2001Q1:2018Q4

$hex^{\star}$ - long-run HICP excluding energy
yed - gdp deflator
hif - HICP food

Short-run equation:

$$\Delta hex_t = -\underset{(0.122)}{0.16}(hex_{t-1} - hex^{\star}_{t-1}) + \underset{(0.098)}{0.37}\Delta yed_t + \underset{(0.101)}{0.10}\Delta yed_{t-1} + \varepsilon^{hex}_t \tag{C.74}$$

$\bar{R}2 = 0.24$ estimation sample = 2007Q4:2018Q4

HICP excluding energy and food

Long-run equation:

$$hef^{\star}_t = \underset{(0.003)}{0.05} + (1 - 0.32)yed_t + 0.32mtdx_t - \underset{(0.000)}{0.000}T - \underset{(0.006)}{0.012}d + \varepsilon^{hef^{\star}}_t \tag{C.75}$$

$\bar{R}2 = 0.97$ estimation sample = 2001Q1:2018Q4

$hef^{\star}$ - long-run HICP excluding energy&food
$mtdx$ - import deflator excluding energy

Short-run equation:

$$\Delta hef_t = -\underset{(0.049)}{0.04}(hef_{t-1} - hef^{\star}_{t-1}) + \underset{(0.098)}{0.379}\Delta yed_t + \underset{(0.098)}{0.21}\Delta yed_{t-1} + \varepsilon^{hef}_t \tag{C.76}$$

$\bar{R}2 = 0.24$ estimation sample = 2007Q4:2018Q4

HICP headline:

$$HICP_t = we \times HEG_t + (1 - we) \times HEX_t + \varepsilon^{hicp}_t \tag{C.77}$$

where we is set at 0.09 and represents a weight of energy component in the HICP.
HICP food:

$$HICP_t = 0.09HEG_t + (1 - 0.09)HEX_t + \varepsilon^{hicp}_t \tag{C.78}$$

$$HIF_t = ((1 - we)HEG_t + (1 - we - wf)HEF_t)/wf + \varepsilon_t^{hif} \tag{C.79}$$

where wf is set at 0.19 and represents a weight of the HICP food component in the HICP.

Appendix C.10. Financial block

The financial block defines financing conditions for economic subjects in Slovenia. The financing conditions are built sequentially, starting first from the risk-free euro area yield curve to characterizing Slovene-specific spreads on government and private sector financing in the ensuing steps (see Figure 3.3). The construction of the risk-free yield curve stems from term-structure expectation theory, whereby a yield of particular maturity reflects the average expected short rate path and the term-premium (Krippner (2015)). Modeling of the short-rate is based on the euro-area monetary policy rule as defined in the New-Area Wide Model (Christoffel et al. (2008)):

$$STN_t = 0.89STN_{t-1} + (1-0.89)(r^\star + \bar{\pi}_t) + (1-0.89)(1.83\hat{\pi}_t) + 0.16\Delta\pi_t + 0.08\Delta\hat{y}_t + \varepsilon_t^{stn} \tag{C.80}$$

where STN is the euro-area short-term nominal rate, in data observed as 3-month Euribor rate, and $r^\star$ is set at 1.2 and represents a real natural rate.

In the model, the risk-free term-structure is characterized by the short rate and the 10-year risk-free Eonia rate (long-term rate, LTN), which in line with the expectation theory is modelled as a combination of average short-rate projections over 40-quarters horizons and the 10-year term-premium:

$$LTN_t = \frac{1}{40}\sum_{z=0}^{40-1} STN_{t+z} + TP_t + \varepsilon_t^{ltn} \tag{C.81}$$

where $\frac{1}{40}\sum_{z=0}^{40-1} i_{t+z,0}$ average of STN projections produced by the Base-VAR expectation model and TP denotes the 10-year term-premium associated with Eonia rate, which is modelled in the following way:

$$TP_t = \underset{(0.078)}{0.15} + \underset{(0.107)}{0.67}\, TP_{t-1} - \underset{(0.160)}{0.11}\, \frac{1}{40} \sum_{z=0}^{m-1} \hat{y}_{t+z} + \underset{(0.089)}{0.25}\, TP^{us}_{t-1} + \varepsilon^{tp}_t \qquad \text{(C.82)}$$

$\bar{R}2 = 0.91$ estimation sample = 2008Q1:2018Q4

$\frac{1}{40}\sum_{z=0}^{m-1} \bar{y}_{t+z}$ - average Base-VAR projections of output gap for 1- to 40-quarters ahead
TP^{us} - US term premium, modelled as a simple AR(1) process

