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Gap Model of the Visegrad Group

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Abstract

We propose a medium scale gap model of the Visegrad Group that incorporates core macroeconomic variables as aggregate demand, aggregate supply, interest rates, exchange rates and unemployment rates and is further enriched by a fiscal block. The model takes a form of global projection model, since it describes mutual linkages between the economies and their most important trading partner, the economy of the euro area. Although it is provided in mostly linear form and not properly derived from micro-foundations as dynamic stochastic general equilibrium models, the combination of relatively simple structure together with plausible impulse responses makes the model suitable for a policy analysis. Furthermore, since we model all trading partners as endogenous, we can capture spillovers between the economies and their final impact on macroeconomic outcomes. Finally, the enrichment for a fiscal block makes the model applicable for fiscal simulations.

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1 Introduction

There is a number of different modelling approaches applied by central banks and economic analysts across the world to simulate and forecast macroeconomic behaviour. The toolkit varies from simple vector autoregressive (VAR) models and structural econometric (ECM) models, which are mostly applied for forecasting purposes, to complex dynamic stochastic general equilibrium (DSGE) models, which are widely used for policy simulations. In this paper, we aim to find a trade-off between macroeconomic fundamentals, proper impulse responses and plausible historical projections that is mostly provided by gap models. In general, we can define a gap model as a macroeconomic model of unobserved gaps, i.e. differences between actual values of macroeconomic variables and their potential counterparts, that is based on a small number of behavioural equations to reflect the macroeconomic fundamentals and underlying stochastic processes to pin down the potential variables. It is important to note that these models are in the form of general equilibrium and can thus simultaneously determine values of all unobserved gaps. Furthermore, since they are usually based on quarterly data and often incorporate mutual linkages between economies, the gap models are also referred to as quarterly projection models (QPM) or global projection models (GPM).

The linear form of these models is in contrast to the DSGE models that are based on agents' utility maximization what eventuates into highly nonlinear systems that need to be approximated to be solved.[1] Furthermore, although the micro-foundations of these models are incomparable with those of the DSGE models, their simple structure together with identification restrictions produce impulse responses that are in line with standard theoretical predictions and thus over-perform, for instance, the VAR models. In addition, it is fairly convenient to extend these models by other sectors and countries.

Our model focuses on the economies of the Visegrad Group, i.e. Poland, Czechia, Hungary and Slovakia, that further interact with the economy of the euro area. While a core structure of the model is based on Carabenciov et al. (2008), we provide some important extensions of the original research. First, we enrich the model by a fiscal block and thus capture (i) a pass-through of a fiscal policy to a real economy and (ii) an empirical impact of a public debt on a set of potential variables. Second, we distinguish between different types of risk premiums and treat them as endogenous allowing for (i) an imperfect control of a monetary authority over money markets, (ii) additional spillovers between the economies that are based on interactions of interbank premiums and (iii) an empirical impact of risk premiums on potential and cyclical components of a domestic output. Furthermore, we incorporate yields on government bonds with 10-year maturity to approximate a term structure of interest rates and thus reflect the expectations of investors on financial markets.

Finally, we extend the model for emerging economies of the Visegrad Group and allow for (i) the potential convergence of emerging economies and (ii) the stochastic targets of monetary authorities, in line with Carabenciov et al. (2013). However, the model still distinguishes from a fully structural model, since we do not incorporate such important components as increasing trade openness, increasing production quality or different inflationary pressures on prices of goods and services, because the implementation of these components would require to model off-balanced growth in a complex way and is behind the scope of this paper. We further abstract from (i) the identification of productivity shocks that are driven by the investors with great market shares and (ii) the identification of one-off shocks that are typical for output and inflation dynamics in small open economies. Of course, if the model is applied for forecasting purposes, we will need to exogenize and properly identify these shocks.

[1] See for example Smets and Wouters (2003) for the model of the euro area or Gali and Monacelli (2005) for its modification for a small open economy. From the perspective of domestic research, we should mention the model by Zeman and Senaj (2009) and the model by Múčka and Horváth (2015) with macro-fiscal interactions.

Since the Visegrad countries are not only the important trading partners to each other but also share the same historical development, it is reasonable to decompose this region into particular economies to capture spillovers from one country to another. On the other hand, the importance of a fiscal policy in the post-crisis years motivated us to extend the model for a fiscal block. We can thus distinguish between (i) short-run cyclical development of model variables that is mostly driven by macroeconomic shocks and a monetary policy, although a fiscal policy also matters, and (ii) long-run structural development of model variables that is pinned down by the decisions of fiscal authorities and their impact on potential outcomes. Finally, even though the model is not constructed for forecasting purposes, it can be applied as a control method to standard forecasting models.

The paper is structured as follows. First, we provide a literature review with a focus on the advantages of our solution. Second, we define a structure of model equations, outline the data that were applied and describe technical aspects of the model. Third, we discuss the model parametrisation that consists of calibration as well as Bayesian estimation. Finally, we evaluate the model with a set of impulse response functions, provide a historical projection of model variables and simulate alternative policies and consolidation scenarios.

2 Related literature

Our model is mainly inspired by the work of Carabenciov et al. (2008) that presents a global projection model of three big economies: United States, European Union and Japan. All these economies are described by five behavioural equations that pin down aggregate demand, aggregate supply, interest rates, exchange rates and unemployment rates. Financial markets are closed by potential exchange rates, which are based on simple random walks, and target inflation rates, which are set as constant values. Later on, Carabenciov et al. (2013) proposed an extension of the original model for a group of emerging economies that allows also for (i) the potential convergence of emerging economies and (ii) the stochastic targets of monetary authorities. This model further operates with a country premium that results from an uncovered interest parity (UIP) and is thus defined as a simple difference between potential interest rates of respective economies that is adjusted for the potential convergence. Implicitly, this model assumes a perfect control of a monetary authority over money markets.

In contrast, a quarterly projection model of Andrle et al. (2014), which focuses on interactions between Polish and European economies, incorporates both country and interbank premiums and treats them as endogenous. The polish premium further responds to financial shocks in the euro area and thus captures the spillovers between these economies on financial markets. In addition, the authors model a pass-through of interbank premiums to market interest rates that influence consumption and investment decisions. This model thus assumes an imperfect control of a monetary authority over money markets.

We apply a similar approach with few exceptions. First, while we model the interbank premium as a cyclical variable that reflects short-term expectations about a monetary policy and affects the output gap, the country premium operates as a potential variable that reflects short-term expectations about a fiscal policy and affects the potential output. Second, we define a credit premium on government bonds that reflects long-term expectations about a fiscal policy and affects the potential output. Finally, we assume that both country and credit premiums respond to a deviation of a public debt from its optimal market value and thus approximate an empirical impact of fiscal variables on potential outcomes.

There are numerous other papers that are related to our work at least indirectly, for example a quarterly projection model of Beneš et al. (2002) that was formerly applied by the Czech National Bank (CNB), a monetary policy model of the Hungarian National Bank (MNB) that was developed by Szilágyi et al. (2013), the model of Beneš et al. (2008) that explores an exchange rate management in the Czech economy and the model of Lyziak (2016) that explores the role of inflation expectations in the Polish economy. From the perspective of domestic research, we should mention a quarterly projection model of Gavura and Reľovský (2005) that is based on a small number of behavioural equations and an exogenous definition of the external environment. In contrast to our solution, the authors applied the method of pre-filtration to distinguish between potential and cyclical variables. Finally, we need to mention the model of Baksa et al. (2020) and the model of Baksa et al. (2021) that enrich a quarterly projection model of a small open economy by macro-fiscal interactions and also the model of Grui (2020) that explains the calibration process for small open economies.

3 Model specification

We now proceed with the specification for a generic economy with a country index *i* and a time index *t*. It is important to note that the specification for a closed economy of the euro area differs from the specification for open economies of the Visegrad Group. On the other hand, the economies of Poland, Czechia, Hungary and Slovakia share the same equations, albeit with different parametrisation. Furthermore, we need to split the model for Slovakia before and after the adoption of Euro to approximate historical evolution of model variables. It is important to note that we do not include rational expectations about the adoption of Euro in this version of the model but it is possible to incorporate them in the future.[2]

We follow a standard approach for notation and use letters for observable variables, bars for trend variables and hats for unobserved gaps between observables and trends. Specifically, we define $\mathbf{y_{i,t}}$ as 100 times the log of an actual GDP level, $\mathbf{\bar{y}_{i,t}}$ as 100 times the log of a potential GDP level and $\mathbf{\hat{y}_{i,t}}$ as an output gap in percentage terms, in other words $\mathbf{\hat{y}_{i,t}} = \mathbf{y_{i,t}} - \mathbf{\bar{y}_{i,t}}$. Similarly, we define $\mathbf{\hat{u}_{i,t}}$ as the difference between an actual rate of unemployment $\mathbf{u_{i,t}}$ and a potential rate of unemployment $\mathbf{\bar{u}_{i,t}}$, in other words $\mathbf{\hat{u}_{i,t}} = \mathbf{u_{i,t}} - \mathbf{\bar{u}_{i,t}}$. Next, we define $\mathbf{p_{i,t}}$ as 100 times the log of HICP in a current quarter, $\boldsymbol{\pi}_{\mathbf{i,t}}$ as 400 times the difference between the log of HICP in a current quarter and the log of HICP in a previous quarter of the same year and $\boldsymbol{\pi}^{*}_{\mathbf{i,t}}$ as 100 times the difference between the log of HICP in a current quarter and the log of HICP in the same quarter of a previous year. A monetary policy rate is then denoted by $\mathbf{i_{i,t}}$ and a difference between a real policy rate $\mathbf{r_{i,t}}$ and its potential counterpart $\mathbf{\bar{r}_{i,t}}$ is denoted by $\mathbf{\hat{r}_{i,t}}$. Similarly, 100 times the log of a nominal exchange rate vis-à-vis the Euro is denoted by $\mathbf{s_{i,t}}$ and a difference between a real exchange rate $\mathbf{z_{i,t}}$ and its potential counterpart $\mathbf{\bar{z}_{i,t}}$ is denoted by $\mathbf{\hat{z}_{i,t}}$.

3.1 Output block

Structure of the model consists of several behavioural equations and underlying stochastic processes. We start with an aggregate demand of the euro area that is defined by a dynamic IS curve of a closed economy (Eq.1), where a real output gap ($\mathbf{\hat{y}_{i,t}}$) is a function of (i) its own lagged term to capture persistence of demand shocks and (ii) an effective interest rate gap ($\mathbf{\hat{r}^{*}_{i,t}}$) in a previous period to approximate an empirical impact of loan prices on private consumption and investment. The effective interest rate gap ($\mathbf{\hat{r}^{*}_{i,t}}$) is thus defined as a weighted average of 3-month and 10-year interest rate gaps, where the short-term component consists of an interest rate gap on policy rates ($\mathbf{\hat{r}_{i,t}}$) and an interbank premium ($\boldsymbol{\theta}_{\mathbf{i,t}}$) and the long-term component consists of an interest rate gap on policy expectations ($\mathbf{\hat{r}^{e}_{i,t}}$). Finally, we denote the weights that are put on the short-term component and the long-term component by the parameter $\boldsymbol{\Xi}_{\mathbf{1}}$ and the parameter $\mathbf{1} - \boldsymbol{\Xi}_{\mathbf{1}}$. The last term in the equation ($\boldsymbol{\varepsilon}^{\mathbf{y}}_{\mathbf{i,t}}$) refers to an aggregate demand shock.

$$\mathbf{\hat{y}_{i,t}} = \boldsymbol{\beta}_{\mathbf{i,1}} * \mathbf{\hat{y}_{i,t-1}} - \boldsymbol{\beta}_{\mathbf{i,2}} * \mathbf{\hat{r}^{*}_{i,t-1}} + \boldsymbol{\varepsilon}^{\mathbf{y}}_{\mathbf{i,t}} \tag{1}$$

We continue with the specification for the Visegrad Group and expand the dynamic IS curve for open economies (Eq.2). The real output gap ($\mathbf{\hat{y}_{i,t}}$) is thus affected by two additional terms, where the first one refers to an effective exchange rate gap ($\mathbf{\hat{z}^{*}_{i,t}}$) and the second one refers to an aggregate external demand ($\mathbf{\hat{y}^{*}_{i,t}}$) of a small open economy. The effective exchange rate gap ($\mathbf{\hat{z}^{*}_{i,t}}$) is further defined as a weighted average of bilateral exchange rate gaps ($\mathbf{\hat{z}_{i,j,t}}$) between the country *i* and its trading partners *j*. Particular weights are then calibrated as a sum of exports and imports between the country *i* and the country *j* against a sum of exports and imports between the country *i* and all of its trading partners to capture the relative importance of these trading partners. It is important to note that the bilateral exchange rate gaps ($\mathbf{\hat{z}_{i,j,t}}$) between the country *i* and its trading partners *j* are defined as a difference between exchange rate gaps of

[2] For the incorporation of structural shifts into models with rational expectations see Kulish and Pagan (2012).

respective currencies vis-à-vis the Euro, in other words $\hat{\mathbf{z}}_{\mathbf{i,j,t}} = \hat{\mathbf{z}}_{\mathbf{i,t}} - \hat{\mathbf{z}}_{\mathbf{j,t}}$. The aggregate external demand ($\mathbf{y}^*_{\mathbf{i,t}}$) is then defined as a weighted average of external output gaps with particular weights calibrated as ratios between exports from the country *i* to the country *j* and exports from the country *i* to all of its trading partners. This term enters the equation with lag and captures an upward pressure of the external demand on the domestic export that further manifests in the domestic output. Finally, we enrich the equation by a fiscal impulse ($\mathbf{d}^*_{\mathbf{i,t}}$) that captures a pass-through of a fiscal policy to a real economy.

$$\hat{\mathbf{y}}_{\mathbf{i,t}} = \boldsymbol{\beta}_{\mathbf{i,1}} * \hat{\mathbf{y}}_{\mathbf{i,t-1}} - \boldsymbol{\beta}_{\mathbf{i,2}} * \widehat{\mathbf{m}}_{\mathbf{i,t-1}} + \boldsymbol{\beta}_{\mathbf{i,3}} * \hat{\mathbf{y}}^*_{\mathbf{i,t-1}} + \boldsymbol{\beta}_{\mathbf{i,4}} * \mathbf{d}^*_{\mathbf{i,t}} + \boldsymbol{\varepsilon}^{\mathbf{y}}_{\mathbf{i,t}} \tag{2}$$

The parameter $\boldsymbol{\beta}_{\mathbf{2}}$ then captures a pass-through of a monetary policy to a real economy that consists of domestic and external components (Eq.3). On the other hand, the parameter $\boldsymbol{\beta}_{\mathbf{5}}$ and the parameter $\mathbf{1} - \boldsymbol{\beta}_{\mathbf{5}}$ represent the weights that are put on the domestic factor ($\hat{\mathbf{r}}^*_{\mathbf{i,t}}$) and the external factor ($\hat{\mathbf{z}}^*_{\mathbf{i,t}}$) in a monetary condition index ($\widehat{\mathbf{m}}_{\mathbf{i,t}}$), while the values of these parameters depend on the relative openness of the economy.

$$\widehat{\mathbf{m}}_{\mathbf{i,t}} = \boldsymbol{\beta}_{\mathbf{i,5}} * \hat{\mathbf{r}}^*_{\mathbf{i,t}} - \left(\mathbf{1} - \boldsymbol{\beta}_{\mathbf{i,5}}\right) * \hat{\mathbf{z}}^*_{\mathbf{i,t}} \tag{3}$$

Potential output ($\bar{\mathbf{y}}_{\mathbf{i,t}}$) is defined by a local linear trend model where shocks to both level and growth rate are assumed. The shocks to the level are considered as permanent, whereas the shocks to the growth rate result in persistent deviations of the productivity growth from its steady-state value. As results from the Eq.4, the growth rate ($\bar{\boldsymbol{\mu}}_{\mathbf{i,t}}$) of the potential output may temporarily deviate from its steady state ($\bar{\boldsymbol{\mu}}_{\mathbf{i,s}}$), due to persistent productivity shocks ($\bar{\boldsymbol{\varepsilon}}^{\boldsymbol{\mu}}_{\mathbf{i,t}}$), but it gradually converges back with the speed of covergence $\boldsymbol{\Lambda}_{\mathbf{1}}$.

$$\bar{\boldsymbol{\mu}}_{\mathbf{i,t}} = \boldsymbol{\Lambda}_{\mathbf{i,1}} * \bar{\boldsymbol{\mu}}_{\mathbf{i,s}} + \left(\mathbf{1} - \boldsymbol{\Lambda}_{\mathbf{i,1}}\right) * \bar{\boldsymbol{\mu}}_{\mathbf{i,t-1}} + \bar{\boldsymbol{\varepsilon}}^{\boldsymbol{\mu}}_{\mathbf{i,t}} \tag{4}$$

A quarterly change in the potential output ($\Delta\bar{\mathbf{y}}_{\mathbf{i,t}}$) is then implied by a quarterly growth rate ($\bar{\boldsymbol{\mu}}_{\mathbf{i,t}}$) and a permanent productivity shock ($\bar{\boldsymbol{\varepsilon}}^{\mathbf{y}}_{\mathbf{i,t}}$) as stated in the Eq.5. Furthermore, we enrich the equations of the Visegrad countries by an annual change in an effective potential interest rate ($\Delta\bar{\mathbf{r}}^*_{\mathbf{i,t}}$) to capture the spillovers from financial markets to potential production. The effective potential interest rate ($\bar{\mathbf{r}}^*_{\mathbf{i,t}}$) is defined as a weighted average of 3-month and 10-year potential interest rates, where the short-term component consists of potential policy rates ($\bar{\mathbf{r}}_{\mathbf{i,t}}$) and the long-term component consists of potential policy expectations ($\bar{\mathbf{r}}^{\mathbf{e}}_{\mathbf{i,t}}$) and a credit premium ($\boldsymbol{\varphi}_{\mathbf{i,t}}$). Again, we denote the weights that are put on the short-term component and the long-term component by the parameter $\boldsymbol{\Xi}_{\mathbf{1}}$ and the parameter $\mathbf{1} - \boldsymbol{\Xi}_{\mathbf{1}}$.

$$\Delta\bar{\mathbf{y}}_{\mathbf{i,t}} = \mathbf{1/4} * \bar{\boldsymbol{\mu}}_{\mathbf{i,t}} - \boldsymbol{\Lambda}_{\mathbf{i,2}} * \Delta\bar{\mathbf{r}}^*_{\mathbf{i,t}} + \bar{\boldsymbol{\varepsilon}}^{\mathbf{y}}_{\mathbf{i,t}} \tag{5}$$

We abstract from cross correlations of output shocks in this version of the model but it is possible to incorporate them in the future. Specifically, we could assume that the persistent productivity shock ($\bar{\boldsymbol{\varepsilon}}^{\boldsymbol{\mu}}_{\mathbf{i,t}}$) puts an upward pressure on stronger demand, what implies its positive correlation with the aggregate demand shock ($\boldsymbol{\varepsilon}^{\mathbf{y}}_{\mathbf{i,t}}$), in line with Carabenciov et al. (2008). On the other hand, we could extend the model for a set of demand shocks to approximate the debt crisis of the euro area, in line with Andrle et al. (2014).[3]

3.2 Inflation block

To reflect the volatility of price development, we distinguish between core and noncore inflation in the model. Specifically, we assume that the inflation rate ($\boldsymbol{\pi}_{\mathbf{i,t}}$) is a weighted average of the core inflation ($\mathbf{c}_{\mathbf{i,t}}$) and the noncore inflation ($\mathbf{n}_{\mathbf{i,t}}$) and calibrate the parameter $\boldsymbol{\Phi}_{\mathbf{1}}$ and the parameter $\mathbf{1} - \boldsymbol{\Phi}_{\mathbf{1}}$ from the historical data (Eq.6). Furthermore, we allow for high frequency shocks to the inflation rate ($\boldsymbol{\varepsilon}^{\boldsymbol{\pi}}_{\mathbf{i,t}}$) that we can interpret as either (i) cost-push factors that are not

[3] The authors distinguish between three types of demand shocks in their model, (i) a one-off shock with a zero degree of persistence, (ii) a persistent shock with a high degree of persistence and (iii) a global shock that affects all economies.

explained by macroeconomic fundamentals or as (ii) measurement errors that need to be further processed by filtration techniques. Decomposition of the headline inflation into its core and noncore components is then implied by the filtration of model shocks, in line with Andrle et al. (2014). Finally, the annual inflation ($\boldsymbol{\pi}^{*}_{i,t}$) is defined as an average value of the headline inflation ($\boldsymbol{\pi}_{i,t}$) over last four periods.

$$\boldsymbol{\pi}_{i,t} = \boldsymbol{\Phi}_{i,1} * \mathbf{c}_{i,t} + \left(\mathbf{1} - \boldsymbol{\Phi}_{i,1}\right) * \mathbf{n}_{i,t} + \boldsymbol{\varepsilon}^{\pi}_{i,t} \tag{6}$$

We now proceed with an aggregate supply of the euro area that is defined by a hybrid Phillips curve of a closed economy (Eq.7), where the core inflation ($\mathbf{c}_{i,t}$) is a function of (i) inflation expectations ($\mathbf{c}^{e}_{i,t}$) of macroeconomic agents and (ii) a real output gap ($\hat{\mathbf{y}}_{i,t}$) in a previous period to approximate an empirical impact of economic slack on domestic prices and wages. The last term in the equation ($\boldsymbol{\varepsilon}^{c}_{i,t}$) refers to an aggregate supply shock.

$$\mathbf{c}_{i,t} = \mathbf{c}^{e}_{i,t} + \boldsymbol{\lambda}_{i,2} * \hat{\mathbf{y}}_{i,t-1} + \boldsymbol{\varepsilon}^{c}_{i,t} \tag{7}$$

As results from the Eq.8, we incorporate both rational and adaptive elements of agents' expectations, where (i) the relative weight of the forward-looking element $\boldsymbol{\lambda}_1$ measures a share of price setters who set their expectations about future inflation in a model-consistent manner and (ii) the relative weight of the backward-looking element $\mathbf{1} - \boldsymbol{\lambda}_1$ includes both direct and indirect indexation to past inflation and a share of price setters who base their expectations about future inflation on its historical values.

$$\mathbf{c}^{e}_{i,t} = \boldsymbol{\lambda}_{i,1} * \mathbf{c}_{i,t+1} + \left(\mathbf{1} - \boldsymbol{\lambda}_{i,1}\right) * \mathbf{c}_{i,t-1} \tag{8}$$

We continue with the specification for the Visegrad Group and expand the hybrid Phillips curve for open economies (Eq.9). The core inflation ($\mathbf{c}_{i,t}$) is thus affected by an additional term that captures an upward pressure of currency depreciation on import prices. In contrast to the specification of Carabenciov et al. (2008), which operates with a quarterly change in a real exchange rate, we base this component on an effective exchange rate gap ($\hat{\mathbf{z}}^{*}_{i,t}$) to ensure the stationarity of the model, due to the convergence process of the Visegrad countries. The effective exchange rate gap ($\hat{\mathbf{z}}^{*}_{i,t}$) is again defined as a weighted average of bilateral exchange rate gaps ($\hat{\mathbf{z}}_{i,j,t}$) between the country *i* and its trading partners *j*. Particular weights are now calibrated as ratios between imports to the country *i* from the country *j* and imports to the country *i* from all of its trading partners. Finally, we assume that the adoption of Euro implies structural changes in inflation expectations of households and investors and thus set the value of the parameter $\boldsymbol{\lambda}_1$ to its euro area counterpart.

$$\mathbf{c}_{i,t} = \mathbf{c}^{e}_{i,t} + \boldsymbol{\lambda}_{i,2} * \hat{\mathbf{x}}_{i,t-1} + \boldsymbol{\varepsilon}^{c}_{i,t} \tag{9}$$

The parameter $\boldsymbol{\lambda}_2$ then captures an empirical impact of marginal costs on domestic prices and wages that consists of domestic and external components (Eq.10). On the other hand, the parameter $\boldsymbol{\lambda}_3$ and the parameter $\mathbf{1} - \boldsymbol{\lambda}_3$ represent the weights that are put on the domestic factor ($\hat{\mathbf{y}}_{i,t}$) and the external factor ($\hat{\mathbf{z}}^{*}_{i,t}$) in real marginal costs ($\hat{\mathbf{x}}_{i,t}$), while the values of these parameters depend on the relative openness of the economy.

$$\hat{\mathbf{x}}_{i,t} = \boldsymbol{\lambda}_{i,3} * \hat{\mathbf{y}}_{i,t} + \left(\mathbf{1} - \boldsymbol{\lambda}_{i,3}\right) * \hat{\mathbf{z}}^{*}_{i,t} \tag{10}$$

The noncore inflation ($\mathbf{n}_{i,t}$) is then implied by world oil prices ($\mathbf{oil}_t$) that oscillate around their steady state ($\mathbf{oil}_s$) with a respect to oil price shocks ($\boldsymbol{\varepsilon}^{o}_{i,t}$). However, the noncore inflation in the Visegrad countries needs to be further adjusted for quarterly changes in a nominal exchange rate ($\boldsymbol{\Delta}\mathbf{s}_{i,t}$) and a potential exchange rate ($\boldsymbol{\Delta}\bar{\mathbf{z}}_{i,t}$) to transform the world oil prices ($\mathbf{oil}_t$) into the national currencies (Eq.11). To summarize, we can distinguish between two price channels of the currency depreciation. First, the currency depreciation puts an upward pressure on exchange rate gaps and real marginal costs with a direct impact on the core inflation. Second nominal exchange rates put an upward pressure on world oil prices in the national currencies with a direct impact on the noncore inflation.

$$\mathbf{n}_{i,t} = \mathbf{oil}_t + \Delta\mathbf{s}_{i,t} - \Delta\bar{\mathbf{z}}_{i,t} \tag{11}$$

We further assume that the inflation target in the euro area is equal to its steady state that is set by the European central bank (ECB). On the other hand, the inflation targets in the Visegrad countries are driven by a simple stochastic process that allows for historical shocks to monetary incentives (Eq.12). It means that the inflation target ($\boldsymbol{\pi}^t_{i,t}$) of a monetary authority may temporarily deviate from its steady state ($\boldsymbol{\pi}^t_{i,s}$), due to target inflation shocks ($\bar{\boldsymbol{\varepsilon}}^{\pi}_{i,t}$), but it gradually converges back with the speed of covergence $\boldsymbol{\Sigma}_1$.

$$\boldsymbol{\pi}^t_{i,t} = \boldsymbol{\Sigma}_{i,1} * \boldsymbol{\pi}^t_{i,t-1} + \left(\mathbf{1} - \boldsymbol{\Sigma}_{i,1}\right) * \boldsymbol{\pi}^t_{i,s} + \bar{\boldsymbol{\varepsilon}}^{\pi}_{i,t} \tag{12}$$

Finally, it is possible to extend the model for a negative correlation between the permanent productivity shock ($\bar{\boldsymbol{\varepsilon}}^{y}_{i,t}$) and the aggregate supply shock ($\boldsymbol{\varepsilon}^{c}_{i,t}$), since the productivity shock boosts the domestic supply and thus puts a downward pressure on domestic prices. However, we need to mention that this relationship is influenced by additional factors in small open economies. First, even though the productivity shock boosts the production in the economy, most of this production is exported abroad and thus does not increase the domestic supply. Second, the productivity shock leads to faster convergence that quantifies through currency and price channels and thus puts an upward pressure on domestic prices. Therefore, we abstract from this extension in this version of the model.

3.3 Unemployment

In line with the output definition, we decompose the unemployment rate into its potential and cyclical components to exploit labour market data in the economy. The unemployment gap ($\hat{\mathbf{u}}_{i,t}$) is defined by a modified version of the Okun's law (Eq.13) and is thus a function of (i) its own lagged term to capture persistence of labour shocks and (ii) a real output gap ($\hat{\mathbf{y}}_{i,t}$) to approximate an empirical impact of a real economy on domestic employment. The last term in the equation ($\boldsymbol{\varepsilon}^{u}_{i,t}$) refers to a labour market shock.

$$\hat{\mathbf{u}}_{i,t} = \boldsymbol{\kappa}_{i,1} * \hat{\mathbf{u}}_{i,t-1} - \boldsymbol{\kappa}_{i,2} * \hat{\mathbf{y}}_{i,t} + \boldsymbol{\varepsilon}^{u}_{i,t} \tag{13}$$

On the other hand, the potential unemployment ($\bar{\mathbf{u}}_{i,t}$) responds to potential unemployment shocks ($\bar{\boldsymbol{\varepsilon}}^{u}_{i,t}$) and converges to its steady state ($\bar{\mathbf{u}}_{i,s}$) with the speed of convergence $\boldsymbol{\Pi}_1$. We thus abstract from the specification of Carabenciov et al. (2008) with both level and growth rate components of the potential unemployment and rather use a simple stochastic process with a steady-state value. It is important to note that even though the unemployment rate does not interact with other model variables in impulse response analyses, it allows us to exploit labour market data and thus correct the measurement errors.

