Financial accelerator mechanism in a small open economy: DSGE model of the Czech economy

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Abstract. Our research is motivated by current experience of worldwide economic difficulties that suggests that it could be the banking sector that can to a certain extent cause and exacerbate economic recessions. In this paper we focus on the effects of financial accelerator mechanism in the Czech economy in recent period of unstable financial sector and the debt crisis in the EU. In order to be able to assess the importance of the financial frictions in this particular economy, a DSGE model of a small open economy is estimated. Model framework containing financial accelerator mechanism proposed by Bernanke, Gertler and Gilchrist (1999) is used for the analysis. The original model specification is slightly altered by adding a shock in entrepreneurial net-worth. Also, we decided to model the foreign sector as a VAR block, which enables us to impose more structure on foreign variables than independent AR processes. Quarterly data from period 1999 to 2011 are used for the estimation. Model parameters are estimated with the use of Bayesian techniques. A method of shock decomposition is used to analyze historical development of endogenous variables and to evaluate particular effects of individual exogenous shocks.

Keywords: DSGE model, financial frictions, financial accelerator, Bayesian methods, variance decomposition, shock decomposition.

JEL classification: E44, E32
AMS classification: 91B64

1 Introduction

In the aftermath of the global financial crisis of 2007–2009 that provoked subsequent global economic slowdown and recently in some European countries even a debt crisis, the economists around the world realize that there exist important relations between the financial sector and the real economy. In fact, current experience of worldwide economic difficulties shows that the macro-financial linkages can to a certain extent influence the aggregate fluctuations.

Thanks to high capitalization, liquidity and rentability of the Czech banking system, the Czech economy was exposed to the subprime crises only marginally. Nevertheless, the global economic economic crisis hit the Czech economy in the last quarter of 2008. The development of the domestic economy during the global crisis was influenced predominantly by the downturn of foreign demand.

Despite the fact that the impacts of the crisis on the domestic financial sector were relatively mild, the interest rate spreads increased substantially. During the period of economic boom of 2006–2008 the interest rate spreads declined slightly. With the outburst of the global economic crisis the difference between the commercial interest rates and the policy interest rate increased sharply, which significantly reduced the efficiency of monetary policy in this period. The central bank started lowering the policy interest rate in 2009. However, much of its effects were countered by the growing spread.

Apparently, there can be times when the development of the policy interest rate differ significantly from the development of commercial interest rates that the households and firms in the economy actually face. The idea of a frictionless banking sector seems, therefore, no longer tenable. Several financial

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frictions mechanisms were considered in academia as well as in the central banks in past years that would enhance current workhorse DSGE macroeconomic models with mechanisms that could explain what we observe. In our paper we use the model framework developed by Shaari [6] that includes financial accelerator mechanism proposed by Bernanke *et al.* [2]. We introduce a net worth shock into the original model and redefine the foreign sector as a VAR(1) block. This appropriately complex medium-sized model of a small open economy incorporates important real as well as nominal rigidities and allows us to describe the Czech economy in a reasonable detail. Using the estimated DSGE model, we employ a method of shock decomposition in this paper to analyse historical development of real output and to evaluate particular effects of individual exogenous shocks with special attention given to the shocks in the entrepreneurial net worth.

2 The model

The model framework follows Shaari [6]. Overall structure of the model is based on Galí and Monacelli [4] and it is modified to incorporate the financial accelerator mechanism in line with Bernanke *et al.* [2].

The model contains households, entrepreneurs, retailers, central bank and foreign sector. The households receive wages for supplied labour, government transfers, profits made by retailers and domestic and foreign bonds returns. Domestic bonds pay fixed nominal return in domestic currency while foreign non-contingent bonds give a risk adjusted nominal return denominated in foreign currency. The definition of debt-elastic risk premium follows Adolfson *et al.* [1] and it contains exogenous AR(1) component of risk-premium or uncovered interest parity shock (A_t^{UIP}). The households then spend their earnings on consumption and domestic and foreign bonds acquisition.

