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Monetary Policy Implications of Financial Frictions in the Czech Republic*

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Abstract
Having witnessed the consequences of the financial crisis for the real economy, we find it desirable to look back and analyze the Czech economy ex post. We work with a Swedish New Keynesian model of a small open economy which embeds financial frictions in light of the financial accelerator literature. Without explicitly modeling the banking sector, this model serves as a tool for understanding how a negative financial shock may spread to the real economy and how monetary policy may react. We use Bayesian techniques to estimate the model parameters to adjust the model structure closer to the evidence stemming from Czech data. Our attention focuses on a set of experiments in which we generate ex post forecasts of the economy prior to the 2009 crisis and illustrate that the monetary policy response to an upcoming crisis implied by the model with financial frictions is stronger on account of an increasing interest rate spread.

1. Introduction

Research during the past decade indicates that modeling of financial frictions has crystallized into two major branches. One of them stresses the importance of collateral constraints (Iacoviello, 2005), in that fluctuating asset prices affect the availability of bank loans since real estate often serves as collateral against bank loans. The other approach builds on the financial accelerator mechanism, in that credit expansion amplifies economic growth in good times and slows the economy down in bad times due to the existence of linkages between the real economy and the financial markets.

It turns out that the financial accelerator approach, which stems mainly from Bernanke et al. (1999), constitutes a channel through which recent events can be explained. This approach was modified numerous times during the past decade—see Dib and Christensen (2008) among many others—and has become a standard toolkit for modeling financial frictions. Brázdik et al. (2012) provide a thorough overview of ongoing research in the area, including models in which banks play an active role.

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We work with the model of Christiano et al. (2011, CTW for short), which was originally developed for the Swedish economy and which makes use of the financial accelerator in explaining business cycle fluctuations.

Previous research carried out at the Czech National Bank supports the idea that financial variables contribute to macroeconomic developments. Brůha (2011) finds that the predictive power of models that include the credit premium is better in terms of real economic activity and the non-performing loan ratio. Havránek et al. (2012) propose an empirical analysis based on Czech data and conclude that financial variables have a great impact on the economy, although the influence of financial variables is time-varying so one cannot rely on a single financial indicator when forecasting. Pang and Siklos (2010) use a fully structural model to study the role of the credit spread, which is closely connected to the interest rate spread, in various phases of the business cycle. They highlight the default rate as an important link between banks' credit portfolios and the real economy and suggest that the reaction of the monetary authority should be strong in times of recession as regards policy rate cutting.

Section 2 describes the model structure. Section 3 contains the data description and examines issues regarding the choice of financial variables. The estimation of the model parameters and the calibration to the Czech specifics are discussed in Section 4. In Section 5 we reveal in detail the story of how an adverse financial shock propagates through the entire economy and how the economy gets back to a balanced growth path. In Section 6 we provide a shock decomposition of several model variables. Section 7 demonstrates an experiment of what monetary policy implications are triggered when the model with financial frictions is put to use. Section 8 concludes.

2. Model

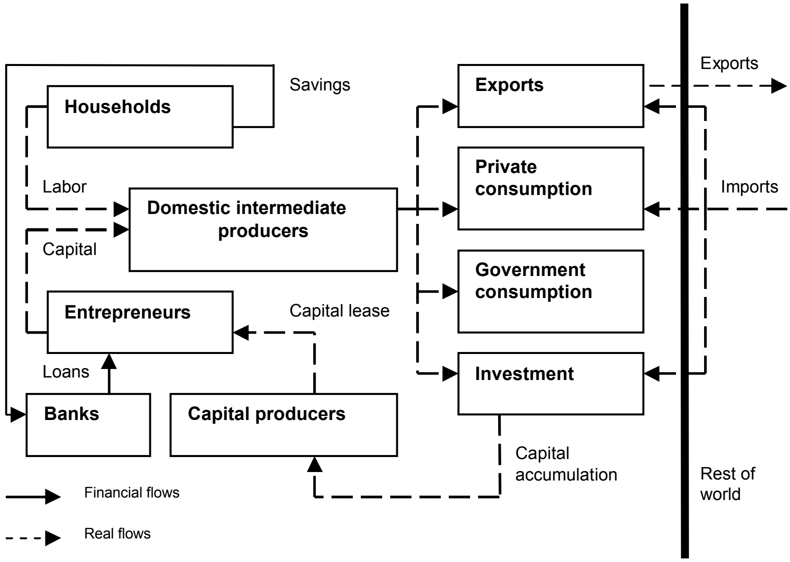
CTW (2011) do not start from scratch, but follow what has become the standard New Keynesian model in Smets and Wouters (2003) and Christiano et al. (2005, CEE for short) by adding a financial frictions block[1] as in Bernanke et al. (1999).

