JEL Classification: E32
Keywords: DSGE model, Bayesian estimation, shock decomposition, business cycle synchronization

Business Cycle Synchronization through the Lens of a DSGE Model*

Martin SLANICAY—Faculty of Economics and Administration, Masaryk University, Brno
(slanicay@mail.muni.cz)

Abstract
The goal of this paper is to examine business cycle synchronization between the Czech economy and the euro area via a fully specified DSGE model. Using a two-country DSGE model I decompose the observed variables into the contributions of structural shocks and then compute conditional correlations. I also examine how these correlations evolve over time. The results indicate that productivity shocks in the tradable sector are the driving forces of different business cycle behavior, while investment efficiency shocks contribute to symmetric behavior of the two economies. The impact of shocks is most symmetric in the case of investment, output, and interest rates; the impact of shocks on these variables is highly correlated. There seems to be convergence of business cycles in the case of consumption, investment, and output, as the overall impact of shocks on these variables is getting more and more symmetric over time.

1. Motivation

In 2004, the Czech Republic joined the European Union and also undertook to join the European Monetary Union in the future. Since then, the attention of academics and the public has been focused on evaluating whether the common monetary policy is optimal for the Czech economy or not (see Hurník, Tůma, and Vávra, 2010).

The issue of the optimality of a common monetary policy is linked with the optimal currency area (OCA) theory developed by Mundell (1961) and refined by Alesina and Barro (2002). The OCA theory examines the circumstances under which participation in a monetary union can be beneficial for a country. The OCA theory states that one of the main factors is synchronization of the business cycle with the rest of the union. This idea is pretty straightforward. Optimal monetary policy should react to business cycle fluctuations in a way that promotes macroeconomic stability and development in the country. If the business cycle fluctuations differ across countries in the monetary union, the common monetary policy is likely to be suboptimal for some countries. Therefore, analysis of business cycle synchronization plays an important role in the evaluation of the costs and benefits of a common currency.

There is a growing literature on business cycle synchronization between the euro area and the countries of Central and Eastern Europe (CEE). Extensive surveys of this literature can be found in de Haan et al. (2008) and Fidrmuc and

* The first, six-page-long draft of this paper was presented at the MME 2011 conference and published in the conference proceedings under the title "Impact of Asymmetric Shocks and Structural Differences between the Czech Economy and the Euro Area 12" (see Slanicay, 2011).
I thank Jan Brůha, Fabio Canova, Jan Čapek, Pavel Herber, Tomáš Motl, and two anonymous referees for helpful comments and suggestions.

Korhonen (2006). The latter paper also offers a related meta-analysis on CEE countries. Basically, there are two prevalent approaches for examining such synchronization: (i) extract the cyclical component from the data using some filtration technique (HP filter, band-pass filter, etc.) or time series models and compute the correlations between the corresponding detrended time series; or (ii) use time series models (e.g. SVARs) to identify demand and supply shocks.

However, neither of these approaches uses a fully specified DSGE model, which leaves one wondering about the structural interpretation of the results. Therefore, the goal of this paper is to examine business cycle synchronization via a fully specified DSGE model. Using a two-country DSGE model I decompose the observed variables into the contributions of structural shocks and then compute conditional correlations. I also examine how these correlations evolve over time.

My approach is similar to the one employed in a recent study by Kolasa (2012), who also reports conditional correlations between various business cycle components in the euro area and new member states of the EU, as well as their evolution over time. The main difference is that he uses the business cycle accounting (BCA) framework proposed by Chari et al. (2007) rather than a fully specified DSGE model. In the BCA framework, the development of the variables is decomposed into the contributions of four time-varying wedges: efficiency, labor, investment, and government consumption wedges. As all four wedges account for all the observed business cycle movements, it is labeled as *business cycle accounting*.[1] According to Kolasa (2012), the advantage of using wedges is that the results from a fully specified DSGE model would be model-specific and can be distorted by model misspecification. He argues that using wedges "*has the advantage of being more flexible as it encompasses a large class of models, with various types of shocks and frictions*" (Kolasa, 2012, p. 4). In my view this argument is not specific to the presented exercise and should be seen rather as a general recommendation for using DSGE models in a more flexible way. On the other hand, the disadvantage of the BCA approach is clear. Although the wedges identified with the BCA framework have some economic interpretation, they still bear only aggregate information, as they summarize the effects of various structural shocks and frictions that are included in more complicated models. In order to determine the real driving forces of different business cycle development among countries, one needs a fully specified DSGE model, even though it has the implicit weakness of its results being potentially model-specific and misspecified.

The rest of this paper proceeds as follows. In the next section I present a non-technical overview of the model. Section 3 discusses the estimation of the model. In Section 4 I examine business cycle synchronization between the Czech economy and the euro area using shock decomposition of the main macroeconomic variables. The last section concludes and summarizes the main findings and contributions.

2. Model

The goal of this paper is to examine business cycle synchronization through the lens of a DSGE model. For this purpose I use a New Keynesian model of two economies, originally presented in Kolasa (2009).[2] I chose a two-country model

[1] In this sense I also use the business cycle accounting framework.

because both economies are modeled in the same way there. This means that the log-linearized equations have the same structural form in both economies and the variables, parameters, and shocks have the same structural interpretation in both economies. This feature allows for consistent evaluation of business cycle synchronization.

Details about the derivation of the model can be found in the *Appendix*. In this section I restrict my description of the model to a brief non-technical overview of its structure. The model assumes that there are only two economies in the world: a domestic economy (represented by the Czech economy) and a foreign economy (represented by the euro area). The problematic fact that one economy is much smaller than the other is solved by parameter n, which governs the relative size of the two economies.

The model assumes five types of representative agents in each economy. Households consume tradable and non-tradable goods produced by firms. There is an assumption of habit formation in consumption and an assumption that consumption of a final tradable good requires consumption of ω units of non-tradable distribution services. Households trade bonds, too, and their intertemporal choice about consumption is influenced by preference shocks. Households supply labor and set wages on a monopolistically competitive labor market. Their labor supply is influenced by labor supply shocks and their wage-setting is subject to a set of labor demand constraints and to the Calvo constraint on the frequency of wage adjustment (see Calvo, 1983). According to the Calvo constraint, in every period each household resets its wage with probability $1-\theta_W$ and keeps its wage unchanged with probability θ_W. Households also accumulate capital, which they rent to firms. Capital accumulation is subject to investment-specific technological shocks and to adjustment costs.