3.4 Interest rates

Central bank affects the economy with changes in a monetary policy rate that is pinned down by a Taylor policy rule (Eq.14). The monetary policy rate ($\mathbf{i}_{i,t}$) is thus a function of (i) its own lagged value to smooth the interest rate movement and (ii) a target interest rate of the central bank ($\mathbf{i}^t_{i,t}$). The last term in the equation ($\boldsymbol{\varepsilon}^{i}_{i,t}$) refers to a monetary policy shock. Finally, since the adoption of Euro implies that the countries accept the common monetary policy of the ECB, we set the monetary policy rate to its euro area counterpart.

$$\mathbf{i}_{i,t} = \boldsymbol{\gamma}_{i,1} * \mathbf{i}_{i,t-1} + \left(\mathbf{1} - \boldsymbol{\gamma}_{i,1}\right) * \mathbf{i}^t_{i,t} + \boldsymbol{\varepsilon}^{i}_{i,t} \tag{14}$$

The target interest rate ($\mathbf{i}^t_{i,t}$) then consists of (i) a policy neutral rate that is equal to a potential policy rate ($\bar{\mathbf{r}}_{i,t}$) plus an inflation target ($\boldsymbol{\pi}^t_{i,t}$) and (ii) a policy response of the central bank to a cyclical position of a real economy ($\hat{\mathbf{y}}_{i,t}$) and a cyclical deviation of an annual inflation from its target value ($\hat{\boldsymbol{\pi}}^*_{i,t}$) three quarters ahead (Eq.15) to approximate a forward-looking nature of the policy rules, in line with Orphanides (2003). This definition of the target interest rate implies that the monetary authority no longer responds to country specificities after the adoption of Euro and we thus need to adjust the monetary policy rate for a country premium. This adjustment can be interpreted as an additional price that needs to be paid by households and firms in a domestic economy with a respect to the economy of the euro area.[4]

$$\mathbf{i}^{\mathbf{t}}_{\mathbf{i,t}} = \bar{\mathbf{r}}_{\mathbf{i,t}} + \boldsymbol{\pi}^{\mathbf{t}}_{\mathbf{i,t}} + \boldsymbol{\gamma}_{\mathbf{i,2}} * \hat{\boldsymbol{\pi}}^{*}_{\mathbf{i,t+3}} + \boldsymbol{\gamma}_{\mathbf{i,3}} * \hat{\mathbf{y}}_{\mathbf{i,t}} \tag{15}$$

We proceed with a real policy rate ($\mathbf{r}_{\mathbf{i,t}}$) that is defined by the Fisher equation and is thus equal to the monetary policy rate ($\mathbf{i}_{\mathbf{i,t}}$) minus the headline inflation ($\boldsymbol{\pi}_{\mathbf{i,t}}$) one quarter ahead, in other words $\mathbf{r}_{\mathbf{i,t}} = \mathbf{i}_{\mathbf{i,t}} - \boldsymbol{\pi}_{\mathbf{i,t+1}}$. On the other hand, we could assume that the potential policy rate ($\bar{\mathbf{r}}_{\mathbf{i,t}}$) responds to potential rate shocks ($\bar{\boldsymbol{\varepsilon}}^{\mathbf{r}}_{\mathbf{i,t}}$) and converges to its steady state ($\bar{\mathbf{r}}_{\mathbf{i,s}}$) with the speed of convergence $\boldsymbol{\Upsilon}_{\mathbf{1}}$. However, this specification holds only for a closed economy of the euro area with the potential policy rate implied by a set of domestic fundamentals. On the other hand, the potential policy rates of the Visegrad countries should be pinned down by the potential version of the uncovered interest parity (Eq.16) to ensure the no arbitrage principle on financial markets. We thus assume that a potential rate differential ($\nabla\bar{\mathbf{r}}_{\mathbf{i,t}}$) between a domestic economy and the euro area is equal to a difference between potential rate expectations ($\bar{\mathbf{z}}^{\mathbf{e}}_{\mathbf{i,t}}$) and a potential exchange rate ($\bar{\mathbf{z}}_{\mathbf{i,t}}$) that is further adjusted for a country premium ($\boldsymbol{\psi}_{\mathbf{i,t}}$).

$$\nabla\bar{\mathbf{r}}_{\mathbf{i,t}} = \mathbf{4}\bar{\mathbf{z}}^{\mathbf{e}}_{\mathbf{i,t}} - \mathbf{4}\bar{\mathbf{z}}_{\mathbf{i,t}} + \boldsymbol{\psi}_{\mathbf{i,t}} \tag{16}$$

Monetary policy expectations ($\mathbf{i}^{\mathbf{e}}_{\mathbf{i,t}}$) are defined by the expectation theory and are thus equal to an average value of a monetary policy rate ($\mathbf{i}_{\mathbf{i,t}}$) over next ten years. Real policy expectations ($\mathbf{r}^{\mathbf{e}}_{\mathbf{i,t}}$) and their potential counterparts ($\bar{\mathbf{r}}^{\mathbf{e}}_{\mathbf{i,t}}$) are defined in the same manner under real ($\mathbf{r}_{\mathbf{i,t}}$) and potential ($\bar{\mathbf{r}}_{\mathbf{i,t}}$) policy rates. The gap on policy expectations ($\hat{\mathbf{r}}^{\mathbf{e}}_{\mathbf{i,t}}$) is then equal to a difference between real policy expectations ($\mathbf{r}^{\mathbf{e}}_{\mathbf{i,t}}$) and their potential counterparts ($\bar{\mathbf{r}}^{\mathbf{e}}_{\mathbf{i,t}}$). Finally, we define an effective interest rate ($\mathbf{i}^{*}_{\mathbf{i,t}}$) as an average value of the monetary policy expectations ($\mathbf{i}^{\mathbf{e}}_{\mathbf{i,t}}$) over last ten years plus an average value of the credit premium ($\boldsymbol{\varphi}_{\mathbf{i,t}}$) over last ten years to approximate the financial costs that are relevant for a fiscal policy.

3.5 Exchange rates

Financial markets interact with each other through changes in a nominal exchange rate that is pinned down by a hybrid version of the uncovered interest parity (Eq.17), in line with Adolfson et al. (2008). The nominal exchange rate ($\mathbf{s}_{\mathbf{i,t}}$) is thus equal to exchange rate expectations ($\mathbf{s}^{\mathbf{e}}_{\mathbf{i,t}}$) minus an interest rate differential ($\nabla\mathbf{i}_{\mathbf{i,t}}$) between a domestic economy and the euro area plus a country premium ($\boldsymbol{\psi}_{\mathbf{i,t}}$). It implies that (i) the investors who expect a national currency to depreciate require an additional price in the form of a higher interest rate and that (ii) a rising interest rate attracts more investors and results in the appreciation of a national currency. After the adoption of Euro, we set the nominal exchange rate to a constant value.

$$\mathbf{4s}_{\mathbf{i,t}} = \mathbf{4s}^{\mathbf{e}}_{\mathbf{i,t}} - \nabla\mathbf{i}_{\mathbf{i,t}} + \boldsymbol{\psi}_{\mathbf{i,t}} \tag{17}$$

The specification with the hybrid UIP operates with both forward-looking and backward-looking elements of exchange rate expectations ($\mathbf{s}^{\mathbf{e}}_{\mathbf{i,t}}$) and has thus an empirical advantage over the one with the standard UIP. As results from the Eq.18, the relative weight of the forward-looking element $\boldsymbol{\omega}_{\mathbf{1}}$ measures a share of investors who set their expectations about a national currency in a model-consistent manner and the relative weight of the backward-looking element $\mathbf{1} - \boldsymbol{\omega}_{\mathbf{1}}$ measures a share of investors that reflect the purchasing power parity and thus base their expectations about a national currency on a target exchange rate ($\mathbf{s}^{\mathbf{t}}_{\mathbf{i,t}}$). The last term in the equation ($\boldsymbol{\varepsilon}^{\mathbf{s}}_{\mathbf{i,t}}$) refers to an exchange rate shock.

[4] While before the adoption of Euro, the monetary authority responds to a potential policy rate of a domestic economy that includes the country premium, this no longer holds after the adoption of Euro. The investors thus require an additional price to lend the money to households and firms in a domestic economy rather than in the economy of the euro area.

$$\mathbf{s^{e}_{i,t} = \omega_{i,1} * s_{i,t+1} + (1-\omega_{i,1}) * s^{t}_{i,t} + \varepsilon^{s}_{i,t}} \tag{18}$$

The target exchange rate ($\mathbf{s^{t}_{i,t}}$) is then equal to (i) its own lagged value to smooth the exchange rate movement, (ii) the potential convergence ($\bar{\boldsymbol{\eta}}_{i,t}$) of a domestic economy and (iii) a target inflation differential ($\boldsymbol{\nabla\pi^{t}_{i,t}}$) between a domestic economy and the euro area (Eq.19). We argue that this definition of the exchange rate expectations is consistent with Beneš et al. (2008) and reflects the view of those investors who have a simple monetarist model in mind, in which the purchasing power parity that is adjusted for the potential convergence always holds and a higher inflation rate thus inevitably leads to a weaker exchange rate.

$$\mathbf{2s^{t}_{i,t} = 2s_{i,t-1} + \bar{\eta}_{i,t} + \nabla\pi^{t}_{i,t}} \tag{19}$$

We proceed with a real exchange rate ($\mathbf{z_{i,t}}$) that is equal to a nominal exchange rate ($\mathbf{s_{i,t}}$) minus a price level differential ($\boldsymbol{\delta}\mathbf{p_{i,t}}$) between a domestic economy and the euro area, in other words $\mathbf{z_{i,t} = s_{i,t} - \delta p_{i,t}}$, and thus approximate the relative purchase power of the Visegrad countries. This definition further implies that after the adoption of Euro, the real exchange rate is equal to the price level differential between a domestic economy and the euro area. The potential exchange rate ($\bar{\mathbf{z}}_{i,t}$) is then defined by a local linear trend model where shocks to both level and growth rate are assumed. As results from the Eq.20, the growth rate ($\bar{\boldsymbol{\eta}}_{i,t}$) of the potential exchange rate may temporarily deviate from its steady state ($\bar{\boldsymbol{\eta}}_{i,s}$), due to persistent convergence shocks ($\bar{\boldsymbol{\varepsilon}}^{\eta}_{i,t}$), but it gradually converges back with the speed of covergence $\boldsymbol{\Omega_1}$.

$$\mathbf{\bar{\eta}_{i,t} = \Omega_{i,1} * \bar{\eta}_{i,s} + \left(1-\Omega_{i,1}\right) * \bar{\eta}_{i,t-1} + \bar{\varepsilon}^{\eta}_{i,t}} \tag{20}$$

A quarterly change in the potential exchange rate ($\boldsymbol{\Delta}\bar{\mathbf{z}}_{i,t}$) is then implied by a quarterly growth rate ($\bar{\boldsymbol{\eta}}_{i,t}$) and a permanent convergence shock ($\bar{\boldsymbol{\varepsilon}}^{z}_{i,t}$) as stated in the Eq.21. Furthermore, we enrich the equations of the Visegrad countries by a quarterly change in the public debt ($\boldsymbol{\Delta}\mathbf{b_{i,t}}$) to capture that (i) a rising public debt puts a national currency towards depreciation and also that (ii) an expected increase in the public debt puts an upward pressure on the potential interest rate and thus negatively affects the potential output.

$$\mathbf{\Delta\bar{z}_{i,t} = 1/4 * \bar{\eta}_{i,t} + \Omega_{i,2} * \Delta b_{i,t} + \bar{\varepsilon}^{z}_{i,t}} \tag{21}$$

Finally, we define the potential rate expectations ($\bar{\mathbf{z}}^{e}_{i,t}$) as model-consistent and thus equal to the potential exchange rate ($\bar{\mathbf{z}}_{i,t}$) one quarter ahead. This choice comes as natural, since we assume that (i) the forward-looking investors are consistent with model expectations and (ii) the backward-looking investors adjust a previous value of the potential exchange rate for an expected value of its growth rate.

3.6 Fiscal block

A target debt path ($\mathbf{b^{t}_{i,t}}$) is set by the government and pinned down by a random walk process that responds to target debt shocks ($\bar{\boldsymbol{\varepsilon}}^{b}_{i,t}$). On the other hand, a gross public debt ($\mathbf{b_{i,t}}$) is a function of an overall public deficit ($\mathbf{d_{i,t}}$) and an outstanding public debt ($\boldsymbol{\vartheta}_{i,t}$) as stated in the Eq.22. We further assume that the outstanding public debt ($\boldsymbol{\vartheta}_{i,t}$) needs to be equal to a gross public debt ($\mathbf{b_{i,t}}$) in a previous period which is adjusted for a discount factor ($\mathbf{df_{i,t}}$) in a current period to account for the growth rate of the nominal output.[5] We can thus write $\boldsymbol{\vartheta}_{i,t} = \mathbf{df_{i,t} * b_{i,t-1}}$. Finally, we allow also for high frequency shocks to the public debt ($\boldsymbol{\varepsilon}^{b}_{i,t}$), due to a number of stock-flow adjustment factors that distort the accumulation function.[6]

$$\mathbf{b_{i,t} = 1/4 * d_{i,t} + \vartheta_{i,t} + \varepsilon^{b}_{i,t}} \tag{22}$$

[5] Discount factor is a sum of quarterly nominal GDP from time t-4 to time t-1 divided by a sum of quarterly nominal GDP from time t-3 to time t. This is in line with the definition of a debt to output ratio as the ratio between a cumulative public debt and an annual nominal output.

[6] For example the difference between a net public debt and a gross public debt, the formation of cash reserves by fiscal authorities or the effects of privatisation of public properties.

Public debt expectations ($\mathbf{b}^{e}_{i,t}$) are then defined by the expectation theory and are thus equal to an average value of a gross public debt ($\mathbf{b}_{i,t}$) over next ten years. On the other hand, we define an effective public debt ($\mathbf{b}^{*}_{i,t}$) as a weighted average of (i) its own lead term to approximate future expectations about fiscal objectives and (ii) a gross public debt ($\mathbf{b}_{i,t}$) to capture a current position of fiscal objectives (Eq.23). Finally, we denote the weights that are put on the future component and the current component by the parameter $\boldsymbol{\Gamma}_1$ and the parameter $\mathbf{1} - \boldsymbol{\Gamma}_1$.

$$\mathbf{b}^{*}_{i,t} = \boldsymbol{\Gamma}_{i,1} * \mathbf{b}^{*}_{i,t+1} + (\mathbf{1} - \boldsymbol{\Gamma}_{i,1}) * \mathbf{b}_{i,t} \tag{23}$$

Next, we decompose the overall public deficit ($\mathbf{d}_{i,t}$) into a cyclical public deficit ($\boldsymbol{\upsilon}_{i,t}$), a structural public deficit ($\boldsymbol{\delta}_{i,t}$) and public debt costs ($\boldsymbol{\nu}_{i,t}$) as stated in the Eq.24. We can thus distinguish between (i) the fiscal component that responds to automatic stabilizers in the economy, (ii) the fiscal component that is pinned down by a fiscal policy of the government and (iii) the fiscal component that is implied by previous decisions of fiscal authorities and the expectations of investors on financial markets.

$$\mathbf{d}_{i,t} = \boldsymbol{\upsilon}_{i,t} + \boldsymbol{\delta}_{i,t} + \boldsymbol{\nu}_{i,t} \tag{24}$$

Since the cyclical public deficit ($\boldsymbol{\upsilon}_{i,t}$) responds to automatic stabilizers, it should be defined in the percentage of a real output gap ($\hat{y}_{i,t}$), in other words $\boldsymbol{\upsilon}_{i,t} = \boldsymbol{\tau}_{i,1} * \hat{\mathbf{y}}_{i,t}$. Furthermore, while the stronger demand puts an upward pressure on taxes and contributions and improves the public deficit, the parameter $\boldsymbol{\tau}_1$ should achieve negative values. On the other hand, we assume that the government affects the economy with changes in the structural public deficit that is pinned down by a fiscal policy rule (Eq.25). The structural public deficit ($\boldsymbol{\delta}_{i,t}$) is thus a function of (i) its own lagged value to smooth the public deficit movement and (ii) a target structural deficit of the government ($\boldsymbol{\delta}^{t}_{i,t}$). The last term in the equation ($\boldsymbol{\varepsilon}^{\delta}_{i,t}$) refers to a fiscal policy shock.[7]

$$\boldsymbol{\delta}_{i,t} = \boldsymbol{\alpha}_{i,1} * \boldsymbol{\delta}_{i,t-1} + (\mathbf{1} - \boldsymbol{\alpha}_{i,1}) * \boldsymbol{\delta}^{t}_{i,t} + \boldsymbol{\varepsilon}^{\delta}_{i,t} \tag{25}$$

The target structural deficit ($\boldsymbol{\delta}^{t}_{i,t}$) then consists of (i) a policy neutral deficit that is equal to a target overall deficit ($\mathbf{d}^{t}_{i,t}$) minus target debt costs ($\boldsymbol{\nu}^{t}_{i,t}$) and (ii) a policy response of the government to a cyclical position of a real economy ($\hat{y}_{i,t}$) and a cyclical deviation of an effective public debt from its target value ($\hat{\mathbf{b}}^{*}_{i,t}$) as stated in the Eq.26. We can thus approximate a forward-looking nature of the policy rules, in line with Baksa et al. (2021).

$$\boldsymbol{\delta}^{t}_{i,t} = \mathbf{d}^{t}_{i,t} - \boldsymbol{\nu}^{t}_{i,t} - \boldsymbol{\alpha}_{i,2} * \hat{\mathbf{b}}^{*}_{i,t} - \boldsymbol{\alpha}_{i,3} * \hat{\mathbf{y}}_{i,t} \tag{26}$$

The target overall deficit ($\mathbf{d}^{t}_{i,t}$) is further equal to a target debt path ($\mathbf{b}^{t}_{i,t}$) minus an outstanding target debt ($\boldsymbol{\vartheta}^{t}_{i,t}$) on the annual basis, in other words $\mathbf{d}^{t}_{i,t} = \mathbf{4b}^{t}_{i,t} - \mathbf{4}\boldsymbol{\vartheta}^{t}_{i,t}$. We also assume that the outstanding target debt ($\boldsymbol{\vartheta}^{t}_{i,t}$) needs to be equal to a target debt path ($\mathbf{b}^{t}_{i,t}$) in a previous period which is adjusted for a discount factor ($\mathbf{df}_{i,s}$) in a steady state. We can thus write $\boldsymbol{\vartheta}^{t}_{i,t} = \mathbf{df}_{i,s} * \mathbf{b}^{t}_{i,t-1}$. Finally, we define a fiscal impulse ($\mathbf{d}^{*}_{i,t}$) as a function of (i) a quarterly change in the structural public deficit ($\boldsymbol{\Delta\delta}_{i,t}$) to capture a current position of a fiscal policy and (ii) a quarterly change in the target debt path ($\boldsymbol{\Delta}\mathbf{b}^{t}_{i,t}$) to approximate future expectations about a fiscal policy (Eq.27).

$$\mathbf{d}^{*}_{i,t} = \boldsymbol{\Delta\delta}_{i,t} + \boldsymbol{\Gamma}_{i,2} * \boldsymbol{\Delta}\mathbf{b}^{t}_{i,t} \tag{27}$$

Next, we assume that the public debt costs ($\boldsymbol{\nu}_{i,t}$) are implied by an effective interest rate ($\mathbf{i}^{*}_{i,t}$) in a previous period and an outstanding public debt ($\boldsymbol{\vartheta}_{i,t}$), in other words $\boldsymbol{\nu}_{i,t} = \mathbf{i}^{*}_{i,t-1} * \boldsymbol{\vartheta}_{i,t}$. On the other hand, we assume that the target debt costs ($\boldsymbol{\nu}^{t}_{i,t}$) are implied by an effective interest rate ($\mathbf{i}^{*}_{i,t}$) in a previous period and an outstanding target debt ($\boldsymbol{\vartheta}^{t}_{i,t}$), in other words $\boldsymbol{\nu}^{t}_{i,t} = \mathbf{i}^{*}_{i,t-1} * \boldsymbol{\vartheta}^{t}_{i,t}$. For convenience, we abstract from government bonds with different maturities and ignore more proper definitions of interest rate costs, in line with Baksa et al. (2020).[8]

[7] The government thus distinguishes between two types of policy shocks, (i) a short-term policy shock to the structural public deficit that captures temporary changes in a fiscal policy and (ii) a long-term policy shock to the target debt path that captures permanent changes in fiscal objectives.
[8] For a detailed version of the fiscal block that includes different types of interest rate costs see Baksa et al. (2021).

3.7 Risk premiums

First, we construct an interbank premium as a simple difference between market interest rates and monetary policy rates. We consider only a cyclical component of the interbank premium, in line with a short maturity of the market interest rates, and thus produce a wedge between the interest rate gap that is implied by a monetary authority and the interest rate gap that is relevant for a real economy. The interbank premium ($\boldsymbol{\theta}_{\mathbf{i,t}}$) is then pinned down by a simple stochastic process (Eq.28) that responds to an interbank premium shock ($\boldsymbol{\varepsilon}^{\boldsymbol{\theta}}_{\mathbf{i,t}}$) and converges to zero in the steady state. Furthermore, we enrich the equations of the Visegrad countries by an aggregate external premium ($\boldsymbol{\theta}^{*}_{\mathbf{i,t}}$) to approximate the interactions between open economies on financial markets. The aggregate external premium ($\boldsymbol{\theta}^{*}_{\mathbf{i,t}}$) is defined as a weighted average of external interbank premiums with particular weights calibrated as a sum of exports and imports between the country *i* and the country *j* against a sum of exports and imports between the country *i* and all of its trading partners to capture the relative importance of these trading partners. Finally, since the adoption of Euro implies that the countries accept the common monetary policy of the ECB, we set the interbank premium to its euro area counterpart.

$$\boldsymbol{\theta}_{\mathbf{i,t}} = \boldsymbol{\chi}_{\mathbf{i,1}} * \boldsymbol{\theta}_{\mathbf{i,t-1}} + \boldsymbol{\chi}_{\mathbf{i,2}} * \boldsymbol{\theta}^{*}_{\mathbf{i,t}} + \boldsymbol{\varepsilon}^{\boldsymbol{\theta}}_{\mathbf{i,t}} \tag{28}$$

Second, we construct a credit premium as a simple difference between government bond yields and monetary policy expectations. We consider only a potential component of the credit premium, in line with a long maturity of the government bond yields, and thus produce a wedge between the potential interest rate that is implied by macroeconomic fundamentals and the potential interest rate that is relevant for the potential output. The credit premium ($\boldsymbol{\varphi}_{\mathbf{i,t}}$) is then pinned down by a simple stochastic process (Eq.29) that responds to a credit premium shock ($\boldsymbol{\varepsilon}^{\boldsymbol{\varphi}}_{\mathbf{i,t}}$) and converges to its equilibrium value ($\overline{\boldsymbol{\varphi}}_{\mathbf{i,t}}$).

$$\boldsymbol{\varphi}_{\mathbf{i,t}} = \boldsymbol{\zeta}_{\mathbf{i,1}} * \boldsymbol{\varphi}_{\mathbf{i,t-1}} + \left(\mathbf{1} - \boldsymbol{\zeta}_{\mathbf{i,1}}\right) * \overline{\boldsymbol{\varphi}}_{\mathbf{i,t}} + \boldsymbol{\varepsilon}^{\boldsymbol{\varphi}}_{\mathbf{i,t}} \tag{29}$$

The equilibrium value of the credit premium ($\overline{\boldsymbol{\varphi}}_{\mathbf{i,t}}$) is implied by its steady state ($\overline{\boldsymbol{\varphi}}_{\mathbf{i,s}}$) but we further enrich the equations of the Visegrad countries by an expected deviation of the public debt from its optimal market value ($\boldsymbol{\delta}\mathbf{b}^{\mathbf{e}}_{\mathbf{i,t}}$) over next ten years to approximate future preferences of risk-aversive investors and thus model a negative impact of an excessive public debt on the potential output in the economy (Eq.30). We further assume that the adoption of Euro results in structural changes on the money markets and thus set the steady state of the credit premium to its euro area counterpart.

$$\overline{\boldsymbol{\varphi}}_{\mathbf{i,t}} = \overline{\boldsymbol{\varphi}}_{\mathbf{i,s}} + \boldsymbol{\zeta}_{\mathbf{i,2}} * \boldsymbol{\delta}\mathbf{b}^{\mathbf{e}}_{\mathbf{i,t}} \tag{30}$$

Finally, we construct a country premium as a residual term from the uncovered interest parity. We consider only a potential component of the country premium, in line with Andrle et al. (2014), and thus produce a wedge between the potential interest rate that is implied by the potential convergence and the potential interest rate that is relevant for a monetary policy. The country premium ($\boldsymbol{\psi}_{\mathbf{i,t}}$) is then pinned down by a simple stochastic process (Eq.31) that responds to a country premium shock ($\boldsymbol{\varepsilon}^{\boldsymbol{\psi}}_{\mathbf{i,t}}$) and converges to its equilibrium value ($\overline{\boldsymbol{\psi}}_{\mathbf{i,t}}$).

$$\boldsymbol{\psi}_{\mathbf{i,t}} = \boldsymbol{\xi}_{\mathbf{i,1}} * \boldsymbol{\psi}_{\mathbf{i,t-1}} + \left(\mathbf{1} - \boldsymbol{\xi}_{\mathbf{i,1}}\right) * \overline{\boldsymbol{\psi}}_{\mathbf{i,t}} + \boldsymbol{\varepsilon}^{\boldsymbol{\psi}}_{\mathbf{i,t}} \tag{31}$$

The equilibrium value of the country premium ($\overline{\boldsymbol{\psi}}_{\mathbf{i,t}}$) is implied by its steady state ($\overline{\boldsymbol{\psi}}_{\mathbf{i,s}}$) but we further enrich the equations of the Visegrad countries by a current deviation of the public debt from its optimal market value ($\boldsymbol{\delta}\mathbf{b}_{\mathbf{i,t}}$) to approximate instant preferences of risk-aversive investors and thus model a negative impact of an excessive public debt on the potential output in the economy (Eq.32). We further assume that the adoption of Euro results in structural changes on the money markets and thus set the steady state of the country premium to zero.

$$\overline{\boldsymbol{\psi}}_{\mathbf{i,t}} = \overline{\boldsymbol{\psi}}_{\mathbf{i,s}} + \boldsymbol{\xi}_{\mathbf{i,2}} * \boldsymbol{\delta}\mathbf{b}_{\mathbf{i,t}} \tag{32}$$

To summarize this section, we distinguish between three types of risk premiums in the model, (i) an interbank premium ($\boldsymbol{\theta}_{\mathbf{i,t}}$) that affects short-term interest rates, (ii) a credit premium ($\boldsymbol{\varphi}_{\mathbf{i,t}}$) that affects long-term interest rates and (iii) a country premium ($\boldsymbol{\psi}_{\mathbf{i,t}}$) that enters an uncovered interest parity. While the first one and the second one capture an imperfect control of a monetary authority over nominal interest rates and thus the domestic money market, the last one capture an imperfect control of a monetary authority over nominal exchange rates and thus the international money market. We further assume that a fiscal policy affect the potential output by three channels, (i) an empirical impact of an expected change in the public debt on the potential convergence, (ii) an empirical impact of a current deviation of the public debt from its optimal market value on the country premium and (iii) an empirical impact of an expected deviation of the public debt from its optimal market value on the credit premium. We thus argue that even though the optimal market value of the public debt ($\mathbf{b}^{\mathbf{t}}_{\mathbf{i,s}}$) does not pin down its target path, it has a significant impact on the potential output in the economy.

4 Methodology and data

We propose a medium scale gap model for the economies of the Visegrad Group, i.e. Poland, Czechia, Hungary and Slovakia, that further interact with the economy of the euro area as their most important trading partner. The model is based on (i) potential and cyclical components of real outputs, unemployment rates, interest rates and exchange rates and (ii) core and noncore components of inflation rates, while respecting mutual linkages and spillovers between the economies. We abstract from the set of financial variables of Carabenciov et al. (2008), due to their minor impact on small open economies, but enrich the model by a fiscal block to capture macro-fiscal interactions in the Visegrad Group.

Visegrad countries operate as small open economies that affect each other through three macroeconomic channels. The first channel reflects an empirical impact of exchange rates on real and price variables, since the currency depreciation puts an upward pressure on price competitiveness and import prices and thus boosts the real output and the inflation rate. The second channel reflects an empirical impact of external outputs on domestic economies, since the external demand puts an upward pressure on the domestic export and thus improves the domestic output. The third channel then reflects the interactions between open economies on financial markets that are reflected in interbank premiums. On the other hand, the euro area operates as a closed economy, due to its relative size with a respect to the Visegrad countries, and thus affects other countries in the model but not vice versa.

We apply six observable variables for each country to pin down gross domestic products ($\mathbf{y}_{\mathrm{i,t}}$), consumer price indices ($\mathbf{p}_{\mathrm{i,t}}$), unemployment rates ($\mathbf{u}_{\mathrm{i,t}}$), monetary policy rates ($\mathbf{i}_{\mathrm{i,t}}$), market interest rates that further consist of monetary policy rates ($\mathbf{i}_{\mathrm{i,t}}$) and interbank premiums ($\boldsymbol{\theta}_{\mathrm{i,t}}$) and government bond yields that further consist of monetary policy expectations ($\mathbf{i}^{\mathrm{e}}_{\mathrm{i,t}}$) and credit premiums ($\boldsymbol{\varphi}_{\mathrm{i,t}}$). In addition, we pin down world oil prices in the Euro ($\mathbf{oil}_{\mathrm{t}}$) and nominal exchange rates of national currencies vis-à-vis the Euro ($\mathbf{s}_{\mathrm{i,t}}$). Finally, we pin down overall public deficits ($\mathbf{d}_{\mathrm{i,t}}$) and gross public debts ($\mathbf{b}_{\mathrm{i,t}}$) in the percentage of gross domestic product and historical values of inflation targets ($\boldsymbol{\pi}^{\mathrm{t}}_{\mathrm{i,t}}$) and target debt paths ($\mathbf{b}^{\mathrm{t}}_{\mathrm{i,t}}$) for the Visegrad countries.

Gross domestic products (GDP) are obtained in chain linked volumes in domestic currencies to exclude historical variations in inflation rates and exchange rates. On the other hand, we define consumer price indices as seasonally adjusted averages of harmonized indices of consumer prices (HICP) that are available on a monthly basis. We obtain both of these variables from the Eurostat database together with the information about unemployment rates, market interest rates, government bond yields, nominal exchange rates, overall public deficits and gross public debts. It is important to note that the gross domestic product of the euro area refers to a total output of core member countries to abstract from historical changes in the composition of the monetary union.[9] Monetary policy rates are equal to historical key rates of central banks that are obtained from their websites together with the information about inflation targets. Finally, we obtain world oil prices from the Bloomberg database and set target debt paths equal to their steady-state values, due to a lack of available information about historical objectives of fiscal authorities in the Visegrad countries.

Rational expectations of representative agents are solved by the Schur decomposition what allows us to transform the model into its vector autoregressive form. The unobserved gaps of model variables are then identified by the Kalman filter and the time series are additionally smoothed by the modified Bryson-Frazier smoother. Parametrisation and evaluation of the model is performed on quarterly data from the first quarter of 2002 to the last quarter of 2017. All computations are implemented in the Matlab software and the IRIS toolbox.

[9] The gross domestic product of the euro area refers to a total output of Germany, France, Italy, Spain, Austria, Netherlands, Belgium, Luxembourg, Ireland, Finland, Portugal and Greece.