Their model is tailored to handle small open economy issues since it contains an exogenous block of foreign variables, following Adolfson et al. (2005) as shown below. The domestic economy is closed by a risk premium according to a modified version of Schmitt-Grohé and Uribe (2003) where households can acquire domestic and foreign assets and the risk premium on domestic assets mixes two effects—the net foreign asset position and the interest rate differential. The former effect has become standard while the latter is motivated by the usual empirical experience, according to which the uncovered interest rate parity assumption in its strict form is counterfactual. A lower domestic interest rate relative to the foreign interest rate may reflect lower country risk and therefore a lower risk premium on domestic assets.

The hump-shaped responses of the core model variables to a monetary policy shock are achieved by incorporating both real and nominal rigidities. In particular, habit formation in consumption of households is introduced, following Fuhrer (2000),

[1] Their model also incorporates a sophisticated labor market block which endogenizes the unemployment rate.

Figure 1 Model Scheme—Nominal and Real Flows



while adjustment costs in investment that affect the capital law of motion follow CEE (2005). Nominal rigidities stem from monopolistic competition. Aggregate variables are derived using the Dixit and Stiglitz (1977) production function with constant elasticity of substitution. Price and wage dynamics feature Calvo frictions, as in Erceg et al. (2000), where agents who do not get to set the price/wage optimally follow an inflation indexation rule of thumb.

Figure 1 depicts the structure of the model, including the interaction among its main blocks. Here we focus on the production side of the economy and explain how the factors of production are captured by the model. Domestic intermediate producers take labor and capital as inputs into their production function. Households provide labor directly, while there is a chain of agents that contribute to the process of capital transformation, in which financial frictions arise. The initial stock of capital is derived in each period from the past actions. Capital producers then use investment and the functional form for the law of motion of capital to generate the amount of capital available to entrepreneurs. Their capital can be backed either by net worth or by a bank loan and the financial friction enters the model via the riskiness of entrepreneurs' business. The expected return on capital can in fact be less than the amount required to be paid off to the bank, including interest, at the end of each period. Thus, it can happen that a portion of entrepreneurs goes bankrupt. This has economy-wide implications, in that it affects the interest rate setting behavior of banks, by which the interest rate spread is captured. Households deposit their domestic savings in banks and these are then converted into loans.

Further on we describe the financial frictions channel, including a simplified version of the core model equations. The interested reader should look directly into CTW (2011) for a proper definition of all the functional forms.

2.1 Financial Frictions Block

Banks in this model do not have an active role because they only function as intermediaries. Entrepreneurs are risk-taking agents who borrow from a bank and invest in capital. Upon successful investment, they profit from a positive return on capital net of the bank loan and interest. Entrepreneurs also face shocks to their return on capital, which can either increase or reduce the final return on capital. For the entrepreneur there exists a certain threshold value, $\omega = \bar{\omega}$, of this shock such that the return on assets times the volume of assets covers the bank loan and the interest, in which case the entrepreneur is left with nothing but has not defaulted, or[2]

$$(1 + r)A\bar{\omega} = (1 + i)B \tag{1}$$

where r is the return on assets, A is the volume of assets, ω is an idiosyncratic shock to the return on assets distributed lognormally with mean centered at one, i is the interest rate, and B is the bank loan. Equation (1) can be rearranged to get $\bar{\omega}$ explicitly:

$$\bar{\omega} = (1 + i)/(1 + r)\ B/A$$

Due to balance sheet constraints, because

$$A = N + B \tag{2}$$

the ratio B/A can be complemented with the ratio of net worth to assets (N/A), the inverse of which is usually referred to as the leverage ratio in the financial frictions literature. The threshold value of the idiosyncratic shock, $\bar{\omega}$, thus depends inversely on the leverage ratio, which serves as a constraint in the model.

We can combine equations (1) and (2) to get a final equation determining the interest rate spread since

$$i - i_p = \frac{(1+r)\bar{\omega}}{1 - N/A} - 1 - i_p \tag{3}$$

where we subtract the policy rate i_p from both sides of the equation. The left-hand side of equation (3) is mapped linearly on the data in a measurement equation. We describe the exact data counterparts in a separate data section.

The equilibrium loan contract is the one in which entrepreneurs maximize their expected welfare given the threshold value, $E_t\{\varpi_{t+1}\}$, and the time t value of leverage (A/N). The associated problem can be written as

$$\frac{E_t\left\{\left(1+r_{t+1}\right)A_t\right\}}{\left(1+r_t^d\right)N_t} - bank\ share_{t+1}$$

where the nominal value of assets is taken relative to the guaranteed profit resulting from depositing the net worth in the bank at a deposit rate r_t^d. The total expected profit is net of the amount which goes back to the bank. This bank share is dependent on the expected cut-off value ϖ_{t+1} and problem maximization is subject to

[2] We omit the time subscripts of the variables in the case of static equations.

the bank's zero profit condition, which is described in the next paragraph. Taking derivatives with respect to ϖ_{t+1} and the leverage yields the first-order conditions, which can be combined together to rule out the Lagrangian multiplier. The optimal contract at time t also specifies the t+1 contingent rate of interest (t+1 actions do not affect the t+1 interest rate).