There are two types of firms in each economy: producers of tradable goods and producers of non-tradable goods. Both of them employ a Cobb-Douglas production function with constant returns to scale. Productivity in both sectors is influenced by productivity shocks. Firms hire labor on the labor market and sell their goods on monopolistically competitive goods markets. They set prices on the goods market subject to a set of demand constraints and to the Calvo constraint on the frequency of price adjustment (see Calvo, 1983). According to the Calvo constraint, in every period each firm resets its price with probability $1-\theta_H$ and keeps its price unchanged with probability θ_H.

The fiscal authority collects lump-sum taxes, which it uses for government expenditures and transfers to households so that the state budget is balanced each period. Government expenditures consist only of domestic non-tradable goods and are modeled as a stochastic process—a government expenditures shock. Given our assumptions about households, Ricardian equivalence holds in this model. The monetary authority follows the backward-looking Taylor rule, and deviations from this rule are explained as monetary shocks. The model is closed with an

[2] I depart from the original specification of the model in several aspects. However, these modifications are generally minor. For the reader's convenience, all of these modifications are mentioned in the *Appendix* (at the web-site of this journal) along with the description of the model.

assumption of a complete bond market and with an assumption of goods and labor markets clearing.

The behavior of the model is driven by seven structural shocks in both economies: a productivity shock in the tradable sector and the non-tradable sector, a labor supply shock, an investment efficiency shock, a consumption preference shock, a government spending shock, and a monetary policy shock. Except for the monetary policy shock, which is modeled as an IID process, all shocks are represented by an AR1 process. I allow for correlations between innovations of corresponding shocks in both economies.

3. Estimation

The model is estimated using Dynare, version 4.2.4.[3] For the estimation of the model I used quarterly data for the Czech economy and the euro area-12 economy from the 1st quarter of 2000 to the 3rd quarter of 2011. The data series were downloaded from the Eurostat web database. I used the following 14 time series (seven for each economy): real GDP, consumption, investment, the HICP, the real wage, the short-term interest rate, and the internal exchange rate (defined as prices of non-tradable goods relative to prices of tradable goods).

Except for nominal interest rates, all the observed variables are seasonally adjusted and expressed as demeaned 100*log differences. Nominal interest rates are demeaned and expressed as quarterly rates in percent.

More details about the software, the data and their seasonal adjustment, along with a visual representation of the data, can be found in the *Appendix*. In the *Appendix* I also discuss several issues related to the estimation of the model, namely, (i) the calibration of several parameters, and (ii) the choice of the priors for the estimated parameters.

Figure 1 depicts the prior and posterior distributions of the estimated parameters so the reader can get some idea about how well the parameters are identified in the data.

In the *Appendix* I also present results of several exercises focused on evaluating the quality of the model estimation, namely, (i) MCMC convergence diagnostics, which are helpful for diagnosing whether the streams of the MH algorithm converge to each other; and (ii) evaluation of smoothed shocks (innovations) as to whether they look like IID processes.

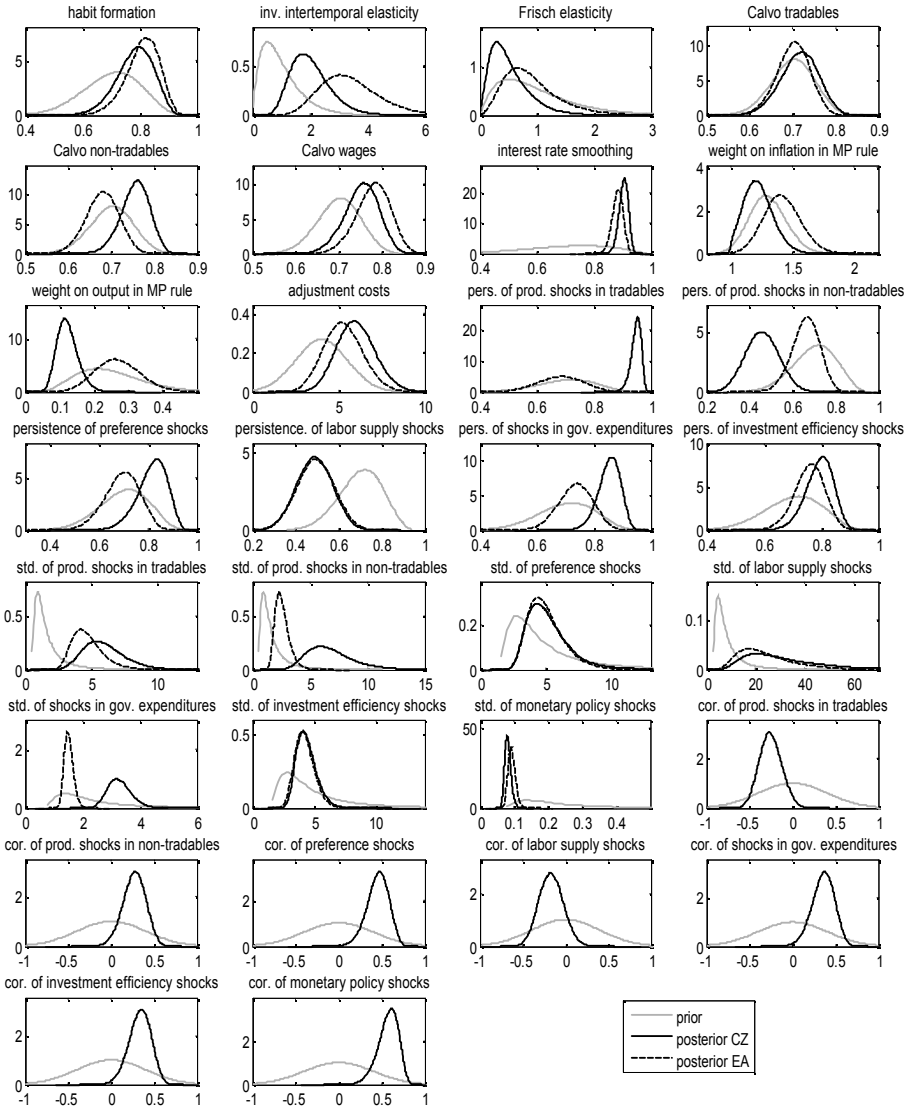
The *Appendix* also contains the results of several exercises focused on evaluating the model performance, namely, (i) a comparison of the model predictions with the actual observations; (ii) a comparison of the second moments implied by the data and the model; and (iii) a comparison of the spectrum density functions implied by the data and the model.