5 Model parametrisation

We distinguish between five groups of model parameters, (i) the equilibrium parameters that pin down the steady states of model variables, (ii) the potential parameters that underpin the convergence process of potential variables and their mutual interactions, (iii) the cyclical parameters that describe the economic development throughout business cycles and determine the policy rules of monetary and fiscal authorities, (iv) the trade parameters that approximate the relative importance of trading partners for open economies, and (v) the stochastic parameters that define the standard deviations of model shocks. The parametrisation of the model consists of the calibration process as well as the Bayesian estimation to produce reasonable impulse responses and historical projections. While the calibration process exploits the related literature and consists of one-by-one estimation of model equations, the Bayesian approach estimates the rest of the model parameters together as a weighted average between their prior distributions and the data generating process that is based on the historical data.

5.1 Eurozone calibration

We start with the economy of the euro area and calibrate the equilibrium value of the real output growth ($\bar{\mu}_s$) to 1.75, the unemployment rate ($\bar{u}_s$) to 4.50, the real policy rate ($\bar{r}_s$) to 1.25, the credit premium ($\bar{\varphi}_s$) to 0.75 and the world oil prices ($\mathbf{oil}_s$) to 2.00, in line with their historical data. Furthermore, we set the equilibrium value of the target inflation (π_s^t) to 2.00 to approximate the monetary incentives of the ECB.[10] Next, we calibrate the Taylor policy rule (Eq.14) in line with Carabenciov et al. (2008) and thus set the smoothing parameter (γ_1) to 0.75, the inflation reactiveness (γ_2) to 2.00 and the output reactiveness (γ_3) to 0.20. On the other hand, we calibrate the dynamic IS curve (Eq.1) and the hybrid Phillips curve (Eq.7) from Priesol and Žúdel (2019) and thus set the persistence of the output gap (β_1) to 0.80, the expectations of the inflation rate (λ_1) to 0.75, the pass-through of a monetary policy to a real economy (β_2) to 0.12 and the empirical impact of marginal costs on domestic prices and wages (λ_2) to 0.06. We further use the historical data to calibrate the persistence on the labour market (κ_1) to 0.65 and the empirical impact of a real economy on domestic employment (κ_2) to 0.15, while the persistence of the interbank premium (χ_1) is set to 0.85 and the persistence of the credit premium (ζ_1) is set to 0.90.

Similarly, we calibrate the share of the core inflation (Φ_1) to 0.99, the share of the noncore inflation ($1 - \Phi_1$) to 0.01, the convergence of the potential output growth (Λ_1) to 0.05 and the convergence of the potential unemployment (Π_1) to 0.02, in line with the historical data.[11] We further calibrate the weight of the short-term interest rates (Ξ_1) to 0.75 and the weight of the long-term interest rates ($1 - \Xi_1$) to 0.25, in line with relative shares of private consumption and private investment. Finally, we set the convergence of the potential policy rate (Υ_1) to 0.01 to approximate the random walk process of the natural rate of interest. For more information about the estimation of the natural rate of interest see Holston et al. (2017).

Next, we calibrate the standard deviations of model shocks from Andrle et al. (2014). We thus set the standard deviation of the aggregate demand shocks (ε_t^y) to 0.50, the aggregate supply shocks (ε_t^c) to 0.20, the headline inflation shocks (ε_t^π) to 0.60, the monetary policy shocks (ε_t^i) to 0.25, the interbank premium shocks (ε_t^θ) to 0.15 and the oil price shocks (ε_t^o) to 10.0. On the other hand, we use the Hodrick-Prescott filter to decompose the unemployment rate into its potential and cyclical components and then set the standard deviation of the potential unemployment shocks ($\bar{\varepsilon}_t^u$) to 0.10 and the labour market shocks (ε_t^u) to 0.15, in line with the

[10] https://www.ecb.europa.eu/ecb/tasks/monpol/html/index.en.html

[11] First, we approximate the core inflation as the headline inflation excluding energy, food, alcohol and tobacco and define the noncore inflation from the world oil prices. Second, we use the Hodrick-Prescott filter to decompose the real output and the unemployment rate into their potential and cyclical components. Finally, we estimate the model parameters by the Ordinary least squares (OLS).

historical data. Finally, we set (i) the standard deviation of the permanent productivity shocks ($\bar{\boldsymbol{\varepsilon}}_{t}^{y}$) to 0.05 and the persistent productivity shocks ($\bar{\boldsymbol{\varepsilon}}_{t}^{\mu}$) to 0.05 to achieve a plausible historical projection of the real output gap that is consistent with Carabenciov et al. (2013) and set (ii) the standard deviation of the potential rate shocks ($\bar{\boldsymbol{\varepsilon}}_{t}^{r}$) to 0.02 and the credit premium shocks ($\boldsymbol{\varepsilon}_{t}^{\varphi}$) to 0.10 to achieve a plausible historical projection of the potential policy rate that is consistent with Holston et al. (2017).

5.2 Visegrad calibration

We now proceed with the Visegrad countries and calibrate the equilibrium value of the real output growth ($\bar{\boldsymbol{\mu}}_{s}$), the unemployment rate ($\bar{\mathbf{u}}_{s}$), the credit premium ($\bar{\boldsymbol{\varphi}}_{s}$) and the country premium ($\bar{\boldsymbol{\psi}}_{s}$) from their historical data. On the other hand, we calibrate the equilibrium value of the real exchange growth ($\bar{\boldsymbol{\eta}}_{s}$) as an equilibrium output differential between a domestic economy and the euro area with a negative sign to approximate the convergence process of the Visegrad countries. Finally, we calibrate the steady state of the target inflation ($\boldsymbol{\pi}_{s}^{t}$) as its current value and the steady state of the target debt path ($\mathbf{b}_{s}^{t}$) as its average value. It is important to note that after the adoption of Euro, the equilibrium value of the inflation rate is not implied by a monetary authority but is rather pinned down by the uncovered interest parity. An equilibrium inflation differential between a domestic economy and the euro area is thus equal to the equilibrium value of the real exchange growth with a negative sign. The equilibrium parameters of the Visegrad countries are provided in the Table 1.

Next, we calibrate the potential parameters and set the convergence of the potential output growth ($\boldsymbol{\Lambda}_{1}$) to 0.05, the spillovers from the potential interest rate ($\boldsymbol{\Lambda}_{2}$) to 0.10, the convergence of the potential exchange growth ($\boldsymbol{\Omega}_{1}$) to 0.05, the spillovers from the gross public debt ($\boldsymbol{\Omega}_{2}$) to 0.02 and the convergence of the potential unemployment ($\boldsymbol{\Pi}_{1}$) to 0.02. Furthermore, we set the persistence of the credit premium ($\boldsymbol{\zeta}_{1}$) to 0.90, the impact of the expected public debt ($\boldsymbol{\zeta}_{2}$) to 0.10, the persistence of the country premium ($\boldsymbol{\xi}_{1}$) to 0.90 and the impact of the current public debt ($\boldsymbol{\xi}_{2}$) to 0.05. Finally, we calibrate the share of future expectations about fiscal objectives ($\boldsymbol{\Gamma}_{1}$) to 0.50 and the pass-through of fiscal objectives to a real economy ($\boldsymbol{\Gamma}_{2}$) to 0.50, due to a lack of available information about historical objectives of fiscal authorities.

We also calibrate the most of the structural parameters and base the relative weights of the rational expectations ($\boldsymbol{\lambda}_{1}$) and the adaptive expectations ($\mathbf{1}-\boldsymbol{\lambda}_{1}$) on the estimation results of Vašíček (2011). On the other hand, we estimate the share of the core inflation ($\boldsymbol{\Phi}_{1}$) and the share of the noncore inflation ($\mathbf{1}-\boldsymbol{\Phi}_{1}$) from historical data on inflation development. We then calibrate the weight of the short-term interest rates ($\boldsymbol{\Xi}_{1}$) and the weight of the long-term interest rates ($\mathbf{1}-\boldsymbol{\Xi}_{1}$) from relative shares of private consumption and private investment on domestic output and base the upward pressure of an external demand on a domestic economy ($\boldsymbol{\beta}_{3}$) on the ratio between domestic export and domestic output. Furthermore, we set (i) the relative weights of the interest rate gap ($\boldsymbol{\beta}_{5}$) and the exchange rate gap ($\mathbf{1}-\boldsymbol{\beta}_{5}$) in a monetary condition index and (ii) the relative weights of the real output gap ($\boldsymbol{\lambda}_{3}$) and the exchange rate gap ($\mathbf{1}-\boldsymbol{\lambda}_{3}$) in real marginal costs from trade to output ratios of the Visegrad countries to approximate the relative openness of these economies.

We further assume that the pass-through of a fiscal policy to a real economy ($\boldsymbol{\beta}_{4}$) corresponds to an instant fiscal multiplier and calibrate it through the bucket approach of Batini et al. (2014), which exploits a number of macroeconomic and fiscal factors that could influence the level of fiscal multipliers.[12] On the other hand, we base the elasticity between a cyclical public deficit and a real output gap ($\boldsymbol{\tau}_{1}$) on the estimation results of the European Commission (EC). We then use the historical data to calibrate the persistence on the labour market ($\boldsymbol{\kappa}_{1}$), the empirical impact of a real economy on domestic employment ($\boldsymbol{\kappa}_{2}$), the persistence of the interbank

[12] For example the degree of trade openness, the level of market rigidities, the degree of automatic stabilizers, the regime of exchange rate, the level of public debt and the effectiveness of debt management.

premium ($\boldsymbol{\chi_1}$), the interactions of risk premiums on financial markets ($\boldsymbol{\chi_2}$) and the persistence of the target inflation ($\boldsymbol{\Sigma_1}$). Similarly, we estimate the smoothing parameter ($\boldsymbol{\gamma_1}$), the inflation reactiveness ($\boldsymbol{\gamma_2}$) and the output reactiveness ($\boldsymbol{\gamma_3}$) in the Taylor policy rules (Eq.14) and also the smoothing parameter ($\boldsymbol{\delta_1}$), the fiscal reactiveness ($\boldsymbol{\delta_2}$) and the output reactiveness ($\boldsymbol{\delta_3}$) in the fiscal policy rules (Eq.25) from the historical data.[13] The structural parameters of the Visegrad countries are provided in the Table 2.

Next, we calibrate the trade parameters as sample averages from the historical data and thus approximate the relative importance of trading partners for the Visegrad countries. We here distinguish between (i) the shares of exports that are relevant for the external demand (ii) the shares of imports that are relevant for the import prices and (iii) the shares of exports plus imports that are relevant for the price competitiveness and the external premium. The trade parameters of the Visegrad countries are provided in the Table 3.

Finally, we calibrate the stochastic parameters to advance the structural interpretation of model shocks and obtain plausible historical projections of model variables. First, we abstract from rational expectations and approximate the expected values of model variables by their current counterparts. Second, we abstract from the forward-looking terms in the hybrid Phillips curve (Eq.8) and the uncovered interest parity (Eq.18) and replace them with the backward-looking ones. Third, we approximate the core inflation as the headline inflation excluding energy, food, alcohol and tobacco and define the noncore inflation from the world oil prices. Fourth, we use the Hodrick-Prescott filter to decompose the real output, the unemployment rate, the real policy rate and the real exchange rate into their potential and cyclical components.

Fifth, we estimate the standard deviation of the aggregate demand shocks ($\boldsymbol{\varepsilon_t^y}$), the aggregate supply shocks ($\boldsymbol{\varepsilon_t^c}$), the labour market shocks ($\boldsymbol{\varepsilon_t^u}$), the potential unemployment shocks ($\boldsymbol{\bar{\varepsilon}_t^u}$), the headline inflation shocks ($\boldsymbol{\varepsilon_t^\pi}$) and the target inflation shocks ($\boldsymbol{\bar{\varepsilon}_t^\pi}$) and also the standard deviation of the monetary policy shocks ($\boldsymbol{\varepsilon_t^i}$), the interbank premium shocks ($\boldsymbol{\varepsilon_t^\theta}$), the fiscal policy shocks ($\boldsymbol{\varepsilon_t^\delta}$), the public debt shocks ($\boldsymbol{\varepsilon_t^b}$) and the exchange rate shocks ($\boldsymbol{\varepsilon_t^s}$) from the historical data.[14] Sixth, we calibrate the standard deviation of the permanent productivity shocks ($\boldsymbol{\bar{\varepsilon}_t^y}$), the persistent productivity shocks ($\boldsymbol{\bar{\varepsilon}_t^\mu}$), the permanent convergence shocks ($\boldsymbol{\bar{\varepsilon}_t^z}$), the persistent convergence shocks ($\boldsymbol{\bar{\varepsilon}_t^\eta}$), the credit premium shocks ($\boldsymbol{\varepsilon_t^\varphi}$) and the country premium shocks ($\boldsymbol{\varepsilon_t^\psi}$) to achieve plausible historical projections of the real output gaps, the potential exchange rates and the potential policy rates. Finally, we set the standard deviation of the target debt shocks ($\boldsymbol{\bar{\varepsilon}_t^b}$) equal to the standard deviation of the public debt shocks ($\boldsymbol{\varepsilon_t^b}$), due to a lack of available information about historical objectives of fiscal authorities. The stochastic parameters of the Visegrad countries are provided in the Table 4.

5.3 Bayesian estimation

On the other hand, we need to estimate the rest of the structural parameters, due to a lack of historical evidence and the absence of related literature. Specifically, we need to estimate the persistence of the output gap ($\boldsymbol{\beta_1}$), the expectations of the exchange rate ($\boldsymbol{\omega_1}$), the pass-through of a monetary policy to a real economy ($\boldsymbol{\beta_2}$) and the empirical impact of marginal costs on domestic prices and wages ($\boldsymbol{\lambda_2}$). We estimate these parameters under a maximum likelihood function with the Bayesian interface to provide a compromise between the standard estimation and the calibration of parameters. We argue that (i) the standard estimation applied on short data samples often provides results that are inconsistent with macroeconomic fundamentals and could even estimate effects that are opposite to standard macroeconomic views and that

[13] First, we abstract from rational expectations and approximate the expected values of the headline inflation, the annual inflation, the gross public debt and the target debt path by their current counterparts. Second, we use the Hodrick-Prescott filter to decompose the real policy rate into its potential and cyclical components. Finally, we estimate the model parameters by the Ordinary least squares (OLS).

[14] We use the prior means to approximate the point estimates of model parameters that were not set by the calibration process and then estimate the sample deviations of model equations to approximate the standard deviations of corresponding shocks.

(ii) the calibration of parameters has no support in data and often reflects nothing more than arbitrary judgements. As a middle ground between these two approaches, the Bayesian estimation has a benefit of putting some weights on prior expectations and some weights on observed data over the estimation period. These weights are further captured by the standard deviations of the prior distributions, what allows us to distinguish between parameters with high and low degree of certainty, in other words between mostly calibrated and mostly estimated parameters. The posterior distributions of model parameters are thus obtained as a weighted average between their prior distributions and the data generating process.

Bayesian approach to model estimation usually consists of two steps. At first, we apply the Maximum a Posteriori (MAP) estimator to obtain the posterior modes of model parameters. This is in fact nothing else than the Maximum Likelihood (ML) estimator that is extended for a deviation of model parameters from their prior modes.[15] However, the application of this estimator has two disadvantages. First, the estimation of posterior modes is performed under a zero-one loss function, in contrast to a quadratic loss function that is consistent with posterior means. Second, we obtain only point estimates and not the entire distributions of model parameters. Therefore, it is convenient to apply the additional step and run the Markov Chain Monte Carlo simulation with the Metropolis-Hastings algorithm to sample from the posterior distributions. As the result, we obtain the approximation of the entire distributions of model parameters and thus the information about their means, standard deviations and confidence intervals. However, we abstract from this additional step for three reasons. First, the complexity of the model implies that the computation time of this simulation is too high. Second, the symmetricity of the prior distributions implies that the posterior modes should be a relevant proxy for the posterior means. Finally, we are mostly interested in the posterior means and not so much in the entire distributions of model parameters. The priors and the posteriors of model parameters are provided in the Table 5.

[15] We apply the Quasi-Newton method for the optimization process.

6 Model evaluation

Evaluation of the model is based on impulse response functions, analysis of model parameters, comparison of consolidation strategies and decomposition of model variables. First, we compute impulse response functions for the most important domestic and external shocks, i.e. shocks to domestic and external demand, domestic and external supply, exchange rate, world oil price, monetary policy, interbank premium, fiscal policy and target debt.[16] The most of the model shocks have the magnitude of 1.00 p.p. in the first quarter and the shock to the world oil price has the magnitude of 100 p.p. in the first quarter. The impulse response functions are presented as deviations from steady-state values of model variables. Next, we provide a set of model simulations under (i) alternative parametrisation of the fiscal block to analyse the sensitivity of model parameters and under (ii) alternative paths for the target debt to compare a set of consolidation strategies. Finally, we filter model shocks to obtain historical projections of model variables and decompose them into potential and cyclical components.

6.1 Impulse responses

We start with a domestic demand shock that corresponds to a positive shock to the output gap of the domestic economy. Stronger domestic demand puts an upward pressure on domestic inflation that activates a monetary policy and thus results in the increase of nominal and real interest rates and the appreciation of nominal and real exchange rates. The rising output is followed by automatic stabilizers and thus leads to the decline of public deficit and public debt. The absence of a sovereign monetary policy results in the decrease of the real interest rate and the appreciation of the real exchange rate in line with the inflation development.

On the other hand, an external demand shock corresponds to a positive shock to the output gap of the euro area. Stronger external demand now puts an upward pressure on domestic output and inflation and activates a monetary policy what results in the increase of nominal and real interest rates. Furthermore, since the reaction of the monetary authority needs to be stronger than in the euro area to ensure stabilization properties of emerging economies, this shock also results in the appreciation of nominal and real exchange rates. Consequently, the real interest rate decreases and the real exchange rate depreciates if the country has no sovereign monetary policy. The activation of automatic stabilizers results in the decline of public deficit and public debt.

We continue with a domestic supply shock that boosts the core inflation in the domestic economy and thus puts a downward pressure on a real interest rate and on a real exchange rate. The inflation development further activates a monetary policy what leads to the increase of nominal and real interest rates and the appreciation of nominal and real exchange rates. Domestic output is put down by the interest rate channel of loan prices and by the exchange rate channel of price competitiveness. The weaker output raises public deficit, while the higher inflation improves public debt in a domestic economy.

On the other hand, an external supply shock boosts the core inflation in the euro area what puts an upward pressure on domestic output and inflation through the depreciation of a real exchange rate. The reaction of a monetary authority then results in the increase of nominal and real interest rates. Furthermore, since the reaction of the monetary authority needs to be stronger than in the euro area to ensure stabilization properties of emerging economies, this shock also results in the appreciation of a nominal exchange rate. Consequently, the real interest rate decreases if the country has no sovereign monetary policy. The activation of automatic stabilizers results in the decline of public deficit and public debt.

[16] The exchange rate shock for Poland, Czechia and Hungary corresponds to the depreciation of domestic currencies vis-a-vis the Euro. On the other hand, the exchange rate shock for Slovakia corresponds to the depreciation of the Euro vis-a-vis other currencies.

An exchange rate shock manifests in the depreciation of nominal and real exchange rates and thus leads to the increase of core and noncore inflation. Higher price competitiveness further improves domestic output, while the inflation development puts a downward pressure on a real interest rate and on a real exchange rate. The reaction of a monetary authority then results in the increase of nominal and real interest rates and the activation of automatic stabilizers leads to the decline of public deficit and public debt.

On the other hand, a world oil price shock boosts the noncore inflation with a limited impact on financial variables. The inflation development activates a monetary policy and thus leads to the increase of nominal and real interest rates what results in the decline of domestic output. The reaction of the domestic currency is uncertain and depends on the share of noncore component in the headline inflation and the degree of policy reactiveness of the monetary authority. Specifically, the higher is the share of the noncore component, the more likely the real exchange rate appreciates, and the higher is the degree of the policy reactiveness, the more likely the nominal exchange rate appreciates. The weaker output raises public deficit, while the higher inflation improves public debt in a domestic economy.

A monetary policy shock manifests in the increase of nominal and real interest rates and thus leads to the decline of domestic output and inflation and the appreciation of nominal and real exchange rates. The activation of automatic stabilizers then results in the increase of public deficit and public debt. The absence of a sovereign monetary policy implies that a small open economy should appreciate in real terms if the inflation rate in the domestic economy declines less than the inflation rate in the euro area.

On the other hand, an interbank premium shock puts a downward pressure on domestic demand through the increase of a real interest rate what further activates a monetary policy and thus results in the depreciation of nominal and real exchange rates. Since the exchange rate channel may be stronger than the economic slack channel in small open economies, we observe a slight increase of domestic inflation. A nominal interest rate might increase right after the shock to limit the inflation growth but needs to decrease afterwards to account for the output drop. The activation of automatic stabilizers then results in the increase of public deficit and public debt. If the country has no sovereign monetary policy, the domestic inflation declines in line with the output development. Consequently, a small open economy should appreciate in real terms if the inflation rate in the domestic economy declines less than the inflation rate in the euro area.

A fiscal policy shock manifests in the increase of public deficit what puts an upward pressure on public debt and fiscal impulse with a positive impact on domestic output and inflation. The reaction of a monetary authority then results in the increase of nominal and real interest rates to stabilize the inflation development. The instantneous character of this shock further implies that more backward-looking expectations result in a stronger increase of the inflation rate, in line with the current economic slack, while more forward-looking expectations result in a stronger decrease of the inflation rate, in line with the future economic slack. Nominal and real exchange rates might appreciate right after the shock, due to the response of the monetary authority, but tend to depreciate afterwards, due to the increase of the country premium. The absence of a sovereign monetary policy results in the decrease of the real interest rate and the appreciation of the real exchange rate in line with the inflation development.

On the other hand, a target debt shock puts an upward pressure on public deficit and implies a gradual increase of public debt. The activation of a fiscal impulse then results in a positive reaction of domestic output and inflation and the reaction of a monetary authority leads to the increase of nominal and real interest rates and the appreciation of nominal and real exchange rates. Furthermore, the increase of the public debt puts an upward pressure on the credit premium what negatively affects the potential output. The absence of a sovereign monetary policy results in the decrease of the real interest rate and the appreciation of the real exchange rate in line with the inflation development.

6.2 Fiscal parameters

Next, we present impulse response functions for a positive shock to a target debt path under alternative parametrisations of the fiscal block to analyse the sensitivity of model parameters. While the baseline scenario corresponds to the original parametrisation of the fiscal block, we provide model simulations also for (i) a stronger response and a milder response of the government to a cyclical deviation of an effective public debt from its target value ($\alpha_{i,2}$) that approximates a degree of policy reactiveness and (ii) a stronger impact and a milder impact of a quarterly change in a target debt path on a fiscal impulse ($\Gamma_{i,2}$) that approximates future expectations about a fiscal policy. The stronger scenario corresponds to an increase of these parameters to double of their original values and the milder scenario corresponds to a decrease of these parameters to half of their original values.

The more reactive is the government, the stronger is the response of the public deficit what improves the convergence of the public debt to its target value. Stronger fiscal impulse, which results from the current position of a fiscal policy, then puts an upward pressure on domestic demand what leads to higher output gap and faster inflation rate. On the other hand, the more robust are the expectations, the stronger is the response of the fiscal impulse that reflects these expectations, what results in higher output gap and faster inflation rate. Stronger domestic demand then activates automatic stabilizers that put a downward pressure on the public deficit and slow down the convergence of the public debt to its target value.

6.3 Consolidation paths

We further compare a set of consolidation strategies that are based on alternative paths for the target debt. These strategies reflect an objective of the government to decline a debt to output ratio by four percentage points in either one year, two years or four years and thus approximate different paces of fiscal consolidation. Our aim here is to compare these different strategies and find out which one should be the least harmful for a domestic economy based on the parametrization of the model.

A decline of the public deficit follows the objective of the government to meet the target path and puts a downward pressure on domestic demand. The public debt evolves in line with the public deficit and reaches the target path at the end of the simulation horizon for all consolidation strategies. The more aggressive is the strategy, the more significant is the decline of domestic demand what cumulates the output loss. On the other hand, a decline of country and credit premiums is more significant under more aggressive strategies what improves the potential output in a domestic economy. As the result, a cumulative output loss at the end of the simulation horizon depends on the strength of these two factors. The 4-year strategy results in the worst outcome for a domestic economy, while the effectiveness of the 1-year strategy and the 2-year strategy depends on the parametrisation of the model. Specifically, the 1-year strategy is the most effective for Hungary and Slovakia and the 2-year strategy is the most effective for Poland and Czechia.

6.4 Historical projections

Historical projections of model variables and their decomposition into potential and cyclical components are performed by the method of Kalman filtering and the method of Kalman smoothing on a sample period from the first quarter of 2002 to the last quarter of 2017. Domestic output gaps move in line with their eurozone counterpart as the key driver of output development in small open economies. On the other hand, potential output growths are stronger than in the steady state to reflect the convergence process of emerging economies. Core inflation rates are mostly pinned down by economic slacks but reflect also the development of import prices. Potential unemployment of the euro area has significantly increased after the economic and financial crisis and the debt crisis of the eurozone. Contrary to this, we observe a decline of potential unemployment in the Visegrad countries, in line with the convergence process. Potential policy rate of the euro area declines on the sample period what results in its negative values in the recent years, in line with Holston et al. (2017). This development could be explained by the global savings glut and the secular stagnation of the euro area. The decline of potential policy rates is present also in the Visegrad countries. Potential exchange rates are country specific and while they might almost stagnate in some countries, the convergence process is rather significant in other countries. Structural deficits are also country specific and reflect the development of demand and fiscal factors in small open economies. Finally, the risk premiums reflect the convergence process and respond to the economic and financial crisis and the debt crisis of the eurozone. The recent years on financial markets are further affected by the Quantitative Easing (QE).

7 Concluding remarks

We outlined a medium scale gap model for the economies of the Visegrad Group that is based on (i) behavioural equations for output gaps, unemployment gaps, inflation rates, interest rates and exchange rates and (ii) underlying stochastic processes for their potential counterparts. The model was further enriched by a fiscal block to capture macro-fiscal interactions in small open economies. Spillovers between the economies are captured by three macroeconomic channels, (i) an impact of external demand on domestic output, (ii) an impact of exchange rates on domestic demand and supply and (iii) market spillovers between risk premiums. On the other hand, the fiscal variables affect both cyclical variables through fiscal impulses and potential variables through risk premiums.

Model parametrisation consisted of the calibration process as well as the Bayesian estimation to produce reasonable impulse responses and historical projections. The evaluation process was then based on impulse response functions, analysis of model parameters, comparison of consolidation strategies and decomposition of model variables. We mention that while a stronger response of the government to a cyclical deviation of an effective public debt from its target value improves the convergence of the public debt, a stronger impact of a quarterly change in a target debt path on a fiscal impulse slows down the convergence of the public debt. Furthermore, while the 4-year strategy of fiscal consolidation results in the worst outcome in terms of a cumulative output loss, the effectiveness of the 1-year strategy and the 2-year strategy depends on the parametrisation of the model.

There are also some extensions of our work that could be applied for future research. First, it would be rather beneficial to incorporate model expectations about the adoption of Euro to approximate historical development of model variables under the European Exchange Rate Mechanism (ERM II). Second, it is possible to extend the model strucutre in line with Szilágyi et al. (2013) and decompose domestic demand into its most important components to obtain additional information about private consumption, domestic investment, public consumption and trade variables. Finally, it is possible to extend the model structure for cross correlations of demand and supply shocks in line with Carabenciov et al. (2008) and for global demand shocks in line with Andrle et al. (2014).