As mentioned above, banks have only a passive role in the model and their expected revenue corresponds with the risk-free rate of return $(1 + i_t)B_t$. The entrepreneurs who survived must pay back the loan plus the interest, and those who went bankrupt lose everything. Banks must, however, pay the monitoring cost, μ, in order to reveal the true condition of a defaulted entrepreneur's assets. Since ω is a random variable whose distribution is assumed to be lognormal, we can work easily with its cumulative distribution function. Banks' clearing condition (zero profit condition) equates expected revenue with costs and can be written as

$$\left(1+i_t\right)B_t=\left[\bar{\omega}_{t+1}\times prob\left\{\omega\geq\bar{\omega}_{t+1}\right\}+\omega_{t+1}(1-\mu)\times prob\left\{\omega<\bar{\omega}_{t+1}\right\}\right]\left(1+r_{t+1}\right)A_{t+1} \quad (4)$$

where $\bar{\omega}_{t+1}$ is the true expected $t + 1$ threshold value for the idiosyncratic shock that makes entrepreneur break even.[3] This is also an equation entering the model after linearization.

The last model equation from the financial frictions block determines the law of motion for the net worth of entrepreneurs. If an entrepreneur survives and his bank loan is paid off, the excess amount can serve as net worth for the next period. Both survivors and losers receive an initial transfer at the beginning of the next period, which guarantees sufficient funds to obtain a loan. The survival rate, γ_t, is a time-varying parameter modeled as an AR(1) process. The underlying equation for the evolution of net worth, nw_{t+1}, reads as follows:

$$nw_{t+1}=\gamma_t\left[\left(1+r_t\right)A_t\bar{\omega}_t-\left(1+i_t\right)B_t\right]+initial\ transfer_t \quad (5)$$

The small open economy setting is captured in the model via an exogenous foreign block of variables that evolve according to a vector autoregressive scheme:

$$\begin{pmatrix} y_t \\ \pi_t \\ r_t \\ \mu_{z,t} \\ \mu_{\psi,t} \end{pmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} & a_{15} \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{25} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} \\ 0 & 0 & 0 & \rho_{\mu_z} & 0 \\ 0 & 0 & 0 & 0 & \rho_{\mu_\psi} \end{bmatrix} \cdot \begin{pmatrix} y_{t-1} \\ \pi_{t-1} \\ r_{t-1} \\ \mu_{z,t-1} \\ \mu_{\psi,t-1} \end{pmatrix} + \begin{bmatrix} \sigma_y & 0 & 0 & c_{14} & c_{15} \\ c_{21} & \sigma_\pi & 0 & c_{24} & c_{25} \\ c_{31} & c_{32} & \sigma_r & c_{34} & c_{35} \\ 0 & 0 & 0 & \sigma_{\mu_z} & 0 \\ 0 & 0 & 0 & 0 & \sigma_{\mu_\psi} \end{bmatrix} \cdot \begin{pmatrix} \varepsilon_{y,t} \\ \varepsilon_{\pi,t} \\ \varepsilon_{r,t} \\ \varepsilon_{\mu_z,t} \\ \varepsilon_{\mu_\psi,t} \end{pmatrix}$$

where the sector-specific technology processes, μ's, are modeled as mutually uncorrelated AR(1) processes that also transmit into the domestic economy. Foreign GDP (y_t), inflation (π_t), and the interest rate (r_t) form a Cholesky block in the VAR.

[3] In reality, easing or tightening of the lending conditions is accomplished not only through adjustments in the price of credit, but also through other non-price factors such as credit rationing—we thank Jaromír Beneš for pointing this out.

2.2 Adjusting the Model to Fit the Czech Specifics

Apart from the estimation itself, we have slightly altered the Swedish version of the model in order to closely capture Czech phenomena. The economic situation of Sweden corresponds quite closely to that of the Czech Republic. Both are small open economies that conduct monetary policy in an inflation targeting regime. The exchange rate channel has proven to have strong implications in these countries. This can be deduced from the empirical evidence—see, for example, Babetskaia-Kukharchuk (2007), who estimates the exchange rate pass-through in the Czech Republic at between 25% and 30% (based on a multivariate analysis), or Flodén and Wilander (2006), who estimate the Swedish pass-through at between 19% and 37% (though based on a univariate analysis). The recent credit crisis hit both countries in 2009 via a decline in foreign demand. Measured by real GDP, the economic downturns in the Czech Republic and Sweden amounted to 4.1% and 5.3%, respectively. Finally, both countries appear to be reluctant to adopt the common euro currency in the medium term.

On the other hand, the CNB used to operate a fixed exchange rate regime until the end of 1997, when this policy stance was abandoned in favor of inflation targeting. The CNB initially targeted the core inflation index, but later switched to targeting of the consumer price index. Moreover, over time, the inflation target levels have dropped from around 6% in 1998 to the current 2% valid as of 2010.