4. Synchronization of Business Cycles

In order to determine the driving forces of the different business cycle behavior of the two economies, we have to make a historical shock decomposition of the main macroeconomic variables in both economies.[4] Shock decomposition dis-

[3] The Dynare code of the model can be found in the *Appendix*.
[4] Shock decompositions of the observed variables can be found in the *Appendix*.

Figure 1 Priors and Posteriors



plays individual contributions of the shocks to the deviations of the examined variable from its respective steady state. Evolution of the examined variable is decomposed into the contributions of the structural shocks in every period. This tells us how structural shocks influenced the historical behavior of both economies.

If we put together contributions of a particular shock to the development of the examined variable in every period, we get the trajectory of the impact of this shock on the evolution of the examined variable. Because a linear model is used, it is also possible to sum the contributions of several shocks in every period. We can, for

example, calculate the joint effect of the domestic and foreign preference shocks on a particular variable simply by summing their contributions to the evolution of this variable.

4.1 Static Results

I restrict my analysis to the five most important variables: consumption, investment, output, inflation, and the interest rate. Using the shock decompositions, we can calculate several things about the impact of the shocks which help me evaluate how much different behavior of the economies the shocks produce. *Tables 1, 2, 3, 4,* and *5* display the results related to the behavior of consumption, investment, output, inflation, and the interest rate.

In order to describe what lies in particular columns and how to interpret the results, let us now focus on *Table 1*, which displays the results related to the behavior of consumption.[5] For example, cor_ind = 0.57, which corresponds to the row "cons. preferences" and the column "cor_ind", is the correlation between the impact of the domestic consumption preference shocks on domestic consumption and the impact of the foreign consumption preference shocks on foreign consumption. This can be regarded as a natural measure of how much different behavior of consumption is induced by the preference shocks.

However, one can argue that the domestic and foreign shocks may have a common cause, or that a shock in the foreign economy may induce the same type of shock in the domestic economy, and vice versa. Because of this I also decided to compute the correlations between the joint impacts of the domestic and foreign shocks as an alternative measure of how much different behavior is induced by the shocks. Therefore, cor_joi = 0.56, which corresponds to the row "cons. preferences" and the column "cor_joi", is the correlation between the joint impact of the domestic and foreign consumption preference shocks on domestic consumption and the joint impact of the domestic and foreign consumption preference shocks on foreign consumption.

It is also interesting to know to what extent each type of shock contributes to the behavior of the examined variable. Thus, dsdv = 52.4%, which corresponds to the row "cons. preferences" and the column "dsdv", means that the behavior of domestic consumption is from 52.4% explained by the domestic consumption preference shocks, fsdv = 1.6%, which corresponds to the row "cons. preferences" and the column "fsdv", means that the behavior of domestic consumption is from 1.6% explained by the foreign consumption preference shocks, fsfv = 60.8%, which corresponds to the row "cons. preferences" and the column "fsfv", means that the behavior of foreign consumption is from 60.8% explained by the foreign consumption preference shocks, and dsfv = 0.0%, which corresponds to the row "cons. preferences" and the column "dsfv", means that the behavior of foreign consumption is from 0.0% explained by the domestic consumption preference shocks.[6] It seems intuitive that the sum of "dsdv" and "fsdv" as well as the sum of "fsfv" and "dsfv" should be 100%.

[5] The results displayed in *Tables 2, 3, 4*, and *5* can be interpreted analogously.

[6] Note that "dsdv" is an acronym for "domestic shock, domestic variable"; "fsdv" is an acronym for "foreign shock, domestic variable"; "fsfv" is an acronym for "foreign shock, foreign variable"; and "dsfv" is an acronym for "domestic shock, foreign variable".

As it is possible to sum the effects of various structural shocks, I also calculate the results for wider sets of shocks, such as productivity shocks, preference shocks, policy shocks, and domestic shocks.[7] Note that "cor_joi" for domestic shocks represents the correlation of the overall impact of shocks and, therefore, is equal to the correlation of the corresponding observed variables.

4.2 Dynamic Results

An interesting question is whether or not there is convergence between the business cycles of the Czech economy and the euro area. Because business cycles are driven by structural shocks, the previous question can be reformulated as follows. Are the impacts of the structural shocks getting more and more symmetric between the Czech economy and the euro area? Therefore, I will examine whether the correlations between the impacts of the shocks are increasing over time.[8]

With the shock decomposition obtained from the estimation of the model on the whole data sample, I performed the same exercise described in subsection 4.1. However, I did so several times for different subsets of the periods. First, I did this exercise for the periods from the 2nd quarter of 2000 (the first observation of the whole data sample) to the 4th quarter of 2003. Then I added one more period to the end of the sample and computed the correlations again. I repeated the computation of the correlations until the last computation of the correlations on the whole data sample. Note that in this exercise I employed the estimation of the model on the whole data sample only. In the end I obtained results from 35 different subsamples, which I display compactly in *Figures 2–6*, ordered from the shortest sample to the longest. If there is convergence between the business cycles of the Czech economy and the euro area, then the displayed streams of correlations between the impacts of shocks should be rising.

In this exercise I expand the examined sample by adding an observation to the end of the sample. However, it is also possible to modify this method in several ways. For example, it is also possible to have the same sample size and examine the dynamics via a "moving window", i.e., besides adding an observation to the end of the sample also removing an observation from the beginning of the sample. It is also possible to reverse the procedure so that one starts with the sample from the 3rd quarter of 2011 (the last observation in the whole data sample) to, let's say, the 4th quarter of 2005 and then adds observations to the beginning of the sample. I decided to use the presented variant, i.e., with a fixed beginning of the sample and adding an observation to the end of the sample, because it has one advantage over the others mentioned in this paragraph, namely, that the initial conditions are always the same.

4.3 Consumption

Table 1 displays the results related to the behavior of consumption. The overall impact of shocks is rather less correlated (cor_ind = 0.39, cor_joi = 0.38), which

[7] The definition of these wider sets of shocks is self-explanatory from the notation in *Tables 1, 2, 3, 4*, and *5*.

[8] Although it is also possible to examine whether the contributions of the structural shocks (in relative terms) are getting similar between the Czech economy and the euro area, i.e., whether the values of "dsdv" and "fsfv" are converging to each other, it turned out that this does not yield any interesting or interpretable results. Therefore, I decided not to present this exercise in this paper.

