Proceedings of 30th International Conference Mathematical Methods in Economics

The macro-financial linkages modelling for the Czech economy

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Abstract. The contribution presents and analyze the model with financial frictions. It is tailor-made for the Czech economy, and thus contains several features for capturing Czech stylized facts (a cascade of nominal rigidities, high openness, real exchange rate appreciation in consumer prices etc.). Linkages between real and financial sectors are incorporated via the state non-contingent debt-contracts within the financial accelerator. Also, the model contains shocks which hit financial variables and propagate through the model into real sectors. The empirical analysis is presented via results of the Bayesian estimation.

Keywords: financial frictions, DSGE models, Bayesian methods

JEL classification: C53, E32, E37
AMS classification: 90C15

1 Introduction

The mid2008-2009 global economy crisis has triggered enormous interest in understanding the interactions between real and financial markets. Many authors use or extend one of canonical workhorse models with financial frictions to analyze how a presence of credit market imperfections can affect the real economic economy. E.g. a significant role of financial frictions in an economy can amplify responses of real variables to various shocks. Also during financial turbulence, shocks that initially hit financial variables can significantly propagate into real sectors and affect a position of an economy in business cycles.

In our contribution, we present a model with financial frictions and analyze it on Czech data. The model incorporates several features that are important for capturing Czech stylized facts along the balanced growth path. The most important are the real exchange rate appreciation in consumer prices, high openness, or gradual exchange rate pass-through modeled via a cascade of nominal rigidities and local currency pricing ([2]). Such framework is sufficiently rich to capture Czech data and its structural parameters are *structural* ([8]). The balance sheet channel is incorporated into the model through the financial accelerator mechanism. The debt-contracts between entrepreneurs and the financial intermediary follow the state non-contingent assumption ([3],[4]). The model also contains 'non-standard' shocks which should capture disturbances coming from the financial sector. Empirical analysis is carried out via analyzing some results from the Bayesian estimation. First, we discuss the choice of observables for the estimation. Then, we present Bayesian impulse responses to two shocks of the financial sector - a capital price bubble shock and higher riskiness of the entrepreneurial sector ('sigma' shock), and show estimation of both shocks.

2 Model description

This section presents the structure of the model. Since the model has relatively rich structure, we present only the financial part of the framework in greater detail. The model is developed for the inflation targeting regime with the conventional monetary policy. It has a balanced growth path where

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all variables are either constant or growth at some growth rate. To be consistent with Czech stylized facts, it incorporates the following frictions: habit formation in consumption, investment adjustment costs, gradual exchange rate pass-through which is modeled via a cascade of nominal rigidities ([2]) and the local currency pricing. The balance sheet channel is incorporated into the model through the financial accelerator mechanism. The debt-contracts between entrepreneurs and the financial intermediary follow the state non-contingent assumption ([3],[4]). The design of the model is shown in figure 1.

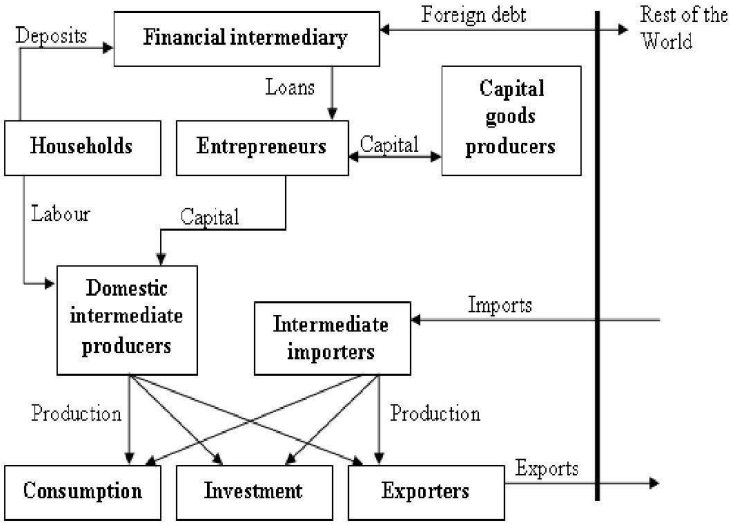

Figure 1: Model structure

Risk-averse households consume all varieties of consumption goods, choose the volume of deposits at the financial intermediary, supply a differentiated labour to domestic intermediate firms and set their nominal wages subject to the downward-sloping demand curve and quadratic adjustment costs. Also, households own all firms in the model. For the model to be tractable, households (and entrepreneurs) cannot store capital in time. Thus, the model contains perfectly competitive capital goods producers who own capital goods and sell it to entrepreneurs in each period. Investment decisions are made by households.

