Gap Model of the Visegrad Group

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Abstract
We estimate a medium-scale gap model of the Visegrad Group including core macroeconomic variables as aggregate demand, aggregate supply, interest rates, exchange rates and unemployment, further enriched by a fiscal block for Slovakia. This model takes a form of global projection model, since incorporating mutual linkages between the economies and also their most important trading partner, aggregated economy of the euro area. Although proposed in mostly linear form and not properly derived from micro-foundations as standard dynamic stochastic general equilibrium models, combination of relatively simple structure together with plausible impulse responses makes the model suitable for policy analysis. In addition, since the trading partners of Slovakia are modelled endogenously, we can capture spillovers between the countries and their final impact on the Slovak economy. Enrichment for the fiscal block makes the model applicable also for fiscal policy purposes.

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1 Introduction

There is a number of different modelling approaches applied by central banks and analysts across the world to simulate and forecast macroeconomic behaviour. The toolkit varies from simple vector autoregressive (VAR) models and structural econometric models applied mostly for forecast purposes to complex dynamic stochastic general equilibrium (DSGE) models widely used for policy simulations. In this paper, we aim to find a trade-off between macroeconomic fundamentals, proper impulse responses and plausible data fit, mostly proposed by gap models. In general, gap model is a macroeconomic model of unobserved gaps, in other words differences between actual values of macroeconomic variables and their long-run trend values, based on a small number of behavioural equations and underlying stochastic processes. As the model is in the general equilibrium form, it simultaneously determines values for all modelled gaps. These models are often referred to as quarterly projection models, since are mostly based on quarterly data, or global projection models, if incorporating a number of countries and their mutual linkages.

Gap models are based on a small number of linear behavioural equations capturing macroeconomic fundamentals and underlying stochastic processes pinning down the long-run trend values. This is in contrast to the standard DSGE models based on the agents’ utility maximization and eventuating into highly nonlinear systems that need to be approximated, mostly linearized, to be solved.1 Though the micro-foundations of the gap models are incomparable with those of the DSGE models, simple structure of these models and their identification restrictions produce impulse responses that are in line with standard theoretical predictions thus over-performing, for instance, the global VAR models. Furthermore, it is fairly convenient to extend these models with other sectors and countries.

Core structure of the presented model is based on Carabenciov et al. (2008), including the economies of the Visegrad Group, i.e. Slovakia, Czech Republic, Poland and Hungary, together with the aggregated economy of the euro area. Yet, we propose important extensions of the original work. First, we enrich the model by a fiscal block for Slovakia thus capturing both the pass-through of fiscal impulse on aggregate demand as well as the impact of government debt on risk premia and exchange rate with secondary effect on potential output. Second, we distinguish between different types of risk premia and treat them endogenously allowing for (i) imperfect control over domestic as well as international money market, (ii) additional spillovers between the economies based on the interaction of interbank risk premia and (iii) risk premia effect on the potential output as well as the output gap. Finally, we incorporate also government bond yields with ten years maturity, thus approximating the term-structure of interest rates, and corresponding risk premium influenced by a fiscal policy.

Furthermore, we extend the model for the emerging economies of the Visegrad Group, allowing for important components like trend real appreciation and historical changes in inflation targeting, mostly in line with Carabenciov et al. (2013). However, the model distinguishes from a fully structural model, since not incorporating phenomenon like increasing trade openness and increasing quality, captured by rising export to output ratio, or different inflationary pressures on prices of goods and services, since implementation of these effects would require modelling off-balanced growth in a complex way and is behind the goals of this paper. We also depart from the identification of structural productivity shocks driven by investors with great market share, like Volkswagen or Samsung, and many one-off effects typical for small open economies, since they are based mostly on judgmental inputs. Of course, if the model is applied for forecasting purposes, we need to exogenize and identify these effects before the forecast.

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1 See for example Smets and Wouters (2003) for the baseline DSGE model or Gali and Monacelli (2005) for the small open economy version of the DSGE model.
Since the Visegrad countries are not only the most important trading partners of Slovakia, except the euro area economies, but also share the same historical development and similar economic structure, it is reasonable to decompose the region into particular economies, since we can capture their structural differences and spillovers from one country to another. On the other hand, importance of the fiscal policy in the post-crisis years motivated the authors to extend the model for the fiscal block. We can thus distinguish between the short-run cyclical development driven mostly by the macroeconomic shocks and the monetary policy, although the fiscal policy also matters, and the long-run potential development influenced by the policy of fiscal authorities. Although the model is not constructed for forecast purposes, it can be also applied as a control method to standard forecasting models.

The paper is structured as follows. First, we propose the literature review with focus on the advantages of our solution. Second, we make the model and data overview and describe the technical aspects of the model. Third, we describe the structure of the model equations, and fourth, we discuss the model parametrization consisting of the calibration as well as the Bayesian estimation techniques. Finally, we evaluate the model with the impulse response functions and historical projection of the model variables, while proposing also simple simulation exercise.
2 Related literature

Our model is inspired by the work of Carabenciov et al. (2008) which presents a global projection model (GPM) for three big economies: United States, European Union and Japan. Each economy is characterized by five behavioural equations capturing output, unemployment, inflation rates, interest rates and exchange rates. Money markets interact via trend exchange rates based on simple random walks, while the steady-state inflation rates operate as constant inflation targets. Later on, Carabenciov et al. (2013) propose an extension of the original model for emerging markets, including also trend real appreciation and historical changes in inflation targets. Both versions of the model incorporate risk premium only in a form of trend country premium in the uncovered interest parity (UIP), described as a simple difference between potential real interest rates of respective countries adjusted for the trend real appreciation. Implicitly, these models assume central banks’ perfect control over market interest rates.

In contrast, the projection model by Andrie et al. (2014), focusing on the interaction between polish and euro area economies, distinguishes between country and interbank risk premia and treats them endogenously. In addition, the polish interbank premium responds to financial shocks in the euro area, thus capturing the spillovers between the countries via additional risk premium channel. According to this, the authors model a pass-through of the risk premium on the market interest rates, arguing with the interbank premium affecting households, and thus assume imperfect control over domestic money market.

We apply similar principle in the presented model with two exceptions. First, while we model the interbank premium as a cyclical variable representing actual investors’ preferences and affecting the output gap, the country premium operates as more persistent variable with lower volatility and affects the potential output. Second, we define the additional premium on government bonds that operates as a potential variable and responds to the expected deviation of government debt from the steady-state value, thus capturing the impact of fiscal policy on potential output and long-term economic development. We exclude from the impact of government debt on the interbank premium, since the short-term variables are mostly driven by monetary policy and actual market development, but include the fiscal policy channel in the country premium dynamics. Additionally, we incorporate the negative impact of rising debt on the trend real appreciation.

From the perspective of domestic research, we should mention the model by Gavura and Reťovský (2005) operating as the open economy gap model based on a small number of behavioural equations and exogenous external environment. In contrast to our solution, the authors applied the method of pre-filtration to distinguish between trend and cyclical variables. Since we focus on the entire region of the Visegrad Group, we propose more complex look on the development of the Slovak economy, while the fiscal block extension is especially important due to the absence of domestic monetary policy. Next, we should mention the structural model by Zeman and Senaj (2009) and the model by Múčka and Horváth (2015) exploring a fiscal policy impact on the Slovak economy.

