MUSE: A Model of Slovakia and the Euro Area[1]

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In this article we present a medium-scale two-country model MUSE – Monetary Union and Slovak Economy Model. A Bayesian method together with the calibration approach is used to confront the model with the data. Parameters controlling the steady state of the model are calibrated in order to match the ratios of a few selected variables to their empirical counterparts. The remaining parameters are estimated via the Bayesian method. Since Slovakia has been a euro area member country for only two years, we cannot estimate the model under the monetary union regime. The model, however, allows switching from an autonomous monetary policy regime to a monetary union regime. This feature enables us to parameterise the model in the case of independent monetary policy (until 2008) and consequently to simulate the impacts of various structural shocks on the Slovak economy as a part of the monetary union.

1 Introduction

In January 2009, Slovakia joined the euro area and the euro became its official currency. As a consequence, the National bank of Slovakia ceased to conduct an autonomous monetary policy, since the European Central Bank conducts monetary policy for the whole euro area, including Slovakia. In this article, we present theoretical foundations and simulation results of a new version of the DSGE model for the Slovak economy and the rest of the euro area. A novelty in the Slovakian context is that parameters of the model have been estimated for the first time by Bayesian technique. Data on the Slovak economy and on the rest of euro area covering the period from 1997 to 2008 were used.

Within the euro area, the Slovak economy is very small, less than 1% in terms of both GDP and population. Moreover, the foreign sector plays a very important role for the Slovak economy, with the export to GDP ratio standing at more than 80%. The most usual way of including the foreign sector is through a small open economy framework. In such a setting, the transmission of shocks is a one-way road – shocks from the large economy affect the small one, but shocks originating in the small country have no impact on the large one. The foreign sector is represented by a few exogenous variables and only shocks of these variables can be transmitted to the domestic economy. This approach has been used in a DSGE model for the Slovak economy by Zeman and Senaj (2009).

The National Bank of Slovakia, as a member of the Eurosystem, participates in policy discussions covering the entire euro area. While its main objective is still to evaluate the effects of different policies and impacts of shocks on the Slovak economy, the Slovak central bank is now more interested in the evaluation of these effects on the whole euro area. This motivation leads us to develop a two-country model in which countries form a monetary union. The Slovak economy represents one country and the rest of the euro area represents the other country. Such a model allows us to analyze various scenarios relating to both regions in a unified framework.

There are several papers devoted to multi–country models. For example, Obstfeld and Rogoff (1995) develop a two-country model based on monopolistic competition and sticky nominal prices. Pytlarczyk (2005) presents a two-country DSGE model with one country representing the German economy and the other one the rest of euro area. The structure of both economies is symmetrical and both countries form a monetary union. This setup enables an examination of how domestic as well as foreign shocks are transmitted in both regions and of their relative impact on both economies. A similar setup was used in the model of the Austrian economy developed by Breuss and Rabitsch, (2008) and in the model at the Banco de Espana by Andres et al., (2006) who augmented it with the housing and durable goods sectors. Large-scale models used in the IMF and the ECB are worth mentioning as well. The Global Economy Model (GEM) prepared by the IMF Research Department was published in 2004. The ECB staff regularly use the New Area Wide Model (NAWM – Christoffel, Coenen, Warne 2008) in the Macroeconomic Projection Exercise. Based on its predecessor, the Area Wide Model, the NAWN is a micro-founded open-economy model of the euro area. It also underpins the Euro Area and GLobal Economy model (EAGLE) developed by Gomes, Jacquinot, Pisani (2010) – which is a four-country model of the euro area and the world economy and is intended to be used for policy analysis of economic relationships across regions of the euro area and between euro area countries and the world economy.

1 *This article is a short version of the NBS working paper 1/2010 (Senaj, Výškrabka and Zeman, 2010).Zhrnutie štúdie je dostupné v slovenskom jazyku online na adrese: http://www.nbs.sk/_img/Documents/PUBLIK/WP_1-2010_netechnickezhrnutie.pdf*

As a benchmark, we chose the DSGE model for the German economy within the euro area. Our departures from the benchmark model include a different form of the investment adjustment cost function and the use of a general CES function instead of a Cobb-Douglas function to bundle differentiated intermediate goods. Furthermore, we have incorporated flexible utilisation of capital in the production process. In our framework, the euro area only trades with Slovakia, which means that the euro area region in the model represents almost a closed economy.