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Model parametrisation

Tab 1: Equilibrium parameters

Description	Notation	Poland	Czechia	Hungary	Slovakia
Output growth	$\bar{\mu}_s$	2.75	2.25	2.00	2.50
Unemployment	$\bar{u}_s$	3.00	1.50	2.00	5.00
Exchange growth	$\bar{\eta}_s$	-1.00	-0.50	-0.25	-0.75
Credit premium	$\bar{\varphi}_s$	1.75	1.00	2.00	1.25
Country premium	$\bar{\psi}_s$	1.25	0.25	1.50	0.50
Target inflation	π_s^t	2.50	2.00	3.00	2.50
Target debt	b_s^t	50.0	30.0	70.0	40.0

Tab 2: Structural parameters

Output block	Notation	Poland	Czechia	Hungary	Slovakia
Persistence	β_1	0.65	0.62	0.71	0.53
Monetary policy	β_2	0.21	0.23	0.24	0.23
External demand	β_3	0.20	0.50	0.45	0.55
Fiscal policy	β_4	0.80	0.60	0.60	0.80
Domestic share	β_5	0.70	0.50	0.40	0.30
Inflation block	Notation	Poland	Czechia	Hungary	Slovakia
Expectations	λ_1	0.60	0.65	0.45	0.50
Marginal costs	λ_2	0.17	0.15	0.22	0.15
Domestic share	λ_3	0.70	0.50	0.40	0.30
Decomposition	Φ_1	0.99	0.99	0.98	0.98
Target inflation	Σ_1	0.65	0.95	0.90	0.80
Unemployment	Notation	Poland	Czechia	Hungary	Slovakia
Persistence	κ_1	0.85	0.70	0.75	0.80
Real economy	κ_2	0.10	0.15	0.10	0.15

Interest rates	Notation	Poland	Czechia	Hungary	Slovakia
Persistence	γ_1	0.70	0.70	0.65	0.65
Inflation gap	γ_2	3.00	3.00	2.50	2.50
Output gap	γ_3	0.60	0.40	0.40	0.60
Decomposition	Ξ_1	0.80	0.70	0.75	0.75
Exchange rates	Notation	Poland	Czechia	Hungary	Slovakia
Expectations	ω_1	0.68	0.64	0.74	0.75
Fiscal block	Notation	Poland	Czechia	Hungary	Slovakia
Persistence	δ_1	0.60	0.50	0.50	0.60
Fiscal gap	δ_2	0.60	0.40	0.40	0.60
Output gap	δ_3	0.40	0.30	0.40	0.30
Cyclical deficit	τ_1	0.55	0.45	0.50	0.40
Risk premiums	Notation	Poland	Czechia	Hungary	Slovakia
Persistence	χ_1	0.80	0.80	0.75	0.75
Interactions	χ_2	0.25	0.20	0.25	0.20

Tab 3: Trade parameters

Trade shares	Eurozone	Poland	Czechia	Hungary	Slovakia
Poland	0.85	0.00	0.08	0.04	0.04
Czechia	0.77	0.09	0.00	0.04	0.10
Hungary	0.82	0.06	0.05	0.00	0.06
Slovakia	0.62	0.08	0.21	0.08	0.00
Export shares	Eurozone	Poland	Czechia	Hungary	Slovakia
Poland	0.83	0.00	0.09	0.04	0.04
Czechia	0.77	0.08	0.00	0.04	0.12
Hungary	0.82	0.06	0.05	0.00	0.07
Slovakia	0.65	0.09	0.18	0.08	0.00

Import shares	Eurozone	Poland	Czechia	Hungary	Slovakia
Poland	0.87	0.00	0.06	0.03	0.04
Czechia	0.78	0.10	0.00	0.04	0.09
Hungary	0.81	0.07	0.06	0.00	0.06
Slovakia	0.60	0.07	0.25	0.08	0.00

Tab 4: Stochastic parameters

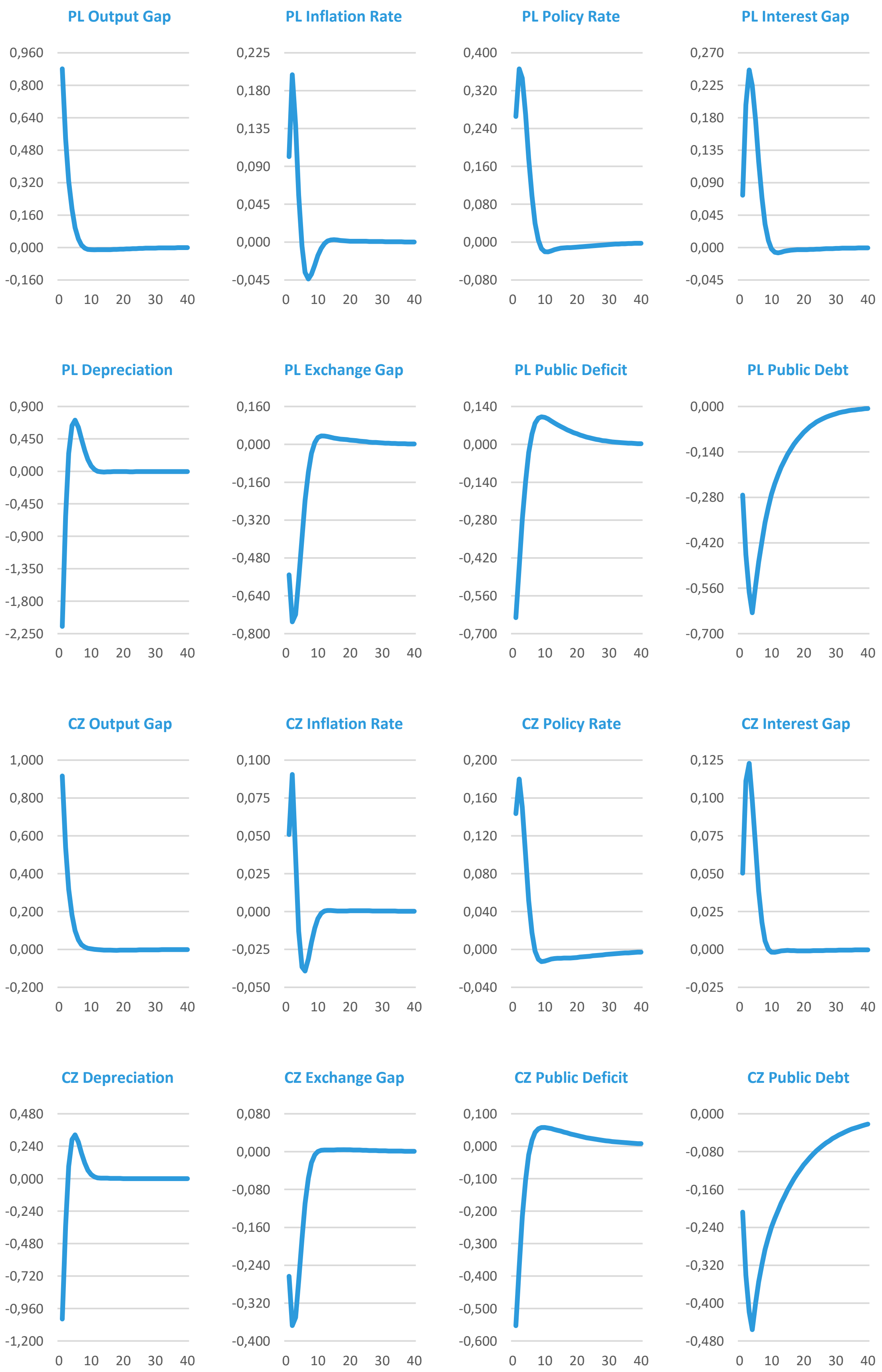
Output block	Notation	Poland	Czechia	Hungary	Slovakia
Demand shock	ε_t^y	0.75	1.00	1.50	1.25
Permanent shock	$\bar{\varepsilon}_t^y$	0.15	0.10	0.10	0.15
Persistent shock	$\bar{\varepsilon}_t^\mu$	0.15	0.10	0.10	0.15
Inflation block	Notation	Poland	Czechia	Hungary	Slovakia
Supply shock	ε_t^c	0.40	0.40	0.60	0.60
Headline shock	ε_t^π	1.20	1.20	1.80	1.80
Target shock	$\bar{\varepsilon}_t^\pi$	0.20	0.15	0.15	0.20
Unemployment	Notation	Poland	Czechia	Hungary	Slovakia
Market shock	ε_t^u	0.40	0.30	0.30	0.40
Potential shock	$\bar{\varepsilon}_t^u$	0.15	0.15	0.20	0.20
Interest rates	Notation	Poland	Czechia	Hungary	Slovakia
Policy shock	ε_t^i	0.75	1.00	1.25	1.50
Exchange rates	Notation	Poland	Czechia	Hungary	Slovakia
Market shock	ε_t^s	4.00	2.50	3.50	3.00
Permanent shock	$\bar{\varepsilon}_t^z$	0.50	0.25	0.50	0.25
Persistent shock	$\bar{\varepsilon}_t^\eta$	0.10	0.05	0.10	0.05
Fiscal block	Notation	Poland	Czechia	Hungary	Slovakia
Policy shock	ε_t^δ	1.25	1.75	2.00	1.50
Debt shock	ε_t^b	1.50	1.25	2.00	1.75

Risk premiums	Notation	Poland	Czechia	Hungary	Slovakia
Interbank shock	ε_t^{θ}	0.20	0.20	0.30	0.30
Credit shock	ε_t^{φ}	0.20	0.15	0.20	0.15
Country shock	ε_t^{ψ}	0.10	0.05	0.10	0.05

Tab 5: Estimation results

Prior means	Notation	Poland	Czechia	Hungary	Slovakia
Persistence	β_1	0.50	0.50	0.50	0.50
Expectations	ω_1	0.75	0.75	0.75	0.75
Monetary policy	β_2	0.25	0.25	0.25	0.25
Marginal costs	λ_2	0.25	0.25	0.25	0.25
Prior st. dev.	Notation	Poland	Czechia	Hungary	Slovakia
Persistence	β_1	0.05	0.05	0.05	0.05
Expectations	ω_1	0.05	0.05	0.05	0.05
Monetary policy	β_2	0.02	0.02	0.02	0.02
Marginal costs	λ_2	0.02	0.02	0.02	0.02
Posterior modes	Notation	Poland	Czechia	Hungary	Slovakia
Persistence	β_1	0.65	0.62	0.71	0.53
Expectations	ω_1	0.68	0.64	0.74	0.75
Monetary policy	β_2	0.21	0.23	0.24	0.23
Marginal costs	λ_2	0.17	0.15	0.22	0.15
Posterior st. dev.	Notation	Poland	Czechia	Hungary	Slovakia
Persistence	β_1	0.05	0.04	0.05	0.04
Expectations	ω_1	0.03	0.03	0.04	0.05
Monetary policy	β_2	0.02	0.02	0.02	0.02
Marginal costs	λ_2	0.01	0.01	0.02	0.02

Domestic demand shock



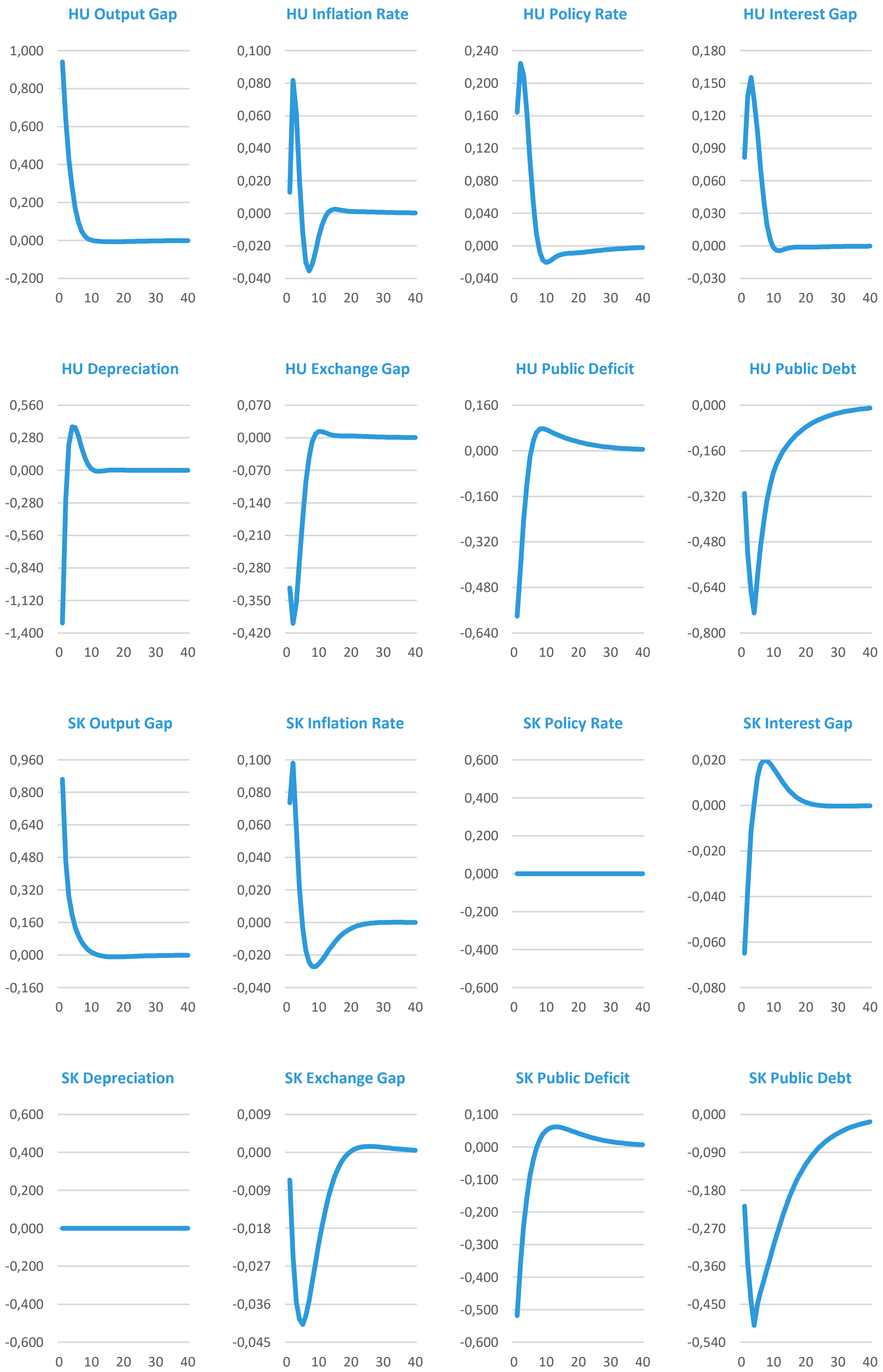
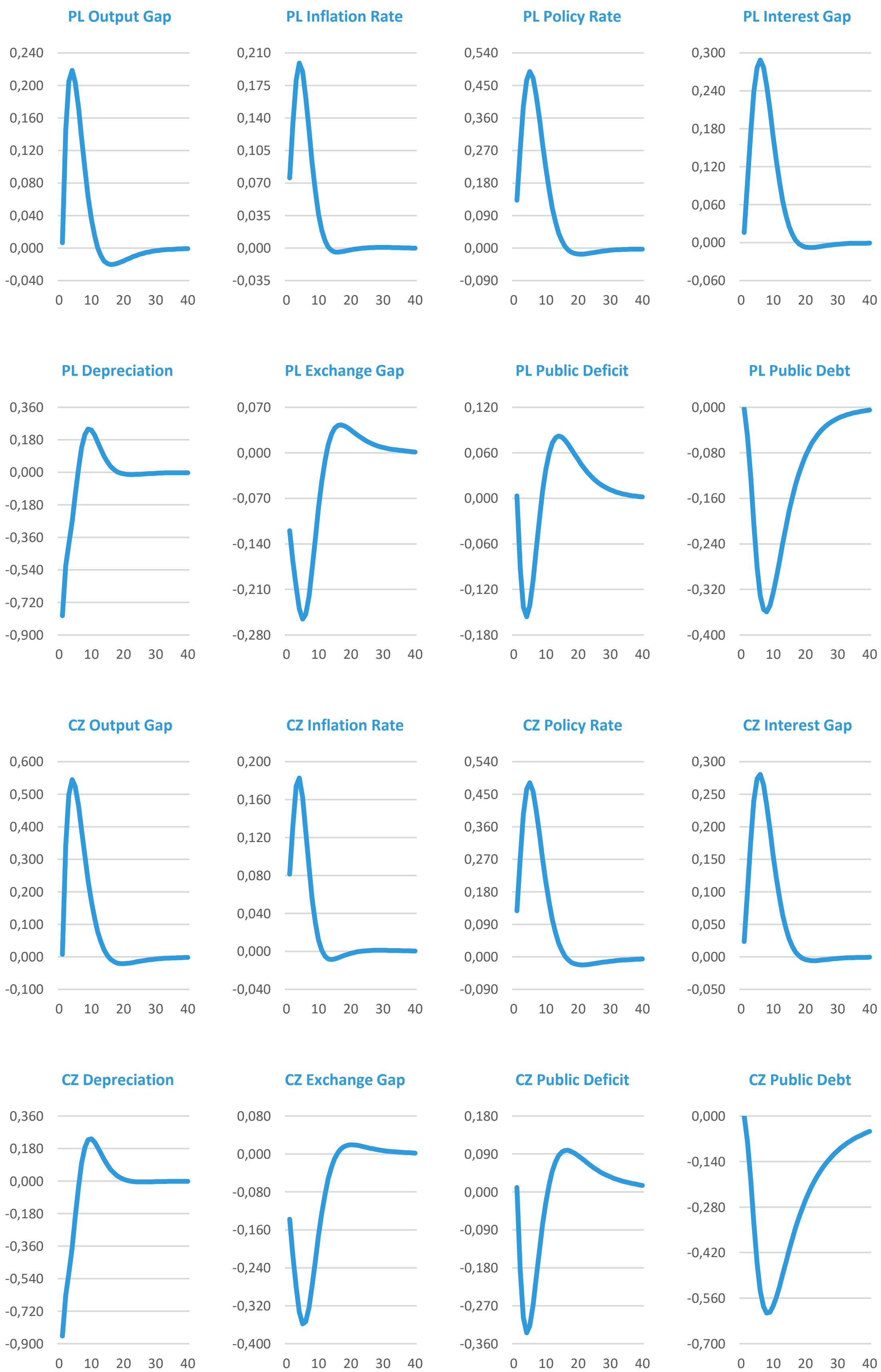


Fig 1: A permanent shock to domestic demand that corresponds to an increase of the output gap in the domestic economy by 1.00 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from steady-state values in percentage points.

External demand shock



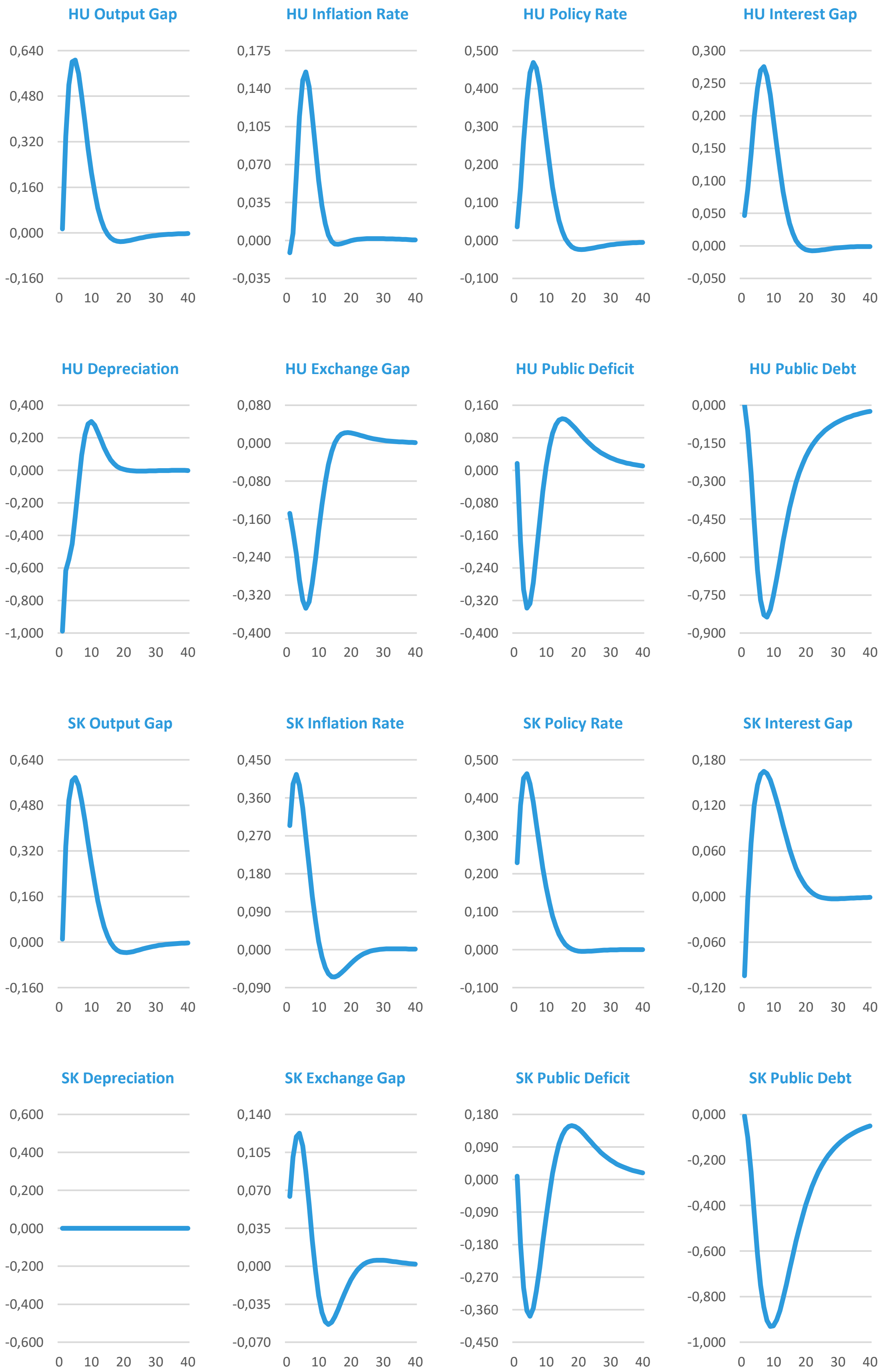
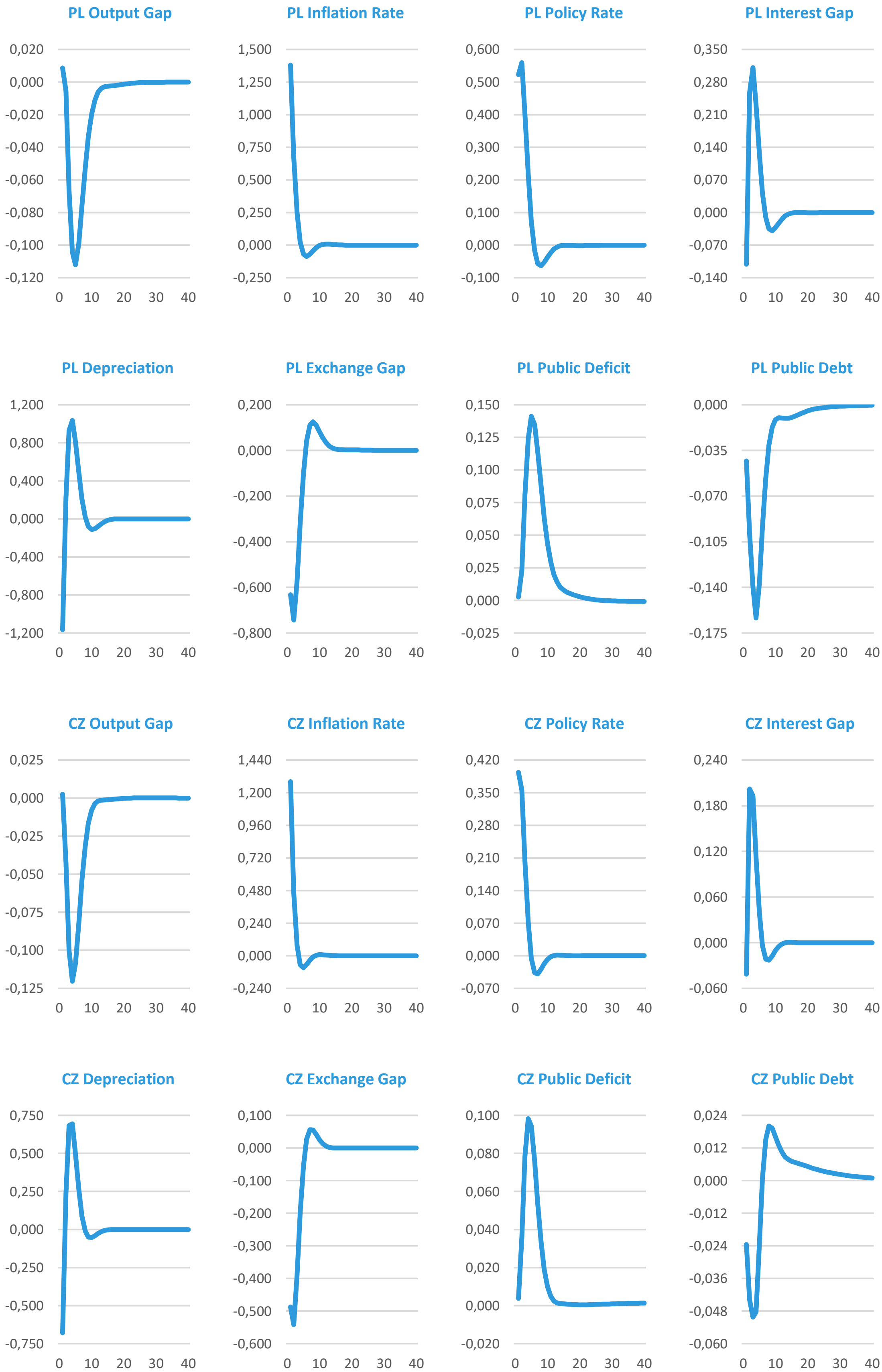


Fig 2: A permanent shock to external demand that corresponds to an increase of the output gap in the euro area by 1.00 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from steady-state values in percentage points.

Domestic supply shock



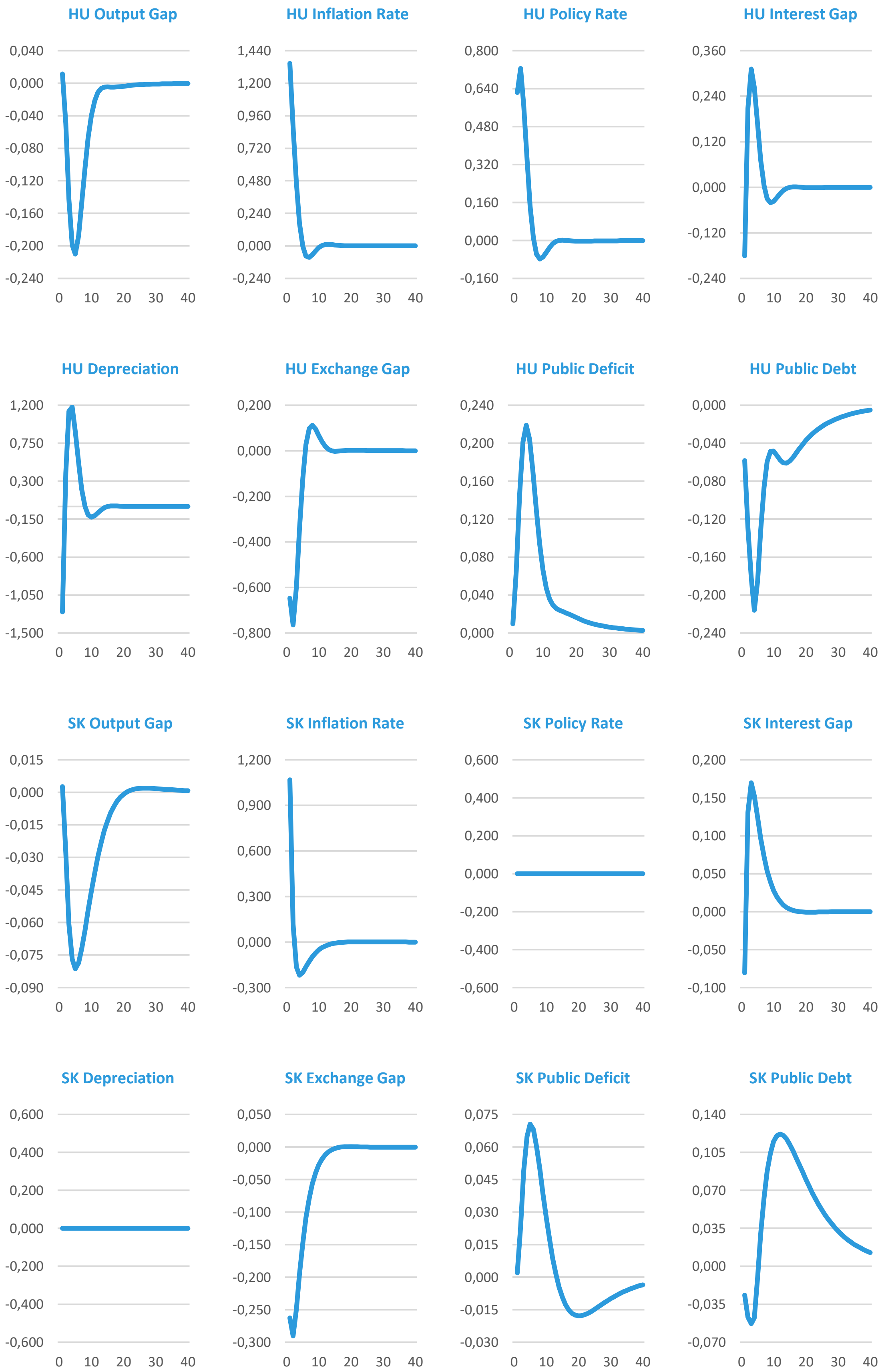
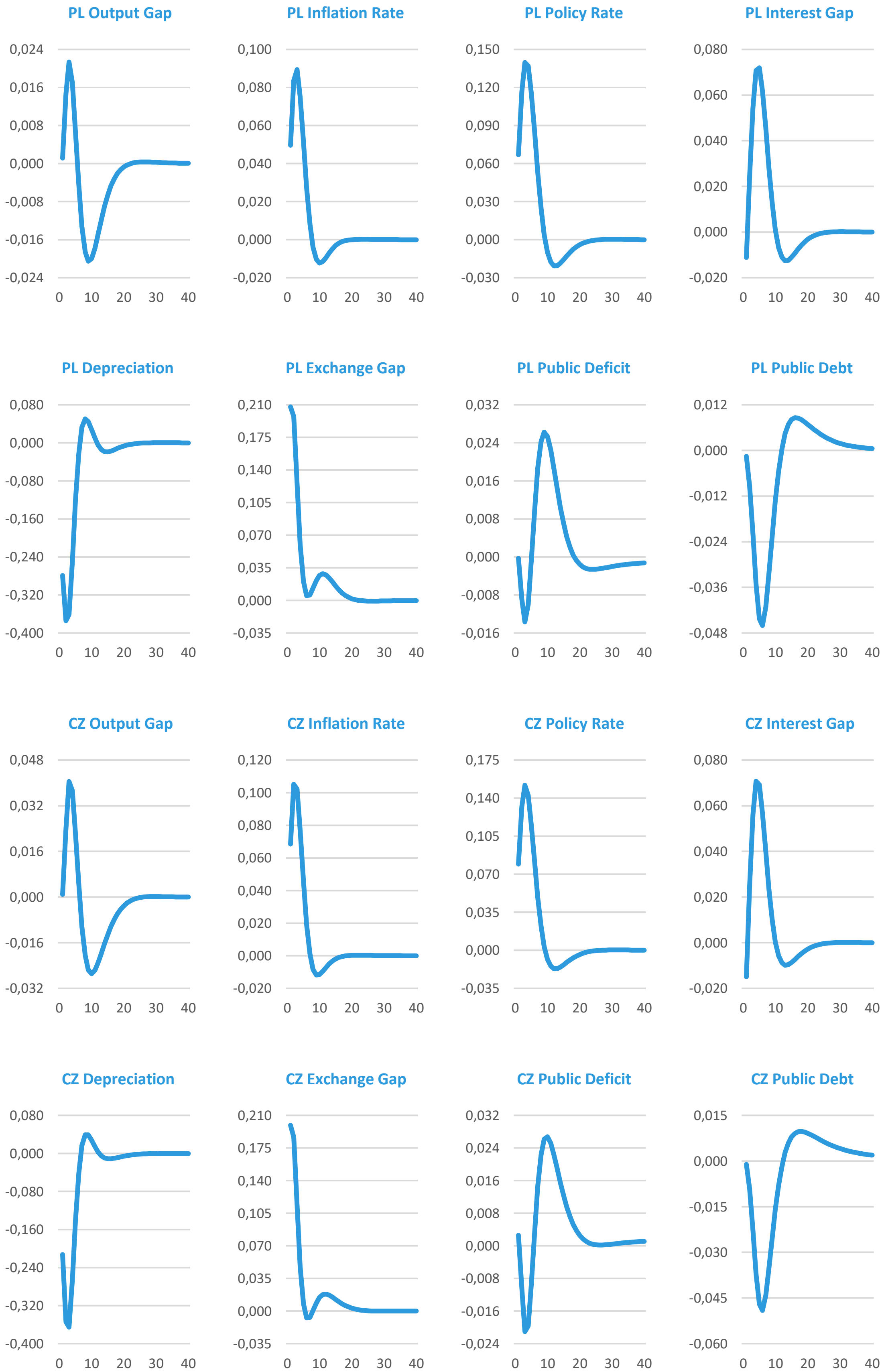


Fig 3: A permanent shock to domestic supply that corresponds to an increase of the core inflation in the domestic economy by 1.00 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from steady-state values in percentage points.