To tie the model prices to this disinflation period in Czech history, we constructed an extra measurement equation that links the model target values to those observed in the data:

$$target_t^{data} = target_t^{model} + \Omega_t \tag{6}$$

We keep the measurement error, Ω_t, in this equation at zero since we do not allow the model structure to deviate from the prescribed target values in history. The target itself is then modeled as an AR(1) process

$$target_t^{model} = \rho\, target_{t-1}^{model} + \varepsilon_t$$

where the shock, ε_t, has non-zero variance so that the model value of the target can always be glued to the data via the measurement equation (6). The time t expected deviation of inflation from the inflation target at $t + 4$ then enters the standard Taylor-type rule, according to which the interest rate is set by the monetary authority.

3. Data

To capture financial frictions in real data, we need to introduce two observable variables concerning financial frictions—a measure of the interest rate spread and a measure of entrepreneurial net worth. We closely follow the choice of CTW (2011), even though it is not clear at all whether this selection of financial variables is the correct one, as will be discussed below.

3.1 Interest Rate Spread

We calculate the interest rate spread as follows. The dip in the PRIBOR during the 2009 crisis was not immediately followed by a general decrease of market interest rates. Therefore, we take the average interest rate on newly issued credit to

Figure 2 Interest Rate Spread, % Changes[a], HP filter (10)[b]

Notes: [a] Observed interest rate spread for model estimation is defined as 100*(log(spread)-log(spread(-1))). See CTW (2011).

[b] Here we show a trend of interest rate spread delivered by Hodrick-Prescott filter (lambda = 10).

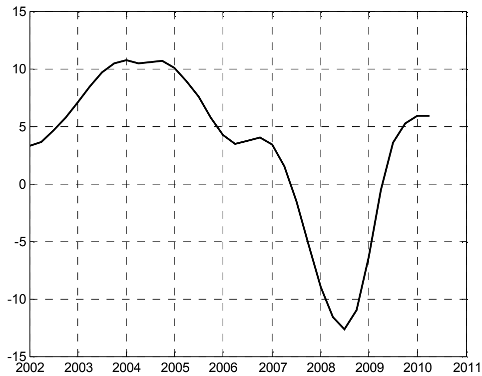
non-financial corporate obligors and subtract the 3-month PRIBOR. The idea behind this choice is that rates for non-financial corporations serve both as a representative market interest rate and as one that is close enough to entrepreneurial borrowing in the model of CTW (2011). On the other hand, the 3-month PRIBOR, being strongly correlated with the regulated 2-week PRIBOR, is believed to track monetary policy actions closely. We do not take the policy rate itself in constructing the interest rate spread because of the maturity mismatch in comparison to the representative market rate. *Figure 2* shows the quarter-to-quarter percentage changes in the interest rate spread. The obvious upward shift in 2009 coincides with the increased risk during the post financial turmoil period.

3.2 Entrepreneurial Net Worth

We take the approach of CTW (2011) and approximate the entrepreneurial net worth in the model with the aggregate stock market index even though this choice has its drawbacks. *Figure 3* shows the quarter-to-quarter percentage changes in the Czech PX index. The double digit falls precede the moment when, in the first quarter of 2009, the real economy was hit hardest by the global crisis.

While it is quite intuitive to find a reasonable data counterpart for the interest rate spread, our choice concerning entrepreneurial net worth is somewhat trickier. In the discussion that follows, let us suppose that stock prices are determined to a great extent by dividend payments. This is in line with Dhillon and Johnson (1994), who examine the impact of dividend changes on the stock and bond markets and provide evidence which does not contradict the information content hypothesis of dividend payments, i.e., that stock prices should increase (decrease) when dividend increases (decreases) are announced. Miller and Modigliani (1961, MM for short) suggest dividend neutrality in their seminal paper on the information content hypothesis of dividends. On the other hand they assume that changes in dividend policy form a signal about the state of a company.

Figure 3 PX Stock Market Index, % Changes, HP filter (10)



In the literature, one can find counterarguments to this theory, often based on the fact that MM (1961) assume perfect capital mobility, perfect information, and zero transaction costs, as argued in Baker (1992). The dividend yield is also subject to higher taxation than the regular capital gain. Growth in dividends can then represent negative information and can cause drops in stock prices.

It is a well-known fact that dividend payments develop very smoothly over time, as claimed by Lintner (1956) and Brav et al. (2005). Stable dividend policy is perceived positively by investors and companies try hard to accomplish this. Therefore, it is up to the management to decide what signals about their company to release, regardless of the true shape of the company. The stronger the correlation between dividend policy and stock prices, the weaker the information content of stock prices regarding the true shape of companies. There are two well-documented examples in U.S. history worth mentioning that depict significant distortions between stock price signals and the real condition of companies.

First, there is an example which dates back to 1919 and which later became known as the Dodge versus Ford case, filed at the Supreme Court of Michigan.[4] This case resulted in the verdict that shareholders' right to claim for a regular (i.e., stable) dividend is justifiable.[5]

Second, during the Great Depression in the USA, firms were even willing to sell their physical capital in order to keep their dividend payments high, as CTW (2011) emphasize. Thus, the real net worth of companies did not correspond to share prices since, from the viewpoint of the preceding discussion, there was bias between what was going on in companies on the one hand and what information the stock

[4] A scholar's version of the verdict is available at http://www.businessentitiesonline.com/professors.html under Dodge v. Ford Motor Company.