A complication of the modeling strategy is that we do not have a sample of data from the monetary union regime on which to estimate the model. The model in Pytlarczyk (2005) has the advantage that we can easily switch between the autonomous monetary policy regime and monetary union regime. Therefore, we can use the data from the period prior to the euro adoption to estimate the model parameters. In DSGE models, it is assumed that a change in policy does not result in a change in parameter values, and thus we can switch the model to the monetary union regime.

2 Main features

The model consists of one closed economy (the euro area) that comprises two countries: home (Slovakia) and foreign (rest of the euro area). There are two regimes under which the model can operate. One regime, with autonomous currencies (including a flexible exchange rate) and autonomous monetary policies in each country, simulates the situation before Slovakia joined EMU in 2009. The other regime, with a common currency and one central bank (the ECB) that conducts monetary policy for the whole euro area, describes the situation after Slovakia joined EMU.

In each country, there are the following agents: firms (two types), households and governments.

Intermediate good firms use labour and capital to produce differentiated goods. Each firm has a monopoly in producing a specific good, hence firms operate in a monopolistic competition environment. They set prices of the produced goods by adding a markup to marginal cost. The intermediate goods are tradable.

Final good firms produce final products by mixing bundles of home and foreign intermediate goods. There is perfect competition in the final goods sector, meaning that the price of the final goods equals their marginal cost and firms earn zero profit. These firms produce three different types of non-tradable goods, namely goods used for private consumption by households, for public consumption by government, and for investment.

There is a continuum of **households**, each maximising a lifetime utility that depends on consumption and hours worked. Each household accumulates capital that rents out to firms and supplies the labour market with differentiated labour. It gives market power to workers in setting their wages. In order to improve dynamic properties, the model is amended with habit formation, investment adjustment cost and varying capacity utilisation features.

There is staggered **price setting** á la Calvo for the prices of home and foreign intermediate goods as well as staggered wage setting in the labour market. This price setting mechanism results in a certain degree of price stickiness, which together with monopolistic competition guarantees that output becomes demand driven in the short run.

Only intermediate goods can be **traded**. There is no price discrimination across markets; the same goods cost the same price in both home and foreign markets i.e. LOOP holds. This, however, does not imply that PPP holds in the short run as shares of home and foreign goods in home and foreign baskets are different in general.

Financial markets are complete, i.e. there is a worldwide market in which households in both countries can sell and buy contingent claims. This international perfect risk sharing arrangement enables us to eliminate the nominal exchange rate variable from the model. This makes switching between the model's two regimes – flexible and fixed exchange rate – very convenient.

In the flexible exchange rate regime, **monetary authorities** in both countries set the interest rate level independently, reacting to inflation and output gaps in their respective countries. In the fixed exchange rate regime, one central monetary authority sets the interest rate level for the whole region (both countries). This level of interest rates closes aggregate gaps and may not be appropriate for an individual country, particularly for the smaller one. This is the well-known problem of synchronisation and asymmetric shocks in a currency area.

Fiscal authorities in both countries run a balanced budget in every period; government expenditure is financed by a non-distortionary lump-sum tax.

All real variables in both countries are assumed to have a common stochastic **trend** inherited from a non-stationary technology process. In the model, this trend is removed and these variables are assumed to be stationary.

It is also assumed that price deflators (expressed in terms of one currency) in both countries have a common trend. This makes both the real exchange rate and terms of trade variables stationary.

3 Parameterisation of the model

The process of parameterisation of the model consists of two steps. First, we calibrate parameters that determine the non-stochastic steady state of the model. In the second step, we estimate the remaining structural parameters and standard deviations of the shocks by the Bayesian method. Because steady state assumptions of the model[2] are not fully in line with the observed data, we decided to calibrate a subset of parameters instead of estimating them. Especially in the beginning

2 The balanced growth incorporated in the model implies that shares of consumption, investment, government spending and net exports in output are constant.

3 *The following countries are assumed to form the euro area: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain.*

of our sample, investment and government expenditure shares of output follow a downward trend. For this reason, we calibrate the steady state on a shorter period, from 2005 to 2008. The details on parameterisation come in the sections following the description of the data used in the estimation.