Entrepreneurs purchase physical capital ($P_t^K K_t$) from capital goods producers combining internal (net worth E_t) and external (bank lending L_t) funds

$$L_t = P_t^K K_t - E_t. \tag{1}$$

They have to use both sources of funding in each time as their net worth is not sufficient and cannot be sufficiently accumulated. Entrepreneurs rent the purchased capital to domestic intermediate firms for production purposes. Return to capital of each entrepreneur is affected by the idiosyncratic productivity ω whose value divides entrepreneurs into defaulting (insufficient return) and surviving. Thus, there is a cuttoff value

$$\omega^* \equiv \frac{R_{t+1}^L L_t}{R_{t+1}^K P_t^K K_t}. \tag{2}$$

where R_{t+1}^L is the lending rate and R_{t+1}^K is the return to capital.

Debt contracts between entrepreneurs and the financial intermediary is captured by the costly state verification ([9]) which determines the optimal behaviour between entrepreneurs who maximize expected profits and the financial intermediary who receives opportunity costs in expectation. This optimization problem incorporates the assumption of state non-contingent contracts ([3],[4]) under which the lending rate is fixed ex ante and cannot be changed after the aggregate return to capital is observed. Thus, the financial intermediary also bears risk of the contracts and makes profits or looses.[1] Under state non-contingent contracts, the maximization problem of entrepreneurs is subjected to a single constraint of the financial intermediary

$$\max_{K_t,\omega^*} \quad R_{t+1}^K P_t^K K_t[1-\Gamma(\omega^*)] + \lambda_t^C[R_{t+1}^K P_t^K K_t[\Gamma(\omega^*) - \mu G(\omega^*)] - R_t(P_t^K K_t - E_t)]$$

[1]The model does not contain capital of the financial intermediary.

where λ_t^C is the lagrange multiplier and μ are monitoring costs. The expected gross share of profits going to the financial intermediary is

$$\Gamma(\omega^*) \equiv \int_0^{\omega^*} \omega f(\omega) d\omega + \omega^* \int_{\omega^*}^{\infty} f(\omega) d\omega.$$

The net share of profits going to the financial intermediary is

$$\Gamma(\omega^*) - \mu G(\omega^*),$$

where the expected monitoring costs are

$$\mu G(\omega^*) \equiv \mu \int_0^{\omega^*} \omega f(\omega) d\omega.$$

The production structure of the economy contains domestic and import intermediate goods producing firms and three (consumption, investment, export) final goods producing firms. All sectors are monopolistically competitive. Such a cascade of nominal rigidities creates desirable interactions among production sectors and delivers multiple stages of exchange rate pass-through [2]. The domestic intermediate goods producers combine labour and capital via the Cobb-Douglas technology. The intermediate importers differentiate costlessly a single foreign good. The packed intermediate goods are purchased by final goods producing firms who utilize them as inputs for final production of consumption, investment and export goods. Following [2], the model incorporates the export-specific and openness technologies. The former captures the Harrod-Balassa-Samuelson effect which implies the real exchange rate appreciation in consumer prices in the steady-state. The latter captures an increase of the trade openness (trend in the nominal trade share in output).

Besides 'standard shocks', two shocks are incorporated into the model to deal with financial frictions issues. First, higher riskiness of the entrepreneurs is implemented by the stationary process for the standard deviation of the idiosyncratic productivity ω distribution

$$\sigma_t = \rho_\sigma \sigma_{t-1} + (1 - \rho_\sigma)\sigma + \varepsilon_t^\sigma.$$

Second, the model contains irrational capital price bubbles A_t^B modeled as exogenous deviations from the arbitrage condition ([5],[3])

$$P_t^{K_{obs}} = P_t^K \exp(A_t^B),$$

where $A_t^B = \rho_{A^B} A_{t-1}^B + \varepsilon_t^{A^B}$.

