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CREDIT SPREADS AND THE LINKS BETWEEN THE FINANCIAL AND REAL SECTORS IN A SMALL OPEN ECONOMY

THE CASE OF THE CZECH REPUBLIC

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In 2014 all ECB publications feature a motif taken from the €20 banknote.

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Abstract

Various approaches have been employed to explore the possibility of non-linear feedback between the real and financial sector. The present study focuses on the impact of real shocks on selected financial sector indicators, and the responses of the real economy to impulses emanating from the financial sector. We estimate the threshold Bayesian VAR with block restrictions and the credit spread as a threshold variable using the example of the Czech Republic. We find that while there is no evidence of asymmetric effects across positive and negative shocks, the responses of the financial sector to real shocks tend to differ in low and high credit spread regimes. Responses in the opposite direction (i.e. from the financial sector to the real economy) are procyclical and similar irrespective of regime. A positive shock to credit and a negative shock to the NPL increase industrial production over the entire time horizon. The direct impact of foreign factors on lending seems to be rather limited.

JEL classification: E51, C15, C32

Keywords: credit, small open economy, non-linearities

Nontechnical Summary

The high vulnerability of financial markets worldwide and its adverse effects on real economic activity have been a subject of much debate in recent years. For a rigorous assessment of the impact of one sector on another it is crucial not only to identify possible transmission channels, but also to know whether or not this relationship is linear. Various approaches have been employed to study the possibility of non-linear feedback links between the real and financial sector. 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.

We use a small empirical model which is generally applied in studies focused on the transmission mechanism in a small open economy and augment it by financial sector aggregates: aggregate credit and non-performing loans (NPLs). The model is estimated as a Bayesian VAR with an endogenous threshold. By allowing for endogenous regime shifts, we impose greater flexibility than in the case of a linear system, so that the potential non-linearities in the transmission of shocks from and to the financial system can be evaluated. The endogenous threshold is determined by the tightness of the credit market conditions, specifically by the value of the credit spread between the rate on newly issued loans and the Pribor rate. Based on this threshold two regimes are identified: high (large credit spread) and low (small credit spread). The model is estimated for the Czech Republic on monthly data over the period January 2004–March 2012.

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. 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 high and low credit spread regimes. We find that shocks to the financial sector matter for the real economy. A positive shock to credit and a negative shock to NPLs support industrial production over the entire time horizon, yet the responses to credit shocks do not differ substantially across credit spread regimes. 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 likewise absent from the responses of the real economy to shocks to NPLs.

Turning to shock transmission in the opposite direction, i.e. to financial variables from the real sector, we find the responses to credit shocks are roughly similar across regimes, with the exception of the monetary policy shock, which is more pronounced when the credit spread is small (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.

Finally, the direct impact of foreign factors on lending seems to be rather limited and credit volumes tend to be affected more through the domestic production sector of the economy. One possible explanation of this result is the fact that the financial sector in the Czech Republic is largely bank based and funded predominantly by domestic deposits in the home currency.

1. Introduction

The persisting climate of financial market vulnerability in Europe has raised pressing questions about the viable options for policymakers and the operability of “traditional” policy instruments. Given the recent crisis and post-crisis experience, the debate has from the outset centred on the interactions between the real and financial sectors. 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. The study explores a simple reduced-form model and takes separate perspectives on 1) the responses of the financial sector to real shocks and 2) the impact of financial shocks on the real economy. It should thus be understood as an initial step towards a more structured assessment of nonlinearities in the Czech economy. Our model incorporates a simple form of non-linearity. By allowing for regime shifts depending on credit market conditions, we impose greater flexibility than in the case of a linear system, so that the potential non-linearities in the transmission of shocks from the financial system can be evaluated. The second contribution is methodological, as we 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.

[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).

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.

2. 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 the standard monetary policy framework augmented by financial sector variables typically investigates the monetary policy mechanisms and 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 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

[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).

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.

3. Methodology and data

3.1 Bayesian threshold 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

[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).

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, we 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 (i.e. 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 (NPLs), and (iii) the external sector, proxied by the nominal exchange rate, the volume of foreign industrial production and the foreign interest rate. We use the Bayesian threshold VAR (BTVAR) 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 y_t stands for a $p \times 1$ 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 $p\times(1+pk)$ matrix of coefficients with block exogeneity restrictions such that for n foreign and m domestic variables we 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 on 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., 2010). The threshold selection in BTVAR accounts for potential volatility shifts across regimes, replacing the 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 (Primiceri, 2005).