3.1 Data

In the estimation, we use the following set of six variables for each country: real GDP, real consumption, real investment, real compensation per employee, short-term (3M) nominal interest rate and GDP deflator. We also use government expenditures to estimate the autoregressive process of the corresponding variable in the model. All variables come from the Eurostat database, are seasonally adjusted, and are expressed in per capita terms. The length of the period in the model is one quarter. We further assume that the euro area consists of twelve countries[3] over the whole sample, although the actual composition changed several times.

The sample starts at the first quarter of 1997 and ends at the fourth quarter of 2008. With Slovakia having been a member of the euro area since the beginning of 2009, the last observation in the sample is the last quarter of autonomous monetary policy in the country. The financial crisis contaminates the last few observations in the sample. Although the model is not capable to explain this episode properly, we keep these observations in the estimation because the sample is short and we want to use as many observations as possible. Since the model is transformed to its stationary version, we remove the trend in the data by using an HP filter.

3.2 Calibration of the coefficients

The parameters that determine the non-stochastic steady state take values such that the ratios of a few selected model variables correspond to their empirical counterparts. In particular, we match the ratios of investment, government, and net exports to output. Table 1 presents the steady state properties of the model.

In order to obtain the specification of the trade, some necessary adjustments to the data need to be made. In the actual data, a substantial part of imported goods is used as an input in the output production of export sectors. In the model, however, all imports are consumed domestically. We assume that about 70% of all Slovak imports enter the production process of the exporting sectors. We also assume that Slovakia exchanges its entire trade volume with the euro area. Thus we set the Slovak imports to GDP ratio at 26%. As for the trade balance, we make a simplifying assumption and set this variable at zero.

Along with the total imports of both countries, we need to specify the share of imported investment and consumption goods. Of total Slovak imports, investment goods represent 40% and consumption goods 60%. The small size of Slovakia compared to the euro area means that the euro area is more or less a closed economy. We assume that Slovakia exports substantially fewer investment goods than consumption goods. Thus, in the euro area, the investment share of imports is only 19% while the consumption share reaches 81%.

The balanced growth assumption adopted in the model requires that the two countries share the long-term technological progress. To meet this assumption we set the technological growth rate in both countries in line with Pytlarczyk (2005), at 1.6% p.a., even though the average growth rate of the Slovak GDP is considerably higher than the growth rate of the euro area GDP. The size of Slovakia in the world is 1% whereas the size of the euro area is 99%.

3.3 Bayesian estimation of the parameters

The Bayesian approach is widely used as an estimation tool when working with DSGE models. The approach is proposed by a clutch of recent books and papers, e.g. Canova (2007), Christoffel et. al. (2009) Smets & Wouters (2007), Almeida (2009), Schorfheide (2000).

The novelty of this paper is that we estimate selected parameters of the model by Bayesian method. To our knowledge, the parameters describing the Slovak economy have not so far been estimated via Bayesian approach.

Using this approach, we estimate 34 parameters of the model, for example, coefficients describing the monetary policy, wage and price setting, and adjustment cost. These parameters, stacked in vector θ, do not affect steady state. Moreover, the parameters calibrating the structural shocks, e.g. autoregressive coefficients and standard errors, are estimated for both countries.

Bayes' theorem tells us that posterior distribution $p(\theta|Y^{data})$ can be obtained from prior beliefs about parameter values, summarised in prior distribution $p(\theta)$, and from information on empirical data and suggested model structure, summarised in the likelihood function $p(Y^{data}|\theta)$. The mathematical representation of the Bayes' rule is as follows:

$$p(\theta|Y^{data}) = \frac{p(Y^{data}|\theta)\, p(\theta)}{p(Y^{data})}$$

Table 1 Steady state ratios

Country\Variable	I/X	C/X	Im/X	ImI/X	ImC/X	G/X	TB/X	n
SK	0.22	0.55	0.26	0.10	0.16	0.18	0.00	0.01
EA	0.20	0.60	0.003	0.001	0.003	0.20	0.00	0.99

Source: NBS.