[5] In particular, Henry Ford, president of Ford Motor Company, intended to retain most of the profits in order to reinvest them in the future. His motivation for putting a large share of profits back into the business was that the company would *"employ more men, to spread the benefits of this industrial system to the greatest possible number, to help them build up their lives and their homes."*

As a result, he planned to cut the dividend amounts, something that was not welcomed by the Dodge brothers, then major shareholders of Ford Motor Company. The Supreme Court affirmed that the release of dividend payments was not entirely at the discretion of the company's management, but was rather an obligation.

prices provided on the other. Of course, fiddling with dividend payments did not prevent a downswing of stock prices after all.

Regardless of the uncertainty concerning the information content of the stock market index, this measure is very sensitive to general public opinion and is quite often used as a leading indicator, although the stock market in the Czech Republic is still relatively shallow—instead, it would be possible to make use of micro-level corporate accounting data, which is left for future investigation.

Finally, we also considered the case where entrepreneurial net worth is not linked to the data at all, and instead we focused on mapping the model default rates on aggregate credit data collected from commercial banks (available for public use in the CNB's ARAD database[6]). However, the default rate data for public use are available only since 2002, which would reduce our sample size by almost a half. We could partially get around the short sample range if we used the "missing data Kalman filter" routine as in Harvey (1989), which we do not attempt.

4. Estimation

Our data sample includes 60 observations covering the period 1996Q2–2011Q1. The data for 1996Q1 are also known but drop out of the sample when first differences are taken. Besides the already discussed interest rate spread and stock market index, which approximate our financial variables, we use a standard set of macro variables which includes the expenditure side of the national accounts in real denomination and the appropriate deflators, the real exchange rate, nominal interest rates for both the domestic economy and the eurozone, foreign GDP and prices, the real wage, the unemployment rate, and hours worked. See CTW (2011) for a precise list of the data transformations used.

4.1 Computational Aspects

To reveal the effects of financial frictions specific to the Czech economy, we process the model[7] through a Bayesian estimation routine in Dynare,[8] which is suitable software capable of handling rational expectations models.

First, the posterior modes and the approximation of the Hessian evaluated in these modes are computed using numerical optimization techniques—nonlinear simplex combined with Newton gradient steps. Second, posterior sampling of the parameters is achieved with the help of the Metropolis-Hastings (MH) algorithm with a random walk transition rule.

We set the MH algorithm to generate 500,000 draws, of which 1/3 are discarded as a burn-in. In total we run two parallel MH blocks. The acceptance ratio of the MH draws fluctuates around 35%. *Appendix*[9] *C* shows the convergence statistics.

4.2 Parameter Setting

Table B1 in *Appendix B* shows a comparison of the Czech and Swedish model calibrations of the parameters that are not estimated. The basic setup of

[6] http://www.cnb.cz/en/statistics/index.html

[7] The entire model code, including the steady state, is adopted from CTW (2011).

[8] Available at www.dynare.org. Koop (2005) derives the underlying mathematical formulas.

[9] available on the web-site of this journal

the prior assumptions concerning the relevant model parameters and respective posterior estimates is summarized in *Table B2* and subsequent output figures from Dynare.

The calibrated parameters include the steady state values, deep parameters, and specifications for several persistence coefficients of shock processes. The prior judgments regarding the parameters that we estimate using Bayesian methods are mostly adopted from CTW (2011). Alternatively, we consider parameter setting according to our previous experience. Unlike in the original Swedish estimation, the parameter measuring banks' monitoring costs, μ, has its posterior mean equal to only 0.05 (i.e., in order to monitor clients in default, banks lose roughly 5% of the amount that they would otherwise receive in the absence of monitoring costs), which suggests that Czech banks do not face severe costly state verification as in the Swedish case (0.56). Concerning the foreign VAR block, our results often referred to parameter $a11$ being greater than 1, which would imply unstable foreign GDP. To overcome this difficulty, we set an extra constraint in Dynare making the $a11$ parameter smaller than 1 in absolute value. In this case the posterior estimate came out at 0.99. Our prior belief that the response of interest rates to the output gap is not significant compared to the response to inflation seems to be true because the ratio of these prior weights went down from 0.043 to 0.026. This of course amplifies the response of interest rates to inflation, which is not surprising for a country in an inflation targeting regime.

5. Response of the Economy to an Adverse Financial Shock

The essence of financial frictions can be clearly seen if we consider a shock that reduces entrepreneurs' net worth and trace its propagation to other relevant variables.[10]

5.1 Link between Leverage and Bankruptcy Rates

In a simplified balance sheet of an individual entrepreneur, there are assets backed by net worth and a bank loan. If the entrepreneur is to pay off the bank loan plus the interest by the end of current period, then the return on assets must be sufficiently high to cover the liabilities payable to the bank, including interest. With respect to an agent-specific shock to the return on assets,[11] the profitability of the investment project can be significantly affected. The entrepreneur declares bankruptcy if the adverse shock reaches a certain threshold value at which the return on assets just covers the bank loan plus interest. Such threshold value is thus a function of the volume of assets and the amount of the bank loan, or the ratio of the two.

