Linkages between the Financial and Real Sectors across Interest Rate Regimes: The Case of the Czech Republic

Vazby mezi finančním a reálným sektorem v různých režimech úrokových sazeb: případ České republiky

TOMÁŠ KONEČNÝ

Abstract

I employ the threshold Bayesian VAR with block restrictions to evaluate the nonlinear dynamics across different interest rate regimes using the example of the Czech Republic. The study compounds the information on aggregate credit and non-performing loans (NPL) to find that the procyclicality of financial sector tends to vary across interest rate regimes. The impulse responses of real economy to shocks to the credit and NPL provide a mixed picture. While the responses to credit shocks are roughly similar across regimes, the reaction to the NPL shocks differ both in size and timing and can be likely aligned with the cyclical factors. The direct impact of foreign factors on lending seems to be rather limited given that the financial sector in the Czech Republic is largely bank-based and funded predominantly by domestic deposits. The measured responses to foreign shocks instead seem to reflect the convergence path of the Czech economy over a longer time horizon.

Keywords

credit, small open economy, non-linearities

Abstrakt

Práce prostřednictvím prahového bayesovského VARu zkoumá nelineární dynamiku v různých režimech úrokových sazeb na příkladu České republiky. Studie používá data o celkových úvěrech a nesplácených úvěrech (NPL) a dochází k závěru, že procykličnost finančního sektoru se mění v rámci režimů úrokových sazeb. Impulsní odezvy reálné ekonomiky vůči šokům na objemu úvěrů a NPL poskytují smíšený obraz. Zatímco reakce na úvěrové šoky jsou zhruba podobné bez ohledu na konkrétní režim, reakce na šoky do NPL se liší co do velikosti i načasování. Přímý vliv zahraničních faktorů na úvěry se zdá být poměrně omezený vzhledem k tomu, že finanční sektor v České republice je z velké části založený na bankách a financovaný převážně z tuzemských vkladů. Naměřené reakce na zahraniční šoky proto spíše odráží konvergenci české ekonomiky v delším časovém horizontu.

Klíčová slova

úvěr, malá otevřená ekonomika, nelinearita

JEL Codes

E51, C15, C32

Introduction

The protracted period of low interest rates and postponed economic recovery, combined with the persisting climate of financial market vulnerability in Europe, has raised imminent questions about the viable options for monetary policy and the operability of "traditional" transmission mechanisms. Given the recent crisis and post-crisis experience, the momentum of the debate has from the outset centred on the interactions between monetary policy, the real sector and finance. The efforts by researchers, industry experts and policymakers have ultimately transformed into a number of both theoretical and empirical studies (for a detailed survey see, for example, BIS 2011) which either build upon existing channels or develop novel ones linking the real and financial sides of the economy. The influential balance sheet or "financial accelerator" framework of Bernanke and Gertler (1995) emphasizes capital-market frictions, including moral hazard, asymmetric information and imperfect contract enforcement problems, and the subsequent need for collateral to access credit. As a result, shocks to collateral value arising in the real economy might in turn feed back from the banking sector into real economic activity.[1] The bank lending and bank capital channels instead focus on banks' asset and liability structure. The former channel relies on the inability of banks to fully substitute for lost liabilities in the event of a monetary contraction (Bernanke and Blinder, 1988), while the latter reflects banks' incentives given exogenous shocks to capital and interactions of capital with regulatory requirements. In such a setting, adverse changes to bank capital can have a pronounced impact on the lending of less capitalized banks (Van den Heuvel, 2002; Meh and Moran, 2010). The literature on capital requirements has identified additional feedback effects of regulation through shifts in risk-weighted assets in the capital-asset ratio (Borio et al., 2001; Goodhart et al., 2004). The liquidity channel, as discussed, for example, by Brunnermeier and Pedersen (2009), has received considerable attention, especially due to the spillover mechanisms amplifying the recent financial crisis.[2]

The interactions between the real sector and the financial sector are not necessarily linear. The endogeneity of credit markets in the financial accelerator mechanism, the propagating sectoral dynamics of the liquidity channel and, for example, the relevance of the bank capital channel for a subset of (less capitalized) banks each point to the potential importance of non-linearities in applied work.

The contribution of this paper is threefold. First, the present study aims to gauge the non-linear interactions both within and between the real sector and the financial sector. I estimate a standard monetary policy model for a small open economy augmented by financial sector aggregates as a Bayesian threshold VAR. By allowing for endogenous high- and low-interest rate regimes, I impose greater flexibility than in the case of a linear system, so that the impact of shifts in the policy rate and the implicit non-linearities in the

1 *Given the dominant position of bank credit in the financing of Czech corporates and households, the authors use the terms banking sector and financial sector interchangeably.*

2 *Other studies on market and funding liquidity include Wagner (2010) and Strahan (2008).*

transmission of shocks from the financial system can be evaluated. The second contribution is methodological, as I extend the single-equation Bayesian threshold model by Chen and Lee (1995) into the multiple-equation setting with block restrictions to account for external factors in a small open economy. Third, given that most of the related empirical studies have focused on developed economies (Çatik and Martin 2012 being the sole exception), the study provides complementary evidence on the role of non-linearities for a small emerging economy.

The remainder of the paper is organised as follows. The next section provides a brief overview of the empirical evidence on real sector-finance linkages. Section 3 describes the data and methodology. Section 4 presents estimated generalized impulse responses for key variables of interest and discusses the results. Section 5 concludes.

1 Empirical Literature

The empirical links between the real economy and the financial sector have been studied extensively within distinct analytical frameworks and from different perspectives. Most empirical studies on feedback effects rely on the vector autoregression (VAR) methodology, which links key macroeconomic variables with a selected indicator, or selected indicators, of financial sector performance. These studies typically emphasize the link from the real sector to the financial sector using aggregate-level data within standard (possibly cointegrated) vector autoregressions.[3]

The literature, oriented largely on credit risk, emphasizes the role of macroeconomic aggregates in the modelling of default rates or other dimensions of credit risk, and addresses possible feedback effects from banks to the real sector with more or less frequent reference to stress-testing. Alves (2005) and Åsberg Sommar and Shahnazarian (2008) employ cointegration techniques to find a significant relationship between the expected default frequencies published by Moody's and selected macro-variables. Aspachs et al. (2007) use panel VAR techniques to measure the impact of banks' default probabilities on the GDP variables of seven industrialized economies, while global VAR studies by Pesaran et al. (2006) and Castrén et al. (2008) establish links between global macroeconomic and financial factors and firm-level default rates.