The entrepreneurs play two important roles in the model. They run wholesale goods producing firms and they produce and own the capital. Market of intermediate goods as well as capital goods market is assumed to be competitive. The wholesale goods production is affected by domestic productivity AR(1) shock (A_t^Y) and the capital goods production is subject to capital adjustment costs. Entrepreneurs finance the production and ownership of capital by their net-worth N_t and borrowed funds F_t. The cost of borrowed funds is influenced by borrower's leverage ratio via external finance premium,

$$EFP_t = \left(\frac{N_t}{Q_{t-1}K_t}\right)^{-\chi}, \tag{1}$$

where Q_t is real price of capital or Tobin's Q and χ is financial accelerator parameter. To maximize profit the entrepreneurs choose the level of capital K_{t+1} and the level of borrowed funds F_{t+1} in accordance with following optimality condition,

$$E_t(R_{K,t+1}) = E_t\left[\left(\frac{N_{t+1}}{Q_t K_{t+1}}\right)^{-\chi} R_t \frac{P_t}{P_{t+1}}\right], \tag{2}$$

where $R_{K,t+1}$ is marginal return from capital investment, R_t is nominal interest rate, P_t is price level and E_t is expectations operator. The entrepreneurial equity develops according to

$$V_t = \left[R_{K,t}Q_{t-1}K_t - \left(\frac{N_t}{Q_{t-1}K_t}\right)^{-\chi} R_{t-1}\frac{P_{t-1}}{P_t}F_t\right]. \tag{3}$$

Each turn a proportion $(1 - A_t^{NW}\varsigma)$ of entrepreneurs leaves the market and their equity $(1 - A_t^{NW}\varsigma)V_t$ is transfered to households in a form of transfers. A_t^{NW} is a shock in entrepreneurial net worth. It influences the development of net worth by changing the effective survival rate of entrepreneurs. Its logarithmic deviation from steady state is assumed to evolve according to AR(1) process. Entrepreneurs also receive wage $W_{E,t}$ for the labour they supply to the production of domestic intermediate goods. Entrepreneurial net-worth is then given by

$$N_{t+1} = \varsigma A_t^{NW} V_t + W_{E,t}. \tag{4}$$

Next, there are two types of retailers in the model. Home goods retailers and foreign goods retailers. Both types of retailers are assumed to operate in conditions of monopolistic competition. Home good

retailers buy domestic intermediate goods at wholesale price and sell the final home goods to the consumers. Foreign good retailers buy goods from foreign producers at the wholesale price and resell the the foreign goods to the domestic consumers. The difference between foreign wholesale price expressed in domestic currency and final foreign goods price, i.e. deviation from law of one price is determined by exogenous AR(1) shock (A_t^{LOP}). By Calvo-type price setting and inflation indexation of the retailers the nominal rigidities are introduced into the model.

The central bank determines the nominal interest rate in accordance with forward-looking Taylor type interest rate rule. Deviations of interest rate from the interest rate rule are explained as monetary policy iid shocks (ε_t^{MP}).

Following Christiano *et al.* [3], the foreign economy variables - real output, CPI inflation and nominal interest rate, are modelled using a VAR(1) model of this form,

$$\begin{pmatrix} y_t^* \\ \pi_t^* \\ r_t^* \end{pmatrix} = \begin{pmatrix} \rho_{y^*y^*} & \rho_{y^*\pi^*} & \rho_{y^*r^*} \\ \rho_{\pi^*y^*} & \rho_{\pi^*\pi^*} & \rho_{\pi^*r^*} \\ \rho_{r^*y^*} & \rho_{r^*\pi^*} & \rho_{r^*r^*} \end{pmatrix} \begin{pmatrix} y_{t-1}^* \\ \pi_{t-1}^* \\ r_{t-1}^* \end{pmatrix} + \begin{pmatrix} 1 & 0 & 0 \\ \sigma_{\pi^*y^*} & 1 & 0 \\ \sigma_{r^*y^*} & \sigma_{r^*\pi^*} & 1 \end{pmatrix} \begin{pmatrix} \varepsilon_t^{y^*} \\ \varepsilon_t^{\pi^*} \\ \varepsilon_t^{r^*} \end{pmatrix}, \tag{5}$$

where $\varepsilon_t^{y^*} \sim iid(0, \sigma_{y^*}^2)$, $\varepsilon_t^{\pi^*} \sim iid(0, \sigma_{\pi^*}^2)$ and $\varepsilon_t^{r^*} \sim iid(0, \sigma_{r^*}^2)$. Autocorrelation coefficients satisfy $\rho_{y^*y^*}, \rho_{\pi^*\pi^*}, \rho_{r^*r^*} \in \langle 0, 1 \rangle$. Remaining coefficients are not constrained. Compared to foreign variables modelled as independent AR(1) processes this approach should capture the relations between foreign variables more closely.