Table 1 Impact of Shocks on Consumption

	shocks	cor_ind	cor_joi	dsdv	fsdv	fsfv	dsfv
1	productivity in tradables	0.10	0.28*	8.7%	2.2%	3.0%	0.3%
2	productivity in non-tradables	0.42***	0.38***	2.4%	0.6%	2.8%	0.0%
3	inv. efficiency	0.85***	0.87***	8.8%	1.5%	12.7%	0.0%
4	cons. preferences	0.57***	0.56***	52.4%	1.6%	60.8%	0.0%
5	labor supply	0.27*	0.36**	3.7%	0.6%	3.0%	0.0%
6	government exp.	0.26*	0.34**	5.0%	0.3%	2.4%	0.0%
7	monetary (IID)	0.63***	0.69***	4.1%	0.5%	7.3%	0.0%
8	initial conditions	0.27*		7.5%		7.5%	
9	productivity (1–2)	0.41***	0.46***	11.1%	2.8%	5.8%	0.4%
10	preferences (4–5)	0.58***	0.56***	56.1%	2.2%	63.8%	0.0%
11	policy (6–7)	0.71***	0.76***	9.1%	0.8%	9.7%	0.0%
12	domestic (1–8)	0.39***	0.38***	92.7%	7.3%	99.4%	0.6%

Note: */**/***– significance level 0.1/0.05/0.01

suggests that the business cycle behavior of consumption is not very synchronized between the Czech economy and the euro area.

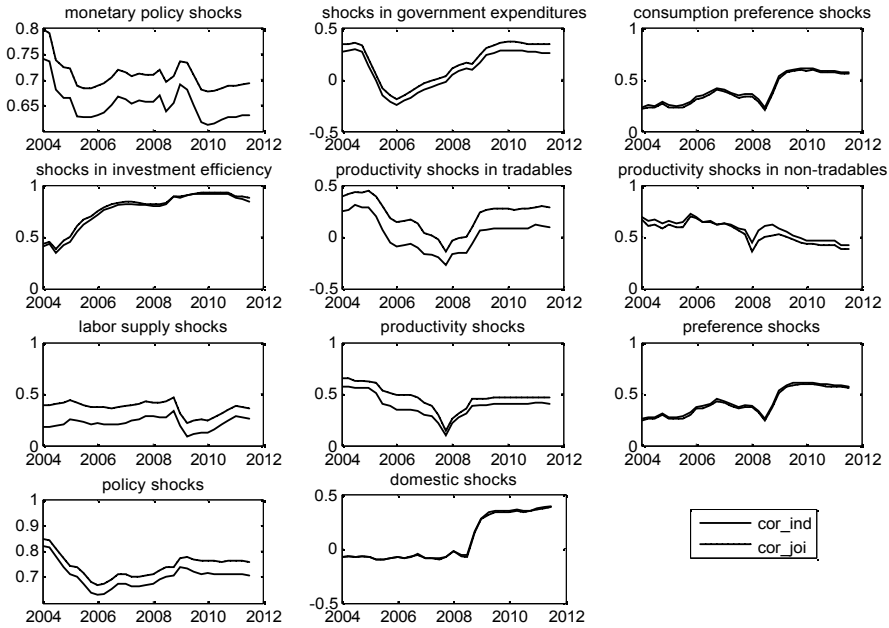
We can see that the shocks with the most correlated impact are investment efficiency shocks (cor_ind = 0.85, cor_joi = 0.87), monetary policy shocks (cor_ind = 0.63, cor_joi = 0.69), and consumption preference shocks (cor_ind = 0.57, cor_joi = 0.56). The impact of these shocks can be regarded as quite symmetric. The impact of productivity shocks in the non-tradable sector can be regarded as moderately symmetric (cor_ind = 0.42, cor_joi = 0.38). The impact of labor supply shocks (cor_ind = 0.27, cor_joi = 0.36), shocks in government expenditures (cor_ind = 0.26, cor_joi = 0.34), and productivity shocks in tradables (cor_ind = 0.10, cor_joi = 0.28) can be regarded as asymmetric.

We can also see that, not surprisingly, consumption preference shocks (dsdv = 52.4% and fsfv = 60.8%) are the most important shocks for the development of consumption. The productivity shocks are almost twice as much important for the development of domestic consumption than for the development of foreign consumption (dsdv = 11.1% and fsfv = 5.8%). This structural difference is caused by much higher importance of productivity shocks in tradables for the development of domestic consumption.

There is also an interesting result concerning policy shocks. The joint impact of policy shocks (cor_ind = 0.71, cor_joi = 0.76) is more symmetric than the individual impact of monetary policy shocks (cor_ind = 0.63, cor_joi = 0.69) and much more symmetric than the impact of shocks in government expenditures (cor_ind = 0.26, cor_joi = 0.34). This can be interpreted as follows. Although these two economies differ in the mix of monetary and fiscal policy, their joint impact on the consumption of households is quite symmetric between the Czech economy and the euro area.

Figure 2 displays how the impact of shocks on consumption changes in time. We can see a clear pattern that the overall impact of shocks on consumption is getting more and more symmetric. In the case of consumption there seems to be convergence of the business cycle between the Czech economy and the euro area. As regards the impact of individual shocks, the impact of consumption preference

Figure 2 Dynamic Impact of Shocks on Consumption



shocks and shocks in investment efficiency on consumption is getting more and more symmetric between the Czech economy and the euro area. The impact of monetary policy shocks and productivity shocks in the non-tradable sector on consumption is getting more and more asymmetric between the Czech economy and the euro area. The impact of other shocks on consumption is rather less correlated, or there is no clear pattern in the dynamics.

4.4 Investment

Table 2 displays the results related to the behavior of investment. The overall impact of shocks is highly correlated (cor_ind = cor_joi = 0.7), which suggests that the business cycle behavior of investment is quite synchronized between the Czech economy and the euro area. We can see that the initial conditions (cor_ind = 0.99) have the most correlated impact, which implies that in the case of investment the two economies were basically in the same business cycle position at the beginning of the examined period.

The consumption preference shocks (cor_ind = 0.77, cor_joi = 0.82), shocks in investment efficiency (cor_ind = cor_joi = 0.72), and monetary policy shocks (cor_ind = 0.69, cor_joi = 0.59) have a highly correlated impact on investment. The impact of productivity shocks in the non-tradable sector (cor_ind = 0.46, cor_joi = 0.49) and labor supply shocks (cor_ind = 0.42, cor_joi = 0.46) can be regarded as moderately symmetric. The impact of shocks in government expenditures (cor_ind = 0.24, cor_joi = 0.23) and productivity shocks in the tradable sector (cor_ind = –0.16, cor_joi = –0.36) can be regarded as very asymmetric.