A literature building upon standard monetary policy framework augmented by financial sector variables typically investigates the transmission channels from finance to the real economy. This includes Gilchrist and Zakrajšek (2011), Helbling et al. (2011) and Meeks (2012), who model the links from credit spreads to business cycle indicators, and de Bondt (1998, 1999), Favero et al. (1999), Altunbas et al. (2002), Hristov et al. (2012) and Milcheva (2013), who focus on the bank lending channel in Europe. Research on Central European economies includes Franta et al. (2011), who study the monetary transmission mechanism in the Czech Republic using a time-varying parameters VAR model, and Vilagi and Tamási (2011), who use Hungarian data and rely on a Bayesian structural VAR model to consider

3 *As DSGE models have only recently moved away from a highly stylized treatment of the financial sector, the present section does not provide a detailed treatment of the DSGE literature (for a survey see Brázdik et al., 2011).*

different types of credit shocks. Égert and MacDonald (2009) provide a detailed survey covering the Central and Eastern European region.

While the empirical literature spans a long list of macro-studies on feedback effects between the real economy and the banking sector, the role of non-linearities has been studied to a somewhat lesser extent. As the precise nature of the non-linearities in most situations is not known, authors have opted for different estimation frameworks. Among the most prominent are the threshold and Markov-switching VAR models (TVAR and MS-VAR respectively). A frequently cited study by Balke (2000) adopts a structural TVAR model with tight and regular credit regimes using the quarterly U.S. GDP data over 1960–1997. It finds a larger effect of monetary policy shocks on output in the "tight" credit regime and a more pronounced effect of contractionary monetary shocks compared to expansionary ones. Atanasova (2003) in a similar TVAR exercise for the UK supports the evidence on the asymmetry of monetary policy effects in credit constrained and unconstrained regimes as well as different output effects of monetary contractions and expansions. Finally, Calza and Sousa (2006) employ Balke's framework to investigate the role of credit shocks in the euro area and conclude that while present, the non-linearities and asymmetric responses seem to be less pronounced than those found by Balke (2000) for the U.S.

Kaufmann and Valderrama (2007), on the other hand, estimate an MS-VAR model for the euro area and the U.S. Depending on the regime, credit shocks have either a positive or an insignificant effect on the sector for both the euro area and the U.S. In another comparative study by Kaufmann and Valderrama (2008), focusing on German and UK bank lending, the authors apply the MS-VAR model to corporate and household sector data and conclude that shocks to real variables and interest rates impact differently on lending both across regimes within countries and across countries for a given regime.

Studies outside the TVAR and MS-VAR framework include higher-order approximation of a non-linear VAR by Drehmann et al. (2006). The authors relate aggregate credit risk in the UK to macroeconomic variables and find that credit risk responds strongly to macro developments, especially for large shocks. De Graeve et al. (2008) introduce an integrated micro-macro framework at the bank level based on German bank data linked to macroeconomic variables. Utilizing the parameters from a micro-based logit model in a macro VAR, the authors identify feedback effects between the banking sector and the real economy which are absent from the standard linear specification. A study of the euro area by Gambacorta and Rossi (2010) employing the asymmetric vector error correction model addresses possible asymmetries in the transmission mechanism and concludes that the effect of a monetary policy tightening on credit, GDP and prices is larger than the effect of a monetary policy easing.

A common feature of all the above-mentioned studies allowing for non-linearities is their focus on developed market economies. To the best of our knowledge, Çatik and Martin (2012) is the only published study focusing on the non-linear feedback effect from the real economy to the financial sector in an emerging market economy. Using TVAR, the study investigates changes to the macroeconomic transmission mechanism in Turkey after a change of monetary policy regime in the early 2000s and finds sharp changes in transmission mechanisms after 2004, when the reforms were implemented.

2 Methodology and Data

2.1 Threshold Bayesian VAR

The potentially non-linear nature of the feedback effects between the real and financial sectors is addressed within the threshold VAR framework.[4] The advantage of TVAR is that it allows for endogenous switching between different regimes as a result of shocks to the modelled variables. Furthermore, the framework is a convenient and straightforward tool for the treatment of certain types of non-linearities, such as regime switching or multiple equilibria (Balke, 2000). The selection of the threshold variable provides an intuitive reference to the source driving the non-linearities. Potential disadvantages include the omission of other drivers, especially in cases where the nature of the non-linearity is uncertain, and the linearity restriction within a given regime.

Given the limited length of the time series, I assume the existence of a single threshold value. Nonetheless, despite the available evidence of distinct feedback effects between regular and "tight" or "crisis" regimes, one should note that it is still not clear to what extent models allowing for single switching of parameters (ie. a unique threshold) capture the actual nature of the non-linearities.

The model contains three blocs of variables: (i) the domestic real sector and domestic monetary policy, as represented by the volume of industrial production, the price level and the short-term interest rate, (ii) the domestic financial sector, as measured by the volume of aggregate credit and the share of non-performing loans (NPL), and (iii) the external sector, proxied by the nominal exchange rate, the volume of foreign industrial production and the foreign interest rate. I use the threshold Bayesian VAR (TBVAR) framework with block restrictions on exogenous foreign industrial production and the CPI to account for the small open economy assumption.

$$y_t = \Pi_1 x_t I[y_{t-d}^{thr} < r] + \Pi_2 x_t I[y_{t-d}^{thr} \geq r] + \varepsilon_t$$
$$t = 1,..,T \qquad \varepsilon_t \approx NI_p(0,\Omega),$$

where stands for a p×1 vector of endogenous variables, $x_t = [1, y_{t-1}^1,.., y_{t-1}^p,.., y_{t-k}^1 .., y_{t-k}^p]'$ is a pk+1 vector of lagged endogenous variables, and Π_i is a p×(1+pk) matrix of coefficients with block exogeneity restrictions such that for n foreign and m domestic variables I have

$$\Pi_i = \begin{bmatrix} \Pi_{nn} & 0 \\ \Pi_{nm} & \Pi_{mm} \end{bmatrix}.$$

The block exogeneity assumption postulates that domestic shocks should not impact upon foreign covariates and has been employed by a number of studies on small open economies (e.g. Cushman and Zha, 1997; Zha, 1999; Maćkowiak, 2006; Havránek et al.,

4 *One possible alternative is the MS-VAR framework, which examines the exogenous (random) transitions between regimes. Time-varying coefficient VARs, on the other hand, are more suited to tracking gradual changes in transmission over time (Boivin et al., 2010).*

2010). The threshold selection in TBVAR accounts for potential volatility shifts across regimes, replacing a restrictive assumption of constant volatility in the TVAR model by Balke (2000) and his successors. Neglecting heteroscedasticity of shocks might cause changes in the magnitude of shocks to be confused with changes in the transmission mechanism (Franta et al., 2011).