External supply shock



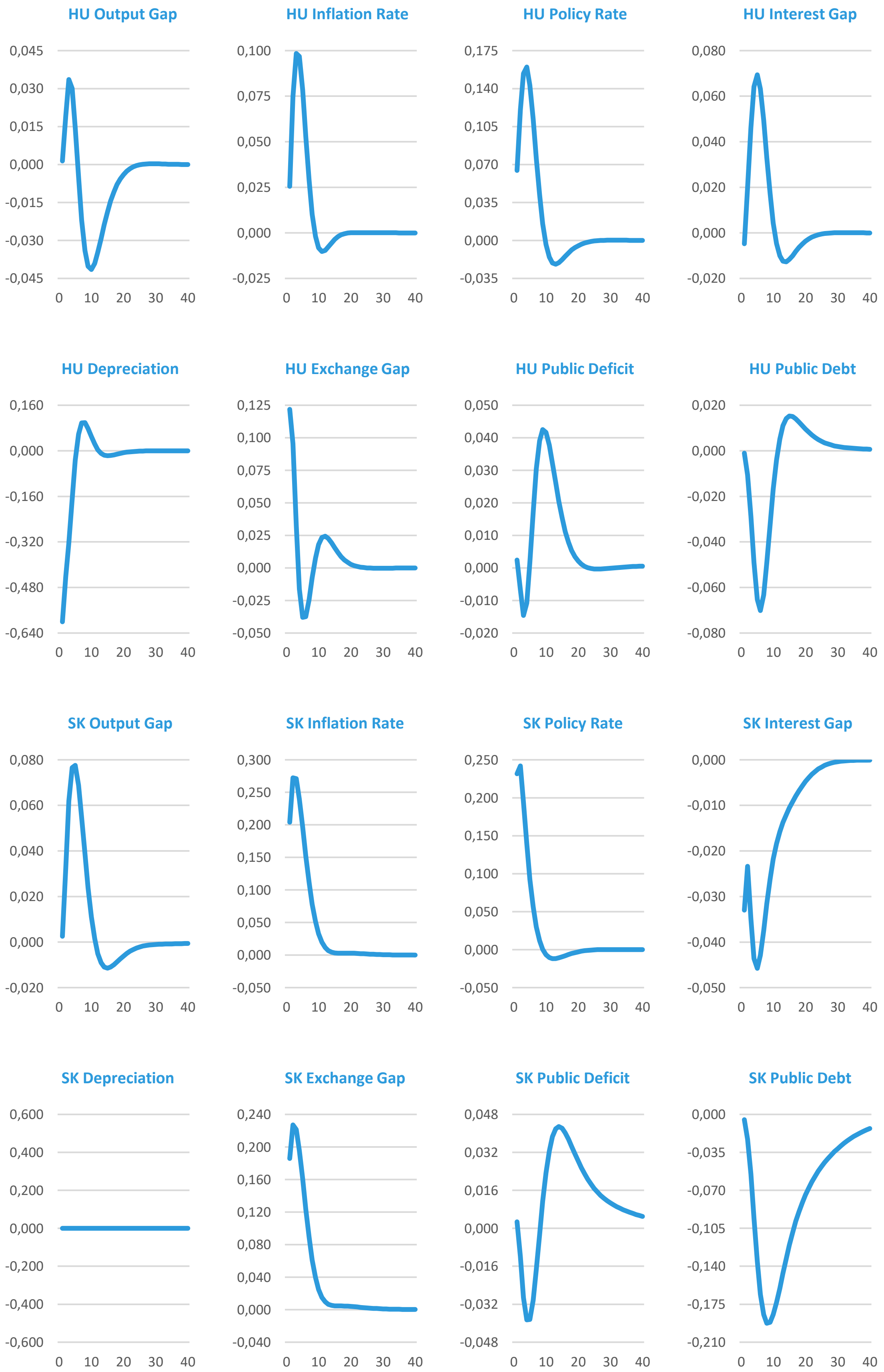
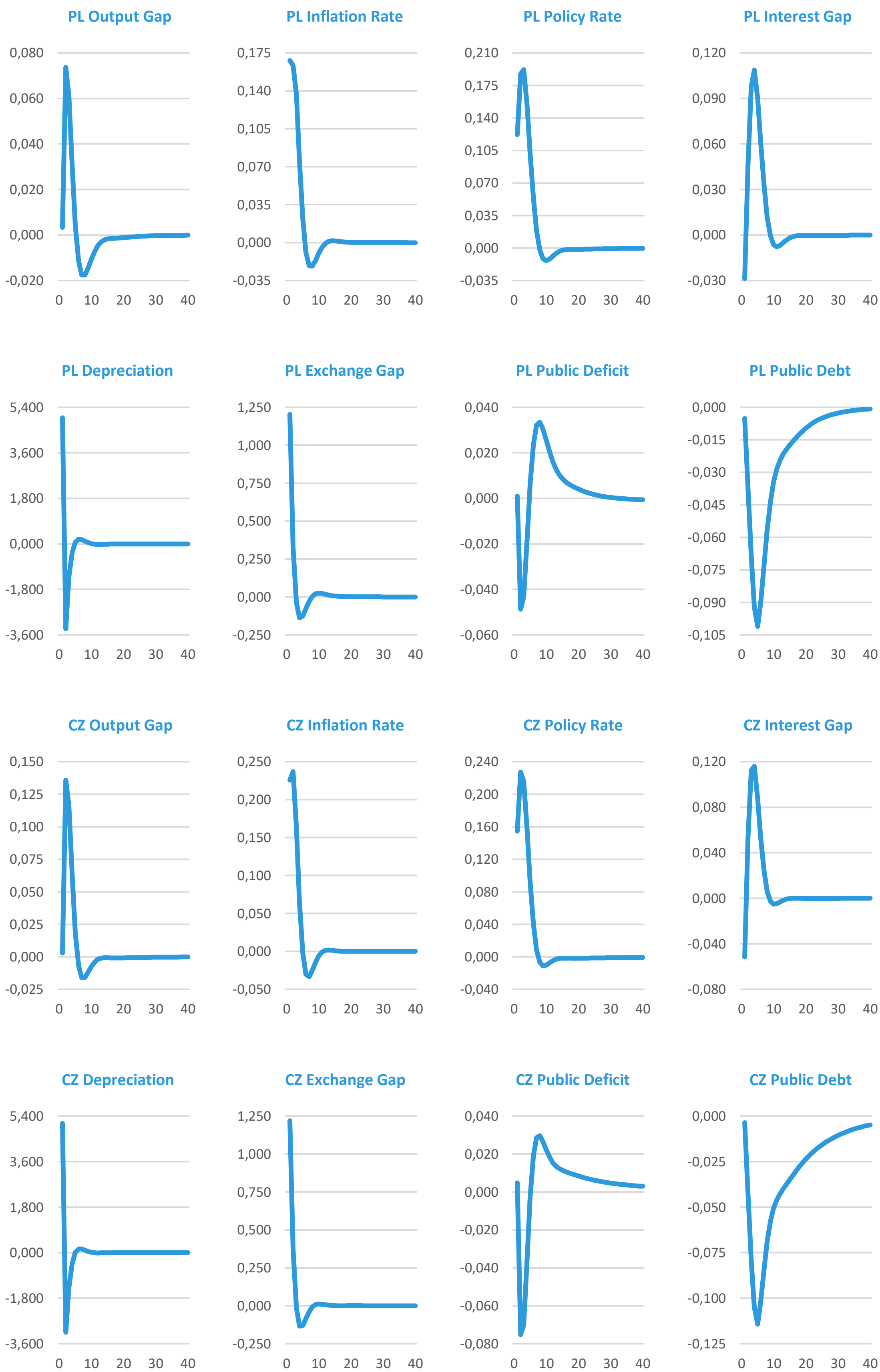


Fig 4: A permanent shock to external supply that corresponds to an increase of the core inflation in the euro area by 1.00 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from steady-state values in percentage points.

Exchange rate shock



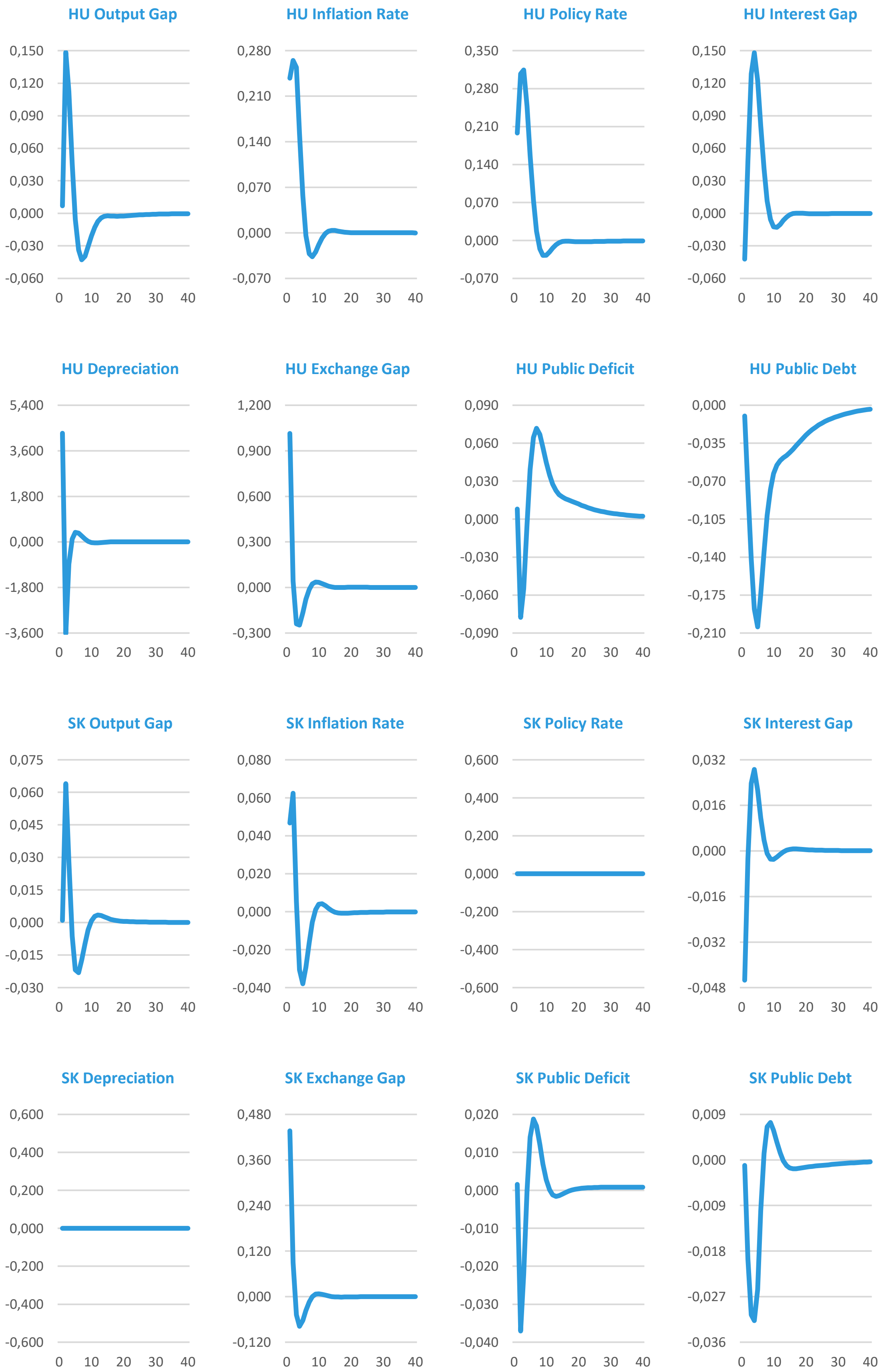
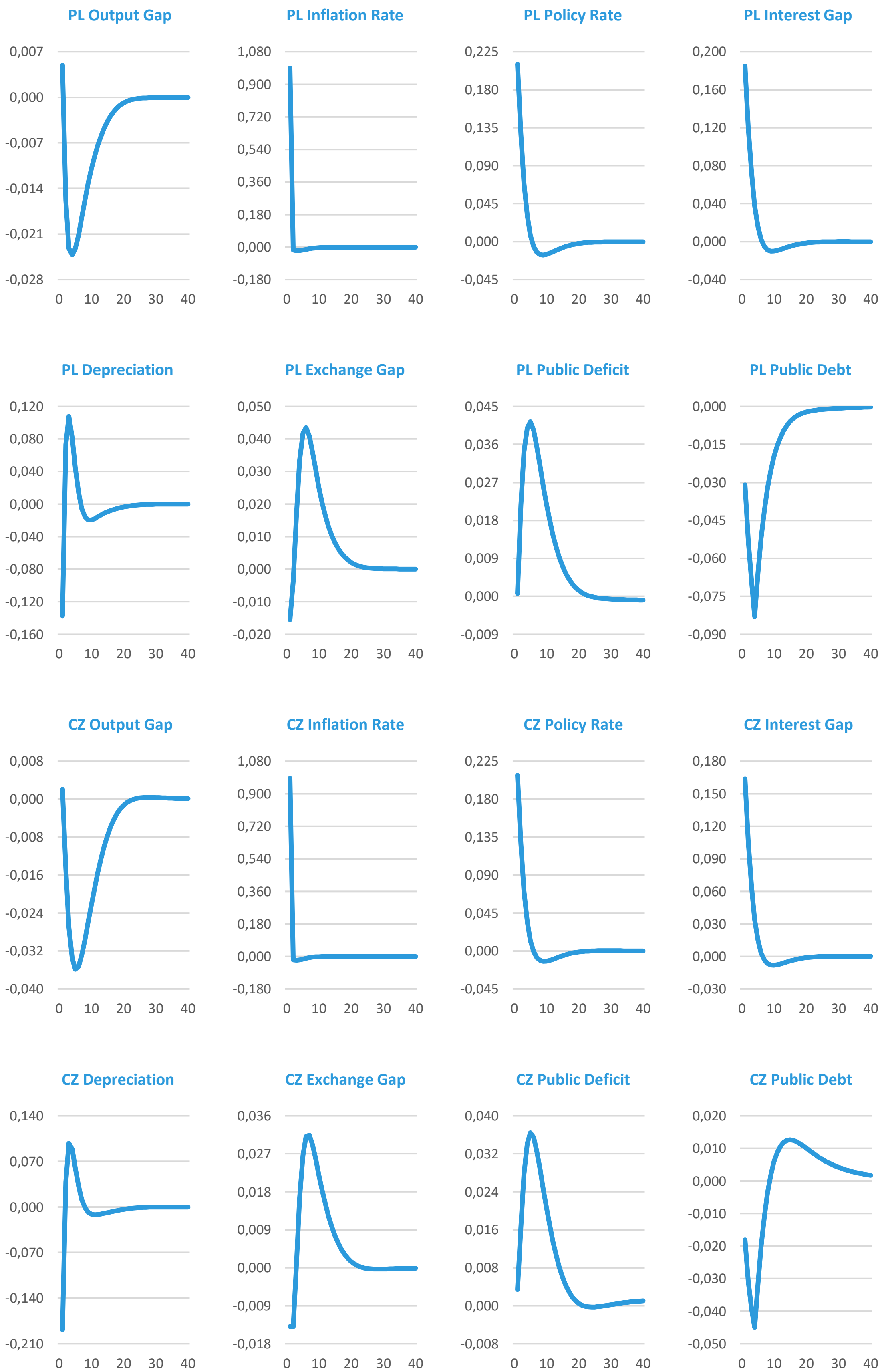


Fig 5: A permanent shock to exchange rate that corresponds to an increase of the exchange rate in the domestic economy by 1.00 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from steady-state values in percentage points.

World oil price shock



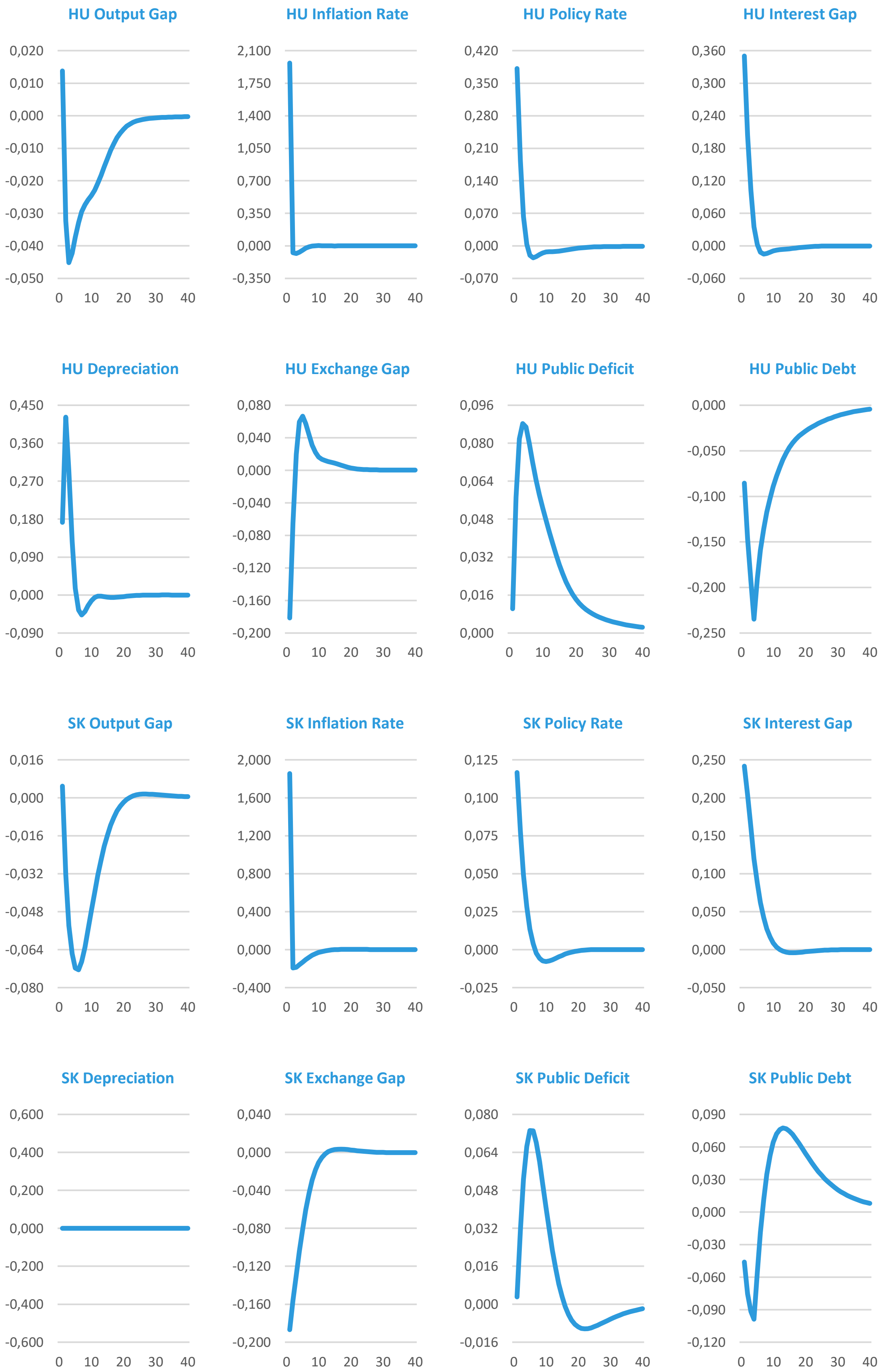
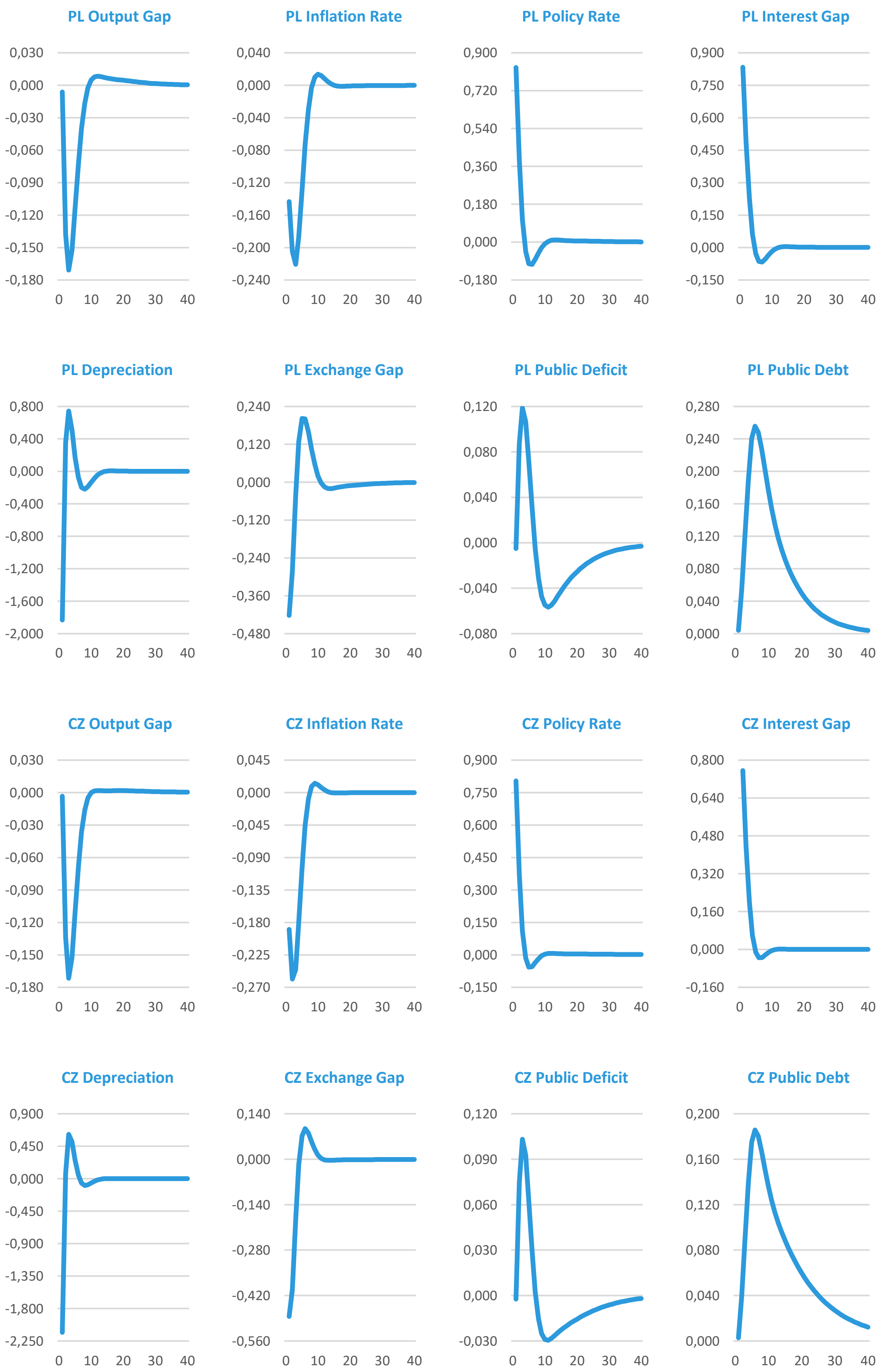


Fig 6: A permanent shock to world oil price that corresponds to an increase of the world oil price in the euro area by 100 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from steady-state values in percentage points.

Monetary policy shock



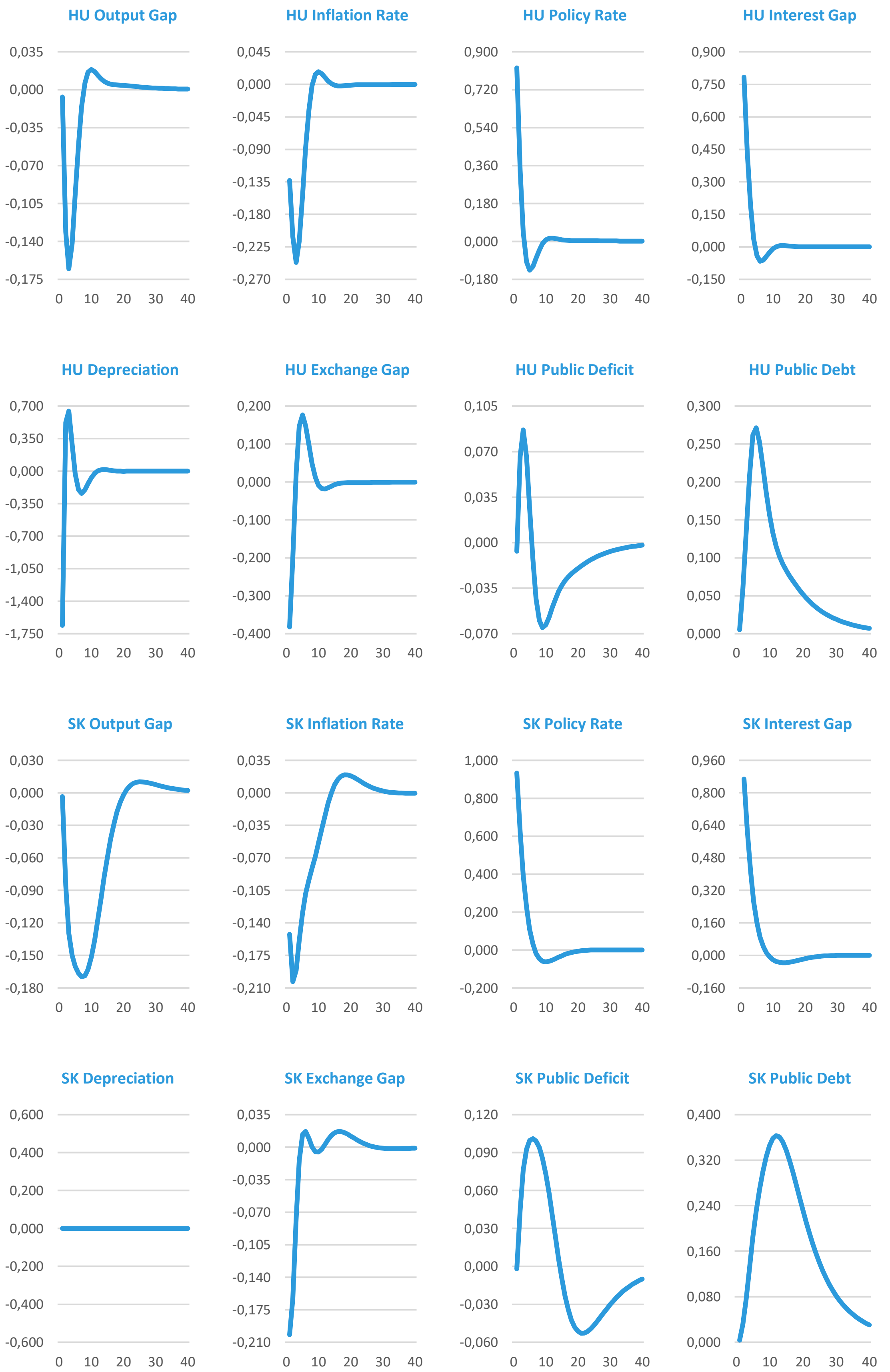
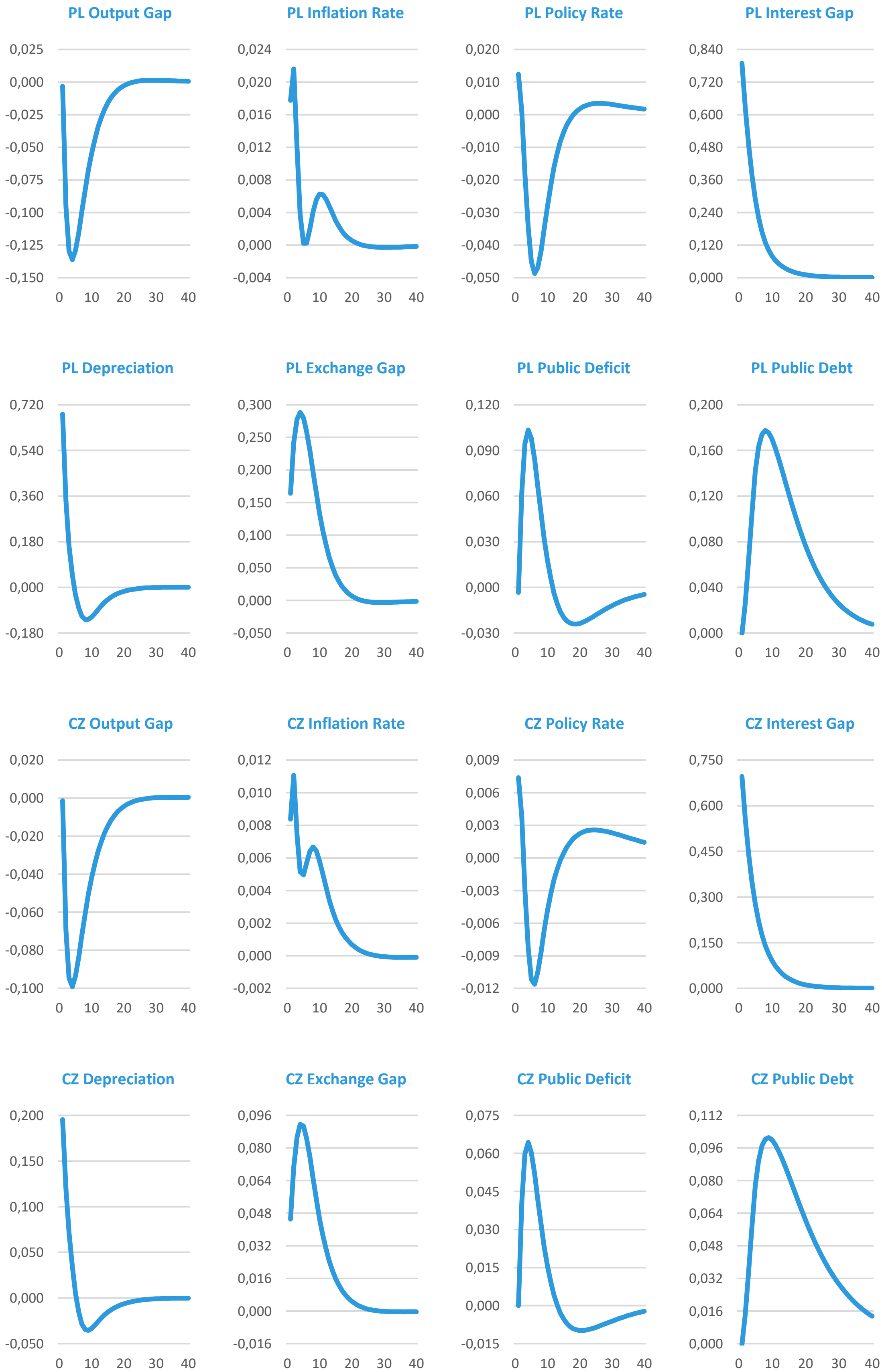


Fig 7: A permanent shock to monetary policy that corresponds to an increase of the policy rate in the domestic economy by 1.00 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from steady-state values in percentage points.