There are numerous other papers related to our work at least indirectly, for example the projection model by Beneš et al. (2003), formerly applied by the Czech National Bank (CNB), the monetary policy model of the Hungarian National Bank (MNB), developed by Szilágyi et al. (2013), the model of Beneš and N’Dìaye (2004), estimating the potential output and unemployment in Czech Republic through the multivariate filter, or the model of Lyziak (2016), exploring the role of model-based inflation expectations in Poland.
3 Methodology and data

We propose a medium-scale gap model of the Visegrad countries, i.e. Slovakia, Czech Republic, Hungary and Poland, further influenced by the economy of the euro area as their most important trading partner. The model is based on the unobserved gaps of real output, unemployment, interest rates and exchange rates, together with the dynamics of inflation rates, while respecting mutual linkages and spillovers between the economies. We exclude from the financial variables as Carabencio et al. (2008), due to relatively minor impact on small open economies. On the other hand, we extend the model with a fiscal block for Slovakia.

Visegrad countries are operating as small open economies affecting each other via two channels. The first one is the effect of exchange rate differentials on real economy through the dynamics of real output and inflation rate, thus capturing the pressure of real depreciation on relative country competitiveness and higher import prices. The second channel is the direct effect of external outputs weighted by mutual export volumes, affecting the domestic output through the pressures in external demand. Furthermore, the euro area operates as a closed economy, due to its relative size with respect to the Visegrad Group, thus affecting the other countries in the model but not vice versa. In addition to the standard effects via output and exchange rate, the euro area is also affecting the Visegrad Group via interbank risk premium, since the development of the euro area risk premium puts the pressure on the risk premia of its trading partners.

We apply five observable variables on quarterly basis for each country, specifically gross domestic product (GDP), harmonised index of consumer prices (HICP), nominal interest rate, monetary policy rate and unemployment rate. Although distinguishing between core and non-core inflation in the model specification, we incorporate only overall price index as the measure for the headline inflation, while the core inflation is identified by the model and not captured by the price index excluding the energy and food prices. In addition, we apply nominal exchange rates of local currencies vis-a-vis Euro for the Visegrad Group, government debt and deficit in the percentage of domestic output for Slovakia and euro-denominated Brent oil prices. We capture also the long end of the euro area yield curve with the yields on ten-years government bonds and complement with the government bonds of Slovakia to capture the impact of the fiscal policy. Finally, we apply historical targets for inflation and government debt.

Level of the GDP is obtained in chain linked volumes and local currencies to exclude additional effects of inflation and exchange rates. GDP of the euro area refers to the core twelve countries to exclude the effects of changing composition. HICP index is averaged from monthly data and seasonally adjusted.\(^2\) We obtain these information from the Eurostat together with interest rates, exchange rates and unemployment rates. Information about government debt and government deficit are also obtained from the Eurostat with the target debt equal to the actual level. Monetary policy rates are constructed from the historical key rates of the central banks, similarly to the historical inflation targets. Brent oil prices are obtained from the Bloomberg database and transformed from US Dollar to Euro.

Rational expectations are solved via generalized Schur decomposition and model evaluation is performed by the method of Kalman filtering. Time series are additionally smoothened by the modified Bryson-Frazier smoother. Calibration and estimation of the model is performed on the quarterly data and the sample period from the January of 2002 to the December of 2017. All computations are performed in the Matlab and the IRIS Toolbox.

\(^2\) Gross domestic product, unemployment rate and government deficit are obtained in the seasonally adjusted form. Price indices are adjusted manually by the method X13-ARIMA-SEATS.
4 Model specification

We proceed with the specification of a generic economy labelled $i$ and time index $t$. Specification of the closed economy of the euro area differs from the open economies of the Visegrad Group, as differs the specification of Slovakia, due to the extension by fiscal variables. We propose the same equations for the economies of Czech Republic, Hungary and Poland, albeit with different parametrisation. Particular equations are described in the subsections.

We follow a standard approach for the notation and use small letters for the observable variables, bars for the trend variables and hats for the unobserved gaps between observables and trends. Specifically, we define $y$ as 100 times the log of actual GDP level, $\bar{y}$ as 100 times the log of potential GDP level and $\gamma$ as the output gap in percentage terms, in other words $\hat{y}_{it} = y_{it} - \bar{y}_{it}$. Similarly, we define $u$ as the difference between the actual unemployment rate $u$ and the potential unemployment rate $\bar{u}$, in other words $\hat{u}_{it} = u_{it} - \bar{u}_{it}$. Next, we define the annualized quarterly rate of inflation $\pi$ as 400 times the difference between the log of HICP in the current quarter and the previous one. Nominal interest rate is denoted $i$, actual real interest rate is $r$, potential real interest rate is $\hat{r}$ and the interest rate gap is denoted $\hat{r}$. Similarly, 100 times the log of the nominal exchange rate against Euro is denoted $s$ and the gap between the actual real exchange rate $z$ and its potential counterpart $\hat{z}$ is denoted $\hat{z}$.

4.1 Output block

Structure of the proposed model is based on several behavioural equations and stochastic processes. We start with an aggregate demand of the euro area determined by the dynamic closed economy IS curve, where the output gap is a function of its own lagged and lead values and effective interest rate gap. The lagged output gap allows for the persistence of demand shocks and the lead term follows the rational expectations forward-looking approach common for the DSGE models. Effective interest rate gap is a weighted average of three-months and ten-years interest rate gaps, while the weights put on the short-term and long-term interest rates are respectively set to 0.80 and 0.20. Interest rate component enters the equation with lag, since the channel of the rising interest rates affecting the real economy via decline in investments and consumption is empirically lagged. The last term refers to a demand shock to the economy.

$$\hat{y}_{it} = \beta_{i1}\hat{y}_{i,t-1} + \beta_{i2}\hat{y}_{i,t+1} - \beta_{i3}\hat{u}_{i,t-1} + \epsilon_{i1}^y$$

(1)

We continue with the specification for the Visegrad Group, expanding the original equation of the euro area for small open economies. Aggregate output is then affected by two additional terms where the first one refers to the effective exchange rate gap and the second one to the aggregate external demand. According to the original specification, parameter $\beta_4$ captures the monetary policy pass-through to the real economy, while the values of $\beta_4$ and 1-$\beta_4$ represent the weights put on the interest rates and the exchange rates in the monetary condition index. Generally, the more open the economy, the lower is the value of parameter $\beta_4$ and vice versa.

$$\hat{y}_{it} = \beta_{i4}\hat{m}_{i,t} - \beta_{i5}\hat{y}_{i,t-1} + \beta_{i6}\hat{m}_{i,t-1} + \beta_{i7}\hat{y}_{i,t-1} + \epsilon_{i2}^y$$

(2)

$$\hat{m}_{i,t} = \beta_{i4}\hat{w}_{i,t} - (1 - \beta_{i4})\hat{s}_{i,t}$$

(3)

Effective exchange rate gap equals the weighted average of the real exchange rate gap of the country $i$ minus the real exchange rate gaps of its trading partners $j$, in other words $z_{ij,t} = z_{it} - z_{jt}$. Weights are calibrated as the sum of exports and imports between country $i$ and country $j$ against the sum of exports and imports between country $i$ and all its trading partners, thus considering relative importance of particular economies. On the other hand, aggregate external demand is defined as the weighted average of external output gaps, where the particular weights are
calibrated as the ratio between export from country i to country j and total export of country i to its trading partners. This term thus captures an upward pressure of external demand on domestic export. Both of these terms are empirically lagged. Since the yields on government bonds are incorporated only for the euro area, to capture the long end of the yield curve, and Slovakia, to model the impact of the fiscal policy, effective interest rates for the rest of the Visegrad Group are equal to the short-term interest rates.