The identification of shocks relies on recursive (Cholesky) decomposition. The ordering of the variables proceeds from a measure of economic activity, the price level, the interest rate, the exchange rate and a measure approximating the Czech financial sector (Goodhart and Hofmann, 2008; Havránek et al., 2010). For the foreign variables I assume ordering from output to the interest rate. I adopt normal-diffuse priors for the autoregressive coefficients following Kadiyala and Karlsson (1997):
$\pi_i \approx N(\widetilde{\pi}_i, \widetilde{V}_i^{pr})$ and $p(\Sigma_i) \propto \Sigma_i^{-(p+1)/2}$ for i=1,2,
where π_i is a vector of stacked coefficients of the matrix Π_i, $\widetilde{\pi}_i$, is a zero column vector with $p(1+pk)$ rows, $\widetilde{V}_i^{pr}$ are matrices with elements corresponding to the coefficients on their own lags equal to ϕ_0 / l^2 and elements on other lags equal to $\phi_0\phi_1\sigma_{i,q}^2/(l^2\sigma_{i,r}^2)$ $\sigma_{i,q}^2$ corresponds to the standard error of an AR(1) process of a variable q estimated separately for each variable. The values of the hyperparameters are set to $\phi_0 = 0.2$, $\phi_1 = 0{,}5$ and $\phi_2 = 10$.[5] The prior on the residual variance-covariance matrix is diffuse and independent of the priors on the autoregressive coefficients.

The prior on the threshold parameter is assumed to follow a uniform distribution on the interval $\left[r_{q=0.1}, r_{q=0.9}\right]$. Finally, the prior for the delay parameter follows a multinomial distribution with the probability of a particular delay equal to $1/d_0$. The likelihood function and the conditional posterior distributions for the individual parameters can be found in the Appendix. For the analysis of feedback between the real sector and the banking sector I computed generalized impulse response functions (GIRFs) based on Koop, Pesaran and Potter (1996). The non-linear GIRFs abandon the symmetry and history independence properties of linear impulse response functions and take into account the size (and sign) of the shock, as well as its evolutionary path (for more details see also Atanasova,, 2003). There would be little justification for applying the threshold model if no statistically significant evidence of non-linearities was present. Before embarking on the TBVAR estimation, I tested for non-linearities using the bootstrapping procedure by Hansen (1996). I ran 1,000 realizations of the standard F_n statistic and then obtained its empirical distribution by collecting the statistics over the grid space of the threshold values.[6]

2.2 Data

The sample has a monthly frequency spanning 2002m1–2012m3. The choice of model variables was guided by similar studies on a small open economy (e.g. Borys et al., 2009; Havránek et al., 2010; Franta et al., 2011). I prefer industrial production as a proxy for the level of economic activity given that more traditionally used measures such as real GDP

5 *For details see Canova (2007).*

6 *The original code for the testing procedure was obtained from Atanasova (2003).*

and the output gap are available only at quarterly frequency.[7] In the literature on real sector-finance feedback, industrial production was used, for example, by Atanasova (2003). The 3-month Pribor approximates the monetary policy rate and the cost of funds in the economy. The remaining variables in the standard monetary policy model for a small open economy include the price level and the nominal exchange rate. Aggregate nominal credit and non-performing loans represent alternative measures of banking sector performance. To save on degrees of freedom, each indicator is employed in a separate model. As the Czech Republic is a small open economy, one needs to control for the external environment. I do so by using the 3-month Euribor and the real GDP index of the 17 members of the European Union as of end-2002.

While empirical studies relying on the TVAR framework use a measure of the credit spread (Balke, 2000; Atanasova, 2003) or credit growth (Calza and Sousa 2006) as a threshold variable to gauge credit market conditions, the present study focusing on interest rate regimes instead employs the 3-month Pribor. The 3-month Pribor is a key determinant of the pricing of loans to the corporate sector and thus represents an approximate measure of credit market conditions as well as the overall state of the economy.[8, 9]

All level variables, i.e. industrial production, the price level, the exchange rate, credit and EU GDP, are expressed in natural logarithms and seasonally adjusted at the source where necessary. For the aggregate data on the real economy I use the information published by the Czech Statistical Office and the ARAD database maintained by the Czech National Bank. Variables capturing the external environment are from Eurostat and Bloomberg. Plots of all the series are available in the Appendix.

3 Empirical Results

The results of Hansen's (1996) procedure indicate a strong presence of non-linearities for both specifications with credit and the non-performing loan ratio (see Table 1). The estimated thresholds correspond to a 3-month Pribor of roughly 1.8% irrespective of specification.[10] As the 3-month Pribor has followed a decreasing trend since the early 2000s, the standard (or *high* hereafter) and accommodative (*low*) interest rate regimes also roughly divide the sample into two unequal time periods. The first period covers the economic expansion and sustained growth of the Czech banking and financial sector. The second (shorter) period spans the years when the post-Lehmann economic and financial crisis began to materialize in the Czech economy. Accordingly, this period has been marked by a steady decline in economic activity, by perturbations to the banking sector surrounded

7 *Borys, Horváth and Franta (2009) originally used quarterly data transformed into monthly frequency using the Hodrick-Prescott filter.*

8 *Kaufmann and Valderrama (2008) employ the MS BVAR framework and thus do not need to consider a threshold variable. Nonetheless, they likewise relate the two regimes identified to the general economic conditions.*

9 *A threshold VAR model with the credit spread as an alternative threshold variable developed by Konečný and Babecká-Kucharčuková (forthcoming) provides a parallel perspective on the interaction between the real and financial sector.*

10 *The mean of the 3-month Pribor totals 2.4%.*

by a high degree of uncertainty about future developments, and by extensive accommodative policies by the Czech National Bank.

Table 1: Threshold estimates and test for nonlinearity

Model	Estimated *r*	Hansen (1996)'s chi-square p-value
Credit	1.879	0.008
NPLs	1.803	0.013

The figures containing the empirical results present generalized impulse response functions conditional on the initial state (*high* or *low*) and the impulse response functions from a constant BVAR model without a threshold (*sym*). The size of shocks is defined as a positive standard deviation at time $t = 0$ and evaluated over a period of 36 months. I do not report results for a negative shock, as our estimates do not find significant asymmetry in the impulse responses, i.e. the impulse responses have broadly the same magnitude in the case of positive and negative shocks.[11,12] An increase in industrial production, the domestic price level and the 3-month Pribor are the domestic shocks, and an increase in EU industrial production, a rise in the 3-month Euribor and exchange rate depreciation are the external shocks.