Interbank premium shock



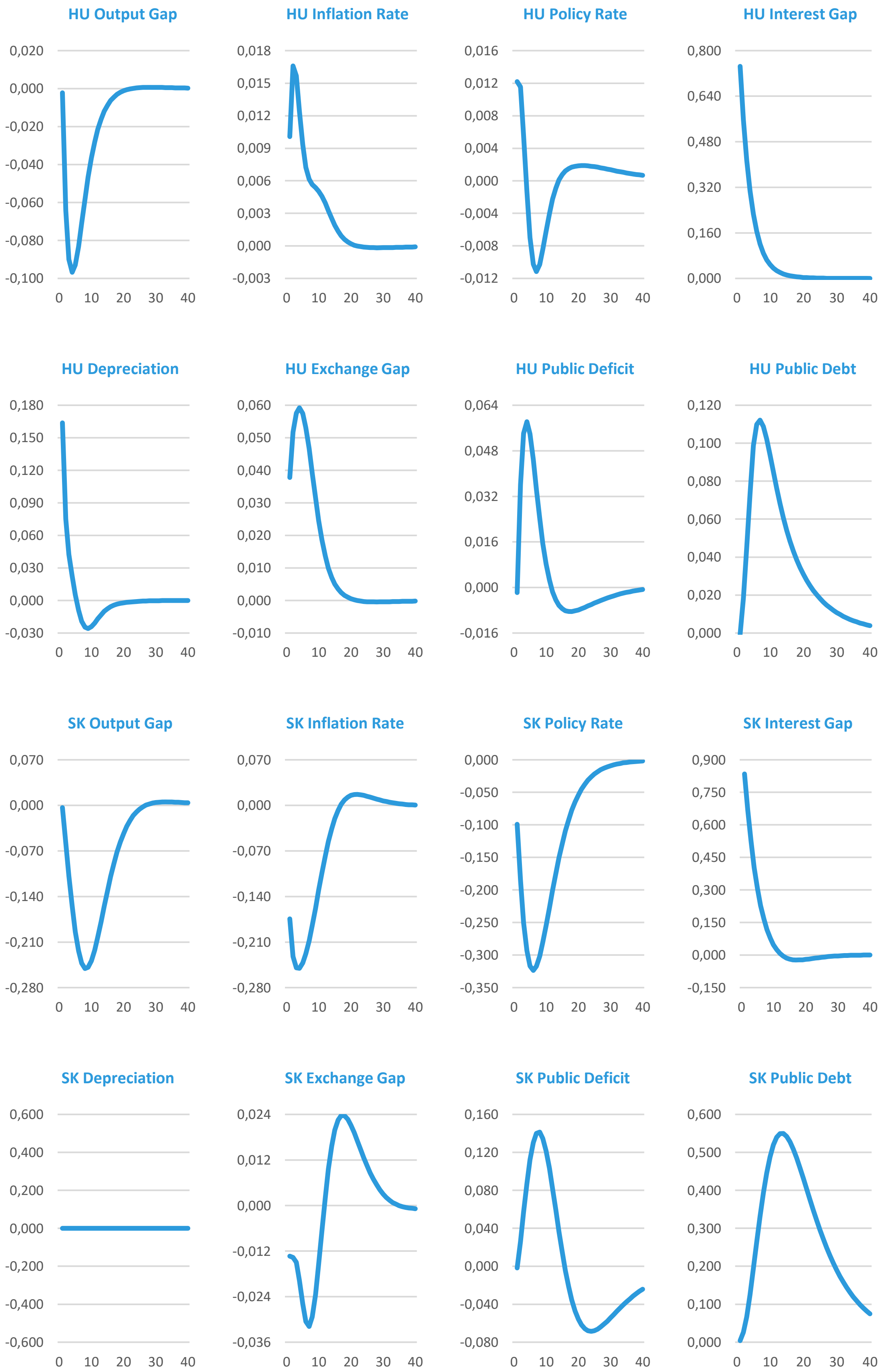


Fig 8: A permanent shock to interbank premium that corresponds to an increase of the interbank premium in the domestic economy by 1.00 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from steady-state values in percentage points.

Fiscal policy shock

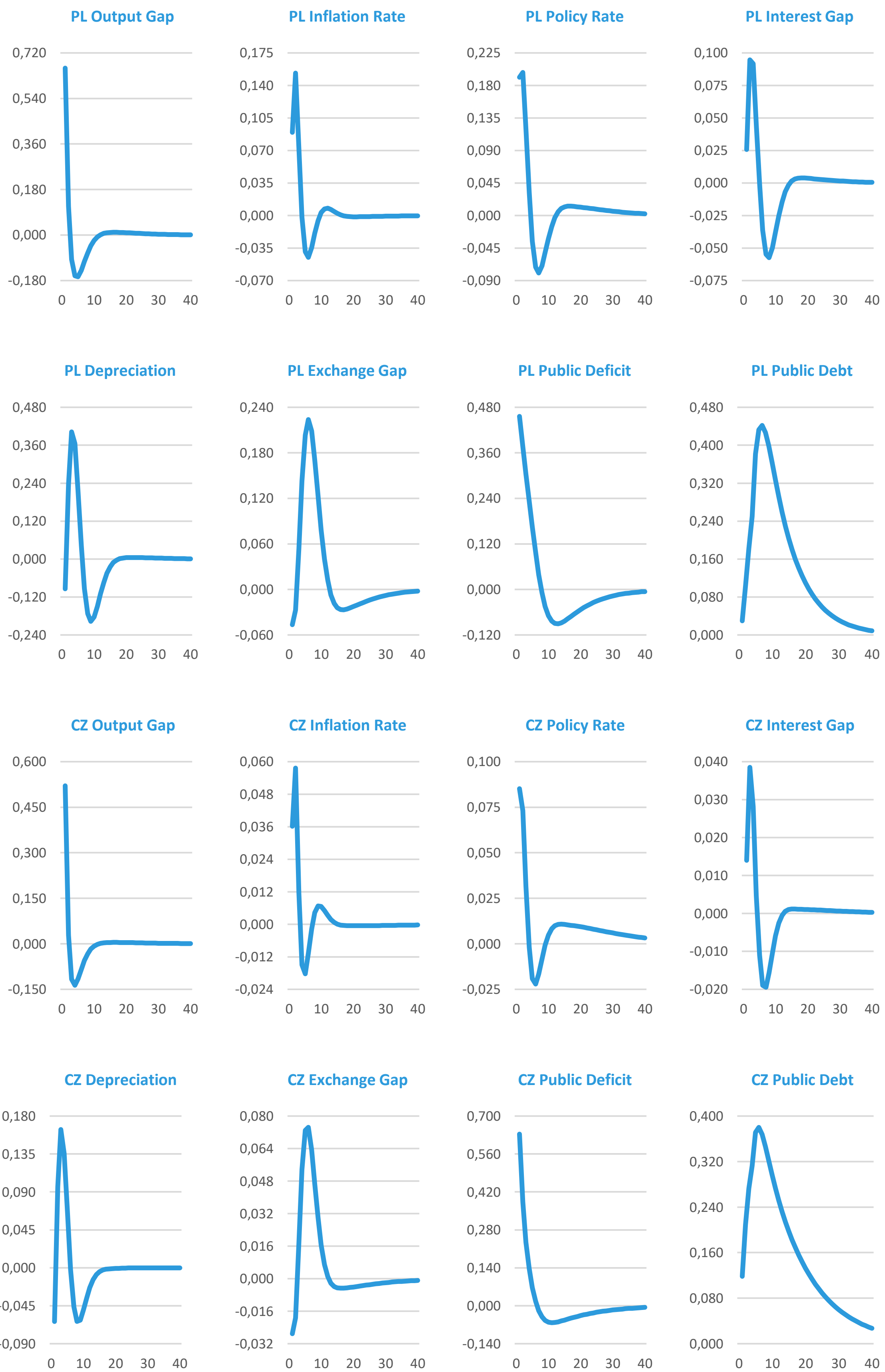
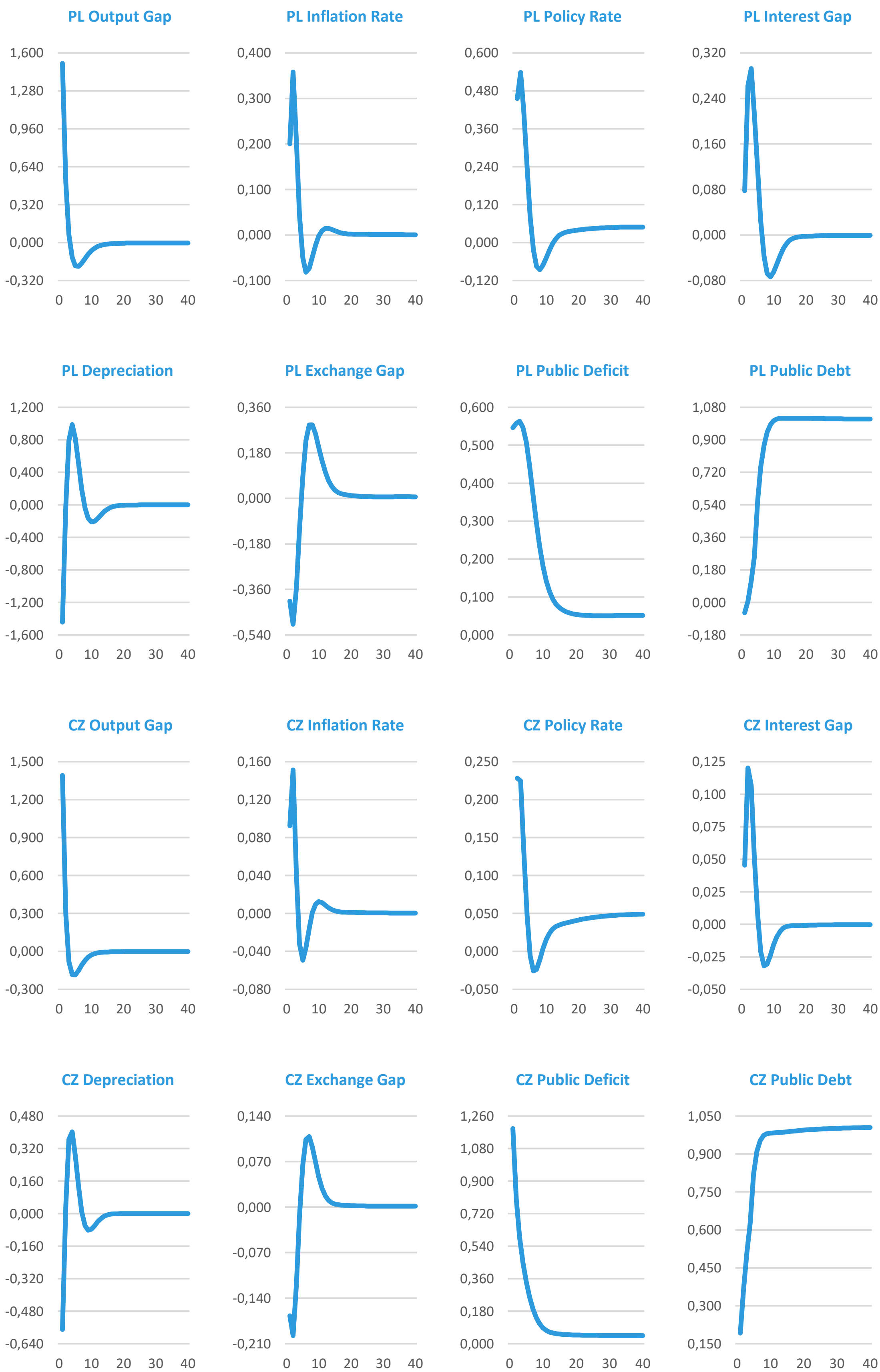


Fig 9: A permanent shock to fiscal policy that corresponds to an increase of the public deficit in the domestic economy by 1.00 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from steady-state values in percentage points.

Target debt shock



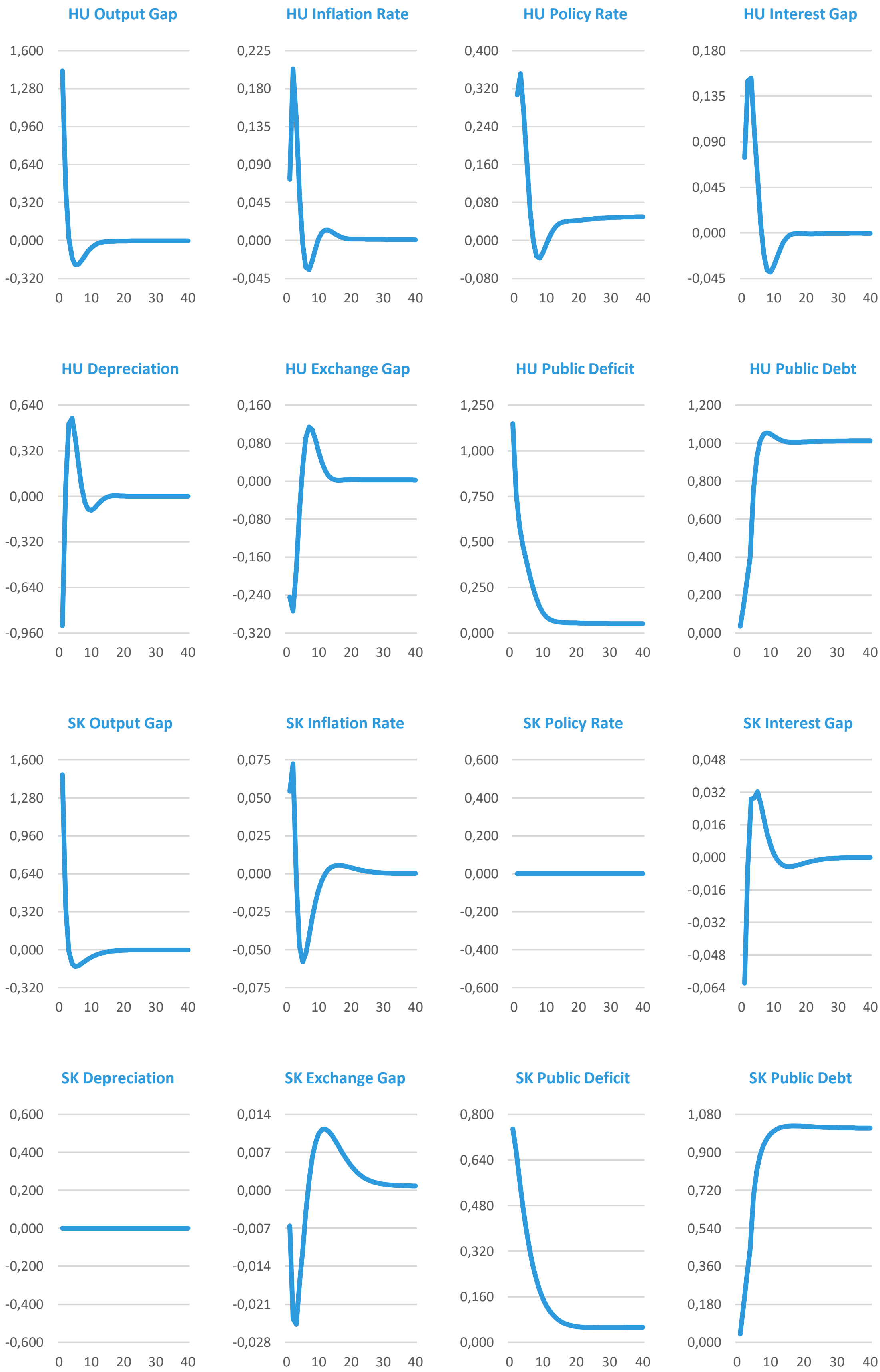
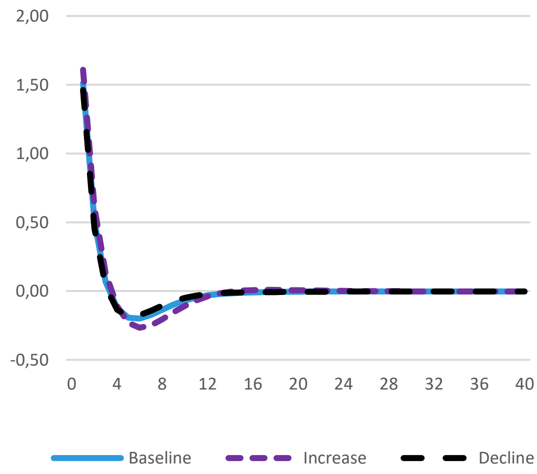


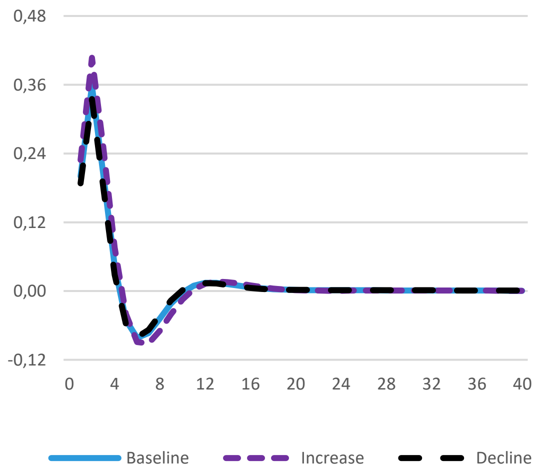
Fig 10: A permanent shock to target debt that corresponds to an increase of the target debt in the domestic economy by 1.00 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from steady-state values in percentage points.

Fiscal reactiveness

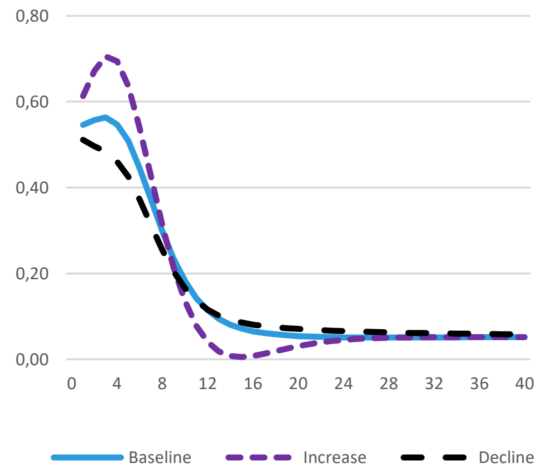
PL Output Gap



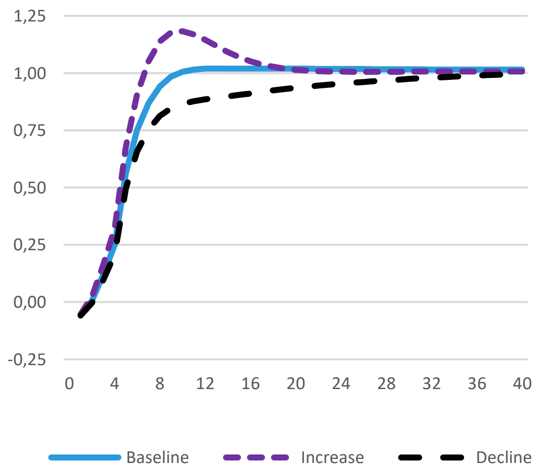
PL Inflation Rate



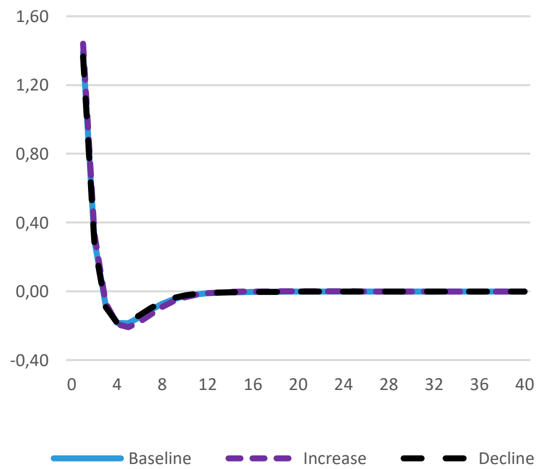
PL Public Deficit



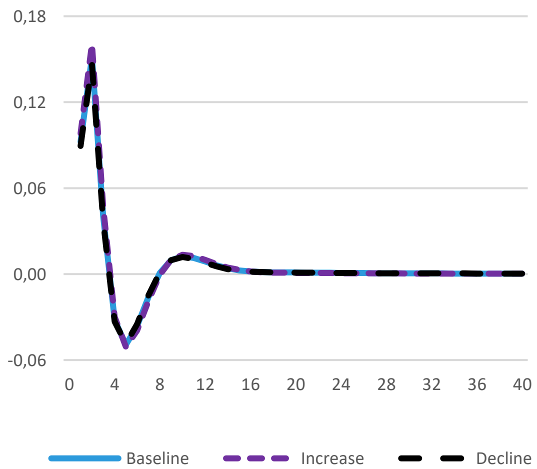
PL Public Debt

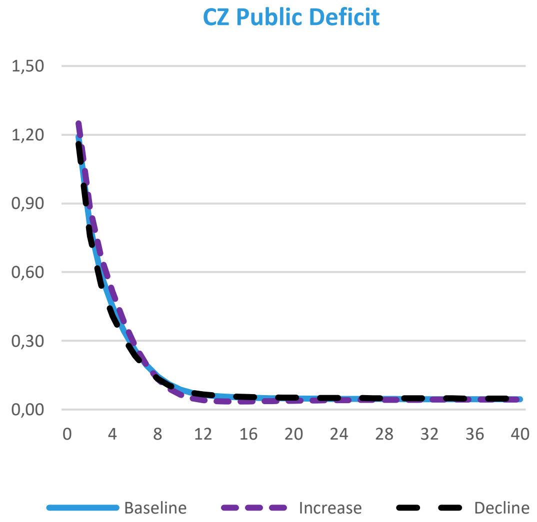


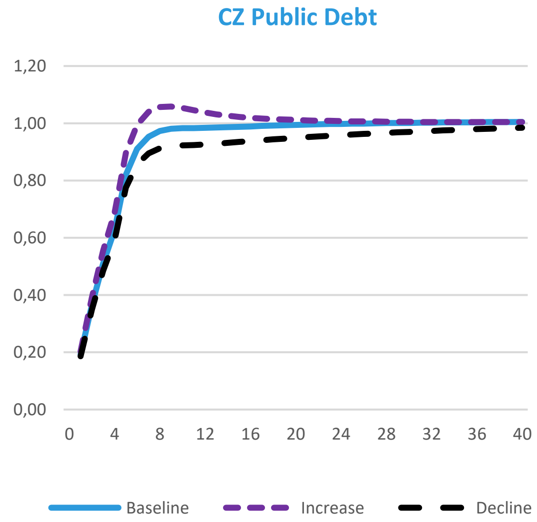
CZ Output Gap

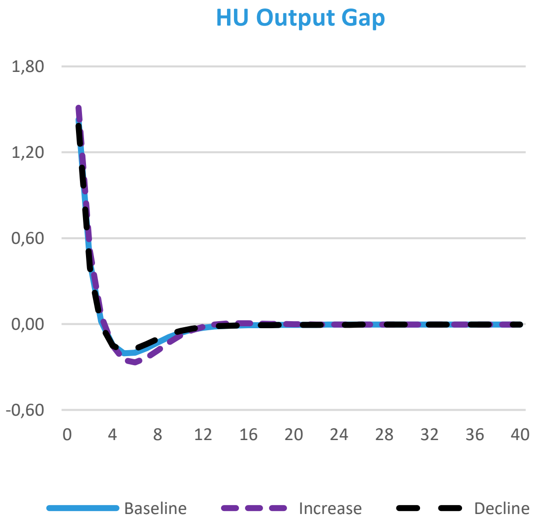


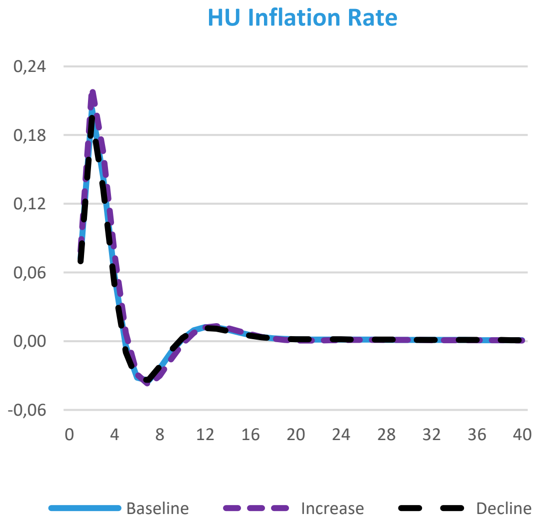
CZ Inflation Rate

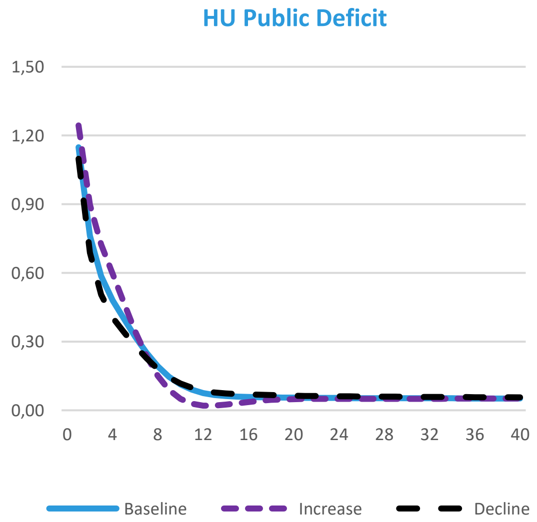


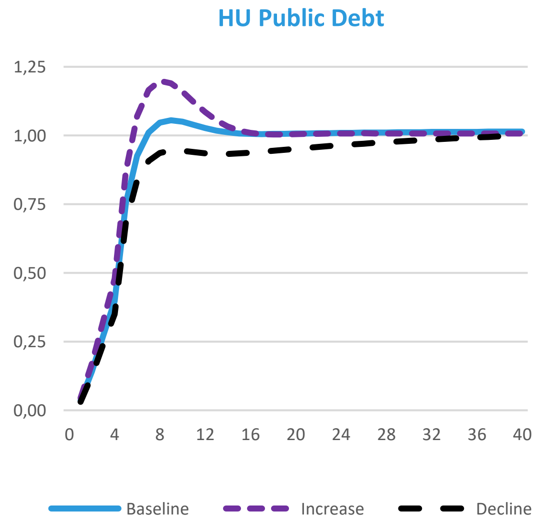

CZ Public Deficit
1,50
1,20
0,90
0,60
0,30
0,00
0 4 8 12 16 20 24 28 32 36 40
Baseline
Increase
Decline


CZ Public Debt
1,20
1,00
0,80
0,60
0,40
0,20
0,00
0 4 8 12 16 20 24 28 32 36 40
Baseline
Increase
Decline


HU Output Gap
1,80
1,20
0,60
0,00
-0,60
0 4 8 12 16 20 24 28 32 36 40
Baseline
Increase
Decline


HU Inflation Rate
0,24
0,18
0,12
0,06
0,00
-0,06
0 4 8 12 16 20 24 28 32 36 40
Baseline
Increase
Decline


HU Public Deficit
1,50
1,20
0,90
0,60
0,30
0,00
0 4 8 12 16 20 24 28 32 36 40
Baseline
Increase
Decline


HU Public Debt
1,25
1,00
0,75
0,50
0,25
0,00
0 4 8 12 16 20 24 28 32 36 40
Baseline
Increase
Decline