3 Estimation

The model parameters were estimated using Random Walk Metropolis-Hastings algorithm as implemented in Dynare toolbox for Matlab. Two parallel chains of 1.000.000 draws each were generated during the estimation. First 75 % of draws were discarded as burn-in sample. The scale parameter was set to achieve the acceptance rates around 30 %.

3.1 Data

Quarterly time series of eight observables were used for the purposes of estimation. These time series cover the period between the first quarter of 1999 and the fourth quarter of 2011 and contain 52 observations each.

For the domestic economy, time series of real aggregate product, consumer price index (CPI), 3-month PRIBOR and Prague stock exchange (PSE) PX index are used. These seasonally adjusted time series were obtained from the database of Czech Statistical Office and PSE.

The foreign economy is represented by eleven founding countries of the Euro area plus Greece that joined the monetary union in 2001. For these twelve economies, the seasonally adjusted time series of real aggregate product, CPI index and 3-month EURIBOR are used. Also, time series of CZK/EUR real exchange rate is used. These data were obtained from the Eurostat database.

The time series of PX index is used as a proxy for the entrepreneurial net worth. Changes in the value of the companies traded on the PSE are expressed in a condensed form in the PX index. We assume that all the companies in the economy are affected by the same events as the companies traded on the PSE and that they are affected in a similar way. Therefore, we come to a conclusion that the development of the PX index should to a reasonable extent capture also the changes in the aggregate value of all the companies in the economy and therefore also the aggregate entrepreneurial net worth.

The original time series were transformed prior to estimation so as to express the logarithmic deviations from steady state. Log values of the CPI indices were taken and their first differences were calculated. Obtained time series were demeaned and identified as the logarithmic deviations of the domestic and foreign CPI inflation from steady state. The logarithmic deviations of remaining observables from their steady state were calculated with the use of Hodrick-Prescott filter (HP filter). Since we are working with quarterly time series in this paper, HP filter with parameter $\lambda = 1600$ was used to find the approximation of their steady state.

3.2 Priors and posteriors

The DSGE model was successfully estimated on historical data of the Czech economy in the period 1999–2011. Prior and posterior distributions of the structural parameters are described in table 1. Obtained estimates are similar to the results reported in the literature.

The parameter of the financial accelerator is estimated at a value of 0.0379, which is a slightly higher value that the estimate of 0.0269 reported by Tonner and Vašíček [7]. The parameter Γ is estimated at the value of 1.8407, which is below the prior mean of 2. Our result is quite close to Bernanke *et al.* [2] who suggest calibration of this parameter to 2. The entrepreneurs' survival rate ς is estimated somewhat below the prior mean at the value of 0.9332, which implies average entrepreneurs' business lifespan of nearly 4 years. Tonner and Vašíček [7] calibrate this parameter to the value of 0.9728, which would imply the business lifespan of almost 10 years.

Interest rate smoothing parameter of the Taylor rule is estimated at the value of 0.6379. Similar value of 0.6647 is reported by Tonner and Vašíček [7]. The posterior mean of parameter β_π suggests a value of inflation weight in the Taylor rule of 1.7260. This result is in accordance with Ryšánek *et al.* [5] who found a value of 1.68. The weight of output gap in the Taylor rule Θ_y is estimated at 0.5772, which is close to the result of 0.5288 reported by Tonner and Vašíček [7].