The upstream financing condition indicator for Slovenia is represented in the model by the 10-year government bond yield, which is modelled as the sum of the long-term risk-free rate and a country premium.

$$YRB10Y_t = LTN_t + CP_t \qquad \text{(C.83)}$$

where the country-premium is modelled as a function of expected output gap and evolution of fiscal debt and deficit variables:

$$CP_t = \underset{(0.683)}{0.93} + \underset{(0.164)}{0.74}\, CP_{t-1} - \underset{(0.098)}{0.03}\, \frac{1}{40} \sum_{z=0}^{m-1} \hat{y}_{t+z} + \underset{(0.017)}{0.005} DBY_t + \underset{(0.017)}{0.005} DFY_t + \varepsilon^{cp}_t \qquad \text{(C.84)}$$

$\bar{R}2 = 0.87$ estimation sample = 2008Q2:2018Q4

DBY - debt-to-nominal GDP ratio
DFY - deficit-to-nominal GDP ratio

Financing conditions relevant for the private sector are then characterized as a combination of the risk-free short rate (STN), 10-year Slovenian bond yield ($YRB10Y$) and respective risk-spread associated with particular funding type. The respective weights assigned to STN and $YRB10Y$ are calibrated based on the ratio between short-run (up to 1 year) and long-term liabilities (beyond 1 year), derived from the Monetary Financial Statistics. The following presents equations of lending rates and corresponding modeling specifications for spreads.

Lending rate for loans to non-financial corporations

$$LRN_t = (1 - 0.75)STN_t + 0.75YRB10Y_t + SLRN_t + \varepsilon_t^{lrn} \tag{C.85}$$

where $SLRN$ represents a credit spread related to loans to non-financial corporations. The dynamic of the spread stems from the following estimation:

$$SLRN_t = \underset{(0.034)}{0.53} + \underset{(0.017)}{0.63} SLRN_{t-1} - \underset{(0.009)}{0.14} \frac{1}{40} \sum_{z=0}^{m-1} \hat{y}_{t+z} + \varepsilon_t^{slrn} \tag{C.86}$$

$\bar{R}2 = 0.41$ estimation sample = 2007Q4:2018Q4

Lending rate for consumer loans

$$LPC_t = (1 - 0.67)STN_t + 0.67YRB10Y_t + SLPC_t + \varepsilon_t^{lpc} \tag{C.87}$$

where $SLRN$ represents a credit spread related to consumer loans. The dynamic of the spread stems from the following estimation:

$$SLPC_t = \underset{(0.072)}{0.40} + \underset{(0.005)}{0.90} SLPC_{t-1} - \underset{(0.008)}{0.15} \frac{1}{40} \sum_{z=0}^{m-1} \hat{y}_{t+z} + \varepsilon_t^{slpc} \tag{C.88}$$

$\bar{R}2 = 0.80$ estimation sample = 2007Q4:2018Q4

Lending rate on mortgage loans

$$LIH_t = (1 - 0.97)STN_t + 0.97YRB10Y_t + SLIH_t + \varepsilon_t^{lih} \tag{C.89}$$

where $SLIH$ represents a credit spread related to mortgage loans. The dynamic of the spread stems from the following estimation:

$$SLIH_t = \underset{(0.013)}{0.04} + \underset{(0.007)}{0.94} SLIH_{t-1} - \underset{(0.008)}{0.16} \frac{1}{40} \sum_{z=0}^{m-1} \hat{y}_{t+z} + \varepsilon_t^{slih} \tag{C.90}$$

$\bar{R}2 = 0.80$ estimation sample = 2007Q4:2018Q4

Corporate bond rate

$$CBR_t = (1 - 0.99)STN_t + 0.99YRB10Y_t + SCBR_t + \varepsilon_t^{cbr} \tag{C.91}$$

where $SCBR$ represents a spread on corporate bond financing. The dynamics of the spread stems from the following estimation:

$$SCBR_t = \underset{(0.018)}{-0.006} + \underset{(0.006)}{0.93} SCBR_{t-1} - \underset{(0.007)}{0.12} \frac{1}{40} \sum_{z=0}^{m-1} \hat{y}_{t+z} + \varepsilon_t^{scbr} \tag{C.92}$$