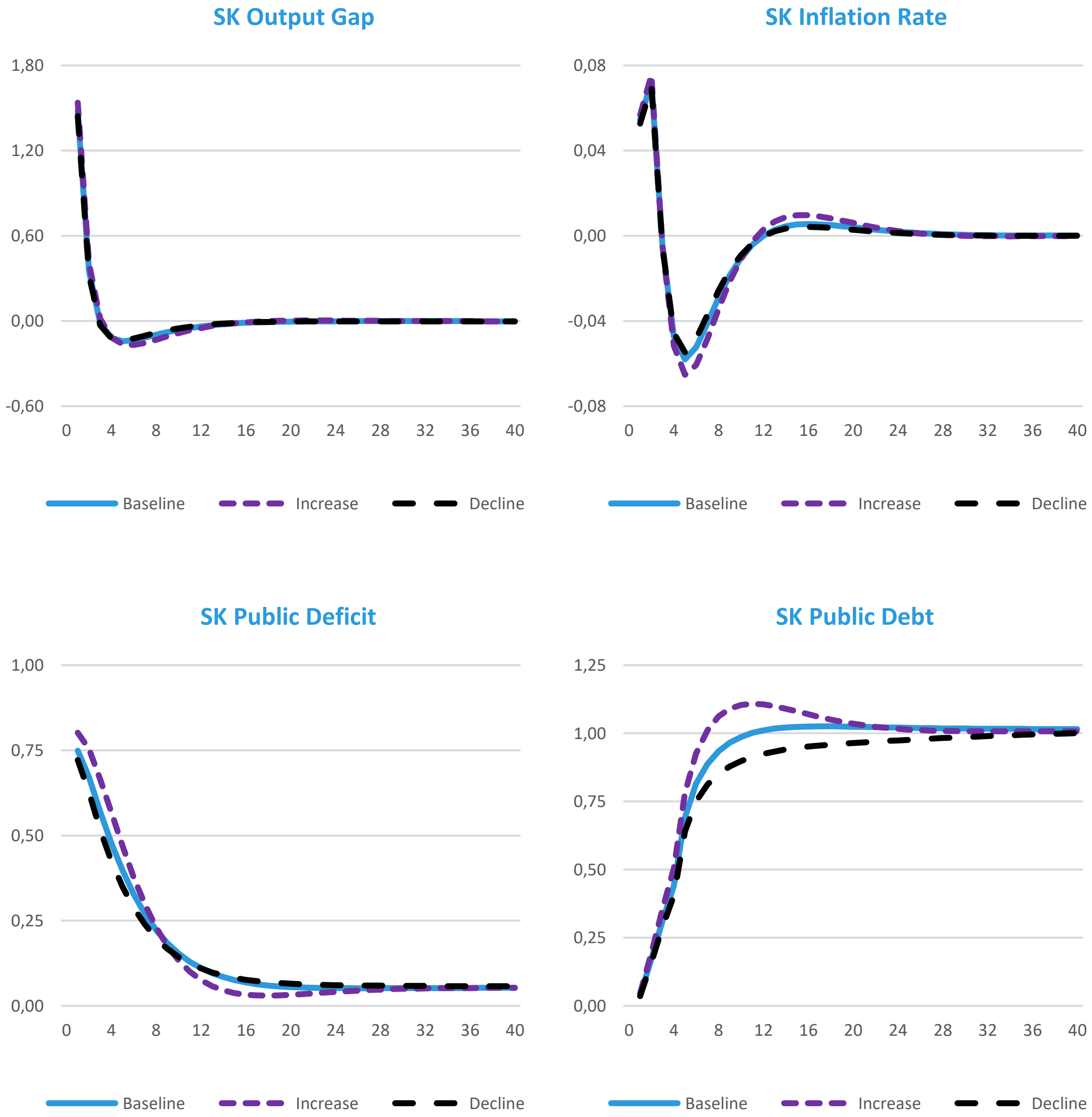
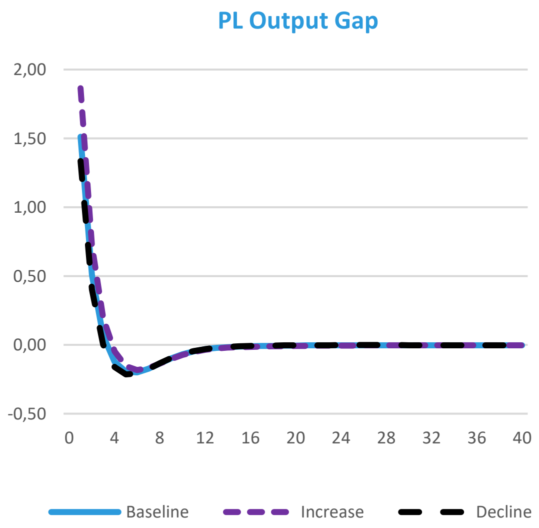
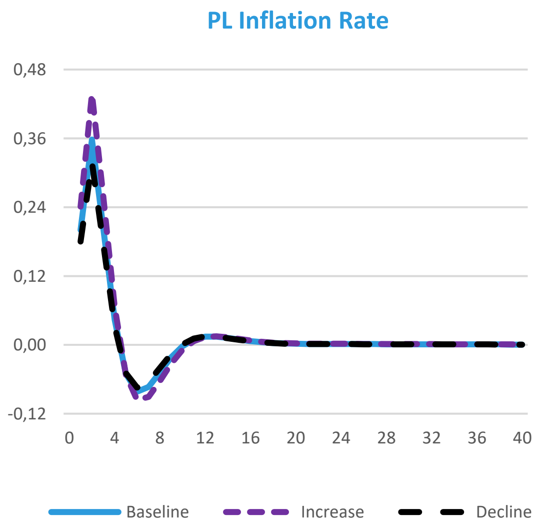
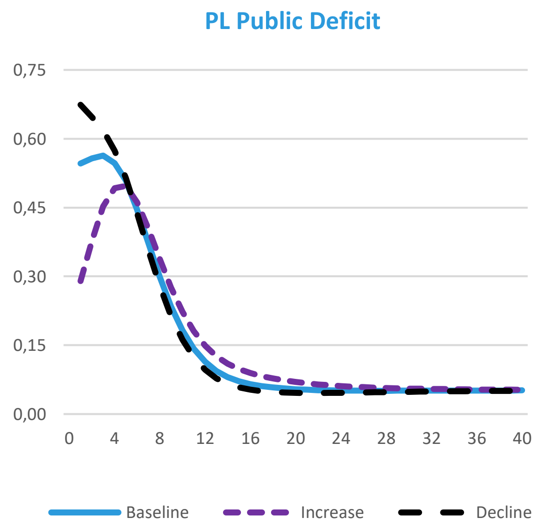


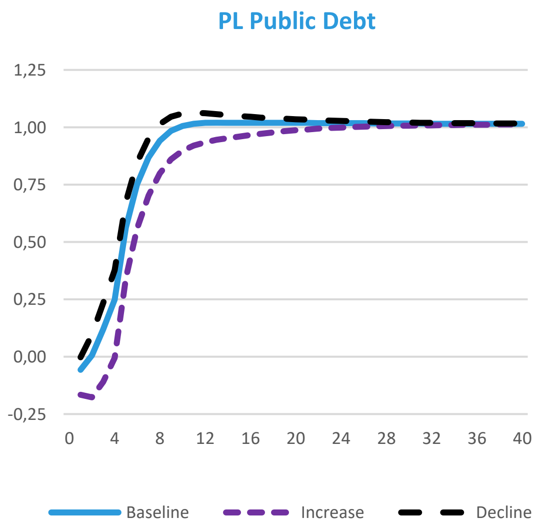
Fig 11: Impulse response functions of model variables after a positive shock to target debt with the magnitude of 1.00 p.p. in the first quarter under (i) a baseline scenario with the calibration of $\alpha_{i,2} = 0.40$ for Poland and Hungary and $\alpha_{i,2} = 0.30$ for Czechia and Slovakia, (ii) an increase scenario with the calibration of $\alpha_{i,2} = 0.80$ for Poland and Hungary and $\alpha_{i,2} = 0.60$ for Czechia and Slovakia and (iii) a decline scenario with the calibration of $\alpha_{i,2} = 0.20$ for Poland and Hungary and $\alpha_{i,2} = 0.15$ for Czechia and Slovakia. X axes label quarters after the shock and Y axes label deviations of model variables from steady-state values in percentage points.

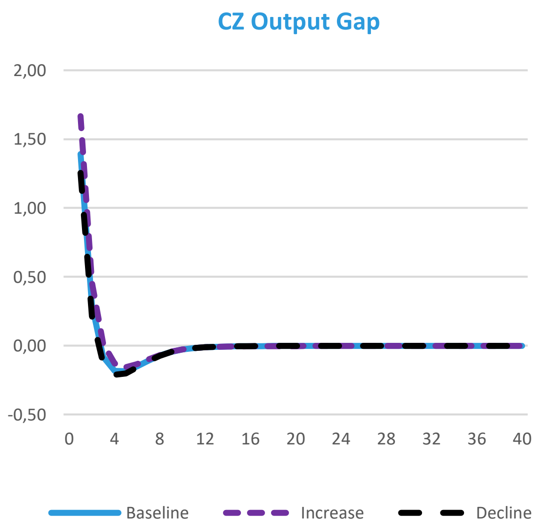
Fiscal expectations

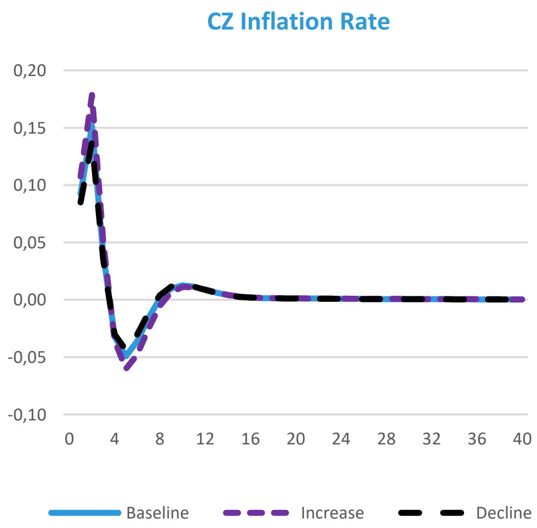


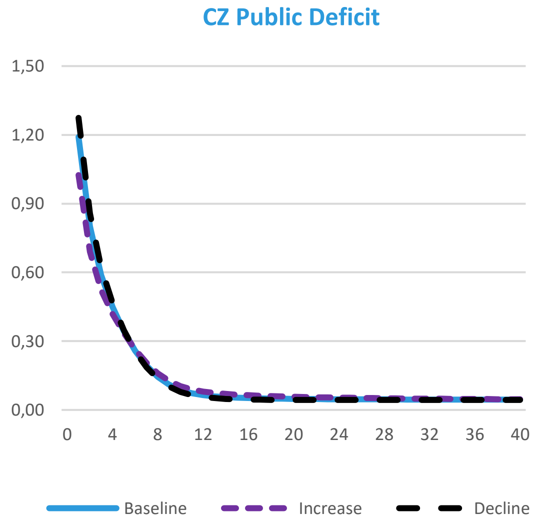


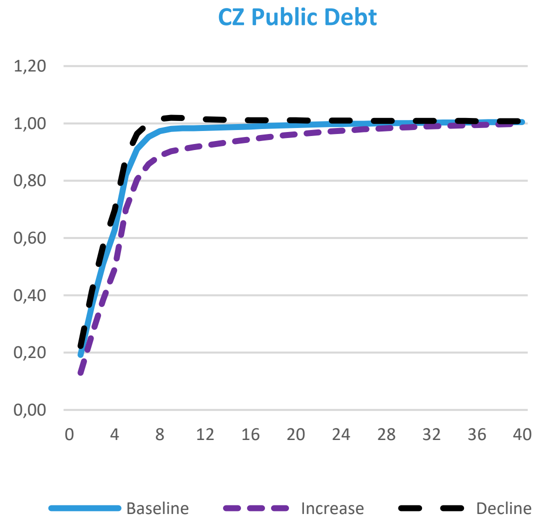


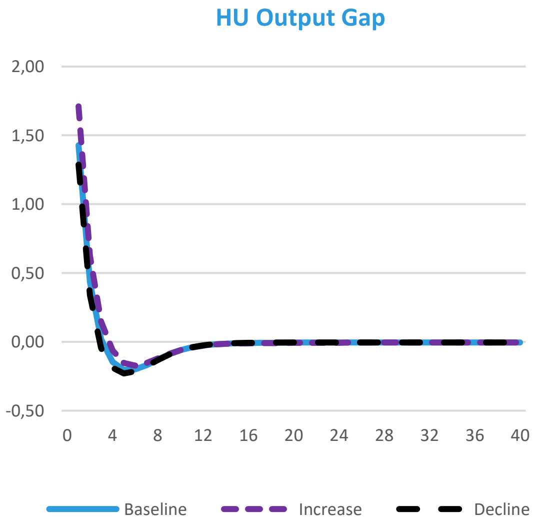


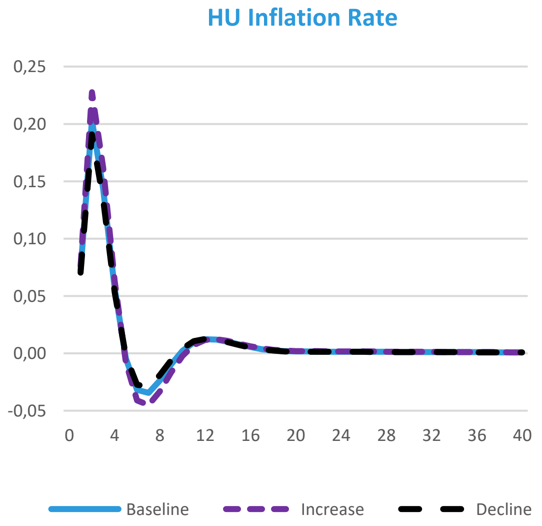


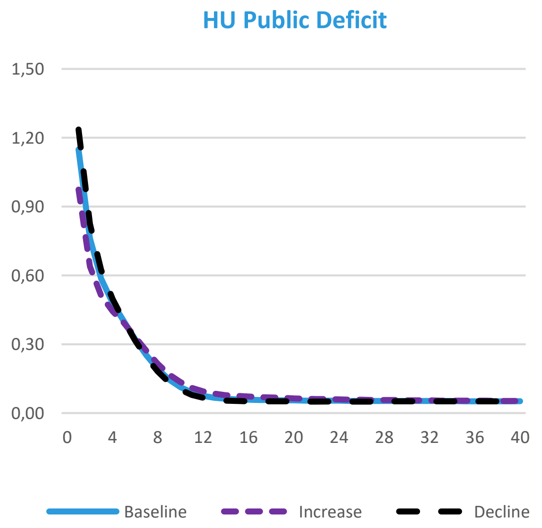


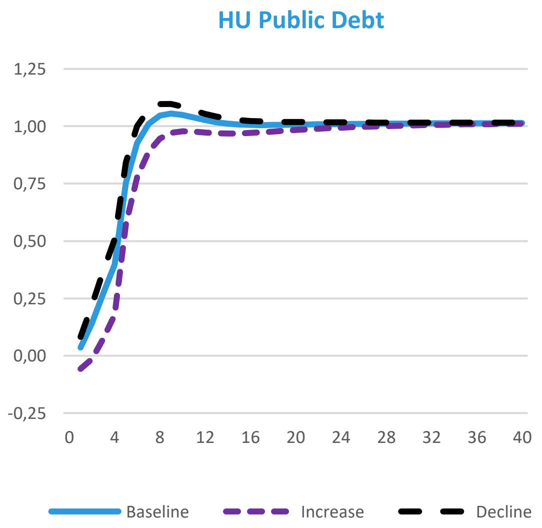

CZ Public Deficit
1,50
1,20
0,90
0,60
0,30
0,00
0 4 8 12 16 20 24 28 32 36 40
Baseline
Increase
Decline


CZ Public Debt
1,20
1,00
0,80
0,60
0,40
0,20
0,00
0 4 8 12 16 20 24 28 32 36 40
Baseline
Increase
Decline


HU Output Gap
2,00
1,50
1,00
0,50
0,00
-0,50
0 4 8 12 16 20 24 28 32 36 40
Baseline
Increase
Decline


HU Inflation Rate
0,25
0,20
0,15
0,10
0,05
0,00
-0,05
0 4 8 12 16 20 24 28 32 36 40
Baseline
Increase
Decline


HU Public Deficit
1,50
1,20
0,90
0,60
0,30
0,00
0 4 8 12 16 20 24 28 32 36 40
Baseline
Increase
Decline


HU Public Debt
1,25
1,00
0,75
0,50
0,25
0,00
-0,25
0 4 8 12 16 20 24 28 32 36 40
Baseline
Increase
Decline

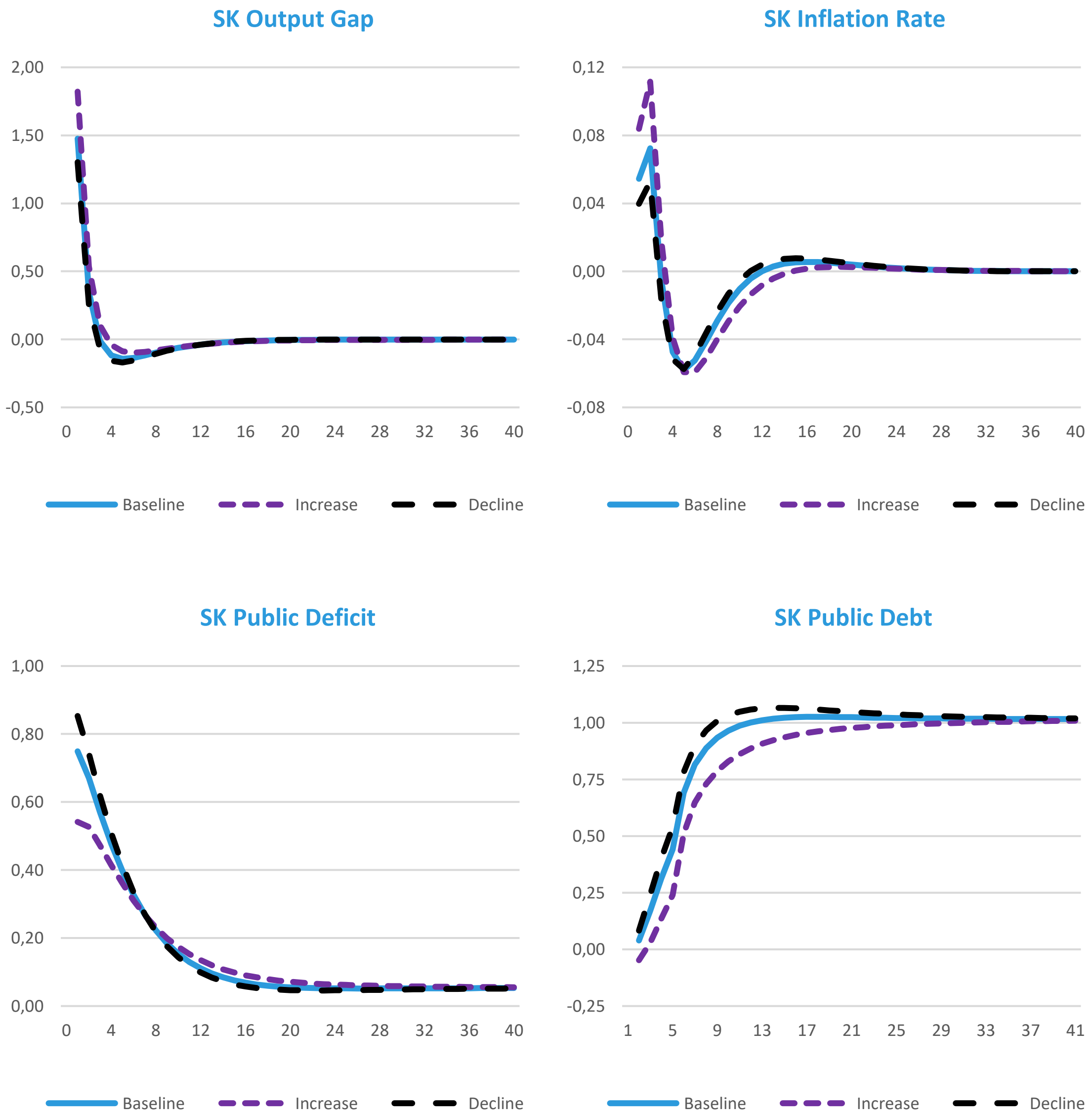
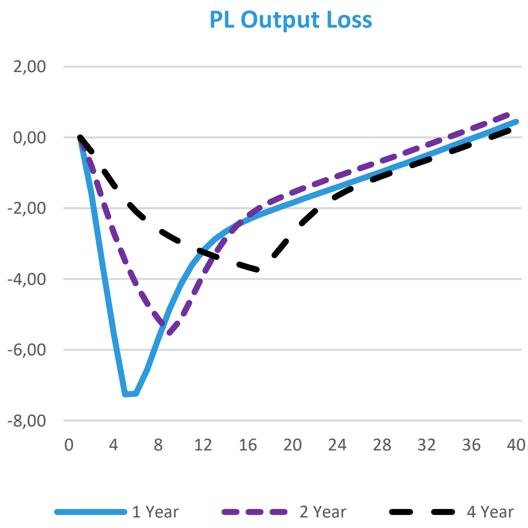
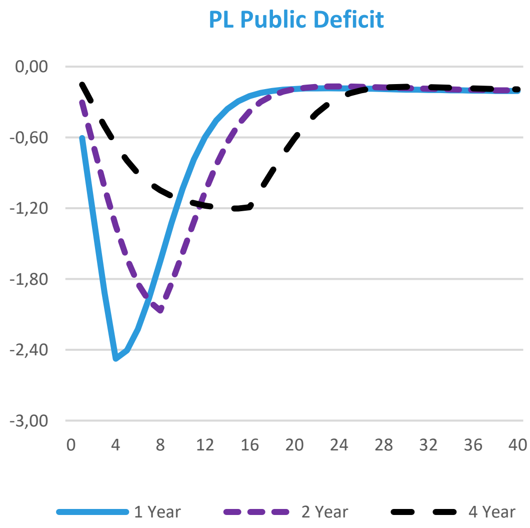
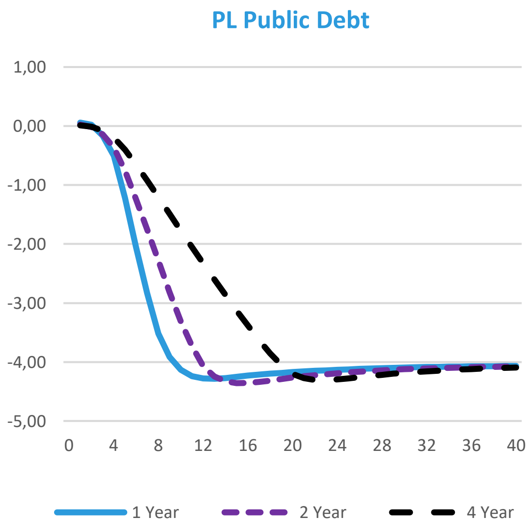


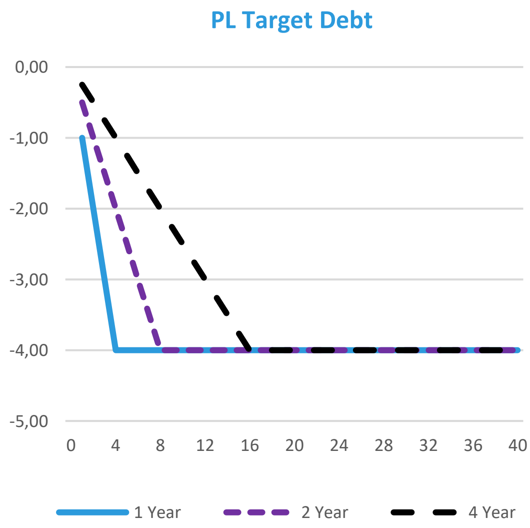
Fig 12: Impulse response functions of model variables after a positive shock to target debt with the magnitude of 1.00 p.p. in the first quarter under (i) a baseline scenario with the calibration of $\Gamma_{i,2} = 0.50$ for the Visegrad countries, (ii) an increase scenario with the calibration of $\Gamma_{i,2} = 1.00$ for the Visegrad countries and (iii) a decline scenario with the calibration of $\Gamma_{i,2} = 0.25$ for the Visegrad countries. X axes label quarters after the shock and Y axes label deviations of model variables from steady-state values in percentage points.

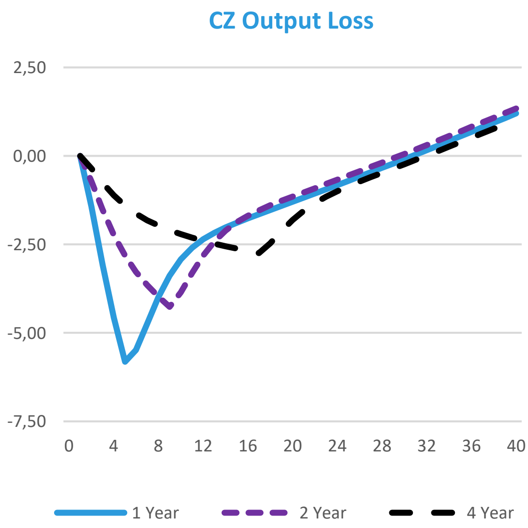
Consolidation strategies

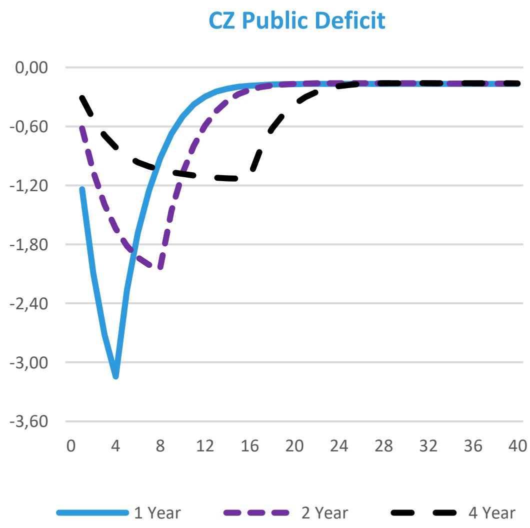


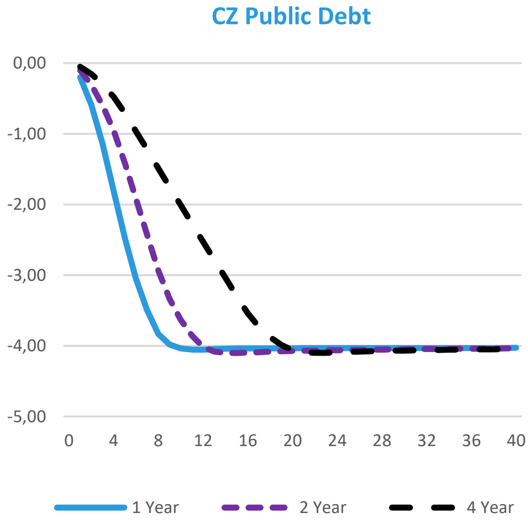


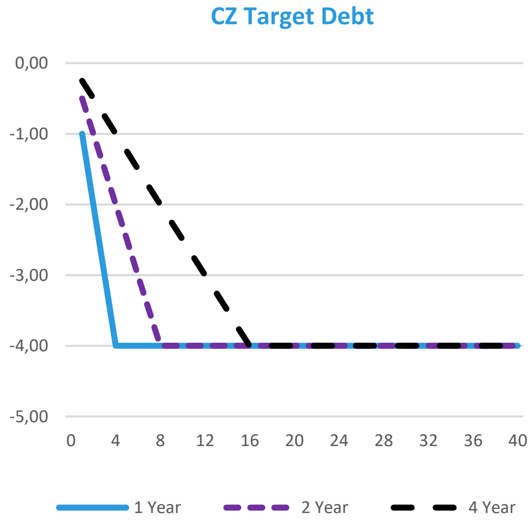


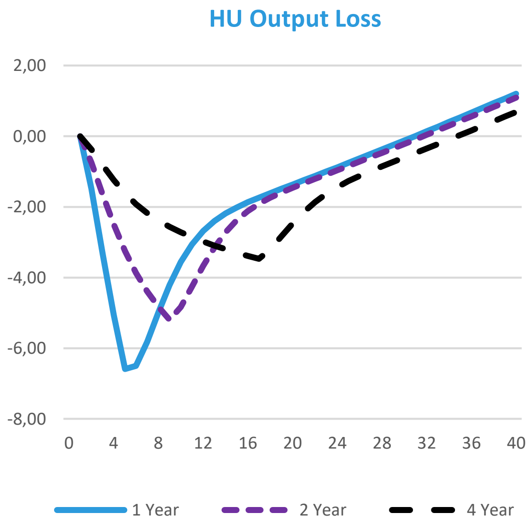


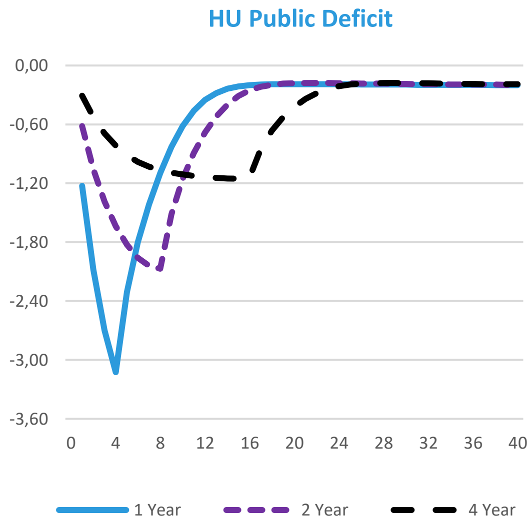


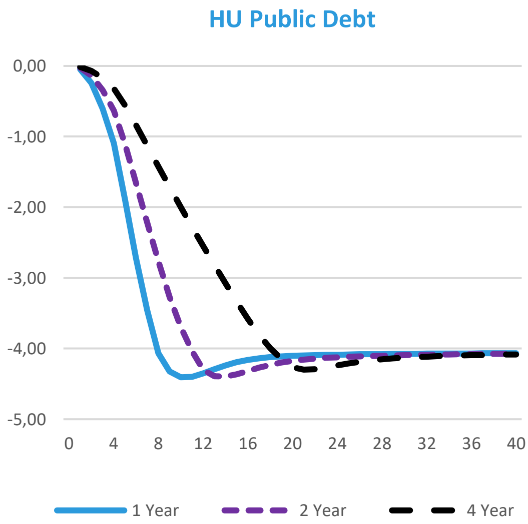


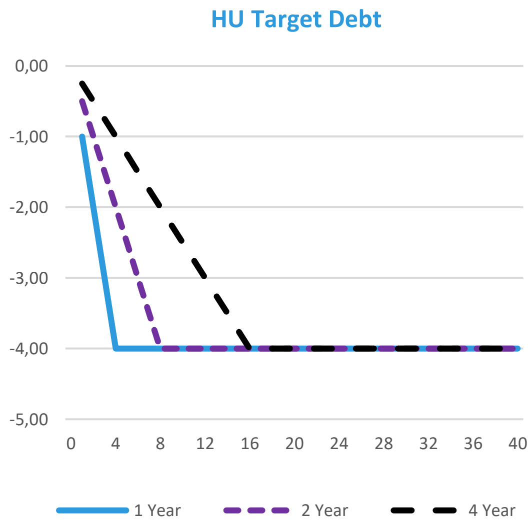

CZ Public Debt
0,00
-1,00
-2,00
-3,00
-4,00
-5,00
0 4 8 12 16 20 24 28 32 36 40
1 Year
2 Year
4 Year


CZ Target Debt
0,00
-1,00
-2,00
-3,00
-4,00
-5,00
0 4 8 12 16 20 24 28 32 36 40
1 Year
2 Year
4 Year