Model specification for Slovakia is similar to the rest of the Visegrad Group with two exceptions. First, since incorporating the fiscal block, some model equations are extended for additional terms capturing their reactivity to fiscal variables. Second, due to the adoption of the Euro currency in the January of 2009, we split the model for Slovakia before and after the monetary switch. We continue with the specification of an aggregate demand and enrich the open economy IS curve by contemporaneous fiscal impulse.

\[
\gamma_{t} = \beta_{11}\bar{\gamma}_{t-1} + \beta_{12}\bar{\gamma}_{t+1} - \beta_{13}\bar{m}_{t-1} + \beta_{15}\bar{y}_{t-1} + \mu_{t} + \epsilon^{y}_{t} \tag{4}
\]

Potential output is determined by a local linear trend model where shocks to both level and growth rate are assumed. Shocks to the level are considered as permanent, whereas shocks to the growth rate may result in persistent deviations of the potential growth from its steady-state value. Potential output equals its own lagged value plus the quarterly growth rate and the error term. In contrast to Carabenciov et al. (2008), we allow also for the impact of the quarterly change in the potential interest rates capturing a negative effect of rising interest rates not only on the output gap but also on the potential production. Weights put on the changes in three-months and ten-years potential rates are equal to 0.80 and 0.20 respectively. Growth rate of the potential output may temporarily deviate from its steady-state but gradually converges back with the speed of parameter \( \tau_{1} \).

\[
\bar{y}_{t} = \gamma_{t-1} + \bar{m}_{t}/4 - \tau_{12}(\bar{w}_{t} - \bar{w}_{t-1}) + \epsilon^{y}_{t} \tag{5}
\]

\[
\bar{m}_{t} = \tau_{11}\bar{m}_{t-1} + (1 - \tau_{11})\bar{y}_{t-1} + \epsilon^{m}_{t} \tag{6}
\]

We exclude from the cross-correlations of model shocks in this version but would like to extend their structure later, similarly to Carabenciov et al. (2008). Specifically, we would like to incorporate a negative correlation between the cost-push shock and the shock to the potential output level, capturing the fact that the productivity shock leads to the growth in the aggregate supply implying a downward pressure on prices in the economy. On the other hand, expected shock to the potential output puts an upward pressure on higher demand not only in the future but also contemporaneously, implying a positive correlation with the demand shock.

However, we should mention that the correlation between potential output and cost-push shocks is influenced by additional factors in small open economies. Specifically, although the shock to the potential output leads to higher productivity, this production is mostly exported thus not increasing the domestic supply and not putting downward pressure on domestic prices. On the other hand, higher productivity leads to faster real convergence that could be quantified nominally or through the inflation channel, thus leading to an upward pressure on prices in the economy.

We would also like to incorporate persistent and global shocks to the aggregate demand, according to Andre et al. (2014). While the first one enhances the persistence of domestic demand shocks, the latter captures additional spillovers between the economies and the dynamics of the economic and financial crisis.

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\(^{3}\) We do not incorporate the expectations about entering the monetary union in this version but would like to extend the model for the expectations afterwards.
4.2 Unemployment block

According to the output, unemployment is also decomposed into its potential and cyclical components. While the potential rate of unemployment, or NAIRU, is pinned down by a standard autoregressive process with the speed of steady-state convergence $\alpha_3$, unemployment gap is captured by a modified version of the Okun’s law, where the unemployment gap is a function of its own lagged value and contemporaneous output gap.

$$u_{it} = \alpha_1 u_{it-1} - \alpha_2 y_{it} + \epsilon_{it}^u$$  \hfill (7)

Although the unemployment is not directly interacting with other model variables, for example in the impulse response analysis, it allows us to exploit the unemployment data and correct the model historical development. We depart from the original specification of NAIRU with both level and growth rate components, as Carabenciov et al. (2008), and rather apply simple autoregressive process with properly defined steady-state.

4.3 Inflation dynamics

To capture dynamics and volatility of price development, we distinguish between core and non-core inflation in our model, similarly to Andrle et al. (2014). Specifically, we suppose that the inflation rate is a weighted average of core and non-core components with the relative weights calibrated by the least squares estimation on the sample period. Non-core component meanwhile refers to the imported oil inflation, thus capturing the spikes in oil prices and exchange rates and their impact on domestic energies. Oil price inflation is then captured by an exogenous process and adjusted for the changes in nominal exchange rate and trend real appreciation. We allow also for the high-frequency shocks to the headline inflation that can be explained as either the cost-push factors unexplained by fundamentals, as proposed by Andrle et al. (2014), or as a form of inflation measurement errors.

$$\pi_t^h = \kappa_1 \pi_{t-1}^h + (1 - \kappa_1) \pi_{t-1}^o + \epsilon_t^h$$  \hfill (8)

We depart from the standard definition of core inflation, as headline inflation adjusted for energy and food prices, and rather define it implicitly through the inflation identity. This approach is identical to Andrle et al. (2014) with the core inflation close to trimmed or winsorized time series. We experimented also with the specification of Szilágyi et al. (2013), with endogenously modelled core as well as non-core inflation and observed price index adjusted for energy and food prices, but decided against, due to the forecasting performance. Core inflation of the euro area is determined by the hybrid closed economy Phillips curve pinning down the inflation rate as a function of its past and expected value, lagged non-core inflation and lagged output gap.

$$\pi_t^c = \lambda_{12} \pi_{t-1}^c + (1 - \lambda_{12}) \pi_{t-1}^o + \lambda_{13} y_{t-1} + \epsilon_{t}^c$$  \hfill (9)

$$\pi_t^e = \lambda_{11} \pi_{t+1}^e + (1 - \lambda_{12}) \pi_{t-1}^c + \epsilon_{t}^e$$  \hfill (10)

Parameter $\lambda_2$ then captures the total effect of past and future indexation to the core inflation and parameter $1 - \lambda_2$ spillovers from the energy prices. Homogeneity of this term is crucial for the model stability. The curve contains both backward-looking and forward-looking elements of agents’ expectations. The relative weight of the forward-looking element is captured by the parameter $\lambda_1$ measuring the share of price setters who set their expectations about future inflation in a model-consistent way. The backward-looking element includes direct and indirect indexation to past inflation and the $1 - \lambda_1$ share of price setters who set their expectations about future inflation based on observed inflation in the past. Again, output gap entering the Phillips curve is empirically lagged and the last term is referring to a supply shock to the economy.
Core inflation of the Visegrad countries is captured by the open economy version of the Phillips curve. The original equation is thus enriched by the additional term capturing an upward pressure of exchange rate depreciation on domestic inflation through the import channel. In contrast to the specification with the quarterly change of real exchange rate applied by Carabenciov et al. (2008), we base the inflation rate on the real effective exchange rate gap with the weights based on the relative imports from country j to country i. This is to ensure the model stationarity, due to the trend real appreciation of emerging economies. Again, this term is empirically lagged.