Since, $p(Y^{data})$ is constant with respect to θ, then it can be rewritten as follows:

$$p(\theta|Y^{data}) \propto p(Y^{data}|\theta)\, p(\theta).$$

Posterior distribution can be evaluated for any given value of θ. But, in general, the whole distribution of $p(\theta|Y^{data})$ is unknown.

Therefore, the Metropolis-Hastings algorithm is used to approximate the posterior distribution. The M-H algorithm belongs to the group of Markov Chain Monte Carlo (MCMC) methods. The basic aim is quite straightforward – to produce a Markov chain with desired ergodic distribution, the distribution in our case being equal to $p(\theta|Y^{data})$. Consequently, after a large number of steps, the state of the chain is used as a sample from posterior distribution.

One of the shortcomings of the Bayesian approach is that the likelihood, and consequently the posteriors, are sensitive to the selection of observables. There is a rule that the number of observables has to be lower or equal to the number of structural shocks embodied in the model. The paper by Guerron-Quintana (2010) provides evidence of the sensitivity mentioned earlier. It estimates the same model on different subsets of observables in which some observable is missing. It claims that, depending on the dataset, the point estimates of habit formation range from 0.7 to 0.97. This paper concludes that point estimates are influenced more by the omission of some observables than by the choice of the shorter sample. Therefore, we use as many observables as we are allowed to.

When estimating the model we use 12 observables, thus the number of structural shocks equals the number of observables. In order to build a link between our model and the empirical data, the model was extended by the measurement equations block.

According to the Bayes rule, the posterior is equal to likelihood times prior, where the priors represent additional information added to the estimation procedure. Thus, priors can be seen as the researcher belief about structural parameters. Fernández-Villaverde (2009) argues that tighter priors are the better option if the model is to be used for policy analysis. By contrast, looser priors (e.g. uniform priors) are the preferred option if the model is to be used for pure research. Loose priors let the likelihood dominate the posterior. Since our model is assumed to be used for policy simulation, we prefer tighter priors with reasonable standard deviation.

When setting the priors in this paper, four types of probability distribution were used. In the case of the parameters constrained between 0 and 1, the Beta distribution is employed. The prior for parameter of investment adjustment cost is set as a Gamma distribution. Normal distribution is used for two parameters in the Taylor rule, namely response to the output gap and response to the deviation of inflation from its steady state value. Finally, Inverse-gamma distribution is used for standard deviations of the structural shocks.

In the following part, we discuss the means of the estimated parameters. Investment is subject to a moderate adjustment cost. The estimated adjustment cost parameter in Slovakia is higher than in euro area, as expected given the higher volatility of Slovakian investment data. Moreover, the volatility of the investment shock in Slovakia is approximately four times higher than in euro area.

In the case of price and wage adjustments, the estimated parameters for the Slovak economy are similar to those for the euro area. In Slovakia, the probability of no wage change is around 0.71, while in the euro area it is estimated at 0.78. The degree of price indexation is 0.5, which is lower than the 0.69 recorded in the euro area. Another difference is price flexibility. According to the estimated fraction of firms that are not allowed to set optimal prices in the current quarter, we can conclude that prices in Slovakia are more flexible than in the euro area. The estimated values are 0.43 and 0.79 in Slovakia and the euro area, respectively. This implies shorter average price contract duration of 1.75 quarters in Slovakia.

The estimated Taylor rule for Slovakia has a very important degree of inertia. The degree of interest rate smoothing is slightly lower than 0.9. The remaining two Taylor rule parameters have different interpretations. On one hand, there is significant sensitivity to consumer price inflation – the estimated weight is around 2. On the other hand, sensitivity to the output gap is relatively low, at 0.2.