3 Empirical Analysis

3.1 Data

There are 16 time series which are used as observables for the empirical analysis. 3M PRIBOR and 3M EURIBOR are used for domestic and foreign interest rates. CZK/EUR is used as the observable for the exchange rate. Consumption, investment, exports, imports and price deflators for investment, export and import come from the Czech statistical office (CZSO). As the model does not contain government sector, the observable for private consumption contains consumption of households, expenditures of non-profit institutions serving households and also government consumption. Gross capital formation (GCF) is used as the observable for investment expenditures. It is a sum of gross fixed capital formation and a change of inventories. Within Czech national accounts data, GCF consists of private as well as government investment expenditures. To simplify the model, it is assumed that the consumption deflator level equals the headline CPI inflation level at each time. Thus, the headline CPI (CZSO) is used as the observable for both time series. The (seasonally adjusted) average nominal wage in the business sector is used as the observable for nominal wages. The effective euro area PPI (Consensus Forecast) is used as the observable for foreign inflation. Similarly, the effective euro area GDP (Consensus Forecast) is used for the calculation of the foreign demand observable.[2]

[2]The weights used in the calculation of the effective variables are the shares of the individual euro area economies in the foreign trade turnover of the Czech Republic [7].

To describe the behaviour of the financial sector, we choose the volume of loans and the lending rate as observables as the methodology of these time series is clear. In the ARAD database, these data are available from January 2004. Except for the short length, these data are relatively volatile and contain methodical changes. In our contribution, we assume that the most important firms in the economy can probably get loans even during the crisis and that these loans are big enough to influence the profile of the time series. Moreover, as banks restrict lending during the crises, loans to most important corporations are significant for them not only because of "a relatively safe return", but banks also try to keep those firms as their clients for future lending. Thus, we choose time series of loans up to 30 mil. and the corresponding lending rate as observables to link the financial accelerator with data. In 2010Q1, there is a methodical change in data of loans as revolving loans were taken away. Thus, the profile is adjusted by the expert judgment as otherwise there would be a problem with a model-consistent filtration.

3.2 Bayesian Estimation

The Bayesian estimation of the model parameters is carried out via the Dynare Toolbox [1]. The model has 44 structural parameters from which 33 is estimated. The rest of parameters is calibrated with respect to several reasons, e.g. estimation difficulties (discount factor), definition of the steady-state in the model (production shares in each final-goods producing sector), model behaviour (debt-elastic premium parameter) or micro data.

Table 1 shows model parameters associated with financial friction. The steady-state parameter of the capital to equity ratio $\frac{P^K K}{E}$ is calibrated with respect to Czech micro data. We do not use any observables of the capital stock, equity, or rate of defaults of entrepreneurs for the estimation. The calibration of the parameter for the steady-state of σ is set with respect to model properties (impulse responses) and a model-consistent filtration. Similarly, we do not estimate the posterior. Following [6], the prior for the monitoring costs parameter is set to 0.2 and the estimated value is slightly lower. The autoregressive parameters for both financial shocks (ρ_σ and ρ_{A^B}) indicate a relatively significant persistence.

	Parameter	Prior	Post. mean	Conf. int.	Distribution
$\frac{P^K K}{E}$	Capital to equity	1.8			
σ	Std. dev. of idios. product. dist.	0.45			
μ	Monitoring costs	0.20	0.1912	0.1752 - 0.2072	Gamma
ρ_σ	Persistence of σ	0.5	0.7719	0.5469 - 0.9592	Beta
ρ_{A^B}	Capital price bubble persistence	0.5	0.5403	0.2930 - 0.7833	Beta

Table 1: Financial frictions parameters

Figure 2 shows Bayesian impulse responses to the capital price bubble shock. Higher observed price of capital implies an increase of investment expenditures and a decrease of private consumption. Investment expenditures increase and private consumption decreases. Nominal exchange rate depreciates and the monetary authority increases interest rates to bring the headline inflation back to the target.Nominal wage growth is temporarily lower.

Figure 3 shows impulse responses to a σ shock which approximates higher riskiness of the entrepreneurial sector. Investment expenditures significantly decrease. As investment is produced mostly from imports, net exports increase. Exchange rate appreciates and the monetary authority decreases interest rate to bring inflation back to the target. Consumption expenditures of households slightly increase. The reaction of a majority of variables is much lower than the response of investment as financial frictions shocks affect primarily investment expenditures.

Figure 4 shows profiles of shocks on Czech data. During the global economy crisis, the smoother identifies a significant riskiness shock in 2009Q1 and moderate shocks during the rest of 2009. During the recovery of investment expenditures in 2010, there is a significant negative shock. The capital price bubble shocks are estimated most significant in the 2008-2009 turn with the peak in 2008Q3.