$\bar{R}2 = 0.80$ estimation sample = 2007Q4:2018Q4

Cost of equity

$$COE_t = (1 - 0.84)STN_t + 0.84YRB10Y_t + SCOE_t + \varepsilon_t^{coe} \tag{C.93}$$

where $SCOE$ represents a spread related to equity financing. The dynamic of the spread stems from the following estimation:

$$SCOE_t = \underset{(0.517)}{0.54} + \underset{(0.058)}{0.96} SCOE_{t-1} - \underset{(0.277)}{0.15} \frac{1}{40} \sum_{z=0}^{m-1} \hat{y}_{t+z} + \varepsilon_t^{scoe} \tag{C.94}$$

$\bar{R}2 = 0.87$ estimation sample = 2007Q4:2018Q4

Deposit rate

$$DPR_t = (1 - 0.84)STN_t + 0.84YRB10Y_t + SDPR_t + \varepsilon_t^{dpr} \tag{C.95}$$

where $SDPR$ represents a return on household deposits over the risk-free component. The dynamics of the deposit return stems from the following estimation:

$$SDPR_t = \underset{(0.007)}{0.21} + \underset{(0.012)}{0.66} SDPR_{t-1} - \underset{(0.006)}{0.22} \frac{1}{40} \sum_{z=0}^{m-1} \hat{y}_{t+z} + \varepsilon_t^{sdpr} \tag{C.96}$$

$\bar{R}2 = 0.81$ estimation sample = 2007Q4:2018Q4

Appendix C.11. Net financial assets

Net foreign assets are in the model assumed to grow in line with the trade balance and a revaluation term encompassing net interest income on foreign assets, exchange rate and relative prices:

$$\Delta NFA_t = XTN_t - MTN_t + rNFA_t; \tag{C.97}$$

where the revaluation term, $rNFA$, is expressed in terms of nominal GDP and follows the process defined below:

$$\begin{aligned} rNFA_t = &- \underset{(0.009)}{0.05} + \underset{(0.038)}{0.11} (\Delta IR_t^{fl} - \Delta IR_t^{fa}) - \underset{(1.806)}{2.56} \Delta eenx_t - \\ &\underset{(1.584)}{2.02} \Delta yed_t + \underset{(1.894)}{0.806} \Delta cxd_t + \varepsilon_t^{nfa} \end{aligned} \tag{C.98}$$

$\bar{R}2 = 0.27$ estimation sample = 2004Q2:2018Q4

IR^{fl} - interest rate on foreign liabilities
IR^{fa} - interest rate on foreign assets
$eenx$ - nominal effective euro exchange rate
yed - GDP deflator
cxd - competitors' export prices

Interest rates on foreign assets and liabilities are expected to co-move with foreign and domestic long-term rates:

$$IR^{fl} = - \underset{(0.357)}{4.13} + \underset{(0.099)}{0.02} LTN_t^{US} + \varepsilon_t^{ltnus} \tag{C.99}$$

$\bar{R}2 = 0.05$ estimation sample = 2004Q1:2018Q4

LTN^{US} - long-term rate on US 10-year treasury

$$IR^{fa} = - \underset{(0.096)}{5.54} + \underset{(0.104)}{0.03} YRB10Y_t + \varepsilon_t^{yrb} \tag{C.100}$$

$\bar{R}2 = 0.25$ estimation sample = 2004Q1:2018Q4

Appendix C.12. Property income and wealth

Apart from labor income and social transfers, the household consumption additionally depends on property and wealth incomes. In line with the non-financial sector accounts, the property income is comprised of gross operating surplus, interest income and dividends.[12] The household gross operating surplus is modelled relative to the nominal GDP and is primarily characterized in terms of housing capital income:

$$\frac{GOS_t}{Y_t^N} = \underset{(0.000)}{0.008}\frac{SKHR_t \times IHD_t}{Y_t^N} + \underset{(0.003)}{0.004}\frac{RPPI_t}{PCD_t} + \varepsilon_t^{gos} \tag{C.101}$$

$\bar{R}2 = 0.83$ estimation sample = 2005Q1:2018Q4

GOS - household gross operating surplus
$SKHR$ - real housing capital stock
RPP - residential property price index

The net interest income of household is modelled relative to GDP and is governed by its own persistence, net foreign asset position, general level of interest rates, and spread between deposit and mortgage rate:

$$\begin{aligned}\frac{IRN_t}{Y_{t-1}^N} =& -\underset{(0.003)}{0.001} + \underset{(0.117)}{0.387}\frac{IRN_{t-1}}{Y_{t-2}^N} - \underset{(0.097)}{0.052}\frac{NFA_{t-1}}{Y_{-1}^N} \\ &+ \underset{(0.000)}{0.001}STN + \underset{(0.000)}{0.0003}(LIH_t - DPR_t) + \underset{(0.000)}{0.000}T + \varepsilon_t^{irn}\end{aligned} \tag{C.102}$$

$\bar{R}2 = 0.58$ estimation sample = 2006Q1:2018Q4

IRN - net interest income

[12]According to the non-financial sector accounts, property income includes additional components (e.g. reinvested earnings), which remain unmodelled in this model.