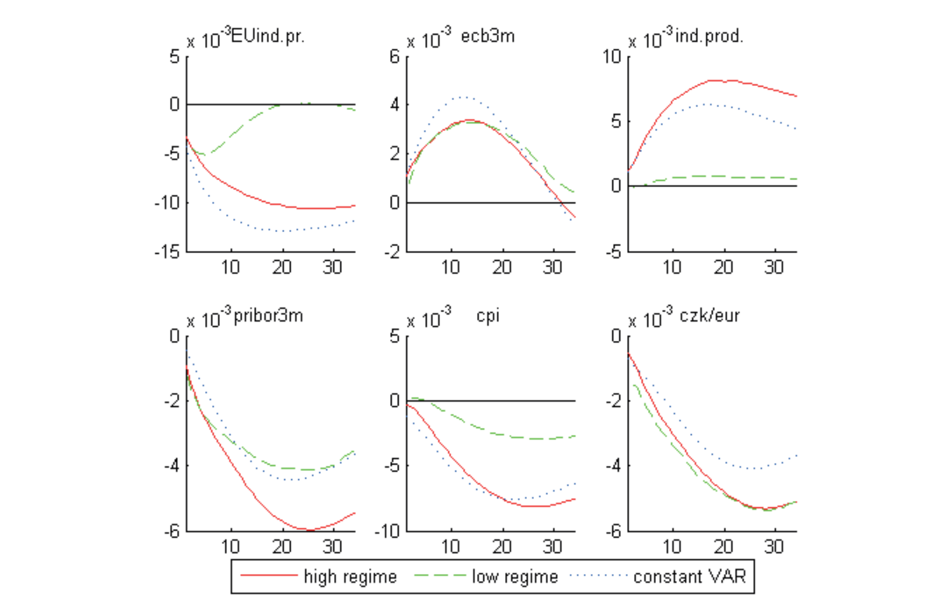
3.1 Responses of the Financial Sector

Figure 1 plots the impulse responses of credit to the three domestic and three external shocks. The responses in the low regime are in general subdued or at most roughly identical to the responses conditioned by the initial state in the *high* regime. The subdued response of aggregate credit to a positive shock to industrial production in the low regime might be partly due to the high uncertainty about the net present value of potential investment projects of firms and/or the future income streams of households and a resulting unwillingness to take on loans except during periods of above-average growth. The negative impact on credit of an increase in the price level and the interest rate in the *high* regime may be related to the tightness of firms' and households' budget constraints. An increase in the domestic price level might raise input costs more than revenues in a small open economy with a large proportion of exporting companies. Similarly, a higher price level reduces households' ability to service debt and reduces banks' willingness to lend. The more pronounced negative impact on credit in the *high* regime may relate to the initial conditions, given that the shock occurred at times when interest rate was already high.

11 *The impulse responses for a negative shock can be provided upon request.*

12 *Our results are consistent with Atanasova (2003), who did not find asymmetric responses for UK data. Balke (2000) and Gambacorta and Rossi (2010), on the other hand, find asymmetric effects for the U.S. and the euro area respectively.*

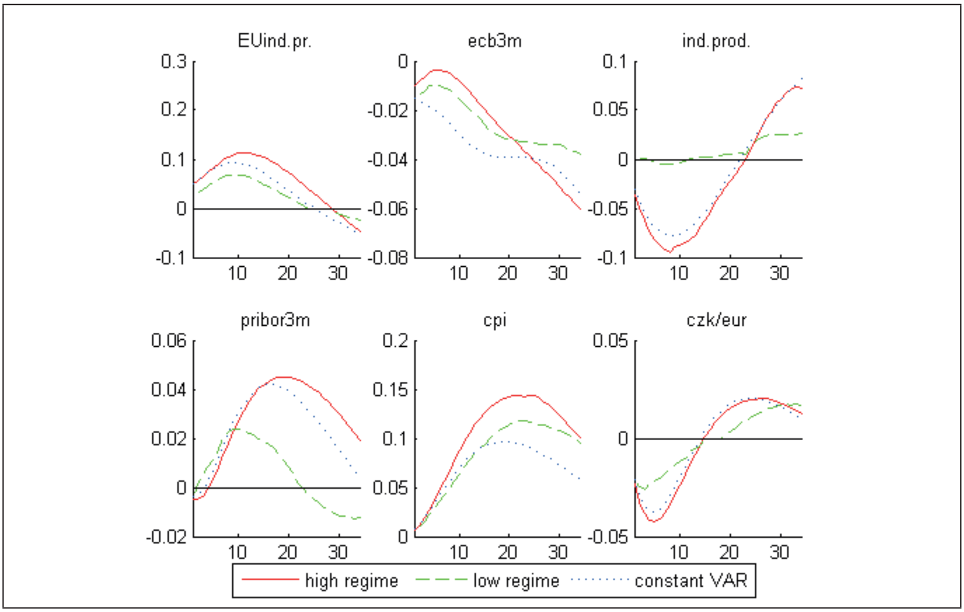
Figure 1: Impulse response functions from real sector variables to credit.



The negative response of credit to a positive shock to foreign industrial production reflects a negative correlation between European industrial production and domestic industrial output (and hence also credit) over the sample length. While Czech domestic industrial production caught up dramatically between 2002 and the end of 2007 against a background of stagnating industrial production in the EU17, the link has changed sharply in the wake of the recent financial crisis, with the correlation switching from -0.13 over 2002–2007 to 0.70 for the period 2008–2012m3. The negative response of aggregate credit to the exchange rate depreciation is largely similar across regimes and can be explained by the convergence process of the Czech economy, marked by steady appreciation of the Czech koruna, expansion of the Czech financial sector and corresponding growth of credit. Finally, given that the overwhelming majority of loans in the Czech financial system are denominated in domestic currency, the positive response to an increase in the Euribor is probably due to mechanisms other than the immediate costs of funds. As the response does not differ across regimes, the explanation might relate to convergence factors (similarly to the currency depreciation) rather than any irregularity in the functioning of the transmission mechanism.

Figure 2 plots the impulse responses of non-performing loans to the remaining model variables. The responses of non-performing loans in the low regime are again either similar to or less pronounced than those in the *high* regime. A one-time positive shock to industrial production might not lead to a stronger decline in NPLs in the *low* regime, a result possibly driven by the insufficient size of the economic upturn and the uncertainty about the length of the recovery. The behaviour of NPLs in the *high* regime, on the other hand, corresponds to the procyclical behaviour of NPLs in the financial system (Borio et al. 2001), where risks begin to materialize at the peak of the financial cycle, i.e. roughly two years after the positive output shock.

Figure 2: Impulse response functions from real sector variables to non-performing loans.