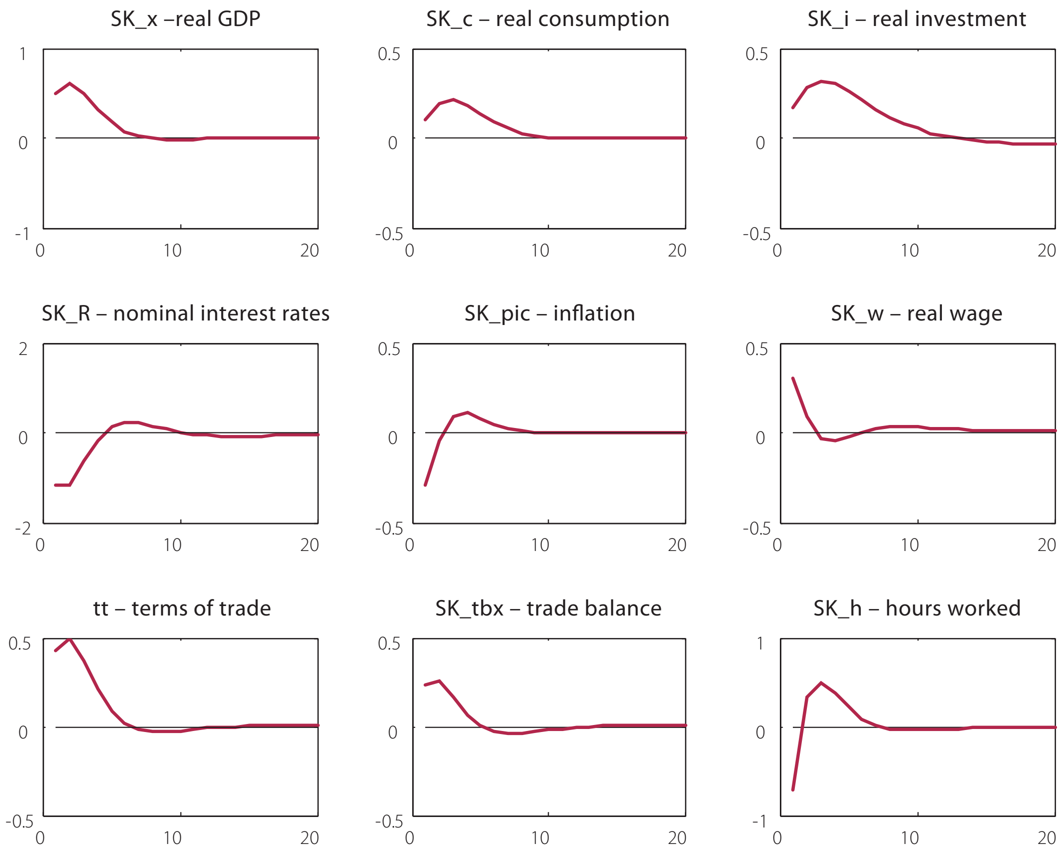
In the case of standard deviations of four comparable structural shocks (namely preference, investment, technology, and monetary shocks), we found that they are significantly higher in Slovakia than in the euro area. The conclusion that exogenous shocks are more volatile in Slovakia is in line with the higher volatility in empirical data.

4. Impulse response functions

In this section we illustrate how the Slovak model economy responds to a temporary technology shock and monetary shock under the monetary union regime.

The technology shock is implemented as a temporary, yet persistent,improvement to the production technology. The size of the initial shock is 1%. Better technology translates into lower prices of production and thus leaves consumers with higher disposable income. Due to the expected higher lifetime income, consumers tend to immediately increase their consumption, and the higher return on capital motivates them to invest more. Higher consumption makes leisure less expensive, hence households decrease their supply of labour initially. However, as the positive impact of technology is only temporary, households increase their labour supply when the shock fades away. Area-wide nominal interest rates remain

Figure 1 Technology shock – euro area



Source: Authors' calculations.

unchanged while the domestic inflation declines, which taken together lead to lower real interest rates and further motivate households to spend more. Lower production prices improve the competitiveness of the economy, which appears as an improvement in the terms of trade and leads domestic consumers to switch away from imported goods and replace them with domestic production. At the same time, foreign consumers demand more imports for the same reason, which results in positive net exports. All these effects lead to a stronger growth of GDP over a protracted period.

The monetary policy shock in the regime of monetary union is implemented as an unexpected one-off 100 basis points (in annualised terms) shock to the common union-wide interest rate. An important difference in the setup of this simulation is that, in this case, the shock hits both regions in the model in line with the monetary union definition.