HU Output Loss
2,00
0,00
-2,00
-4,00
-6,00
-8,00
0 4 8 12 16 20 24 28 32 36 40
1 Year
2 Year
4 Year


HU Public Deficit
0,00
-0,60
-1,20
-1,80
-2,40
-3,00
-3,60
0 4 8 12 16 20 24 28 32 36 40
1 Year
2 Year
4 Year


HU Public Debt
0,00
-1,00
-2,00
-3,00
-4,00
-5,00
0 4 8 12 16 20 24 28 32 36 40
1 Year
2 Year
4 Year


HU Target Debt
0,00
-1,00
-2,00
-3,00
-4,00
-5,00
0 4 8 12 16 20 24 28 32 36 40
1 Year
2 Year
4 Year

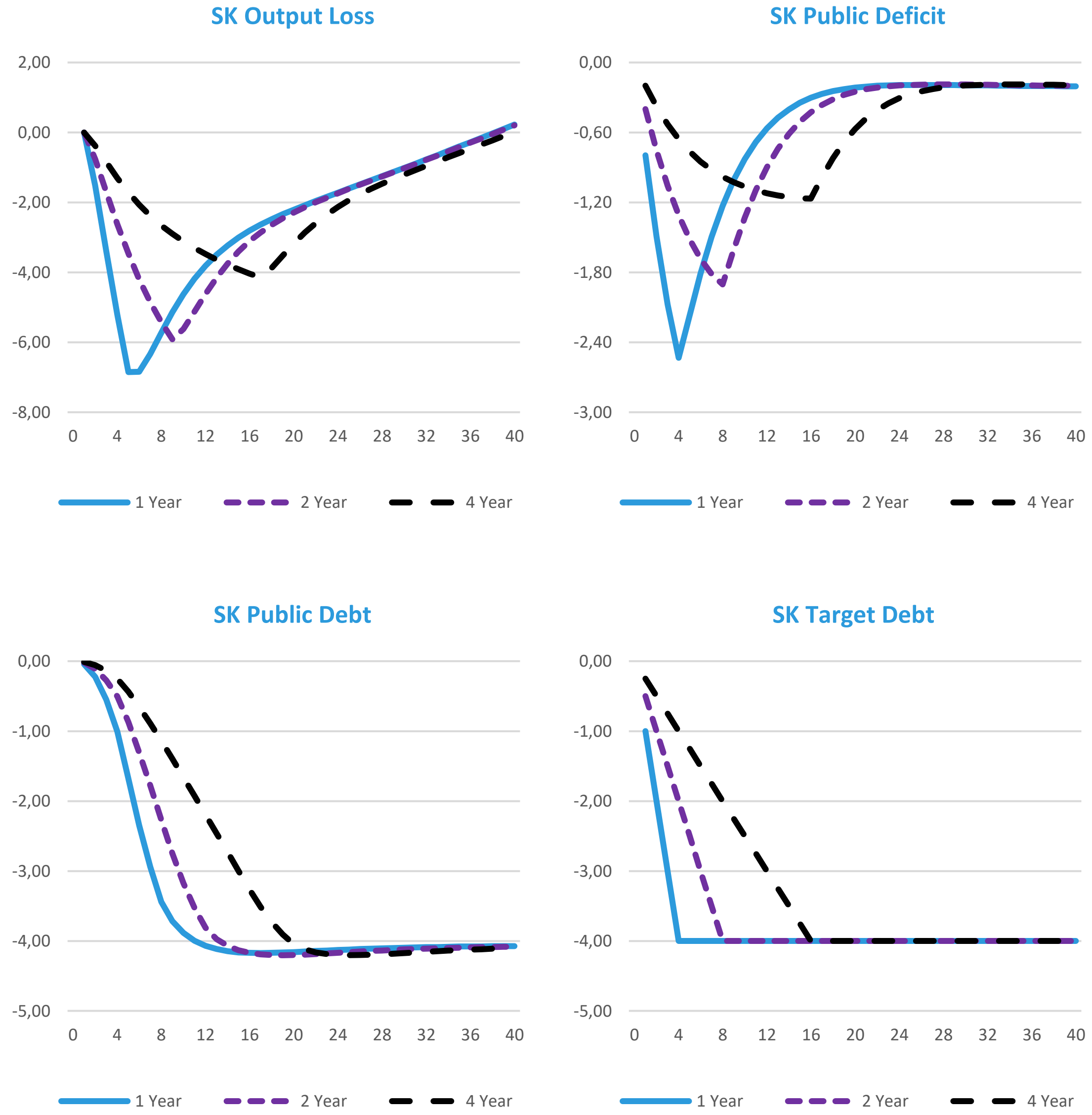
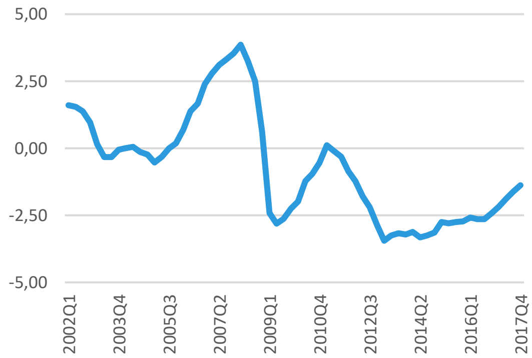


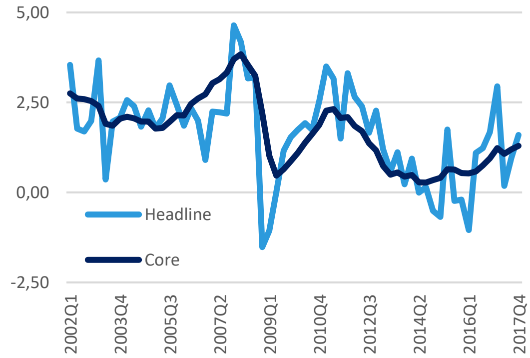
Fig 13: Impulse response functions of model variables after a negative shock to target debt with the magnitude of 4.00 p.p. on the simulation horizon under (i) a 1-year strategy that corresponds to a decline of the target debt by 1.00 p.p. in the first four quarters, (ii) a 2-year strategy that corresponds to a decline of the target debt by 0.50 p.p. in the first eight quarters and (iii) a 4-year strategy that corresponds to a decline of the target debt by 0.25 p.p. in the first sixteen quarters. X axes label quarters after the shock and Y axes label deviations of model variables from steady-state values in percentage points.

Historical projections

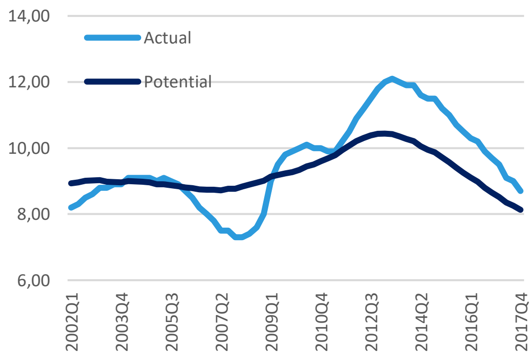
EA Output Gap



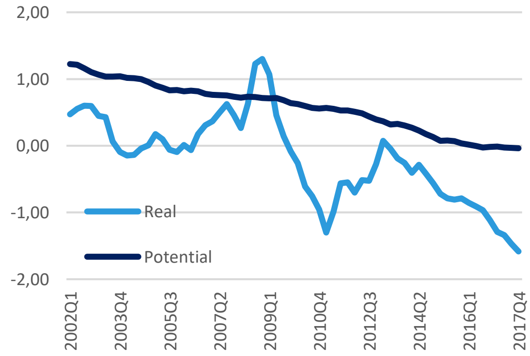
EA Inflation Rate



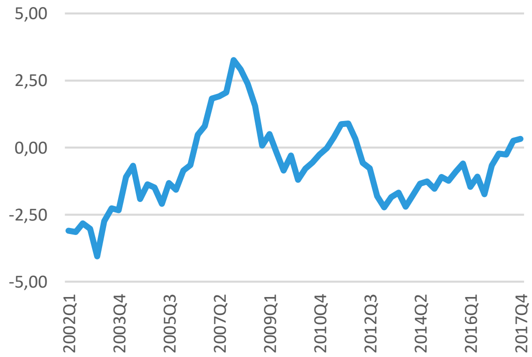
EA Unemployment



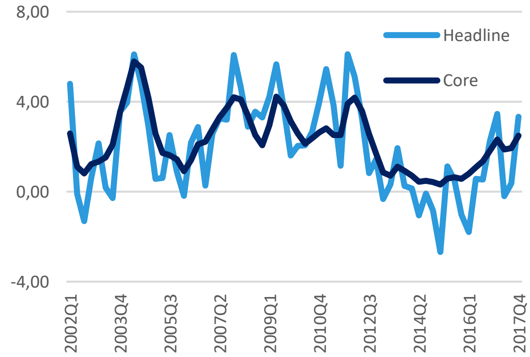
EA Policy Rate



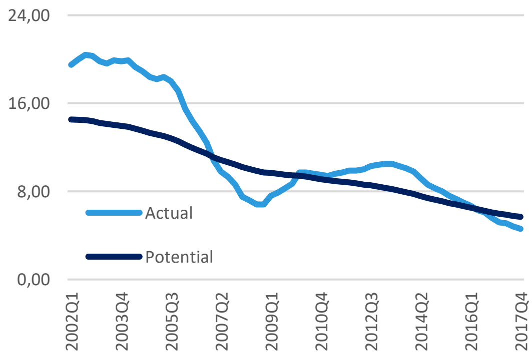
PL Output Gap



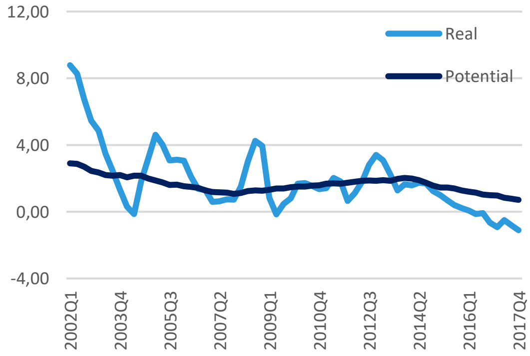
PL Inflation Rate

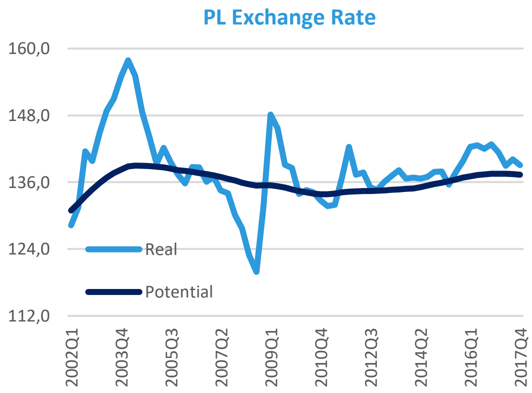


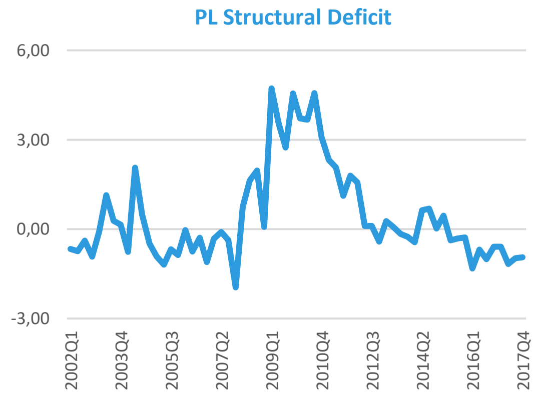
PL Unemployment

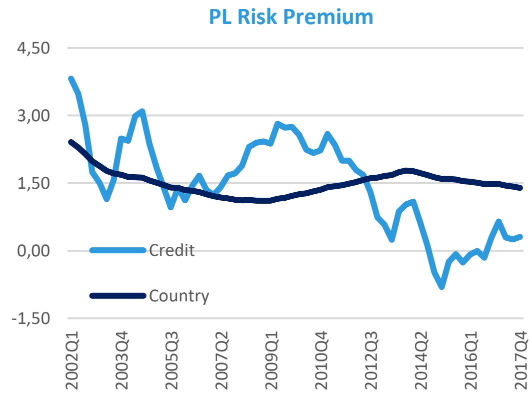


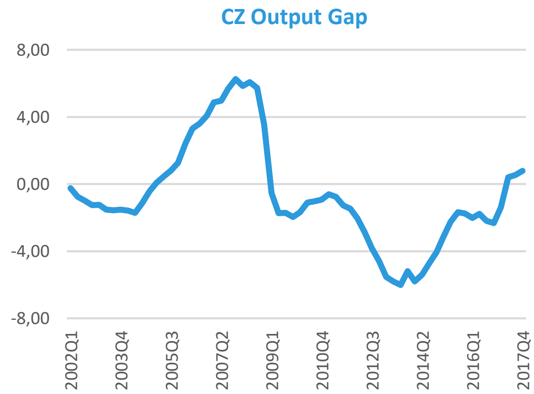
PL Policy Rate

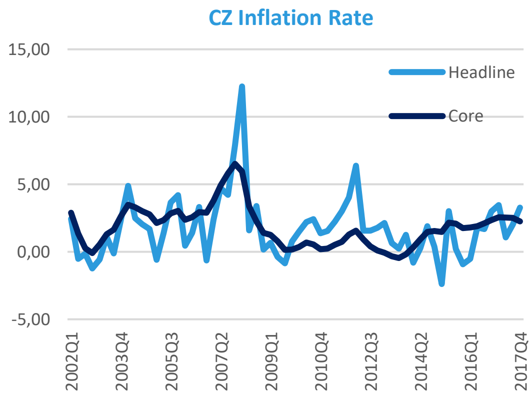


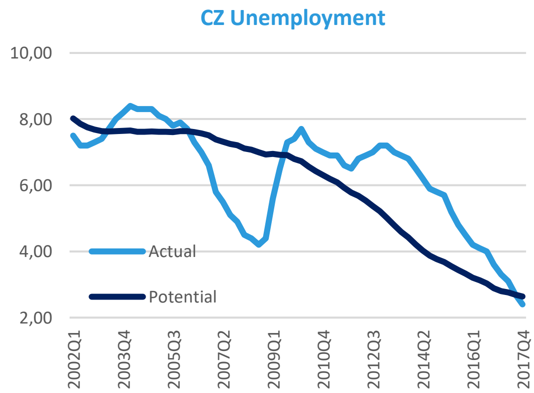

PL Exchange Rate
160,0
148,0
136,0
124,0
112,0
Real
Potential
2002Q1
2003Q4
2005Q3
2007Q2
2009Q1
2010Q4
2012Q3
2014Q2
2016Q1
2017Q4

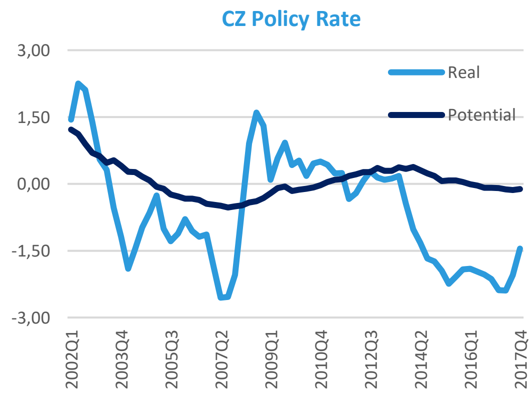

PL Structural Deficit
6,00
3,00
0,00
-3,00
2002Q1
2003Q4
2005Q3
2007Q2
2009Q1
2010Q4
2012Q3
2014Q2
2016Q1
2017Q4

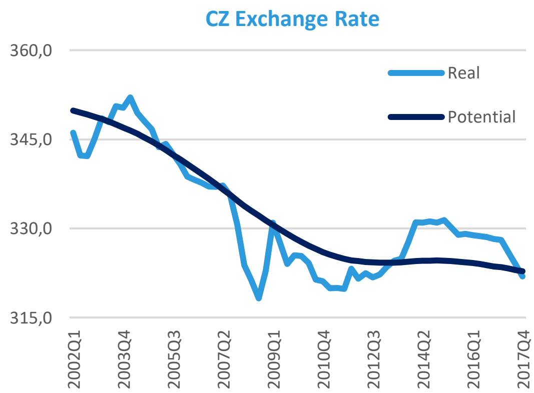

PL Risk Premium
4,50
3,00
1,50
0,00
-1,50
Credit
Country
2002Q1
2003Q4
2005Q3
2007Q2
2009Q1
2010Q4
2012Q3
2014Q2
2016Q1
2017Q4


CZ Output Gap
8,00
4,00
0,00
-4,00
-8,00
2002Q1
2003Q4
2005Q3
2007Q2
2009Q1
2010Q4
2012Q3
2014Q2
2016Q1
2017Q4

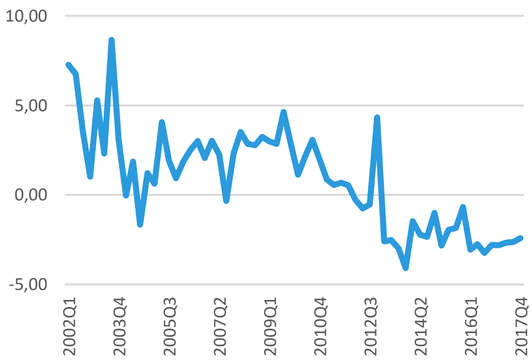

CZ Inflation Rate
15,00
10,00
5,00
0,00
-5,00
Headline
Core
2002Q1
2003Q4
2005Q3
2007Q2
2009Q1
2010Q4
2012Q3
2014Q2
2016Q1
2017Q4


CZ Unemployment
10,00
8,00
6,00
4,00
2,00
Actual
Potential
2002Q1
2003Q4
2005Q3
2007Q2
2009Q1
2010Q4
2012Q3
2014Q2
2016Q1
2017Q4

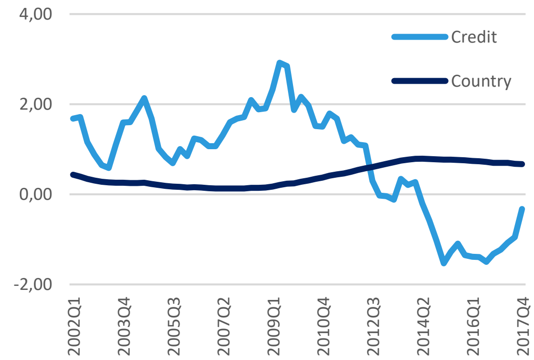

CZ Policy Rate
3,00
1,50
0,00
-1,50
-3,00
Real
Potential
2002Q1
2003Q4
2005Q3
2007Q2
2009Q1
2010Q4
2012Q3
2014Q2
2016Q1
2017Q4


CZ Exchange Rate
360,0
345,0
330,0
315,0
Real
Potential
2002Q1
2003Q4
2005Q3
2007Q2
2009Q1
2010Q4
2012Q3
2014Q2
2016Q1
2017Q4

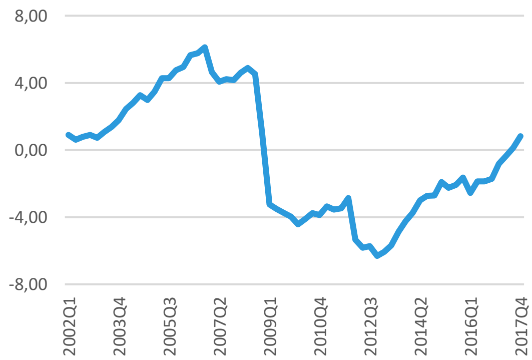
CZ Structural Deficit



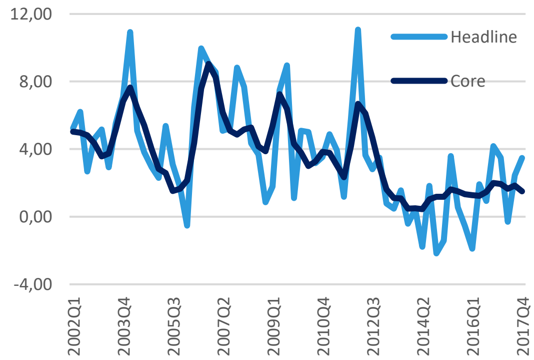
CZ Risk Premium



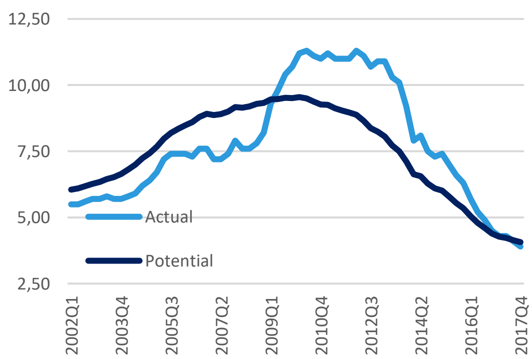
HU Output Gap



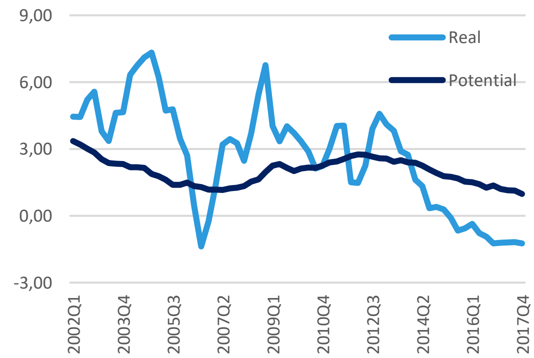
HU Inflation Rate



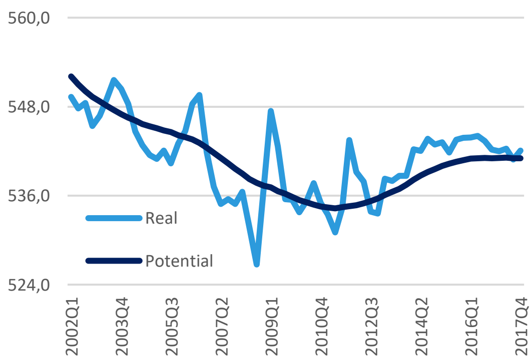
HU Unemployment



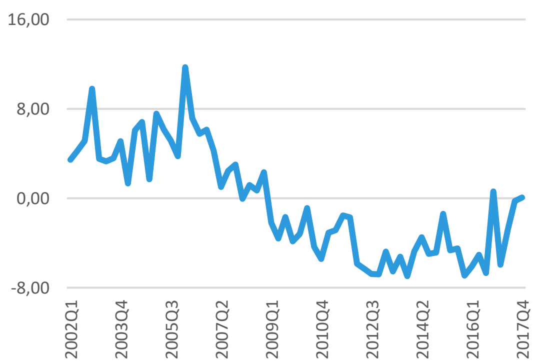
HU Policy Rate

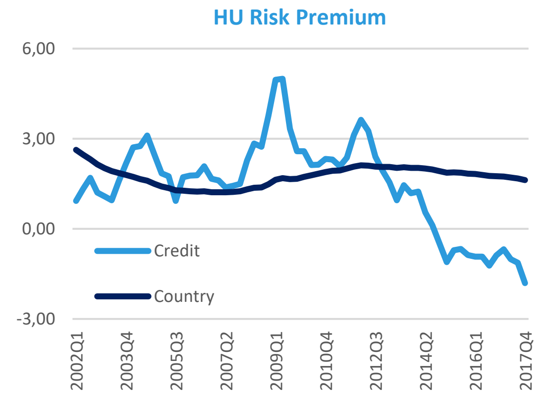


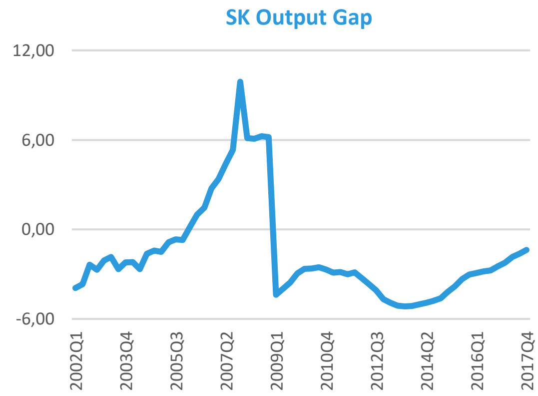
HU Exchange Rate

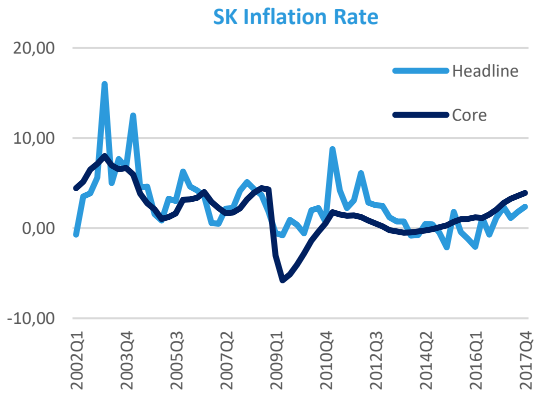


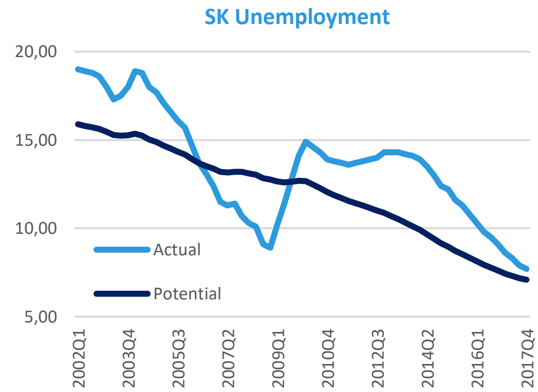
HU Structural Deficit

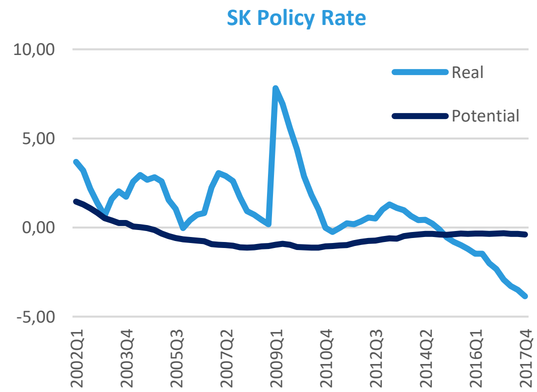


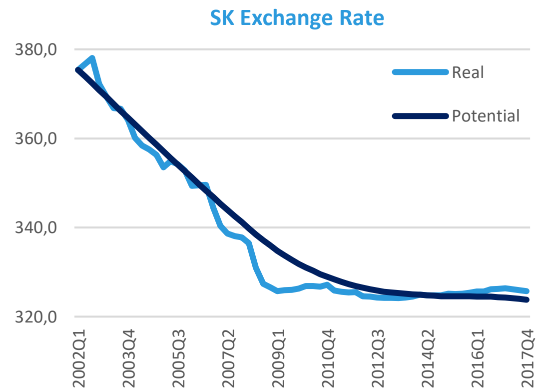

HU Risk Premium
6,00
3,00
0,00
-3,00
Credit
Country
2002Q1
2003Q4
2005Q3
2007Q2
2009Q1
2010Q4
2012Q3
2014Q2
2016Q1
2017Q4

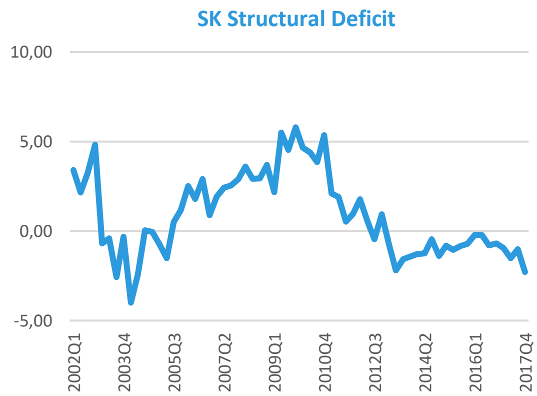

SK Output Gap
12,00
6,00
0,00
-6,00
2002Q1
2003Q4
2005Q3
2007Q2
2009Q1
2010Q4
2012Q3
2014Q2
2016Q1
2017Q4

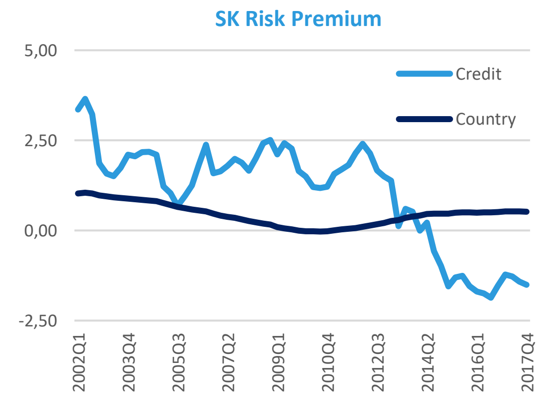

SK Inflation Rate
20,00
10,00
0,00
-10,00
Headline
Core
2002Q1
2003Q4
2005Q3
2007Q2
2009Q1
2010Q4
2012Q3
2014Q2
2016Q1
2017Q4


SK Unemployment
20,00
15,00
10,00
5,00
Actual
Potential
2002Q1
2003Q4
2005Q3
2007Q2
2009Q1
2010Q4
2012Q3
2014Q2
2016Q1
2017Q4


SK Policy Rate
10,00
5,00
0,00
-5,00
Real
Potential
2002Q1
2003Q4
2005Q3
2007Q2
2009Q1
2010Q4
2012Q3
2014Q2
2016Q1
2017Q4


SK Exchange Rate
380,0
360,0
340,0
320,0
Real
Potential
2002Q1
2003Q4
2005Q3
2007Q2
2009Q1
2010Q4
2012Q3
2014Q2
2016Q1
2017Q4


SK Structural Deficit
10,00
5,00
0,00
-5,00
2002Q1
2003Q4
2005Q3
2007Q2
2009Q1
2010Q4
2012Q3
2014Q2
2016Q1
2017Q4


SK Risk Premium
5,00
2,50
0,00
-2,50
Credit
Country
2002Q1
2003Q4
2005Q3
2007Q2
2009Q1
2010Q4
2012Q3
2014Q2
2016Q1
2017Q4