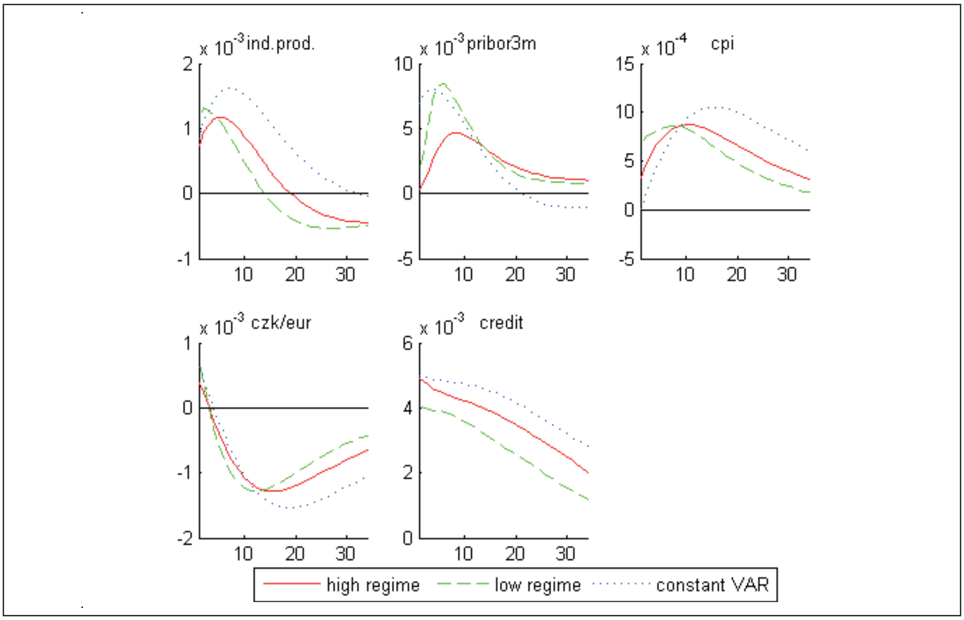


Price and interest rate increases impact upon the financial sector's performance not only through the extensive margin (the amount of credit extended), but also through the intensive margin (the debt service capacity of existing lenders). Complementing the picture from the response of the credit aggregates, the NPLs react more distinctly in the *high* regime. The EU17 industrial production index raises the NPLs of the financial sector along the argument of the relationship between the Czech and EU17 industrial production cycles discussed in Figure 1. The depreciation of the domestic currency boosts the profits of exporters and connected supply chains for an initial period of 15 months. The transitory impact of the shock is nonetheless not strong enough to support all the beneficiaries of the depreciation, and NPLs start to rise again in the second half of the response period.

3.2 Responses of the Real Economy

The response of the domestic economy and the exchange rate to the shocks to credit and NPLs are shown in Figure 3 and Figure 4. The impulse responses for credit in Figure 3 are of similar size and shape irrespective of regime, perhaps with the exception of the interest rate response. A positive shock to credit initially boosts industrial production over the first year and a half. The procyclical effect evaporates thereafter and the overall impact becomes zero or even slightly negative depending on the model specification (linear or threshold VAR). The negative impact from the TBVAR on industrial production might be linked to the misallocation of resources during the period of credit expansion, as banks' perceptions of credit risk are biased downwards (Borio et al. 2001), or could simply be a result of sampling variability, which is ignored in the construction of the generalized impulse responses. While not directly comparable, our finding differs from Balke (2000), who finds that a credit spread shock approximating credit market conditions has substantially larger effects on output growth when the system is in the tight credit regime. Calza and Sousa (2006) likewise report the response of real GDP to a positive shock to real loan growth to be somewhat bigger but less persistent in the low credit growth regime than in the high credit growth regime. While the impulse response from credit to industrial production in Figure 3 slightly resembles the story by Calza and Sousa (2006), I do not find the differences to be convincing enough to reach a similar conclusion.

Figure 3: Impulse response functions from credit to real sector variables.



The price level increases as more credit flows into the economy. The positive response of the interest rate tends to reflect the efforts of the monetary authority to curb the inflationary pressures spurred by the credit inflows. The policy response is smaller in the *high* regime, where the initial interest rate is already elevated, than it is in the *low* regime, where the rate is more favourable and there is more scope for monetary policy reaction. The exchange rate appreciation following a positive shock to credit can be explained by the convergence process of the Czech economy, similarly to the reverse direction from the exchange rate to credit.

Figure 4: Impulse response functions from non-performing loans to real sector variables.

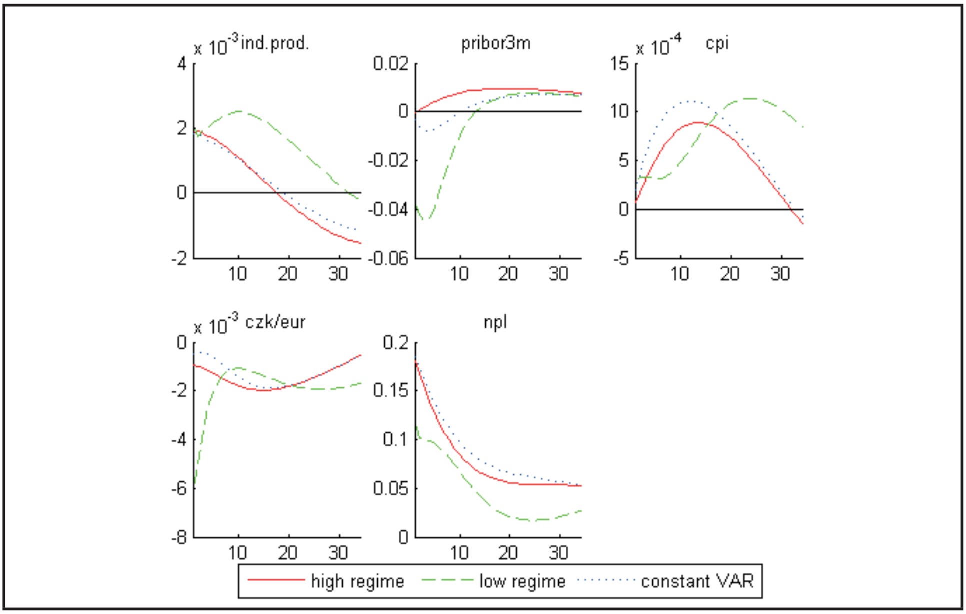


Figure 4 reports the impulse responses for a one-time positive shock raising NPLs by one standard deviation. Contrary to the impact of the credit shock, the initial state impacts upon both the size and timing of the impulse responses. The increase in industrial production and the gradual rise in prices might be explained by cyclical considerations as output and prices rebound from a cyclical trough. In the *low* regime, the responses tend to be more pronounced and the output recovery more delayed. In the low regime, uncertainties and agents' confidence in the future prospects of the economy come into play and the monetary policy response thus needs to be more vigorous.[13] The exchange rate depreciation is also consistent with the cyclical explanations of the NPL shock.