			Prior		Posterior		
Parameter		**Distribution**	**Mean**	**Std**	**Mean**	**95% HPDI**	
Υ	habit persistence	Beta	0.60	0.05	0.5991	0.5112	0.6833
Ψ	inverse elast. of labour supply	Gamma	2.00	0.50	1.7852	1.0604	2.4561
ψ^B	elast. of debt-elastic risk prem.	Gamma	0.05	0.02	0.0393	0.0182	0.0612
η	home/foreign goods elast. subst.	Gamma	0.50	0.10	0.4885	0.3825	0.5956
κ	price indexation	Beta	0.50	0.10	0.2881	0.1705	0.4053
γ	preference bias to foreign goods	Beta	0.65	0.10	0.5236	0.4260	0.6199
θ_H	home goods Calvo parameter	Beta	0.75	0.10	0.7494	0.6913	0.8108
θ_F	foreign goods Calvo paremeter	Beta	0.75	0.10	0.7913	0.7341	0.8498
ψ^I	capital adjustment costs	Gamma	20.0	5.00	26.085	17.059	34.369
Financial frictions							
Γ	s-s. capital/net worth ratio	Gamma*	2.00	0.50	1.8407	1.3360	2.3197
ς	entrepreneurs' survival rate	Beta	0.973	0.015	0.9332	0.8988	0.9684
χ	financial accelerator	Gamma	0.05	0.02	0.0379	0.0133	0.0621
Taylor rule							
ρ	interest rate smoothing	Beta	0.70	0.10	0.6379	0.5643	0.7169
β_π	inflation weight	Gamma*	1.50	0.2	1.7260	1.3713	2.0669
Θ_y	output gap weight	Gamma	0.50	0.2	0.5772	0.3799	0.7775

*Shifted gamma distribution is used for these parameters, because they are assumed to take values from interval $\langle 1, \infty)$.

Table 1 Estimated structural parameters

3.3 Variance decomposition

The table 2 contains asymptotic variance decomposition of model variables. The variance of the model variables is decomposed into the contributions of exogenous shocks based on a simulation with infinite horizon.

Obviously, the net worth shock is a one of the driving forces of this model in the long run. More than half of the variance of real output, consumption, nominal interest rate and inflation is explained by this shock. Nearly 75 % of the variance of the real return to capital investment and over 85 % of the real investment, real price of capital and capital stock is explained by the net worth shock. The variance of entrepreneurial net worth and external finance premium is explained predominantly by this shock.

In general, we can say that the shocks in entrepreneurial net worth, domestic productivity, law of one price gap and foreign output explain predominant part of the variance of the model variables. The remaining shocks play only marginal role in the long run.

Variable		NW	Y	MP	UIP	LOP	r^*	π^*	y^*
y	real output	59.86	1.93	8.14	9.47	12.84	3.10	0.93	3.73
c	real consumption	59.34	1.66	1.56	6.79	20.52	0.47	0.77	8.89
inv	real investment	86.93	2.92	1.01	1.67	5.71	0.02	0.07	1.67
k	capital stock	87.29	2.98	0.40	0.26	7.29	0.00	0.04	1.73
r	nominal interest rate	63.50	2.63	1.52	11.27	13.60	0.53	0.36	6.59
rer	real exchange rate	26.17	0.76	1.45	4.31	64.08	0.84	0.33	2.05
π	CPI inflation	60.11	19.39	2.83	5.43	8.97	0.70	0.11	2.46
z	net foreign assets position	6.48	0.15	1.47	5.29	53.99	0.38	2.14	30.10
l_H	households' labour supply	1.82	83.52	3.35	4.19	3.89	1.35	0.41	1.47
w_H	households' wages	6.75	74.12	3.79	1.50	9.82	0.86	0.52	2.64
w_E	entrepreneurs' wages	2.33	81.20	3.73	2.10	7.21	1.05	0.47	1.92
r_G	gross rental rate of capital	17.36	69.27	3.23	1.81	5.48	0.89	0.39	1.56
r_K	gross return on capital invest.	72.16	16.44	7.72	1.28	1.81	0.05	0.12	0.43
q	real price of capital	86.83	2.90	1.16	2.03	5.31	0.03	0.08	1.66
mc	marginal costs	0.07	74.56	3.64	3.05	16.57	1.26	0.41	0.45
n	entrepreneurial net worth	95.17	3.35	0.65	0.09	0.54	0.03	0.01	0.16
efp	external finance premium	95.55	3.41	0.65	0.12	0.14	0.05	0.01	0.07
r^*	foreign interest rate	0.00	0.00	0.00	0.00	0.00	14.67	5.31	80.01
π^*	foreign CPI inflation	0.00	0.00	0.00	0.00	0.00	0.16	79.22	20.63
y^*	foreign output	0.00	0.00	0.00	0.00	0.00	0.58	4.70	94.72

Table 2 Variance decomposition (in percent)

3.4 Shock decomposition

In the following section, we discuss the shock decomposition of the real output gap, that is depicted in figure 1 and is expressed in percent of the potential output. The instrument of shock decomposition allows us to see the effects of particular exogenous shocks on this smoothed variable in time.