Consistently with the original specification, parameter \( \lambda_3 \) captures the impact of real marginal costs on the inflation rate, while the values of \( \lambda_4 \) and \( 1 - \lambda_4 \) represent the weights put on the domestic and external components in the real marginal costs. Again, the value of parameter \( \lambda_4 \) depends on the relative openness of the economy.

\[
\begin{align*}
\pi_{it} &= \lambda_{i2}\pi_{it} + (1 - \lambda_{i2})\pi_{it-1} + \lambda_{i3}\hat{c}_{it-1} + \varepsilon_{it} \\
\hat{c}_{it} &= \lambda_{i4}\hat{y}_{it} + (1 - \lambda_{i4})\hat{y}_{it-1}
\end{align*}
\] (11, 12)

We thus distinguish between two effects of currency depreciation. First, rising exchange rate leads to higher imported oil prices with primary effect on the energy inflation and secondary pass-through to the core inflation. Second, nominal depreciation leads to the real depreciation and positive exchange rate gap with direct impact on the core inflation. We exclude from the impact of real oil price gap as Andrle et al. (2014), since it is difficult to either set steady-state level or growth rate of the oil prices, decompose the nominal oil price into real and inflationary components or decompose the real oil price into trend and gap components.

In contrast to the euro area specification, inflation targets for the Visegrad countries are modelled endogenously as random walk processes and not fixed to the steady-state inflation rates, thus allowing for historical changes in their dynamics. Furthermore, the inflation target in Slovakia is defined by a simple autoregressive process to capture the long-term inflation expectations implied by the inflation target that are crucial for a correct identification of the short rate expectations and the long-term risk premium. We further suppose that adopting the European Central Bank (ECB) monetary policy implied changes in the inflation expectations and set the value of parameter \( \lambda_1 \) after the monetary switch to the euro area level.

### 4.4 Monetary policy

Central bank is affecting the economy via changes in the policy rate, considered as a risk-free nominal interest rate that is pinned down by the Taylor policy rule, similarly to the DSGE models. Specifically, we assume that the policy rate is a function of its own lagged value, to smooth the interest rate movement, policy neutral rate and monetary authority responses to the deviations of inflation rate and output gap from their target values. We should mention that the steady-state of the euro area inflation rate is equal to the constant inflation target of the ECB. We further assume that the monetary authority responses to the annual inflation three quarters ahead, according to Orphanides (2003). After adopting the ECB monetary policy, policy rate of Slovakia is set to its euro area counterpart. However, due to the absence of the nominal exchange rate vis a vis the euro area, the nominal interest rate in Slovakia could differ from its euro area counterpart by the debt-related country premium.

\[
i_{it} = \gamma_{i1}i_{it-1} + (1 - \gamma_{i1})(r_{it} + \pi_{it+3} + \gamma_{i2}(\pi_{it+3} - \pi_{it+1}) + \gamma_{i3}\hat{y}_{it}) + \varepsilon_{it}
\] (13)

Real interest rate is then determined by the Fisher equation and thus equal to the nominal interest rate minus the inflation expectations one quarter ahead, in other words \( r_{it} = i_{it} - \pi_{it+1} \). Definition of the potential real interest rate is country-specific and while the euro area potential rate is pinned down by a simple autoregressive process with the speed of steady-state convergence \( \psi_s \), potential rates of the Visegrad countries are captured by the international interest rate parity, as described in the next subsection.
Government bond yields are determined by the expectations theory and thus as the average short rate expectations over the next ten years on quarterly basis plus the corresponding risk premium. Real government yields and their potential counterparts are defined in the same way, only replacing the nominal short rate expectations by the real and potential ones. Long-term interest rate gap is then defined as a simple difference between real and potential short rate expectations, according to the absence of cyclical premium.

4.5 International markets

Nominal exchange rate is determined by a modified version of the uncovered interest parity, incorporating forward-looking as well as backward-looking expectations about future exchange rate development. Specification with the hybrid UIP is according to Adolfson et al. (2008), arguing that this model has an empirical advantage over the standard UIP. Relative weight of the forward-looking element is then captured by parameter $\phi_1$, measuring the share of investors with model-consistent expectations, and relative weight of the backward-looking element by $1 - \phi_1$, measuring the share of investors with expectations based on the observed values of the nominal exchange rate, considering the trend real appreciation and expected inflation differential. This specification is thus similar to the one of Beneš et al. (2003).

Finally, the difference between the exchange rate expectations and actual exchange rate is equal to the short rate differential between the domestic economy and the euro area minus the country risk premium, capturing the fact that the investors expecting the currency depreciation require additional compensation in the form of higher interest rates and also the fact that a rise in the interest rates attracts the investors and thus leads to the instant currency appreciation.

$$I_t - I_t^* = 4S_t^f - 4S_t + \psi_{1,t} + 4\epsilon_{1,t}^f$$

$$S_t^f = \phi_{1,t}S_{t,t+1}^f + (1 - \phi_{1,t})(S_{t,t-1}^f + 2\bar{g}_{1,t}/4 + 2\pi_{1,t+1}/4 - 2\pi_{1,t-1}/4)$$

In contrast to the specification of Carabenciov et al. (2008), with potential interest rates determined by simple stochastic processes, potential rates in the presented model are captured by the trend version of the international interest rate parity. We thus assume that the potential interest rates of small open economies are not based on the economic fundamentals but rather on the potential rate of the world economy, trend real appreciation and country risk premium, since we believe that this specification better captures the drivers behind the interest rate parity. Furthermore, we prefer this specification to capture the fiscal policy impact on the country premium.

$$\bar{r}_{1,t} - \bar{r}_{1,t}^* = 4Z_{1,t+1} - 4Z_{1,t} + \psi_{1,t}$$

Real exchange rate is defined as the nominal exchange rate minus the price level in the domestic economy plus the price level in the euro area, in other words $z_{1,t} = s_{1,t} - p_{1,t} + p_{1,t}^*$, thus capturing the relative purchase power of the domestic economy. After the adoption of the Euro currency, we exclude from the nominal exchange rate growth, real exchange rate growth thus equal to the inflation differential. Potential real exchange rate is then determined by a local linear trend model, similarly to the potential output, considering the trend real appreciation that gradually converges to its steady-state and shocks to the potential level as well as the potential growth rate.

$$Z_{1,t} = Z_{1,t-1} + \bar{g}_{1,t}/4 + \phi_{13}(b_{1,t} - b_{1,t-1}) + \epsilon_{1,t}^Z$$

$$\bar{g}_{1,t} = \phi_{12}\bar{g}_{1,t-1} + (1 - \phi_{12})\bar{g}_{1,t-1} + \epsilon_{1,t}^g$$

Furthermore, we expand the original equations for the quarterly change in the government debt, thus capturing the fact that the rising government debt leads to the currency depreciation and the expectations of rising debt put an upward pressure on the potential interest rates and negatively affects the potential output through the interest rate channel.
4.6 Risk premiums

We distinguish between three types of risk premia in the model specification, (i) interbank market premium affecting the short-term interest rates, (ii) government bonds premium affecting the long-term interest rates and (iii) country-specific premium affecting the uncovered interest parity. While the first and second one capture the monetary authority’s imperfect control over domestic interest rates, the third one captures the imperfect control over exchange rate development. This is in contrast to the specification of Carabenciov et al. (2008), assuming only imperfect control over international money market. We should also mention that after the adoption of the Euro currency, from definition, the nominal exchange rate equals unity. However, since the international parity needs to hold, the country premium is materialized in higher domestic interest rates in contrast to the interest rates of the euro area.