NFA - net financial assets
LIH - mortgage rate
DPR - deposit rate
STN - short-term nominal rate

Modelling of the dividend income follows the PAC framework. In the long-run it is assumed that the real dividend income aligns with its estimated mean historical fraction of the gross operating surplus:

$$ddr_t^{\star} = -\underset{(0.120)}{3.26} + (gos_t - pcd_t) - \underset{(0.002)}{0.003}T + \underset{(0.064)}{0.113}D + \varepsilon_t^{ddr^{\star}} \tag{C.103}$$

$\bar{R}2 = 0.58$ estimation sample = 2005Q1:2018Q4

ddr - real dividend income
gos - gross operating surplus of households
pcd - private consumption deflator

In the short-run, the dividends income adjusts towards the long-term target following the PAC dynamics:

$$\begin{aligned}\Delta ddr_t = & \underset{(0.023)}{0.05}\,(ddr_{t-1}^{\star} - ddr_{t-1}) + \underset{(0.757)}{0.14}\,\Delta ddr_{t-1} + \underset{(0.204)}{0.42}\,\Delta ddr_{t-2} - \\ & \underset{(0.139)}{0.39}\,\Delta ddr_{t-3} + E_{t-1}\sum_{j=0}^{\infty} d_j \Delta ddr_{t+j}^{\star} + \varepsilon_t^{ddr}\end{aligned} \tag{C.104}$$

$\bar{R}2 = 0.85$ estimation sample = 2008Q2:2018Q4

Appendix C.13. House prices

Modelling of real house prices follows the PAC framework. In the long-run, real house prices are positively related to the excessive demand indicator, reflected by a ratio between real household disposable income and real housing stock and inversely related to user cost of property ownership:

$$rppi_t^\star = \underset{(0.775)}{2.34} + \underset{(0.045)}{0.002}(dir_t - skhr_t) - \underset{(0.285)}{0.873}uc_t^{skhr} \tag{C.105}$$

$\bar{R}2 = 0.23$ estimation sample = 2007Q3:2018Q4

ddr - real residential property price index
dir - real disposable household income
$skhr$ - housing capital stock
uc^{skhr} - user cost of property ownership

The user cost of property ownership is characterized by the mortgage rate, specified in Appendix C.10, and expected house price growth:

$$UC_t^{skhr} = 0.34 + (LIH_t - \bar{\pi}_t) + \tau_t^{skhr} - 0.4E_t\Delta RPPI_t \tag{C.106}$$

LIH - mortgage rate
τ^{skhr} - tax rate on housing capital
$E\Delta RPPI$ - expected house price growth approximated by a 16-quarters moving average of real quarterly house price growth

In the short-run, house prices adjust to their long-run equilibrium following the PAC dynamic:

$$\Delta rppi_t = \underset{(0.031)}{0.11}(rppi_{t-1}^\star - rppi_{t-1}) + \underset{(0.113)}{0.34}\Delta rppi_{t-1} + E_{t-1}\sum_{j=0}^{\infty} d_j \Delta rppi_{t+j}^\star + \varepsilon_t^{rpp} \tag{C.107}$$

$\bar{R}2 = 0.29$ estimation sample = 2008Q4:2018Q4

Appendix C.14. Inventories

Stock of real inventories evolve around a trend share of real inventories to GDP. The trend share is observed in data as an HP filtered series of real inventories to GDP and in modelling terms is specified as:

$$T\_Y\_SIVR_t = T\_Y\_SIVR_{t-1} + 0.005(Y\_SIVR_t - T\_Y\_SIVR_{t-1}) \tag{C.108}$$

T_Y_SIVR - trend share of stock of inventories to GDP
Y_SIVR - stock of real inventories to GDP ratio

The modelling specification assumes a gradual adjustment of stock of real inventories to the trend share, encapsulated by the following error correction specification:

$$\begin{aligned} \Delta sivr_t = & \underset{(0.027)}{0.09}(t\_y\_sivr_{t-1} - y\_sivr_{t-1}) + \underset{(0.071)}{0.69}\Delta sivr_{t-1} \\ & + (1 - \underset{(0.071)}{0.69})\Delta y_{t-1} + \varepsilon_t^{sivr} \end{aligned} \tag{C.109}$$

$\bar{R}2 = 0.70$ estimation sample = 2005Q3:2018Q4

Appendix C.15. Identities and model closure

This sections presents the most important identities and accounting that provides coherence from the perspective of the System of National Accounts, consistency between real and nominal categories, and other block-specific closing conditions. To emulate the national accounts representation, the model identities provide the expenditure side of the economy, production of goods and services, and generation and allocation of income.