Conclusions

Our results indicate that the omission of non-linearities might lead to an imprecise understanding of the interactions and transmission mechanisms between the real economy and the financial sector. I combine the TBVAR framework with information on credit and non-performing loans as measures of the stance of the financial sector in an attempt to provide a more general picture of the feedback in the specific setting of a small open economy. Despite the absence of asymmetries in the effects of positive and negative shocks, the magnitude and, less frequently, the timing of the impulse responses differ in the standard and accommodative interest rate regimes. The uncertainty and lack of confidence in the accommodative (*low*) regime weakens the incentives for economic agents to take on loans and reduces the cyclicality of the financial sector. As the financial sector in the Czech Republic is largely bank-based and funded predominantly by domestic deposits, the di-

13 The positive yet relatively small increase in the interest rate in the high regime is somewhat surprising and is perhaps a result of sampling variability.

rect impact of foreign factors on lending seems to be rather limited and credit volumes tend to be affected indirectly through the situation within the production sector of the economy. The responses to foreign shocks thus appear to reflect the convergence path of the Czech economy over the longer term. The complementary investigation of non-performing loans indicates that the procyclicality of NPLs in the *low* regime (represented mostly by the economic environment of the current crisis) is lower. The recovery from the low regime thus needs to be sufficiently robust to translate into lower NPLs.

While the financial sector feeds back into the real sector, the responses to credit shocks are roughly similar across regimes, with the exception of the policy reaction of the monetary authority, which is more pronounced in the low regime. This finding differs from the results of other studies employing the threshold VAR framework, which report asymmetric feedback from credit to the real economy. Asymmetries are nonetheless present in the responses of the real economy to shocks to NPLs, which differ in both size and timing and are probably aligned with cyclical factors.

References

ALTUNBAS, Y., O. FAZYLOV, and P. MOLYNEUX (2002) Evidence on the Bank-lending Channel in Europe. *Journal of Banking and Finance* 26/11:2093-2110.

ALVES, I. (2005) Sectoral Fragility: Factors and Dynamics. In *Investigating the Relationship Between the Financial and Real Economy*, BIS Papers 22: 450–480.

ÅSBERG SOMMAR, P., and H. SHAHNAZARIAN (2008) Macroeconomic Impact on Expected Default Frequency. *Sveriges Riksbank Working Paper Series* 219.

ASPACHS, O., C. A. E. GOODHART, D. P. TSOMOCOS, and L. ZICCHINO (2007) Towards a Measure of Financial Fragility. *Annals of Finance* 3/1: 37–74.

ATANASOVA, C. (2003) Credit Market Imperfections and Business Cycle Dynamics: A Nonlinear Approach. *Studies in Nonlinear Dynamics & Econometrics* 7/4, Article 5.

BALKE, N. S. (2000) Credit and Economic Activity: Credit Regimes and Nonlinear Propagation of Shocks. *Review of Economics and Statistics* 82/2: 344–349.

BERNANKE, B. S., and A. S. BLINDER (1988) Credit, Money, and Aggregate Demand. *American Economic Review* 78/2: 435–439.

BERNANKE, B. S., and M. GERTLER (1995) Inside the Black Box: The Credit Channel of Monetary Policy Transmission. *Journal of Economic Perspectives* 9/4: 27–48.

BIS (2011) The Transmission Channels Between the Financial and Real Sectors: A Critical Survey of the Literature. *BIS Working Paper* 18.

BOIVIN, J., M. T. KILEY, and M. S. MISHKIN (2010) How Has the Monetary Transmission Mechanism Evolved Over Time? *NBER Working Paper* 15879.

BORIO, C. E. V., C. FURFINE, and P. W. LOWE (2001) Procyclicality of the Financial System and Financial Stability: Issues and Policy Options. In *Marrying the Macro and Microprudential Dimensions of Financial Stability*, BIS Papers 1, Basel.

BORYS, M., R. HORVÁTH, and M. FRANTA (2009) The Effects of Monetary Policy in the Czech Republic: An Empirical Study. *Empirica* 36/4: 419–443.

BRÁZDIK, F., M. HLAVÁČEK, and A. MARŠÁL (2011) Survey of Research on Financial Sector Modeling Within DSGE Models: What Central Banks Can Learn from It. *Czech National Bank Research and Policy Note* 3/2011.

BRUNNERMEIER, M. K., and L. H. PEDERSEN (2009) Market Liquidity and Funding Liquidity. *Review of Financial Studies* 22/6: 2201–2238.

CALZA, A., and J. SOUSA (2006) Output and Inflation Responses to Credit Shocks: Are There Threshold Effects in the Euro Area? *Studies in Nonlinear Dynamics & Econometrics* 10/2: 1–21.

CANOVA, F. (2007) *Methods for Applied Macroeconomic Research*. Princeton University Press. Princeton University Press.

CASTRÉN, O., S. DÉES, and F. ZAHER (2008) Global Macro-Financial Shocks and Expected Default Frequencies in the Euro Area. *ECB Working Paper* 875.

ÇATIK, A. N., and C. MARTIN (2012) Macroeconomic Transitions and the Transmission Mechanism: Evidence from Turkey. *Economic Modelling* 29/4: 1440–1449.

CHEN, C. W. S., and J. C. LEE (1995) Bayesian Inference of Threshold Autoregressive Models. *Journal of Time Series Analysis*, 16/5: 483-492.

CUSHMAN, D. O., and T. ZHA (1997) Identifying Monetary Policy in a Small Open Economy under Flexible Exchange Rates. *Journal of Monetary Economics* 39/3:433-448.

DE BONDT, G. J. (1998) Credit Channels in Europe: Bank-level Panel Data Analyses, *De Nederlandsche Bank Research Memorandum WO&E* 567.

DE BONDT, G. J. (1999) Credit Channels in Europe: Cross-country Investigation, *De Nederlandsche Bank Research Memorandum WO&E*, 569.

DE GRAEVE, F., T. KICK, and M. KOETTER (2008) Monetary Policy and Financial Instability: An Integrated Micro-Macro Approach. *Journal of Financial Stability* 4/3: 205–231.

DREHMANN, M., A. PATTON, and S. SORENSEN (2006) Corporate Defaults and Large Macroeconomic Shocks. Bank of England, mimeo.

ÉGERT, B., and R. MACDONALD (2009) Monetary Transmission Mechanism in Central and Eastern Europe: Surveying the Surveyable. *Journal of Economic Surveys* 23: 277

FAVERO, C. A., F. GIAVAZZI, and L. FLABBI (1999) The Transmission Mechanism of Monetary Policy in Europe: Evidence from Banks' Balance Sheets. *NBER Working Paper* 7231.

FRANTA, M., R. HORVÁTH, and M. RUSNÁK (2011) Evaluating Changes in the Monetary Transmission Mechanism in the Czech Republic. *CNB Working Paper* 13.

GAMBACORTA, L., and C. ROSSI (2010) Modelling Bank Lending in the Euro Area: A Nonlinear Approach. *Applied Financial Economics* 20/14: 1099–1112.

GILCHRIST, S., and E. ZAKRAJŠEK (2011) Monetary Policy and Credit Supply Shocks. *IMF Economic Review* 59: 195–232.

GOODHART, C., and B. HOFMANN (2008) House Prices, Money, Credit, and the Macroeconomy. *Oxford Review of Economic Policy* 24/1:180-205.