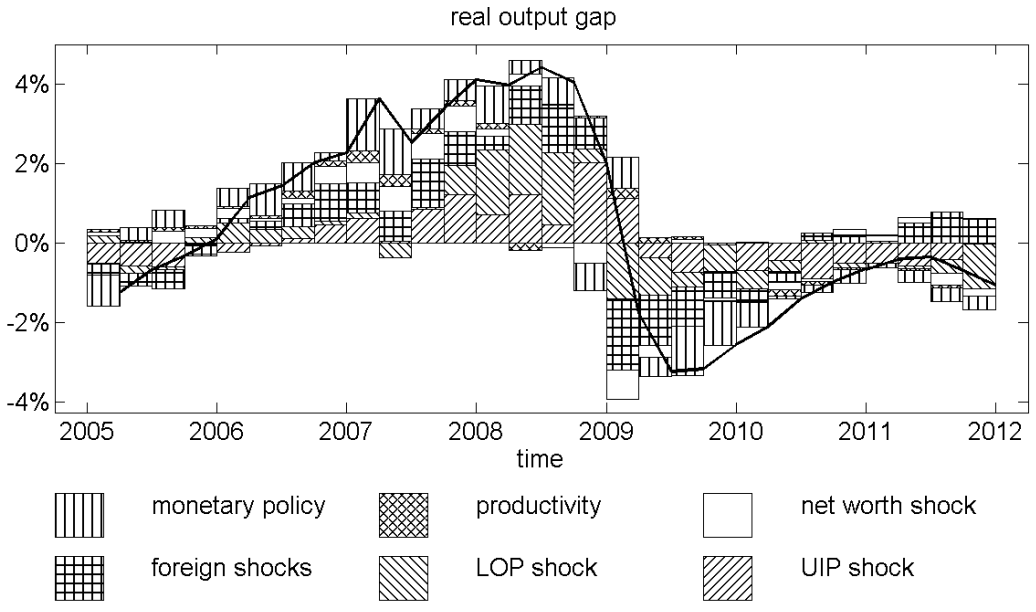

Figure 1 Shock decomposition of real output gap

According to the model, the foreign output shock played important role in the economic upswing of 2006–2008. Growing foreign output in this period boosted the foreign demand and net exports. Positive shock in the entrepreneurial net worth played its role as well, especially in 2007. Rather low nominal interest rate in this period also supported the economic growth. In the second half of 2007, the debt-elastic risk premium shock and the shock in the law of one price gap further stimulated the growth of real output.

In the last quarter of 2008, the foreign demand started to subside. Together with the exogenous decline in entrepreneurial net worth and relatively high nominal interest rate this caused a swift decline of the real output in this period. In the beginning of 2009, the shock in the law of one price gap caused a quick depreciation of the real exchange rate and further accelerated the decline of the real output. Low foreign demand affected the domestic real output mainly in the 2009 and in the beginning of 2010. The exogenous reduction of the entrepreneurial net worth took the biggest effect in the beginning of 2009, when it contributed around 0.75 percentage points to the negative real output gap. During 2010, the negative effects of the majority of exogenous shocks diminished and the real output returned to the neighbourhood of its potential.

4 Conclusion

It was a goal of this paper to evaluate the importance of financial frictions in the Czech economy during the period of global financial and economic crisis. A DSGE model framework proposed by Shaari [6] was chosen for this purpose. This model of a small open economy contains the financial accelerator mechanism introduced by Bernanke *et al.* [2] and it also includes important real and nominal rigidities. Original model was slightly modified by introducing exogenous shock in the entrepreneurial net worth into the model. Furthermore, the foreign sector was redefined as a VAR(1) block.

According to the variance decomposition, the shock in entrepreneurial net worth is one of the driving forces of the model economy. Together with the shock in domestic productivity, law of one price gap and the foreign output, it explains predominant part of the variance in the long run. The shock decomposition of the real output showed considerable effects of the shock in the net worth during the period of economic boom of 2006–2008 and also in the early phase of the economic crisis. Even though the development of the Czech economy in the period 2006–2010 was mainly affected by the situation abroad and especially by the development of foreign demand, the results of this model suggest relatively significant effects of the financial frictions as well.

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