We construct the interbank premium as a simple difference between three-month money market rates and key policy rates of the central banks. According to the short-term maturity of the underlying assets and historical evidence we consider only cyclical component of the interbank premium, thus producing a wedge between the short-term interest rate gap and the interest rate gap implied by the central bank. After entering the monetary union, interbank premium of Slovakia is set to its euro area counterpart.

Furthermore, we allow for additional spillovers from the euro area to the Visegrad Group through the risk premium channel. Due to the relative size of respective economies, we expect the spillovers from the euro area premium but not vice versa. Interbank premium of the euro area thus follows a simple autoregressive process, while the interbank premia of the Visegrad countries are adjusted by the additional component capturing the market spillovers.

\[ x_{it} = \eta_{i1} x_{i,t-1} + \eta_{i2} x_{i,t}^e + \xi_{it} \]

On the other hand, we consider only potential components of the other premia and capture them by standard stochastic processes. While the gap component of the government premium is considered trivial according to the long-term maturity of government bonds, the gap component of the country premium is captured by the shocks to the uncovered interest parity. Government premium is further affected by the expected deviation of government debt from its steady-state value over the next ten years, thus approximating the behaviour of risk-aversion investors and negative impact of excessive government debt on the potential output through the interest rate channel. Similarly, the country premium is influenced by the contemporaneous government debt.

\[ \phi_{it} = \omega_{i1} \phi_{i,t-1} + (1 - \omega_{i1}) \left( \phi_{i,ss} + \omega_{i2} (b_{it}^e - b_{i,ss}) \right) + \epsilon_{i,t}^\phi \]

\[ \psi_{it} = \theta_{i1} \psi_{i,t-1} + (1 - \theta_{i1}) \left( \psi_{i,ss} + \theta_{i2} (b_{it}^e - b_{i,ss}) \right) + \epsilon_{i,t}^\psi \]

Impact of the fiscal policy on the potential output is thus captured by (i) negative impact of expected growth in government debt through the trend real depreciation, (ii) negative impact of excessive actual debt through the country premium and (iii) negative impact of expected excessive debt through the government premium. After entering the monetary union, steady-state value of the government premium is set to its euro area counterpart, thus lowering the yields on government bonds by half percentage point, and steady-state value of the country premium is considered trivial. Steady-state levels of the domestic interest rates, short-term as well as long-term, are then equal to the interest rates in the euro area.
4.7 Fiscal policy

Government debt is a function of actual government deficit and outstanding government debt from the previous period adjusted by the discount factor. We allow also for additional shocks to the government identity, due to the stock-flow adjustment factors, as a formation of the cash reserve and privatisation effects. On the other hand, target path for the debt is set by the government and pinned down by a simple random walk process.

\[ b_{t} = f_{t}b_{t-1} + d_{t} + \varepsilon_{t}^{b} \]  

(22)

Consistently with the target debt, we define the sustainable deficit, which is adjusted by the expected nominal output growth over the next year, thus approximating the government policy one year ahead. Structural government deficit then fluctuates around the sustainable one in order to meet the target. This equation might be augmented with the government objective to smooth the output throughout business cycles by adding the term reflecting the deviation of actual nominal output from its potential counterpart.

\[ d_{t}^{\prime} = (1 - f_{t+4})b_{t}^{\prime} \]  

(23)

\[ \ddot{a}_{t} = \delta_{13}a_{t-1} + (1 - \delta_{11})d_{t}^{\prime} + \varepsilon_{t}^{d} \]  

(24)

Overall government deficit then fluctuates around the structural one, depending on a cyclical position of the economy and according to a deviation of government debt from its target one year ahead. The former reflects the impact of automatic stabilizers on the government budget whereas the latter follows the fiscal reactivity approximating the government policy one year ahead. Finally, the fiscal impulse is determined as the difference between actual and structural deficit, thus capturing the cyclical position of the fiscal policy, and the quarterly change in the target debt, evaluating the impact of fiscal consolidation.

\[ d_{t} = \ddot{a}_{t} - \delta_{12}\dot{y}_{t} - \delta_{13}b_{t+4} + \varepsilon_{t}^{d} \]  

(25)

\[ \ddot{a}_{t}^{\prime} = \ddot{a}_{t} + \delta_{14}(b_{t}^{\prime} - b_{t-1}^{\prime}) \]  

(26)

In the future, we would like to extend the fiscal block for additional variables to capture the macroeconomic channels of the fiscal policy. Specifically, we want to incorporate the effects of the direct and indirect taxes on the aggregate demand as well as the aggregate supply and decompose the overall government deficit into the primary deficit and the interest rate costs to quantify the true impact of the fiscal policy on the real economy and future economic development.

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4 Discount factor is the sum of the quarterly nominal GDP from time t-4 to time t-1 divided by the sum of the quarterly nominal GDP from time t-3 to time t. This is due to the definition of the debt to output ratio as the ratio between cumulative government debt and annual nominal output.
5 Parametrisation

We distinguish between five basic groups of model parameters. First, steady-state parameters pinning down the long-run convergence of the model variables. These parameters are usually calibrated as sample averages from historical data. Second, structural parameters capturing the model development throughout the business cycles and corresponding policy reactivity. These parameters are entering the behavioural equations. Third, trend parameters capturing the development of the potential variables, fourth, trade parameters defining the relative importance of the trading partners, and finally, stochastic parameters capturing the dynamics of the model shocks. Since we exclude from the cross-correlations of the model shocks, these parameters capture only their standard deviations.

Due to the number of model equations, we need to calibrate majority of the parameters to produce reasonable outcomes. Specifically, we calibrate the steady-state values from the historical averages, trend parameters from the related literature, trade parameters from the historical shares and stochastic parameters from the historical projection. On the other hand, we estimate the key model elasticities, as the pass-through of the monetary and fiscal policy to the real economy, elasticity of the inflation rate on the real marginal costs, reaction parameters in the monetary policy rule, and magnitude of the automatic stabilizers in the government deficit. However, most of the structural parameters like persistence or expectations terms are still calibrated. Estimation procedure is based on the Bayesian techniques of the maximum posterior estimation and the Monte Carlo Markov Chain (MCMC) sampling based on the Metropolis-Hastings algorithm.