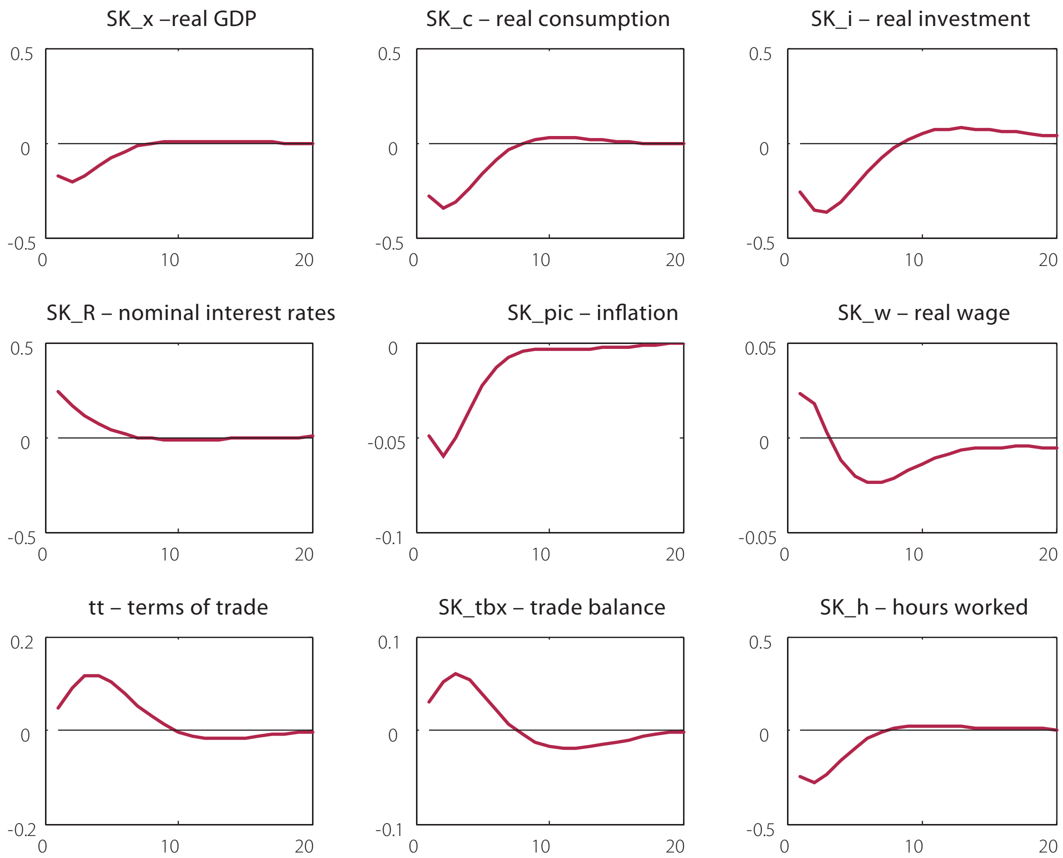
The tightening of the monetary policy results in a higher cost of borrowing and in households postponing consumption. In order to meet lower demand, firms reduce labour. The resulting fall in output leads to lower marginal productivity of production factors, which in turn means lower return on capital. As a consequence households cut investment and thus further decrease output. Due to the evolution of the terms of trade, the overall effect is such that the trade balance improves initially and mitigates the negative impact of the domestic demand on output. Despite considerable stickiness of nominal wages, real wages tend to grow at a slower pace after their initial pick up.

5 Conclusion

In this article, we provide a brief description of the two-country DSGE model suitable for policy analysis of the Slovak economy as a part of the euro area. There are several standard features incorporated in the model, such as external habit formation, investment adjustment costs, sticky prices and wages, and flexible capital utilisation. The model allows switching between two types of monetary policy regime. In one regime, the model can be specified for two countries that each have an autonomous monetary policy; in the other regime, the two countries constitute the euro area with a common monetary policy.

The possibility of regime switching is a very practical tool especially for countries that have joined a monetary union in recent history, as is the case with Slovakia. Utilising this type of model and quarterly data covering the years 1997 to 2008, we estimated selected parameters of the model. The parameterisation of the model consisted of two steps. Firstly, all parameters controlling the steady

Figure 2 Monetary policy shock – euro area



Source: Authors' calculations.

state were calibrated. Here, the aim was to match the deep ratios (such as the ratios of investment, government, and trade to output) determined by the model with their empirical counterparts. Secondly, the remaining structural parameters and all parameters describing the structural shocks were estimated via Bayesian method.

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