Table 2 Impact of Shocks on Investment

	shocks	cor_ind	cor_joi	dsdv	fsdv	fsfv	dsfv
1	productivity in tradables	-0.16	-0.36**	12.2%	0.6%	1.5%	0.4%
2	productivity in non-tradables	0.46***	0.49***	4.0%	0.3%	6.5%	0.0%
3	inv. efficiency	0.72***	0.72***	45.6%	2.3%	56.1%	0.2%
4	cons. preferences	0.77***	0.82***	5.8%	0.8%	12.5%	0.0%
5	labor supply	0.42***	0.46***	7.2%	0.5%	5.2%	0.0%
6	government exp.	0.24	0.23	8.7%	0.1%	4.0%	0.0%
7	monetary (IID)	0.69***	0.59***	6.0%	1.1%	11.2%	0.0%
8	initial conditions	0.99***		4.7%		2.3%	
9	productivity (1–2)	-0.03	-0.07	16.2%	1.0%	8.0%	0.4%
10	preferences (4–5)	0.69***	0.73***	13.0%	1.3%	17.7%	0.1%
11	policy (6–7)	0.74***	0.70***	14.7%	1.2%	15.2%	0.0%
12	domestic (1–8)	0.70***	0.70***	94.2%	5.8%	99.3%	0.7%

Note: */**/***– significance level 0.1/0.05/0.01

We can also see that, not surprisingly, shocks in investment efficiency (dsdv = 45.6% and fsfv = 56.1%) are the most important shocks for development of investment. As in the case of consumption, the productivity shocks are almost twice as much important for the development of domestic investment than for the development of foreign investment (dsdv = 16.2% and fsfv = 8%). This is caused by much higher importance of productivity shocks in tradables for the development of domestic investment.

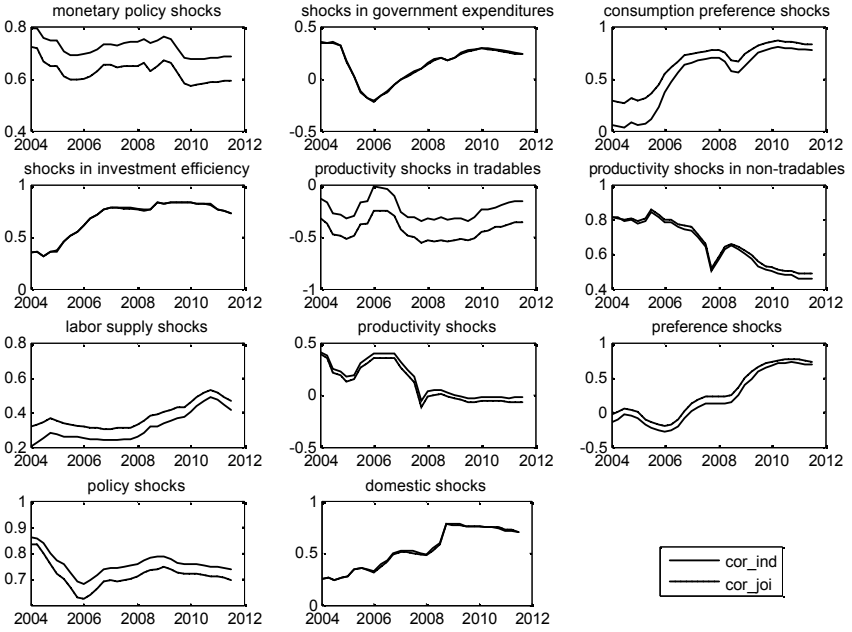
As in the case of consumption, the joint impact of policy shocks (cor_ind = 0.74, cor_joi = 0.7) is much more symmetric than the individual impact of monetary policy shocks (cor_ind = 0.69, cor_joi = 0.59) and shocks in government expenditures (cor_ind = 0.24, cor_joi = 0.23). It seems that although these two economies differ in the mix of monetary and fiscal policy, their joint impact on investment is quite symmetric between the Czech economy and the euro area.

Figure 3 displays how the impact of shocks on investment changes in time. We can see a clear pattern that the overall impact of shocks on investment is getting more and more symmetric. This can be interpreted such that in the case of investment there is business cycle convergence between the Czech economy and the euro area. As regards the impact of individual shocks, the results indicate that the impact of consumption preference shocks, shocks in investment efficiency, and labor supply shocks on investment is getting more and more symmetric between the Czech economy and the euro area. On the other hand, the impact of monetary policy shocks and productivity shocks in the non-tradable sector on investment is getting more and more asymmetric between the Czech economy and the euro area. The correlations of the impact of other shocks on investment are rather low, or there is no clear pattern in the dynamics.

4.5 Output

As regards the impact of shocks on output, the results related to the development of output are presented in *Table 3*. There are remarkable differences (between cor_ind and cor_joi) in the correlations of particular shocks. The overall correlation

Figure 3 Dynamic Impact of Shocks on Investment



of the impact of shocks is rather high (cor_ind = 0.57, cor_joi = 0.81), with the joint correlation being much higher than the individual correlation. This suggests that the business cycle behavior of output is quite synchronized between the Czech economy and the euro area.

We can see that while for some shocks, the individual correlation (i.e., cor_ind) is much lower than the joint correlation (i.e., cor_joi), see the investment efficiency shocks (cor_ind = 0.59, cor_joi = 0.93) and the consumption preference shocks (cor_ind = 0.41, cor_joi = 0.71), for some shocks the individual correlation (i.e., cor_ind) is much higher than the joint correlation (i.e., cor_joi), see the monetary policy shocks (cor_ind = 0.41, cor_joi = 0.16) and the labor supply shocks (cor_ind = 0.25, cor_joi = 0.09).

We can also see that, unlike domestic consumption and domestic investment, domestic output is heavily influenced by foreign shocks (fsdv = 28.4%). As in the previous cases, the productivity shocks are almost twice as much important for the development of domestic output than for the development of foreign output (dsdv = 16.2% and fsfv = 8%). This is caused by much higher importance of productivity shocks in tradables for the development of domestic output.