5.1 Calibration

Steady-state values of the real output growth are calibrated as sample medians on the estimation period from the January of 2002 to the December of 2017. We apply medians instead of means to ensure robustness of the parameters, especially in the period of the economic and financial crisis. We further adjust the values for the emerging economies of the Visegrad Group, since the high-level growths at the beginning of the sample period are not sustainable in the long-term horizon. Steady-state growth of the euro area is thus set to 1.75%, Czech Republic to 2.75%, Hungary to 2.25%, Poland to 3.25% and Slovakia to 3.00%.

Similarly, we set the steady-state values for the unemployment rate as the median long-term unemployment, thus approximating the structural unemployment, and adjust the results for the emerging economies, due to the historical decline in these variables. Specifically, steady-state unemployment of the euro area is set to 4.50%, Czech Republic to 2.00%, Hungary to 2.50%, Poland to 3.00% and Slovakia to 6.50%. Steady-state values of the real appreciation are then calibrated as the averages of the historical medians and the differences between the steady-state growths of the Visegrad countries and the euro area, thus capturing the historical evidence as well as the Harrod-Balassa-Samuelson effect. Specifically, steady-state appreciation of Czech Republic is set to 0.75%, Hungary to 0.50%, Poland to 1.00% and Slovakia to 0.75%.

On the other hand, steady-state values for the real interest rates are calibrated on the shortened period from the January of 2002 to the December of 2007 to exclude the subsequent impact of the zero-lower bound. According to the historical decline in the country premium, we further adjust the values for the emerging economies. Steady-state rate of the euro are is thus set to 1.25%, Czech Republic to 0.75%, Hungary to 2.50%, Poland to 2.50% and Slovakia to 1.25%. After the adoption of the Euro currency, we exclude from the country premium in the equilibrium, thus setting the steady-state rate of Slovakia to 0.50%. Government premium is then set to 0.75% for the euro area and to 1.25% for Slovakia, while lowering the steady-state yields on government bonds by half percentage point after the monetary switch. Steady-state level of the government debt is calibrated to 40.00% following the historical evidence.
Finally, steady-state values for the inflation rates are pinned down by the actual inflation targets and set to 2.00% for Czech Republic, 3.00% for Hungary and 2.50% for Poland. Furthermore, we distinguish between two different steady-states for Slovakia, before and after the monetary switch. While the former is set to 2.50% according to the historical evidence, the latter is pinned down by the exchange rate identity and thus equal to its euro area counterpart minus the steady-state real appreciation. Inflation target of the euro area is constant and set to 1.90%.

We continue with the trend variables and set the potential output growth convergence ($\tau_1$) to 0.05 and the pass-through of the potential interest rates ($\tau_2$) to 0.10 for all economies. On the other hand, potential exchange rate growth convergence ($\phi_2$) is country-specific and calibrated due to the historical evidence. Specifically, we set this parameter to 0.05 for Czech Republic and Hungary, since their historical exchange rate growths fluctuate around the steady-state values. On the other hand, exchange rate growth of Slovakia historically overcomes its steady-state values, while the opposite holds for Poland. We thus set these parameters to 0.02 to capture the lower degree of convergence. Impact of the government debt ($\phi_3$) is then set to 0.03.

Potential unemployment rate convergence ($\alpha_3$) also follows the historical evidence. Parameter of the euro area is thus set to 0.01, Czech Republic to 0.03, Hungary to 0.01, Poland to 0.03 and Slovakia to 0.03. Similarly, since the potential interest rate of the euro area shows a low degree of convergence, we calibrate the convergence parameter ($\gamma_4$) to 0.01. Government premium ($\omega_1$) and country premium ($\theta_1$) persistence equals 0.90, while the impact of the government debt on the former ($\omega_2$) is set to 0.10 and the impact on the letter ($\theta_2$) is set to 0.05. Finally, persistence of the structural deficit ($\delta_1$) is calibrated to 0.90, reactivity of the government deficit ($\delta_3$) to 0.10 and pass-through of the fiscal consolidation ($\delta_4$) to 0.20.

Persistence of the output gap ($\beta_1$), persistence of the unemployment gap ($\alpha_1$) and their mutual relationship ($\alpha_2$) are based on the results of the Hodrick-Prescott filter and adjusted due to the historical projection of the model variables. Output gap expectations ($\beta_2$) are then set to 0.10 according to the parametrization of Carabenciov et al. (2008) and Carabenciov et al. (2013). Inflation shares for the headline inflation ($\kappa_1$) as well as the core inflation ($\lambda_2$) are calibrated by the Ordinary Least Squares (OLS), while the same holds for the interbank premium persistence ($\eta_1$) and spillovers ($\eta_2$), although these parameters are slightly adjusted to match the historical picture. Inflation expectations ($\lambda_1$) are based on the results of Vašíček (2011), estimating the Phillips curves of the Visegrad economies, while the target persistence ($\lambda_2$) is set to 0.80 by the OLS estimation. On the other hand, following Andrle et al. (2014), the policy rate persistence ($\gamma_1$) is set to 0.75 and the exchange rate expectations ($\phi_1$) are set to 0.70.

Structural parameters of the open economies are calibrated from the trade to output ratio ($\beta_4$), the export to output ratio ($\beta_5$) and the import to output ratio ($\lambda_4$), while considering also the stabilization properties of the model. We calibrate also the structural parameters of the euro area and the monetary parameters of Slovakia. While the former ones could be properly estimated outside the model, according to the closed economy framework, the latter ones are relevant only for the historical development and not actual policy simulations.

Stochastic parameters are calibrated to further advance the structural interpretation of historical variables, while considering the historical data evidence as well as the historical projection of the model variables. Finally, trade parameters capturing the proportional shares of the external economies are calibrated as the sample averages from the historical data. Although the shares of the euro area are set over 80% for Poland as well as Hungary and over 75% for Czech Republic, relative importance of the euro area for Slovakia is not either 65%. Czech Republic is second with approximately 20%, followed by Poland and Hungary, both with 8%. Structural, stochastic and trade parameter values are proposed in Appendix.

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5 Information about the trade volumes of the model economies are obtained on the quarterly basis from Eurostat.
5.2 Bayesian estimation

We estimate the rest of the model parameters using the Bayesian interface that provides a compromise between the standard estimation and the calibration of the model parameters. The reason is that the standard estimation applied on a short data sample usually provides results that are inconsistent with the macroeconomic fundamentals, often estimating effects that are opposite to the standard macroeconomic views. This is especially problematic when these models are applied for policy simulations. On the other hand, calibrated models have no support in data and often reflect nothing more than the modellers’ judgement. As the middle ground between these two approaches, Bayesian estimation has a benefit of putting some weights on the prior expectations and some weights on the observed data over the estimation period. These weights are meanwhile captured by the standard deviations of the priors, thus allowing to distinguish between parameters with high and low degree of initial certainty, in other words mostly calibrated and mostly estimated parameters. As the result, posterior distributions of the model parameters are obtained as the weighted average between the prior and data generating distributions.

Bayesian approach proposed in this paper consists of a two-step estimator. At first, we apply the maximum posterior estimation to obtain the posterior modes of the model parameters, similarly to Carabenciov et al. (2008). This is in fact nothing else than the standard Maximum Likelihood Estimation (MLE) extended for the deviation of the parameters from their prior modes. We use standard Quasi-Newton method with the BFGS update step for the optimization process. We considered also application of global optimization methods, especially the Differential Evolution algorithm, but decided against, due to the number of estimated parameters.