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 we assume ordering from output to the interest rate.

We adopt normal-diffuse priors for the autoregressive coefficients following Kadiyala and Karlsson (1997), which are commonly used in the literature on Bayesian VARs:[5]

[5][5] See Koop and Korobilis 2010 for an excellent survey of Bayesian macroeconometrics, and Giannone et al. (2012) for a discussion specifically on prior selection.

$\pi_i \approx N(\tilde{\pi}_i, \tilde{V}_i^{pr})$ 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, $\tilde{\pi}_i$ is a zero column vector with *p(1+pk)* rows, $\tilde{V}_i^{pr}$ 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 $\phi_0 = 0.2$, $\phi_1 = 0.5$.[6] 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 $\left[r_{\underline{q}=0.1}, r_{\overline{q}=0.9}\right]$, where $\underline{q}$ represents the 10% quantile and $\overline{q}$ the 90% quantile of the threshold variable *r*. Employing the simple Metropolis-Hastings algorithm (e.g. Chen and Lee, 1995; Koop and Potter, 2014), the candidate draws r^* are accepted with the probability $p = \min\left(1, \frac{f(r^*)}{f(r)}\right)$, where $f(\cdot)$ is the log-likelihood function.[7] Finally, the prior for the delay parameter accounts for possible lagged effects of the shift to another regime and is assumed to follow a multinomial distribution generating the probability of a particular delay equal to $1/d_0$, where d_0 represents the maximum number of delay periods considered.

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 we 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. The practical computation of the GIRFs is based on the repeated simulation of impulse responses with and without the initial shock to the i-th variable of concern. In particular, after the specification of the initial shock to the i-th variable corresponding to one standard deviation, we pick a history Ω_{t-1}^r of the *m*-dimensional time series over the period *k*. We then impose a sequence of shocks of the same length *k* drawn with replacement from the estimated BTVAR residuals and calculate the implied system dynamics. In the next step, we impose an alternative sequence of shocks, which is identical to the previous one except for the addition of one standard deviation to the relevant variable in period 0, and again simulate the implied impulse responses. The GIRF is then the difference between the two simulated paths. The whole procedure was repeated for R = 1,000 histories Ω_{t-1}^r and B = 200 drawn shocks and the ultimate GIRF was calculated as the average impulse response function over the BR rounds.[8]

There would be little justification for applying the threshold model if no statistically significant evidence of non-linearities was present. Before embarking on the BTVAR estimation, we tested for non-linearities using the procedure by Hansen (1996). The procedure uses the standard F_n-statistic

[6] A detailed exposition is provided in Canova (2007).
[7] See the Appendix for the likelihood function of the threshold parameter.
[8] For more details see also Atanasova (2003).

$$F_n = \sup_{r \in \Gamma_n} F_n(r)$$

which, given that the threshold r is not identified under the H_0, does not have the chi-square distribution. The appropriate asymptotic distribution can nonetheless be approximated by a bootstrap procedure. We ran 1,000 realizations of the standard F_n statistic under the null hypothesis of symmetry for each grid point and then obtained its empirical distribution by collecting the statistics over the grid space of the threshold values.[9]

3.2 Data

The sample has a monthly frequency spanning 2004m1–2012m3. The choice of model variables was guided by similar studies on a small open economy (e.g. Borys-Morgese et al., 2009; Havránek et al., 2010; Franta et al., 2011). We prefer industrial production as a proxy for the level of economic activity given that more traditionally used measures such as real GDP and the output gap are available only at quarterly frequency.[10] 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. We do so by using the 3-month Euribor and the real GDP index of the 17 members of the European Union following the Eurostat definition as of end-2012.

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. Balke (2000) employs three alternative indicators of credit market conditions, namely the commercial paper to T-bill spread, the mix of bank loans and commercial paper in firms' total external finance, and the difference between the growth rates in the short-term debt of small and large manufacturing firms. Atanasova (2003) uses the corporate bond spread defined as the redemption yield on ten-year investment-grade corporate bonds minus the equivalent maturity yield on risk-free government debt.[11]

The present study cannot rely on a measure based on corporate bond spread given the thin corporate bond market in the Czech Republic. Instead, we define credit spread as a difference of the average rate charged on newly issued loans and 1-year Pribor rate. The average rate is calculated as a weighted average of rates applied to corporate and household loans, with volumes of newly issued corporate and household loans as respective weights. The Pribor rate is a key reference rate for the cost of funds on the interbank market and serves as an approximation to a risk-free interest rate.[12]

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[9] The original Gauss code for the testing procedure was obtained from Atanasova (2003).