The **demand** side of the economy is closed by the chain-linked expression for the real GDP growth:

$$\begin{aligned}\Delta y_t =& 0.53\Delta c_t + 0.11\Delta ib_t + 0.05\Delta ih_t + 0.17\Delta gcr_t + 0.03\Delta gir_t \\ & + 0.41\Delta xtr_t - 0.36\Delta mtr_t + 0.40\Delta sivr_t - 0.40\Delta sivr_{t-1} + \varepsilon_t^y\end{aligned} \tag{C.110}$$

Where the weights in C.110 are derived as average contributions to the real GDP growth between 2005 and 2022. The nominal counterparts of the GDP and its expenditure sub-components are derived via their respective deflators.

$$CN_t = C_t \times PCD_t \tag{C.111}$$

$$IBN_t = IB_t \times IBD_t \tag{C.112}$$

$$IHN_t = IH_t \times IHD_t \tag{C.113}$$

$$GCN_t = GCR_t \times PCD_t \tag{C.114}$$

$$GITN_t = GITR_t \times GITD_t \tag{C.115}$$

$$XTN_t = XTR_t \times XTD_t \tag{C.116}$$

$$MTN_t = MTR_t \times MTD_t \tag{C.117}$$

and nominal GDP as:

$$Y_t^N = Y_t \times YED_t \tag{C.118}$$

The **supply** side of the economy has been derived from the Cobb-Douglass production function, which yields an expression for the potential output given by equation C.61. In the short-run, the model allows for temporary deviations between the demand and supply sides, so that:

$$Y \neq \bar{Y} \tag{C.119}$$

Finally, the **income** side of the economy aggregates revenues generated within the production process, that is compensation allocated to labor (CEN), gross operating surplus and mixed income ($GOSMIN$), and tax revenues related to domestic production and imports (TIN):

$$Y_t^N = CEN_t + GOSMIN_t + TIN_t \tag{C.120}$$

The process for real compensation per employee is derived from the wage Phillips curve, given by equation C.60. The total aggregate compensation allocated to labor is then given as nominal compensation per employee times total employment:

$$CEN_t = C\_CER_t \times PCD_t \times N_t \tag{C.121}$$

Given the implicit tax and social contribution rates provided in Appendix C.5, the aggregate compensation then provides a revenue base for social contributions paid by employees and direct taxes collected associated with labor income:

$$SCN_t = R\_SCN_t^{HH} \times CEN_t \tag{C.122}$$

$$DTN_t = R\_SCN_t^{HH} \times CEN_t \tag{C.123}$$

Similarly, the indirect taxes collected by the government are given by the implicit tax rate, defined in Appendix C.5, and household nominal consumption:

$$TIN_t = R\_TIN_t \times CN_t \tag{C.124}$$

Given the nominal output, aggregate compensations and indirect taxes collected, the residual term represents the economy's total gross operating surplus and mixed income:

$$GOSMIN_t = Y_t^N - CEN_t - TIN_t \tag{C.125}$$

A shift from domestic to gross national income can then be provided by accounting for net property income:

$$GNI_t = Y_t^N + NPI_t \tag{C.126}$$

Given that in the model the net property income, NPI, is only derived for the household sector, the full account of the income side is only provided for households. In this regard, the household equivalent for GNI is given by the gross balance of personal income, $GBPI$:

$$GBPI_t = CEN_t + GOSMIN_t^{HH} + NPI_t^{HH} \tag{C.127}$$

where NPI^{HH} is given by net interest and dividends incomes provided in Appendix C.12:

$$NPI_t^{HH} = IRN_t \times PCD_t + DDR_t \times PCD_t \tag{C.128}$$

Adjusting gross balance of personal income of direct taxes and social contributions then yields gross disposable income of households:

$$GDI_t^{HH} = GBPI_t - SCN_t - DTN_t \tag{C.129}$$