If the assets are backed mostly by a bank loan, then the interest costs trim down the profit tremendously and the entrepreneur is more vulnerable to adverse shocks. Likewise, should the assets be covered mainly by net worth, the interest costs from the bank loan would not affect the profits very much and the entrepreneur would therefore be relatively immune to adverse shocks. Through this channel we introduce a balance sheet constraint into the model.

[10] The analysis of impulse-response functions is based on a first-order approximation of the model.

[11] Heterogeneity of agents is emphasized by the fact that each entrepreneur faces his or her specific shock to return on assets. The model then works with the distribution of all entrepreneurs.

The ratio of assets to the amount of the bank loan can be complemented with the ratio of assets to net worth (leverage). *Ceteris paribus*, an adverse shock to net worth implies that a constant volume of assets is backed by a higher bank loan amount and the leverage ratio increases.[12] Consequently, even a slight adverse shock to the return on assets makes the entrepreneur more likely to go bankrupt, which increases the default rate of all entrepreneurs from the aggregate viewpoint.

5.2 Shock Propagation

Appendix B (*Figure B1*) contains the economy's response to an adverse shock to entrepreneurial net worth. The shock is accompanied by a higher default rate (see the explanation in the preceding subsection), which pushes down overall investment activity since increasing numbers of entrepreneurs go bankrupt. Imports also shrink owing to the import intensity of investment. This causes a reaction on the forex market and the domestic currency appreciates on account of the trade surplus, which decreases the inflationary pressures due to lower import prices. In this situation the monetary authority lowers the policy rate, which in normal circumstances should lead to a general decline in market rates. But instead, financial frictions suppress this decline because commercial banks face higher provisions due to write-offs and keep interest rates high to offset the worse credit risk conditions. Thus, monetary policy efforts are dampened by an elevated interest rate spread.

In what usually follows in reality, banks are forced to ease the credit conditions because, first, they face competition, and second, the spread closes after several quarters. This gradually pulls up investment activity and the economy recovers.

Specifically, the model contains a built-in stabilizer that helps to explain why the economy returns to a steady state after experiencing an adverse shock to entrepreneurial wealth. When the economy slows on account of weak investment, asset prices freeze and this has two consequences. First, investment activity is automatically stimulated since it becomes cheaper. Second, given the entrepreneurial balance sheet constraint, the volume of nominal assets shrinks, which pushes down the leverage ratio and investment activity is stimulated again. These two effects together outweigh the higher default rate and the economy eventually reaches a stationary state. Finally, defaulted entrepreneurs are given an initial amount of net worth every period, which also helps the economy to reach a stationary state (see the initial transfer in equation 5).

6. Shock Decomposition

In a class of linearized models, it is possible to identify fluctuations of endogenous variables resulting from shocks that hit the model in each period. In the absence of shocks, the model variables would stick to their steady state values. To uncover whether financial frictions help to explain a substantial portion of

[12] The final balance sheet effect of the lowered net worth is questionable. On the one hand, net worth could be offset by a larger bank loan to keep the volume of assets constant, or, on the other hand, the lowered net worth could result in a reduction in both assets and liabilities. The model we work with assumes the first approach, but equilibrium is restored with help of the latter approach as discussed later.

Figure 4 GDP Growth (Deviation from its Mean)—Decomposition to Shocks

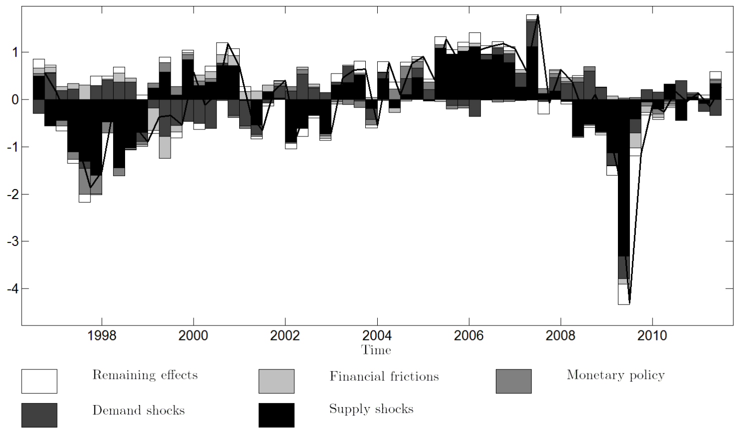
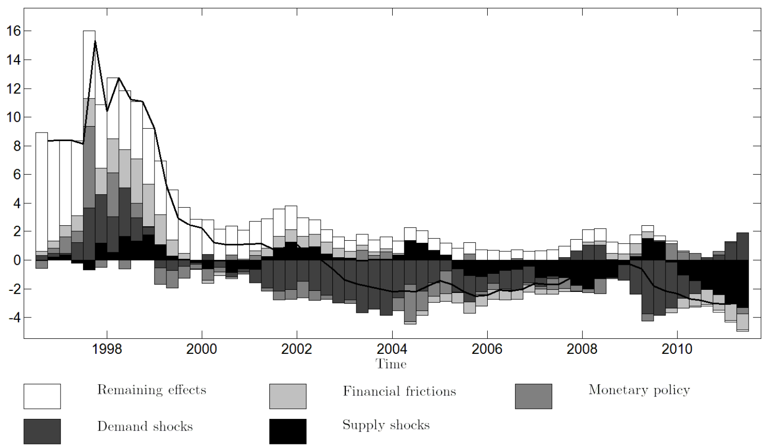