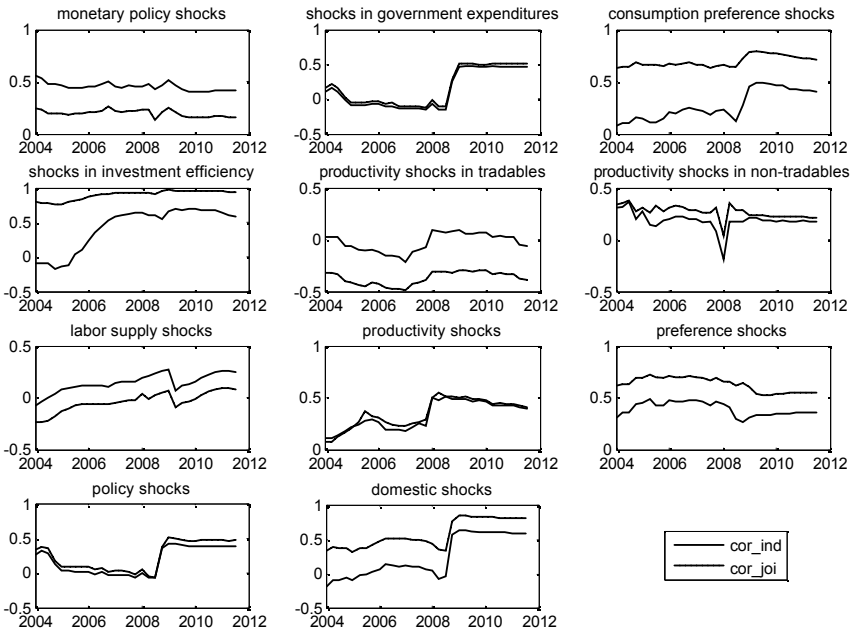
Figure 4 displays how the impact of shocks on output changes in time. We can see a clear pattern that the correlation of the overall impact of shocks on output is getting higher and higher. This can be interpreted such that in the case of output there is business cycle convergence between the Czech economy and the euro area. As regards the impact of individual shocks, the impact of consumption preference shocks, shocks in investment efficiency, and shocks in government expenditures on

Table 3 Impact of Shocks on Output

	shocks	cor_ind	cor_joi	dsdv	fsdv	fsfv	dsfv
1	productivity in tradables	-0.06	-0.39***	12.7%	5.1%	1.5%	0.4%
2	productivity in non-tradables	0.18	0.21	4.4%	4.2%	4.6%	0.2%
3	inv. efficiency	0.59***	0.93**	9.2%	8.9%	30.3%	0.4%
4	cons. preferences	0.41***	0.71***	6.4%	2.9%	14.4%	0.1%
5	labor supply	0.25*	0.09	6.2%	2.6%	4.1%	0.1%
6	government exp.	0.47***	0.51***	21.9%	1.1%	30.8%	0.0%
7	monetary (IID)	0.41***	0.16	7.3%	3.6%	9.3%	0.2%
8	initial conditions	0.04		3.5%		3.6%	
9	productivity (1–2)	0.39***	0.41***	17.1%	9.3%	6.1%	0.5%
10	preferences (4–5)	0.35**	0.54***	12.6%	5.5%	18.5%	0.2%
11	policy (6–7)	0.39***	0.47***	29.2%	4.7%	40.1%	0.3%
12	domestic (1–8)	0.57***	0.81***	71.6%	28.4%	98.5%	1.5%

Note: */**/***– significance level 0.1/0.05/0.01

Figure 4 Dynamic Impact of the Shocks on Output



output is getting more and more symmetric between the Czech economy and the euro area. As regards the impact of other shocks on output, the correlations are rather low, or there is no clear pattern in the dynamics.

4.6 Inflation

Table 4 presents results related to the development of inflation. The initial conditions (cor_ind = 0.92) have the most correlated impact, which implies that in

Table 4 Impact of Shocks on Inflation

	shocks	cor_ind	cor_joi	dsdv	fsdv	fsfv	dsfv
1	productivity in tradables	-0.12	0.08	21.5%	3.9%	20.1%	0.3%
2	productivity in non-tradables	0.44***	0.34**	19.9%	2.5%	33.0%	0.0%
3	inv. efficiency	0.81***	0.78***	11.7%	5.0%	14.8%	0.2%
4	cons. preferences	0.14	0.87***	1.1%	1.4%	2.8%	0.0%
5	labor supply	0.29**	0.26*	16.2%	1.2%	16.3%	0.0%
6	government exp.	0.24	0.64***	1.7%	0.6%	2.5%	0.0%
7	monetary (IID)	0.56***	0.35**	4.2%	1.9%	5.3%	0.0%
8	initial conditions	0.92***		7.3%		4.3%	
9	productivity (1–2)	0.79***	0.78***	41.4%	6.3%	53.2%	0.4%
10	preferences (4–5)	0.32**	0.31**	17.4%	2.6%	19.1%	0.1%
11	policy (6–7)	0.25*	0.26*	5.9%	2.5%	7.7%	0.2%
12	domestic (1–8)	0.50***	0.54***	83.6%	16.4%	99.2%	0.8%

Note: */**/***– significance level 0.1/0.05/0.01

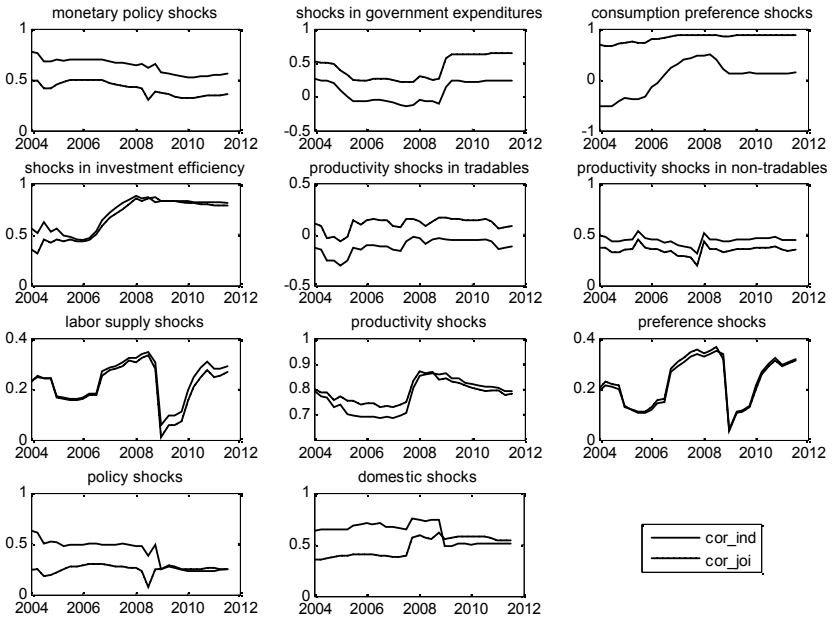
the case of inflation the two economies were basically in the same business cycle position at the beginning of the examined period. We can see that the overall impact of the shocks is moderately symmetric (cor_ind = 0.50, cor_joi = 0.54).