[10] Borys-Morgese, Horváth and Franta (2009) originally used quarterly data transformed into monthly frequency using the Hodrick-Prescott filter.

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

[12] We do not adopt the Czech government debt yield as an alternative risk-free rate given the impact of recent sovereign crisis on the volatility of sovereign bonds across Europe.

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 we 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.

4. 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 credit spread of 3.28% for the BTVAR specification with the credit variable and 2.73% for the specification with NPL.[13] The estimated threshold from the specification with credit highlights the importance for credit developments of the (postponed) advent of the post-Lehmann economic crisis in February 2009 and the following two and a half years of pronounced economic downturn (Figure 1). The threshold from the BTVAR with NPLs as the financial sector variable, on the other hand, points to a pronounced impact of the financial crisis on banks' credit losses extending over the whole post-2009 period (Figure 2).

<Figure 1 about here>

<Figure 2 about here>

<Table 1 about here>

The figures containing the empirical results present generalized impulse response functions conditional on the initial state (*high* or *low* credit spread regime) and the impulse response functions from a symmetric BVAR model without a threshold (benchmark VAR). The size of the permanent shocks corresponds to a positive standard deviation at time $t = 0$. The impulse responses are evaluated over a period of 36 months. We 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.[14,15] 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.

4.1 Responses of the financial sector

Figure 3 plots the impulse responses of credit to the three domestic and three external shocks. The comparison of the impulse responses from the benchmark VAR and BTVAR provide a mixed picture, with some responses showing a markedly different level and, in the case of CPI, even direction. The subdued response of aggregate credit to a positive shock to industrial production in the *high* credit spread regime might be partly due to the 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. The credit response to the interest

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[13] The mean of the credit spread is 2.8%.

[14] The impulse responses for a negative shock can be provided on request.

[15] 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.

rate shock is, as expected, negative and more pronounced in the threshold specification as compared to the benchmark linear VAR.[16]

Our results in some cases indicate notably different GIRFs as compared to the baseline VAR. For example, the negative response of credit to a positive shock to CPI from the benchmark VAR is somewhat counterintuitive given that credit is expressed in nominal terms.[17] The more flexible BTVAR framework, on the other hand, generates responses that are in line with expectations.

<Figure 3 about here>

Similarly, the responses of credit to a positive shock to foreign industrial production vary depending on the estimation framework. While the benchmark VAR indicates a positive and long lasting reaction of credit, the BTVAR results suggest a mild and only transitory response path reverting quickly to zero.[18] 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 probably reflects a systemic response of the European Central Bank to inflation pressures rather than shifts in the costs of funds.[19]

The uniformly negative response of aggregate credit to the exchange rate depreciation can be explained by the convergence process of the Czech economy during the sample period, marked by steady appreciation of the Czech koruna, expansion of the Czech financial sector and corresponding growth of credit.

Figure 4 plots the impulse responses of non-performing loans to the macroeconomic variables. The responses of non-performing loans are qualitatively the same regardless of the estimation framework and initial regime, yet in the case of domestic macroeconomic variables show a distinctly muted pattern in the BTVAR setup. A one-time positive shock to industrial production leads to intuitively negative and transitory responses from the threshold estimates as compared to the benchmark VAR, implying a positive effect over the long term. The tamed results in particular in the *high* credit spread regime might possibly be driven by the insufficient size of the economic upturn and the uncertainty about the length of the recovery over the crisis years.

<Figure 4 about here>

Price and interest rate increases are likewise notably less pronounced using the BTVAR estimates (similarly to the case of industrial production). Conforming to expectations, NPLs

[16] The results indicate a relatively high sensitivity of credit to interest rate shifts. Table 1A in the Appendix lists the peak responses of credit and non-performing loans with respect to industrial production and the 3-month Pribor rate respectively.

[17] 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.

[18] Given the relatively small size of the impulse responses from the BTVAR, the counterintuitive negative sign in this case might point to low precision of the estimates rather than model misspecification.