Figure 5 Nominal Interest Rate Decomposition to Shocks



the business cycle in the Czech Republic, we construct *ex post* decomposition graphs for relevant model variables (see *Appendix*).

The output gap is positive in the period 2006–2007, mainly due to technological shocks, mark-up shocks, and increasing habit shocks in consumption. The sharp downturn in output in 2009Q1 is mainly caused by a negative technological shock and foreign demand shock (*Figure 4*). The real investment gap is explained to a great extent by the marginal efficiency of the investment shock and financial shock. This is a result of how investment decisions are modeled—a separate agent called an entrepreneur, who is bound by financial conditions from his balance sheet, decides on the utilization of capital. The real import gap is also affected by investment shocks (MEI and financial) due to the high share of imports in investment. The interest spread and net worth are financial variables themselves, therefore a major part of the fluctuations in these variables results from financial shocks. This is partially offset by marginal investment efficiency shocks in the opposite direction in the case of the interest rate spread.

On the other hand, foreign demand shocks dominate in explaining real export fluctuations. Private consumption features very persistent preference shocks. Debt elastic premium shocks contributed to lower inflation and lower interest rates in the period 2003–2007 (*Figure 5*) against financial friction and cost-push shocks. Government consumption is exogenous in the model, so only fiscal shocks take effect.

Tonner et al. (2011) emphasize the importance of sector-specific technological processes as a primary source of business cycle fluctuations. Our model assumes only aggregate technology growth, which is a bundle of neutral technology with positive drift and a stationary investment specific technology. Augmenting the model by various technologies related, for example, to foreign trade and the openness of the economy would surely strengthen the contributions of technological shocks in the decomposition graphs, making the financial frictions even less relevant.

7. Ex post Perspective on the Policy Rate Setting

To demonstrate the impact of financial frictions on the model dynamics, we carried out forecast exercises conditional on the current knowledge of the model's exogenous variables. We take known data up to 2008Q3 and replicate the forecasts in turn for the model with financial frictions as discussed above and the model in which financial frictions are turned off. In the end we compare all the forecasts with the actual development of the relevant variables. *Figure 6* shows the predictions for the CPI, the interest rate, the real exchange rate, real exports, real GDP, and unemployment rate change The simulations begin in 2008Q3 and run six quarters ahead. In this set of scenarios, the outlook for foreign exogenous variables is taken according to the known reality and the forecast simulation is calculated forward as if the model agents did not anticipate the development of the foreign outlook[13] in advance. On the contrary, the 2% inflation target holds over the entire forecast range and is fully anticipated. We do not make any other expert judgments, leaving both predictions genuinely model implied and thus comparable.

Considering the size of the economic slump in 2009, the simulated interest rate paths of both model variants closely trace the realized paths given the outlook for foreign exogenous variables. However, the model with financial frictions suggests a more significant interest rate cut compared to the model in which the financial frictions block is neglected. The effect of financial frictions, which mostly results from the elevated interest rate spread, increases over time—the difference between the models with and without frictions is more than 100 basis points at the end of the forecast horizon. This outcome is in line with Tonner and Vašíček (2011), who estimate the effect of financial frictions at around 50 basis points. However, to draw proper conclusions, one should not interpret *Figure 6* in favor of the model with financial frictions turned off just because the implied prediction fits the realized trajectory of the interest rate better. Expert judgments, which we do not impose at all,

[13] The rational expectations modeling approach allows us to generate a forecast based on the future expected paths of the relevant variables, which we do not attempt here.