GOODHART, C. A. E., B. HOFMANN, and M. SEGOVIANO (2004) Bank Regulation and Macroeconomic Fluctuations. *Oxford Review of Economic Policy* 20/4: 591–615.

HAVRÁNEK, T., R. HORVÁTH, and J. MATĚJŮ (2010) Do Financial Variables Help Predict Macroeconomic Environment? *CNB Working Paper* 6.

HELBLING, T., R. HUIDROM, M. A. KOSE, and C. OTROK (2011) Do Credit Shocks Matter? A Global Perspective. *European Economic Review* 55/3: 340–353.

HRISTOV, N., O. HÜLSEWIG, and T. WOLLMERSHÄUSER (2012) Loan Supply Shocks During the Financial Crisis: Evidence for the Euro Area. *Journal of International Money and Finance* 31/3: 569–592.

KADIYALA, K.R., and S. KARLSSON (1997) Numerical Methods for Estimation and Inference in Bayesian VAR-Models. *Journal of Applied Econometrics* 12:99-132.

KAUFMANN, S., and M. T. VALDERRAMA (2007) The Role of Credit Aggregates and Asset Prices in the Transmission Mechanism: A Comparison Between the Euro Area and the US. *ECB Working Paper* 816.

KAUFMANN, S., and M. T. VALDERRAMA (2008) Bank Lending in Germany and the UK: Are There Differences between a Bank-Based and a Market-Based Country? *International Journal of Finance and Economics* 13: 266–279.
KONEČNÝ, T., and O. BABECKÁ-KUCHARČUKOVÁ (2013) Evaluating Feedback Links Between the Financial and Real Sectors in a Small Open Economy: The Case of the Czech Republic *ČNB Working Paper*, forthcoming.
KOOP, G., M. PESARAN, and S. POTTER (1996) Impulse Response Analysis in Nonlinear Multivariate Models, *Journal of Econometrics*, 74:119-148.
MAĆKOWIAK, B. (2006) How Much of the Macroeconomic Variation in Eastern Europe is Attributable to External Shocks? *Comparative Economic Studies* 48/3: 523-544.
MEEKS, R. (2012) Do Credit Market Shocks Drive Output Fluctuations? Evidence from Corporate Spreads and Defaults. *Journal of Economic Dynamics and Control* 36:568–584.
MEH, C., and K. MORAN (2010) The Role of Bank Capital in the Propagation of Shocks. *Journal of Economic Dynamics and Control* 34:555–576.
MILCHEVA, S. (2013) A Bank Lending Channel or a Credit Supply Shock? *Journal of Macroeconomics*, accessed April 20, http://dx.doi.org/10.1016/j.jmacro.2013.03.004.
PESARAN, M. H., T. SCHUERMANN, B.-J. TREUTLER, and S. M. WEINER (2006) Macroeconomic Dynamics and Credit Risk: A Global Perspective. *Journal of Money, Credit, and Banking* 38/5: 1211–1261.
STRAHAN, P. (2008) Liquidity Production in 21st Century Banking. *NBER Working Papers* 13798.
VAN DEN HEUVEL, S. J. (2002) Does Bank Capital Matter for Monetary Transmission? *Federal Reserve Bank of New York Economic Policy Review* 8/1: 259–265.
VILAGI, B., and B. TAMÁSI (2011) Macroprudential Shocks in an SVAR Framework in Hungary. Work in progress.
WAGNER, W. (2010) Diversification at Financial Institutions and Systemic Crises. *Journal of Financial Intermediation* 19: 373-386.
ZHA, T. (1999) Block Recursion and Structural Vector Autoregressions. *Journal of Econometrics* 90:291-316.

Contact address

Ing. Tomáš Konečný, M.A. et M.A., Ph.D.
Czech National Bank / Česká národní banka
(tomas.konecny@cnb.cz)

Appendix

The likelihood function for the threshold BVAR follows Kadiyala and Karlsson (1997):

$$L(\Pi_1,\Pi_2,\Sigma_1,\Sigma_2,r,d\,|\,Y)\propto|\Sigma_1|^{-\frac{n_1}{2}}|\Sigma_2|^{-\frac{n_2}{2}}\exp\left\{-\frac{1}{2}tr\left[\sum_{i=1}^{2}(Y_i-X_i\Pi_i)^{'}\Sigma_i^{-1}(Y_i-X_i\Pi_i)\right]\right\}=$$

$$=|\Sigma_1|^{-\frac{n_1}{2}}|\Sigma_2|^{-\frac{n_2}{2}}$$

$$\exp\left\{-\frac{1}{2}\sum_{i=1}^{2}\left(\pi_i-\pi_i^{OLS}\right)^{'}\left(\Sigma_i^{-1}\otimes X_i^{'}X_i\right)\left(\pi_i-\pi_i^{OLS}\right)-\frac{1}{2}tr\left[\sum_{i=1}^{2}\Sigma_i^{-1}\left(Y_i-X_i\Pi_i^{OLS}\right)^{'}\left(Y_i-X_i\Pi_i^{OLS}\right)\right]\right\}$$

$$=N\left(\pi_i\,|\,\pi_i^{OLS},\Sigma_i\otimes\left(X_i^{'}X_i\right)^{-1}\right)\times iW\left(\Sigma_i\,|\left(Y_i-X_i\Pi_i^{OLS}\right)^{'}\left(Y_i-X_i\Pi_i^{OLS}\right),n_i-1+pk-1\right),$$

where $n_1=\sum_{t=1}^{T-k}I_{\{y_i^{thr}\}}$ and $n_2=T-k-n_1$ are parameters dependent on the threshold value r.

For the estimation of the autoregressive coefficients and the residual variance-covariance matrix I employ the Gibbs sampler:

1) AR coefficients:

$$\pi_i\,|\,\Sigma_i,r,d,Y\approx N\left(\pi_i^{post},\left(\left(V_i^{prior}\right)^{-1}+\Sigma_i^{-1}\otimes X_i^{'}X_i\right)^{-1}\right),$$

$$\text{where }\pi_i^{post}=\left(\left(V_i^{prior}\right)^{-1}+\Sigma_i^{-1}\otimes X_i^{'}X_i\right)^{-1}\left(\left(V_i^{prior}\right)^{-1}\pi_i^{prior}+\left(\Sigma_i^{-1}\otimes X_i^{'}X_i\right)\pi_i^{OLS}\right)^{-1}$$

2) Residual variance matrix

$$\Sigma_i^{-1}\Big|\pi_i,Y,r,d\approx W\left(\left[\left(Y_i-X_i\Pi_i^{OLS}\right)^{\prime}\left(Y_i-X_i\Pi_i^{OLS}\right)+\left(\Pi_i-\Pi_i^{OLS}\right)^{\prime}X_i^{'}X_i\left(\Pi_i-\Pi_i^{OLS}\right)\right]^{-1},n_i\right)$$

3) Threshold value

For the estimation of the conditional posterior probability of the threshold *r* I employ the Metropolis-Hastings algorithm following Chen and Lee (1995):

4) Delay parameter

The conditional posterior follows a multinomial distribution with probability.

$$p(d\,|\,\Pi_1,\Pi_2,\Sigma_1,\Sigma_2,d,Y)=\frac{L(\Pi_1,\Pi_2,\Sigma_1,\Sigma_2,r,d\,|\,Y)}{\sum_{d=1}^{d_0}L(\Pi_1,\Pi_2,\Sigma_1,\Sigma_2,r,d\,|\,Y)}.$$

Tables and Figures:

Table 1: Threshold estimates and test for nonlinearity

Model	Estimated r	Hansen (1996)'s chi-square p-value
Credit	1.879	0.008
NPLs	1.803	0.013

Figure 1: Impulse response functions from real sector variables to credit.