Application of the maximum posterior estimator has two main disadvantages. First, estimation of the posterior modes is performed under the true/false loss function, in contrast to the standard quadratic loss function applied for the posterior means. Second, we obtain only the point estimates and not the entire distributions of the posterior parameters. Therefore, we apply an additional estimation step where we sample from the posterior distributions using the MCMC sampling algorithm based on the random walk Metropolis-Hastings simulation. As the result, we obtain the approximation of the entire posterior distributions and thus information about the means, the standard deviations and the confidence intervals of the estimated parameters. Prior distributions are set according to the related literature. Priors as well as posteriors of the estimated parameters are proposed in Appendix.

While the posterior mean of the monetary policy pass-through ($\beta_3$) is estimated close to the prior for Czech Republic, the opposite holds for the rest of the economies, with the most significant decline for Poland. On the other hand, posterior estimation of the fiscal policy pass-through ($\beta_6$) for Slovakia is close to the prior. Posterior means of the real marginal costs ($\lambda_3$) are estimated below the priors for all economies, with the most significant decline for Slovakia and the least significant decline for Hungary. Taylor rule parameters are also estimated below the priors, with the highest inflation reactiveness ($\gamma_2$) for Hungary and the lowest output reactiveness ($\gamma_3$) for Poland. Finally, posterior estimation of the automatic stabilizers ($\delta_2$) for Slovakia is significantly below the prior mean. Posterior standard deviations were reduced for all estimated parameters with the most significant decline of the automatic stabilizers.
6 Model evaluation

Evaluation of the model performance is based on the impulse response analysis and historical projection of the model variables. We propose the impulse response functions to the most important domestic and external shocks, including shocks to the domestic and external demand, cost-push and exchange rate shocks, shocks to the policy rate and interbank premium and shocks to the government deficit and target debt. All shocks have magnitude of one percentage point as common in the related literature. Impulse response functions are presented in the percentage points and not as the deviations from the steady-state values.

On the other hand, we perform the historical estimation of the potential and cyclical variables, including the core inflation and the output gap. We propose also simple simulation exercise based on the positive shock to the target debt and different government policies as well as the consolidation strategies based on the estimated historical time series and pre-set path for the target debt.\(^6\) Model evaluation together with the simulation exercise are proposed in Appendix.

6.1 Impulse response functions

Starting with the domestic demand shock, output gap puts an upward pressure on the core inflation multiplied by the rational expectations. Reaction of the monetary policy follows the output and inflation development putting an upward pressure on the nominal and real interest rates and leading to the appreciation of both nominal and real exchange rates. On the other hand, due to the absence of the domestic monetary policy, we observe initial decline in the real interest rate and expected appreciation of the real exchange rate in Slovakia. Rising output gap is then followed by the automatic stabilizers and thus leads to the decline in the government deficit as well as the government debt. Latter is further reduced by the nominal output growth.

On the other hand, external demand shock puts an upward pressure on the domestic output gap followed by the core inflation and both nominal and real interest rates. Since the reaction of the domestic monetary policy is stronger than in the external economy, according to the weaker stabilization properties, external demand shock leads to the nominal and real appreciation of the domestic economies. However, due to the absence of the domestic currency, real exchange rate effectively depreciates in Slovakia. Furthermore, since the magnitude of the external monetary policy is not stronger than the domestic inflation rate, real interest rate originally declines. Finally, after initial increase of the structural deficit based on the forward-looking pressure of the nominal output, we observe decline in the government deficit as well as the government debt.

We continue with the cost-push shock, when rising inflation puts a downward pressure on the real interest rate as well as the real exchange rate, followed by the monetary policy reaction and decline in the output gap. Reaction of the nominal exchange rate is uncertain and depends on the rigidity of domestic prices and monetary policy reactivity. Specifically, the more active is the monetary authority, the more likely the currency appreciates. In addition, due to the forward-looking nature of the policy rule, more persistent inflation leads to the increase in the policy rate and thus to the currency appreciation. Negative output gap puts an upward pressure on the government deficit while the nominal output growth reduces the government debt.

Exchange rate shock leads to the nominal and real depreciation, thus increasing the headline inflation (blue line) as well as the core inflation (red line) and putting an upward pressure on the output gap. Rising inflation and output gap activate the monetary policy and thus lead to the increase in both nominal and real interest rates. On the other hand, simultaneous appreciation of the trading partners leads to the depreciation of the euro currency. Finally, fiscal variables follow the development of the output gap.

\(^6\) Target path for the government debt is set to reduce the debt to output ratio by six percentage points in the three-years or six-years horizon.
Monetary policy shock leads to the decline in the output gap followed by the core inflation, increase in the nominal and real interest rates and nominal as well as real appreciation. Furthermore, after initial decline of the structural deficit, we observe increase in the government deficit as well as the government debt, due to the impact of the automatic stabilizers. On the other hand, shock to the international premium leads to the decline in the policy rate, with stronger magnitude than in the external economy, and thus to the depreciation of the domestic currency. Since the external shock is equal to the domestic shock in Slovakia, increase of the interbank premium as well as the real interest rate is immediate and not gradually transferred through the market spillovers. Again, fiscal variables follow the development of the output gap.

Fiscal policy shock positively affects the output gap via contemporaneous fiscal impulse and increases the government debt, thus leading to the potential exchange rate depreciation. On the other hand, the government debt is expected to decline in the future, thus pushing the future potential exchange rate towards appreciation, lowering the potential interest rates and increasing the potential output growth. On the other hand, potential output is negatively affected by the government debt through the government premium channel. Gap components of the real interest rate as well as the real exchange rate compensate the development of their potential counterparts. Initial increase in the core inflation implied by the output gap is thus overcome by the subsequent exchange rate impact.

Finally, shock to the target debt leads to the increase in the government deficit, gradually increasing government debt and positive reaction of the output gap through the fiscal impulse channel as well as the changes in the target debt. Furthermore, increase in the output gap puts an upward pressure on the core inflation. On the other hand, expected increase in the government debt pushes the future potential exchange rate towards depreciation, thus increasing the potential interest rates and lowering the potential output growth. Again, gap components of the real interest rate as well as the real exchange rate compensate their potential counterparts.

6.2 Historical decomposition

Historical projection of the model variables is performed by the methods of Kalman filtering and Kalman smoothing on the sample period from the January of 2002 to the December of 2017. We propose the estimation of the potential and cyclical variables, including the core inflation and the output gap but also real interest rates, real exchange rates and unemployment rates.

Core inflation (red line) is proposed against its headline counterpart (blue line) with the estimated time series close to the trimmed or winsorized inflation rates, similarly to Andrle et al. (2014). Output gap (blue line) is then proposed against the external demand (red line), as the key driver of the output gap development in the small open economies. While the domestic and external demand of Poland show a similar degree of volatility, domestic demand of Slovakia fluctuates around the external one with significantly higher variance, due to a number of one-off effects. Spike in the domestic demand of Slovakia at the end of 2007 is driven by the prepositioning of tobacco firms, due to the expected increase in the taxes on tobacco.