Figure 6 Conditional Prediction (Model Comparison)

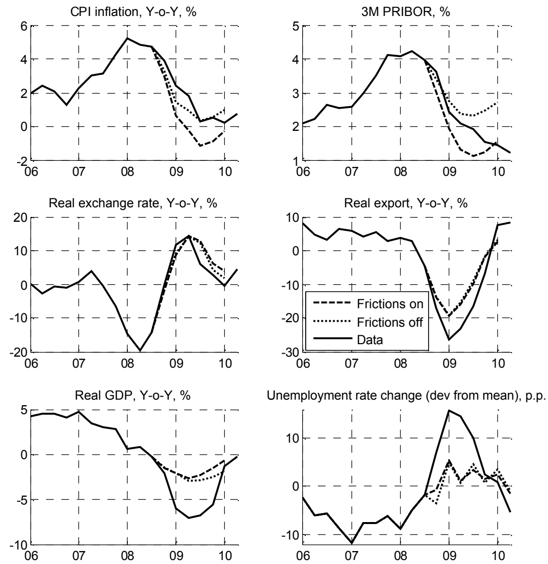
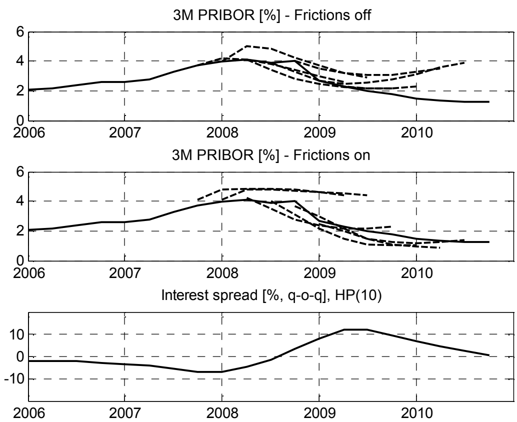


Figure 7 Recursive Forecast Exercise



form a significant part of the whole forecasting process. Thus, *Figure 6* only suggests that the interest rate cutting process with respect to the financial frictions channel would be firmer and longer lasting than in the case of no financial frictions.

From the technical point of view, financial frictions are switched off in the model as follows. The parameter of monitoring costs of banks is fixed at zero, which results in banks knowing the current status of the obligor's property with certainty without the need for further costly inspection. Furthermore, the persistence of the net worth of entrepreneurs is kept at zero, allowing greater flexibility of entrepreneurial borrowing because shocks to net worth no longer propagate to the future and the net worth of entrepreneurs is thus more likely to wander more closely around its steady state value. On the other hand, we still have the entrepreneur as an agent who makes decisions about capital utilization.[14]

During the pre-crisis period the CTW models with and without financial frictions suggest a similar interest rate trajectory. *Figure 7* illustrates the gradual dispersion between the two forecast scenarios as the interest rate spread began to rise. This exercise was calculated as a recursive forecast. Since early 2009 the CTW model with financial frictions captures the reality with substantially greater success.

The inclusion of the financial frictions implies higher pro-activeness of the monetary authority at times of increasing interest spread and in a way more reasonable forecasts while the effects of financial frictions are not clearly visible when the interest spread is close to its long-run level. The importance of financial frictions is thus time-varying and there are periods when other transmission channels dominate.

8. Summary and Conclusions

Having witnessed the consequences of the financial crisis for the real economy, we try to evaluate the relevance of macro-financial linkages in the case of the Czech Republic. We focus on the interest rate spread as a key factor that makes monetary authority actions ineffective at times of adverse risk conditions and limited interest rate pass-though.

We work with the Swedish model of CTW (2011), which incorporates several mechanisms with various frictions in a small open economy setting. We concentrate on the channel of financial frictions based on the financial accelerator literature in the light of Bernanke et al. (1999). The core model parameters are calibrated with respect to the Czech specifics, and the rest of the parameters are estimated using Bayesian techniques. The original model structure of CTW is slightly altered in order to capture the differences between Sweden and the Czech Republic. For example, we introduce a disinflation scheme as an observed variable and link this data to the model inflation target.

To explore the influence of financial frictions, we conduct a pair of experiments to reveal the extent of macro-financial linkages in the Czech Republic. First, we run pre-crisis judgment-free forecasts with the CTW model with financial frictions turned on and off and compare them with the actual development of the interest rate. The results suggest that the monetary authority should react faster with policy rate cutting when financial frictions are taken into consideration. The effects on GDP of the monetary policy reaction can be summarized as follows. A GDP shock decomposition suggests that the influence of financial frictions is moderate. Also, a GDP forecast comparison of the two experiments shows that the effect of lower interest rates on GDP using the financial friction model would be about 0.15 pp. There is also a big difference between the real evolution of GDP and the model forecasts. The reason is partially a poor ability of the model to predict unemployment. This will be an issue for further research.

[14] The proper way to turn off financial frictions would involve capital decisions being made by households.

Second, we investigate whether the effects of financial frictions are time dependent. On a series of recursive forecasts we demonstrate that the effect of financial frictions seems to be limited at times when the interest rate spread is relatively low, since the CTW models with and without frictions show similar behavior. The difference in the forecasting powers between these two models becomes significant as the interest rate spread increases.

According to the Czech experience, the exchange rate channel connected with the balance of net exports is believed to be the main driver of the business cycle. The inclusion of financial frictions does not contradict the relevance of other channels, in that the effects of financial frictions do not tend to dominate during various business cycle phases. Perhaps the Czech economy is "too open" to be affected by a mechanism that propagates through real investment.

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