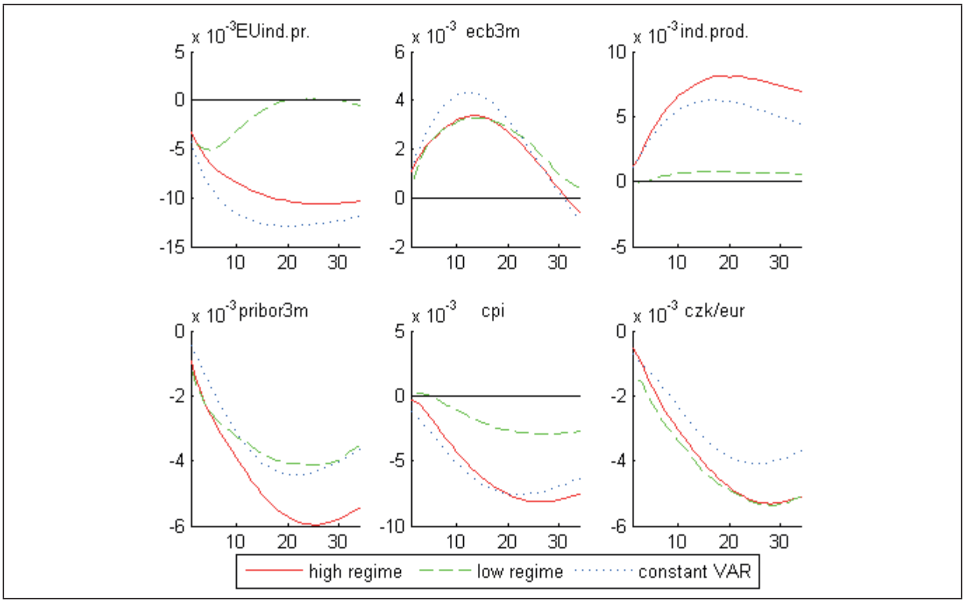


Figure 2: Impulse response functions from real sector variables to non-performing loans.

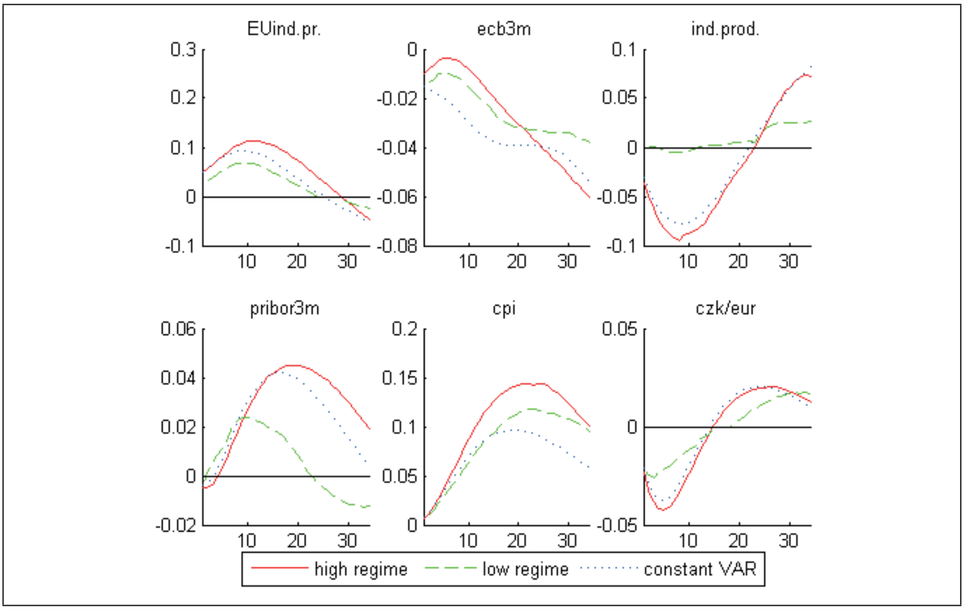


Figure 3: Impulse response functions from credit to real sector variables.

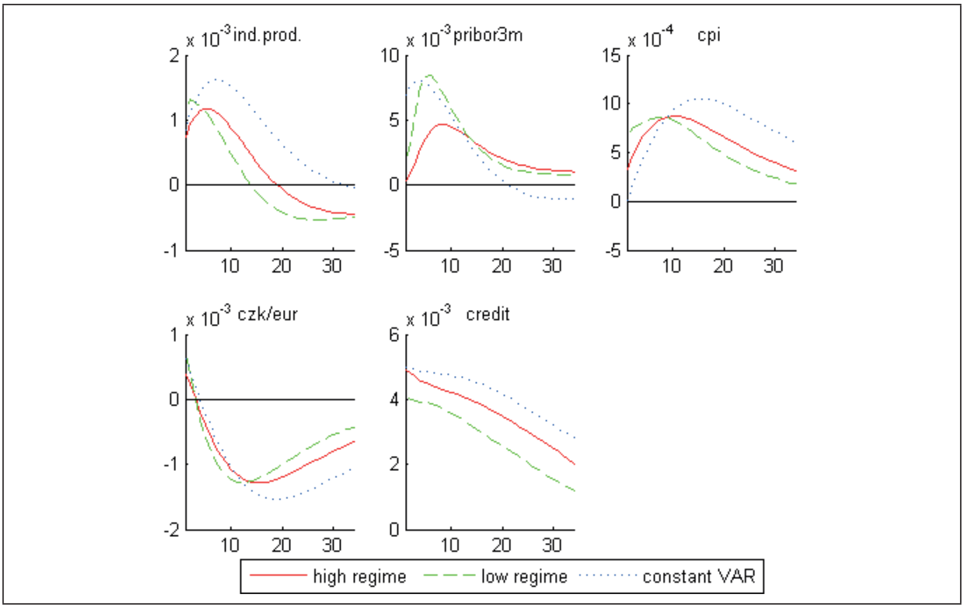


Figure 1A: Plots of model variables.