Although the two aggregate correlations are of the same magnitude, there are remarkable differences (between cor_ind and cor_joi) in the correlations of particular shocks. We can see that while for some shocks the individual correlation (i.e., cor_ind) is much lower than the joint correlation (i.e., cor_joi), see the consumption preference shocks (cor_ind = 0.14, cor_joi = 0.87) and the shocks in government expenditures (cor_ind = 0.24, cor_joi = 0.64), for some shocks the individual correlation (i.e., cor_ind) is much higher than the joint correlation (i.e., cor_joi), see the monetary policy shocks (cor_ind = 0.56, cor_joi = 0.35) and the productivity shocks in the non-tradable sector (cor_ind = 0.44, cor_joi = 0.34).

There is an interesting result concerning productivity shocks. Although the individual impact of productivity shocks in tradables is quite asymmetric (cor_ind = -0.12, cor_joi = 0.08) and the individual impact of productivity shocks in non-tradables is slightly symmetric (cor_ind = 0.44, cor_joi = 0.34), the joint impact of productivity shocks on inflation is highly symmetric (cor_ind = 0.79, cor_joi = 0.78). It seems that although these two economies differ in the way productivity shocks influence inflation in the tradable and non-tradable sectors, their joint impact on inflation is quite symmetric between the Czech economy and the euro area. It also seems that productivity shocks in non-tradables are much more important for the development of foreign inflation (dsdv = 19.9% and fsfv = 33%).

Figure 5 displays how the impact of shocks on inflation changes in time. In the case of inflation there is no evidence of convergence of business cycles, as the correlation of the overall impact of the shocks remains almost constant over time. As regards individual shocks, we can see that the impact of consumption preference shocks and shocks in investment efficiency on inflation is getting more and more symmetric between the Czech economy and the euro area, while the impact of monetary policy shocks on inflation is getting more and more asymmetric between

Figure 5 Dynamic Impact of Shocks on Inflation



the Czech economy and the euro area. As regards the impact of other shocks on inflation, the correlations are rather low, or there is no clear pattern in the dynamics.

4.7 Interest Rates

Table 5 shows the results related to the impact of shocks on interest rates. The overall impact of shocks on interest rates is highly symmetric (cor_ind = 0.75, cor_joi = 0.86), which implies that the business cycle behavior of interest rates is quite synchronized between the Czech economy and the euro area. The initial conditions (cor_ind = 0.89) have a highly correlated impact, which implies that in the case of interest rates the two economies were basically in the same business cycle position at the beginning of the examined period.

As regards the individual shocks, shocks in investment efficiency (cor_ind = 0.79, cor_joi = 0.92), monetary policy shocks (cor_ind = cor_joi = 0.77), consumption preference shocks (cor_ind = 0.7, cor_joi = 0.83), and labor supply shocks (cor_ind = 0.7, cor_joi = 0.73) have the most correlated impacts. Shocks in government expenditures (cor_ind = 0.09, cor_joi = 0.12) have the least correlated impact.

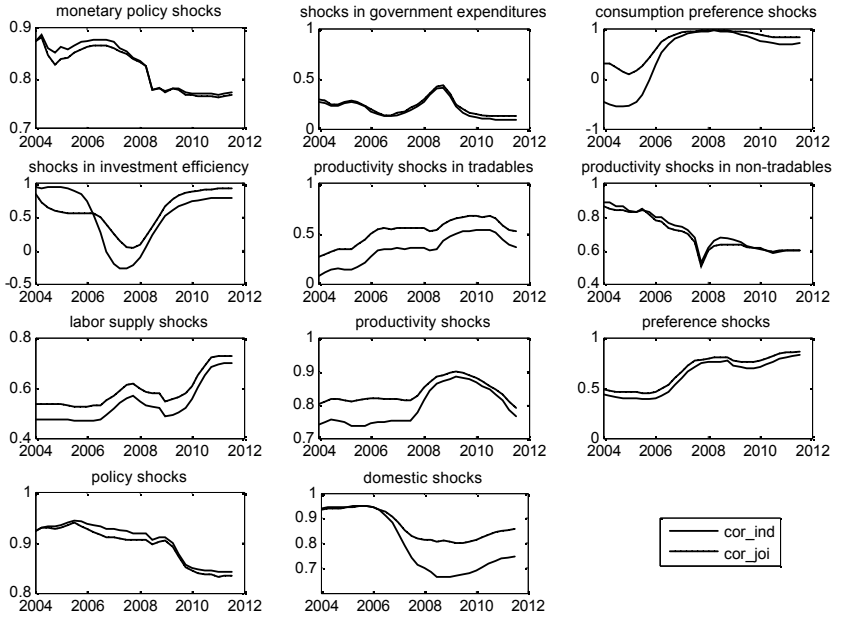
There are several interesting results. The joint impact of productivity shocks (cor_ind = 0.77, cor_joi = 0.79) is much more symmetric than the individual impact of productivity shocks in tradables (cor_ind = 0.37, cor_joi = 0.51) and productivity shocks in non-tradables (cor_ind = cor_joi = 0.6). It seems that although these two economies differ in the way productivity shocks influence inflation and output in the tradable and non-tradable sector, their joint impact on interest rates is quite symmetric between the Czech economy and the euro area.

Table 5 Impact of Shocks on Interest Rates

	shocks	cor_ind	cor_joi	dsdv	fsdv	fsfv	dsfv
1	productivity in tradables	0.37**	0.51***	17.5%	2.3%	7.4%	0.6%
2	productivity in non-tradables	0.60***	0.60***	3.4%	0.8%	8.8%	0.0%
3	inv. efficiency	0.79***	0.92***	15.3%	3.9%	16.1%	0.3%
4	cons. preferences	0.70***	0.83***	4.3%	0.9%	11.2%	0.0%
5	labor supply	0.70***	0.73***	16.3%	0.5%	11.6%	0.0%
6	government exp.	0.09	0.12	5.6%	0.2%	4.0%	0.0%
7	monetary (IID)	0.77***	0.77***	7.8%	1.0%	23.5%	0.0%
8	initial conditions	0.89***		20.3%		16.2%	
9	productivity (1–2)	0.77***	0.79***	20.9%	3.1%	16.2%	0.7%
10	preferences (4–5)	0.83***	0.86***	20.6%	1.4%	22.9%	0.2%
11	policy (6–7)	0.84***	0.84***	13.3%	1.2%	27.5%	0.1%
12	domestic (1–8)	0.75***	0.86***	90.4%	9.6%	98.7%	1.3%

Note: */**/***– significance level 0.1/0.05/0.01

Figure 6 Dynamic Impact of the Shocks on the Interest Rate



The joint impact of policy shocks (cor_ind = 0.84, cor_joi = 0.84) is more symmetric than individual impact of monetary policy shocks (cor_ind = cor_joi = 0.77) and much more symmetric than shocks in government expenditures (cor_ind = 0.09, cor_joi = 0.12). It seems that although these two economies differ in the mix of monetary and fiscal policy, their joint impact on interest rates is highly correlated between the Czech economy and the euro area.