Potential real interest rate of the euro area declines on the sample period resulting into negative real interest rates in the recent years. This observation is in line with the related literature, for example Holston et al. (2017), and is usually explained through the phenomenon of the global savings glut and the secular stagnation. Downward trend in the potential real interest rates is observable also in the Visegrad countries. Potential real exchange rate, proposed as 100 times the log of the original variable, declines for all economies except Poland, with the most significant decline for Slovakia. Potential unemployment of the euro area has significantly increased after the economic and financial crisis, especially during the debt crisis of the eurozone. Although the potential unemployment dynamics of Hungary has changed over time, we observe significant downward trend in the unemployment rates of the rest of the Visegrad countries.
Government premium of Slovakia (blue line) and its euro area counterpart (red line) show a high degree of co-movement, with historically higher levels of the domestic premium. However, after the adoption of the Euro currency, we observe convergence of the domestic premium to its euro area counterpart. Sharp decline in the recent years is according to the impact of the Quantitative Easing (QE). Finally, structural deficit of Slovakia has significantly declined after the economic and financial crisis, due to the decline in the nominal output growth.

6.3 Fiscal simulations

Next, we propose the impulse response functions to the positive shock to the target debt for three different government policies. While the baseline policy is set according to the original model parametrisation, we experiment also with more effective government by (i) increasing the reactivity to the government debt deviation from the target value, thus assuming the government wants to meet the target more aggressively, and (ii) increasing the direct effect of the fiscal stimulations, thus increasing the impact of the target debt shocks on the fiscal impulse and the real economy. The first scenario corresponds to the increase of parameter $\delta_3$ to 0.50 and the second one to the increase of parameter $\delta_4$ to 0.50.

The first scenario with more proactive government shows significant differences for the fiscal variables, with higher government deficit and sharply rising government debt, as well as the potential variables, with the real exchange rate pushed towards depreciation and the real interest rate rising through the expectations channel. Furthermore, output gap gradually increases through the fiscal impulse, reflecting the government objective to meet the target, thus increasing the output growth. Core inflation follows the development of the output gap at the beginning and the development of the exchange rate afterwards. On the other hand, the second scenario with more effective stimulations instantly increases the output gap, through the direct impact of the fiscal stimulation on the fiscal impulse, and declines the government deficit, due to the activation of the automatic stabilizers. Government debt increases more gradually, since following the development of the government deficit.

6.4 Consolidation strategies

Finally, we propose two different consolidation strategies based on the estimated historical values and pre-set path for the target debt, reflecting the government objective to decline the debt to output ratio by six percentage points in (i) three years by the aggressive strategy and (ii) six years by the mild strategy. Government debt follows the target path through the evolution of the government deficit and while the aggressive strategy reaches the target at the end of the simulation period, the opposite holds for the mild strategy with approximately half percentage point deviation from the target over the last simulation year.

Structural deficit increases through the nominal output growth with higher values under the mild strategy according to the evolution of the target debt. On the other hand, decline in the government deficit follows the consolidation effort of the government and the excessive output gap, with higher decline and sharper growth under the aggressive strategy. Dynamics of the government deficit is mostly influenced by the deviation of the government debt from the target path and thus by the nominal output growth. Fiscal impulse follows the evolution of the government deficit while evaluating also the direct impact of the fiscal consolidation.

Government premium increases through the external factors, for example termination of the bond-purchasing program of the ECB, with similar outcomes for both consolidation strategies, thus lowering the equilibrium premium by more than half percentage point. On the other hand, country premium declines according to the fiscal consolidation with significantly better results under the aggressive strategy. Stabilization mechanism for the output gap as well as the core inflation is also better under the aggressive strategy, with lower output growth at the beginning and higher output growth afterwards.
7 Concluding remarks

In this paper, we proposed the medium-scale gap model of the Visegrad Group, based on the behavioural equations for output gaps, unemployment gaps, inflation rates, interest rates and exchange rates, that was further enriched by the fiscal block for Slovakia. In addition, we approximated the term structure of interest rates by incorporating the yields on ten-years government bonds. Spillovers between the economies are captured by three macroeconomic channels, (i) impact of the external demand on the domestic output, (ii) impact of the exchange rates on the domestic output and prices and (iii) market spillovers through the interbank premiums. On the other hand, government deficit and debt are affecting the economy via fiscal impulse, potential premiums and trend appreciation.

There is a number of potential extensions of our work. First, we want to incorporate the expectations about entering the monetary union, thus better capturing the historical development of the model variables under the European Exchange Rate Mechanism (ERM II). Second, we want to extend the original model according to Szilágyi et al. (2013) and decompose the output gap into the most important components to obtain additional information about domestic consumption, domestic investments, government expenditure and trade variables. Third, we want to extend the structure of the model shocks for basic cross-correlations according to Carabencio et al. (2008) and complex demand shocks according to Andrle et al. (2014). Finally, we want to extend the fiscal block for additional variables to capture the true channels of the fiscal policy.
Bibliography


## Appendix

### Calibrated structural parameters

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## Estimated structural parameters

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Calibrated stochastic parameters

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Priors and posteriors

CZ Monetary Policy

HU Monetary Policy

PL Monetary Policy

SK Monetary Policy

SK Fiscal Policy

CZ Marginal Costs

HU Marginal Costs

PL Marginal Costs
Domestic demand shock
External demand shock
Cost-push shock

CZ Output Gap

CZ Inflation Rate

CZ Policy Rate

CZ Interest Rate Gap

CZ Nominal Depreciation

CZ Exchange Rate Gap

HU Output Gap

HU Inflation Rate

HU Policy Rate

HU Interest Rate Gap

HU Nominal Depreciation

HU Exchange Rate Gap
Exchange rate shock

CZ Output Gap

CZ Inflation Rate

CZ Policy Rate

CZ Interest Rate Gap

CZ Nominal Depreciation

CZ Exchange Rate Gap

HU Output Gap

HU Inflation Rate

HU Policy Rate

HU Interest Rate Gap

HU Nominal Depreciation

HU Exchange Rate Gap
Monetary policy shock

CZ Output Gap

CZ Inflation Rate

CZ Policy Rate

CZ Interest Rate Gap

CZ Nominal Depreciation

CZ Exchange Rate Gap

HU Output Gap

HU Inflation Rate

HU Policy Rate

HU Interest Rate Gap

HU Nominal Depreciation

HU Exchange Rate Gap
Interbank premium shock

CZ Output Gap

CZ Inflation Rate

CZ Policy Rate

CZ Interest Rate Gap

CZ Nominal Depreciation

CZ Interbank Premium

HU Output Gap

HU Inflation Rate

HU Policy Rate

HU Interest Rate Gap

HU Nominal Depreciation

HU Interbank Premium

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Fiscal policy shock

Target debt shock
Historical decomposition

- EA Inflation Rate
- CZ Inflation Rate
- HU Inflation Rate
- PL Inflation Rate
- SK Inflation Rate
- EA Output Gap
- CZ Output Gap
- HU Output Gap
- PL Output Gap
- SK Output Gap
Fiscal simulations

- SK Output Gap
- SK Output Growth
- SK Inflation Rate
- SK Interest Rate Gap
- SK Exchange Rate Gap
- SK Government Deficit
- SK Fiscal Impulse
- SK Government Debt
Consolidation strategies