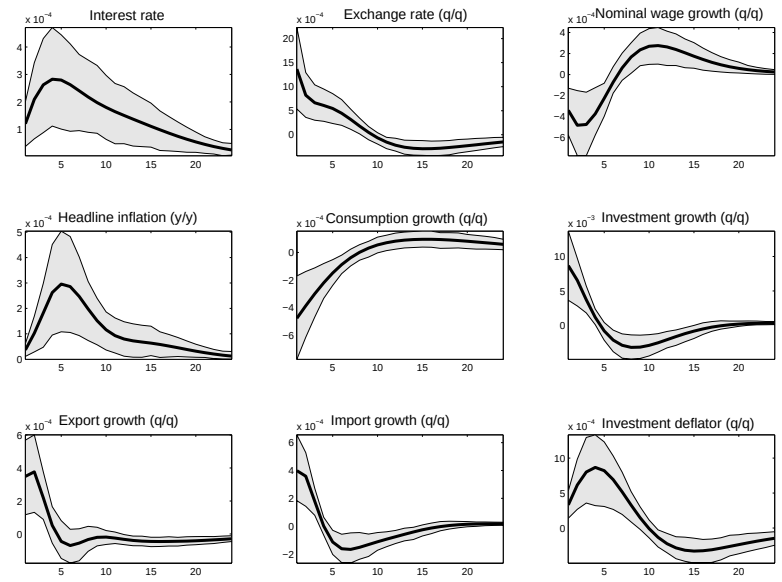

Figure 2: Capital price bubble shock

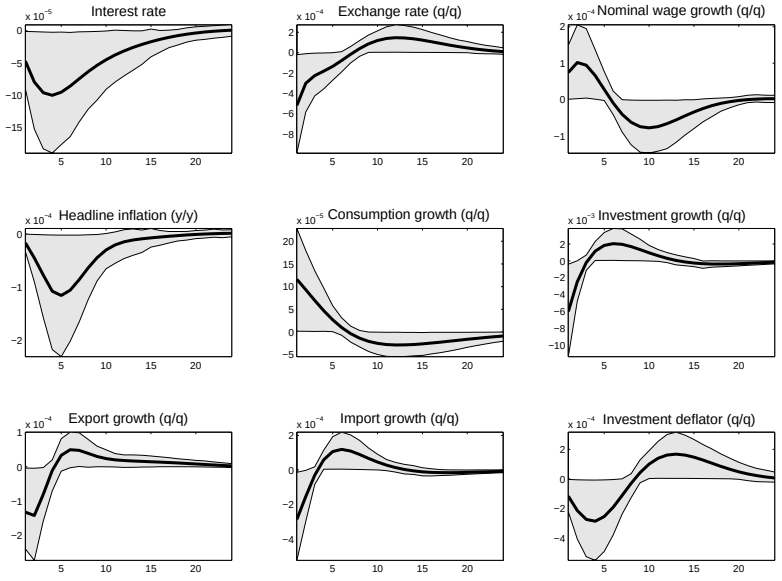

Figure 3: Sigma shock

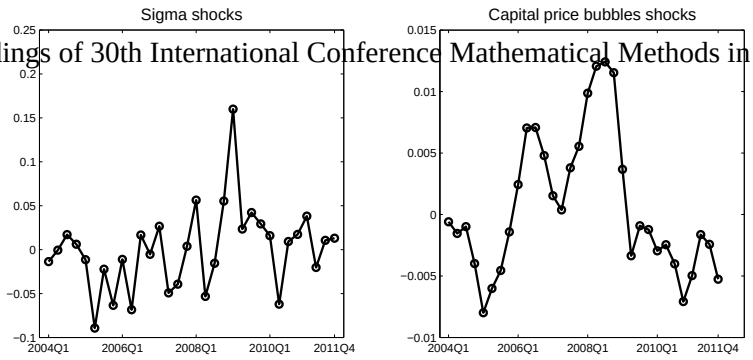

Figure 4: Sigma and capital price bubble shocks

4 Conclusion

In our contribution, we present structure of the model with the financial accelerator which is tailor-made for the czech economy. Besides several features capturing the main trend-cyclical components of Czech stylized facts, it contains state non-contingent debt-contracts between entrepreneurs and the financial intermediary. We estimate the model on Czech and euro area data and show Bayesian impulse responses to two shocks associated with financial frictions.

Acknowledgements

The financial support of specific research at Faculty of Economics and Administration, project MUNI/A/0780/2011 and the Research Project B2/10 at the Czech National Bank are gratefully acknowledged. We are grateful to Mirek Beneš and Jan Brůha for many helpful comments and advices.

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