The results also suggest that the monetary policy of the ECB is more discretionary than the monetary policy of the CNB; monetary policy shocks play much larger role in explaining the development of the main macroeconomic variables in the euro area than in the Czech economy. The development of the foreign interest rate in particular is from 23.5% explained by foreign monetary policy shocks, while the development of the domestic interest rate is only from 7.8% explained by domestic monetary policy shocks. One can also argue that such big correlations between the impacts of monetary policy shocks on interest rates (cor_ind = cor_joi = 0.77) suggest that the CNB follows the ECB in its discretionary policy, i.e., when the ECB deviates from the Taylor rule, the CNB deviates as well, and in the same direction.

Figure 6 displays how the impact of shocks on interest rates changes in time. We can see a clear pattern that the impact of consumption preference shocks, productivity shocks in the tradable sector, and labor supply shocks on interest rates is getting more and more symmetric between the Czech economy and the euro area, while the impact of monetary policy shocks and productivity shocks in the nontradable sector on interest rates is getting more and more asymmetric between the Czech economy and the euro area. As regards the impact of other shocks on interest rates, the correlations are rather low, or there is no clear pattern in the dynamics.

5. Conclusion

In this paper I examined business cycle synchronization via a fully specified DSGE model. Using a two-country DSGE model I decomposed the observed variables into the contributions of structural shocks and then computed conditional correlations. I also examined how these correlations evolve over time.

Although the results differ across all the variables under examination, some results appear to be robust across the examined variables. Productivity shocks in the tradable sector have the most asymmetric impacts, while shocks in investment efficiency have the most symmetric impacts. This suggests that productivity shocks in the tradable sector are the driving forces of different business cycle behavior, while investment efficiency shocks contribute to symmetric behavior of the two economies.

The impact of shocks is quite asymmetric in the case of consumption, moderately symmetric in the case of inflation, and highly symmetric in the case of investment, output, and interest rates. One can argue that the interest rate is the most important variable in our analysis. Synchronization of business cycles is analyzed with respect to the implementation of monetary policies. The monetary policies of the CNB and the ECB are conducted mainly by setting interest rates. The results suggest that the impact of shocks on this variable is highly correlated between the Czech economy and the euro area.

When it comes to the question of convergence of business cycles in the Czech economy and the euro area, there seems to be convergence in the case of consumption, investment, and output, as the overall impact of shocks on these variables is getting more and more symmetric over time. There seems to be no evidence for convergence in the case of inflation and interest rates. In the latter case, it can be argued that the synchronization of the business cycle behavior of interest rates is already quite high, so there is virtually no space for further convergence.

As regards the impact of individual shocks in general, the impact of consumption preference shocks and shocks in investment efficiency is getting more and more symmetric between the Czech economy and the euro area. The impact of monetary policy shocks and productivity shocks in the non-tradable sector, on the other hand, is getting more and more asymmetric between the Czech economy and the euro area.

It is also worth mentioning some remarkable structural differences between the Czech economy and the euro area concerning the impact of shocks. These differences are robust in the sense that they appear to be systematically present for all the examined variables. It seems that productivity shocks in the tradable sector are much more important for the development of the domestic variables than for the development of the foreign variables, yet productivity shocks in the non-tradable sector are more important for the development of the foreign variables than for the development of the domestic variables. It also seems that the variables in the euro area are relatively more influenced by shocks in investment efficiency than the variables in the Czech economy.

The results also suggest that the monetary policy of the ECB is more discretionary than the monetary policy of the CNB; monetary policy shocks play a much larger role in explaining the development of the main macroeconomic variables in the euro area than in the Czech economy. One can also argue that such big correlations between the impacts of monetary policy shocks on interest rates suggest that the CNB follows the ECB in its discretionary policy, i.e., when the ECB deviates from the Taylor rule, the CNB deviates as well, and in the same direction.

REFERENCES

Alesina A, Barro RJ (2002): Currency Unions. *Quarterly Journal of Economics*, 117(2):409–436.

Calvo G (1983): Staggered Prices in a Utility-maximizing Framework. *Journal of Monetary Economics*, 12(3):383–398.

Chari VV, Kehoe PJ, McGrattan ER (2007): Business Cycle Accounting. *Econometrica*, 75(3): 781–836.

Haan J de, Inklaar R, Jong-A-Pin R (2008): Will Business Cycles in the Euro Area Converge? A Critical Survey of Empirical Research. *Journal of Economic Surveys*, 22(2):234–273.

Fidrmuc J, Korhonen I (2006): Meta-analysis of the business cycle correlation between the euro area and the CEECs. *Journal of Comparative Economics*, 34(3):518–537.

Hurník J, Tůma Z, Vávra D (2010): The Euro Adoption Debate Revisited: The Czech Case. *Finance a úvěr-Czech Journal of Economics and Finance*, 60(3):194–212.

Kolasa M (2009): Structural Heterogeneity or Asymmetric Shocks? Poland and the Euro Area through the Lens of a Two-country DSGE Model. *Economic Modelling*, 26(6):1245–1269.

Kolasa M (2012): *Business cycles in EU new member states: How and why are they different?* Available at: http://www.macromodels.uni.lodz.pl/abstracts/634886825523125000544.pdf.

Mundell RA (1961): A Theory of Optimum Currency Areas. *American Economic Review*, 51(4): 657–665.

Slanicay M (2011): Impact of Asymmetric Shocks and Structural Differences between the Czech Economy and Euro Area 12. In: Dlouhý M, Skočdopolová V (eds): *Proceedings of the 29th International Conference Mathematical Methods in Economics 2011*. University of Economics, Prague, 635–640.