[19] Foreign inflation has not been included in our model due to degrees of freedom considerations.

initially rise following an interest rate hike.[20] A shock to CPI might proxy for the worsening economic environment with negative repercussions in the level of NPLs, especially so in the *high* regime. The depreciation of the domestic currency boosts the profits of exporters and connected supply chains, but the impact of the shock for the BTVAR impulse responses is nonetheless not strong enough to support all the beneficiaries of the depreciation, and the effect on NPLs fades away in the second half of the response period.

A shock to the EU17 industrial production index lowers NPLs, but to a lower extent in the *high* regime. The negative response of NPLs to the Euribor interest rate rise conforms to the systemic reaction of the ECB to rising inflation.

4.2 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 5 and Figure 6.[21] The impulse responses for credit in Figure 5 are of similar size and shape irrespective of regime. A positive shock to credit boosts industrial production over the entire time horizon. The benchmark VAR generates a strong procyclical effect over the first twelve months, which nonetheless returns to the response levels obtained from the BTVAR framework. The response of industrial production tends to be somewhat more pronounced in the *low* as opposed to *high* credit spread regime. 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.

<Figure 5 about here>

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 nonetheless smaller in the BTVAR framework in comparison to the benchmark case, where the initial interest rate reaction is elevated. The exchange rate appreciation following a positive shock to credit can be explained by the convergence process of the Czech economy during the sample period, similarly to the impulse response function from the exchange rate to credit.

<Figure 6 about here>

Finally, Figure 6 reports the impulse responses for a one-time positive shock raising NPLs by one standard deviation. The responses from the BTVAR are unanimously milder in comparison to the benchmark model and do not differ across regimes. Furthermore, the threshold responses imply zero or close to zero long-term effects of an increase in NPLs on the macroeconomy. The results indicate a negative path for industrial production and lower inflation, as well as depreciation of the currency.

5. Conclusions

[20] See Table 1A for the (purely indicative) quantification of a 10 bps rise in the interest rate.
[21] Table 2A in the Appendix lists the peak responses of industrial production and the interest rate with respect to credit and non-performing loans respectively.

We combine the BTVAR 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. The estimated thresholds obtained from BTVAR identify different cut-off values for the credit spread, indicating the importance of the initial two and a half years of the crisis for credit developments and the pronounced impact of the financial crisis on banks' credit losses extending over the whole post-2009 period.

Our results indicate that the omission of non-linearities might lead to a possibly simplistic understanding of the interactions and transmission mechanisms between the real economy and the financial sector. In particular, the magnitude and, in some cases, even the direction of the impulse responses differ in the benchmark and BTVAR frameworks. Furthermore, the impulse responses are in some cases strongly dependent on the initial state. This relates, for example, to the tamed response of aggregate credit to a positive shock to industrial production in the *high* credit spread.

The complementary investigation of non-performing loans reveals weak procyclicality of NPLs, which, however, vanishes after approximately 18 months. The economic recovery thus needs to be sufficiently robust to translate into lower NPLs.

While the financial sector shocks impact on the real sector, the responses to credit shocks are roughly similar across regimes. A positive shock to credit supports industrial production over the entire time horizon, yet the responses do not differ substantially across credit spread regimes. 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 likewise absent from the responses of the real economy to shocks to NPLs.

Our results imply that policymakers should take into account the unstable transmission mechanism from the real sector to the financial sector, and in particular from output to credit. Moreover, the financial sector feeds procyclically back into the real economy, thus supporting the argument for regulation of the mechanisms amplifying the current economic crisis (e.g. Borio et al., 2001).

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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 we employ the Gibbs sampler:

1) AR coefficients:

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

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

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

3) Threshold value

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

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

4) Delay parameter

The conditional posterior follows a multinomial distribution with probability $p(d\,|\,\Pi_1,\Pi_2,\Sigma_1,\Sigma_2,d,Y) = \dfrac{L(\Pi_1,\Pi_2,\Sigma_1,\Sigma_2,r,d\,|\,Y)}{\sum_{d=1}^{d_0} L(\Pi_1,\Pi_2,\Sigma_1,\Sigma_2,r,d\,|\,Y)}$.

Tables and figures

Table 1: Threshold estimates and test for non-linearity

Model	Estimated *r*	Hansen (1996)'s chi-square p-value
Credit	3.2821	0.003
NPLs	2.733	0.010

Figure 1: Credit spread and estimated threshold from BTVAR with credit.

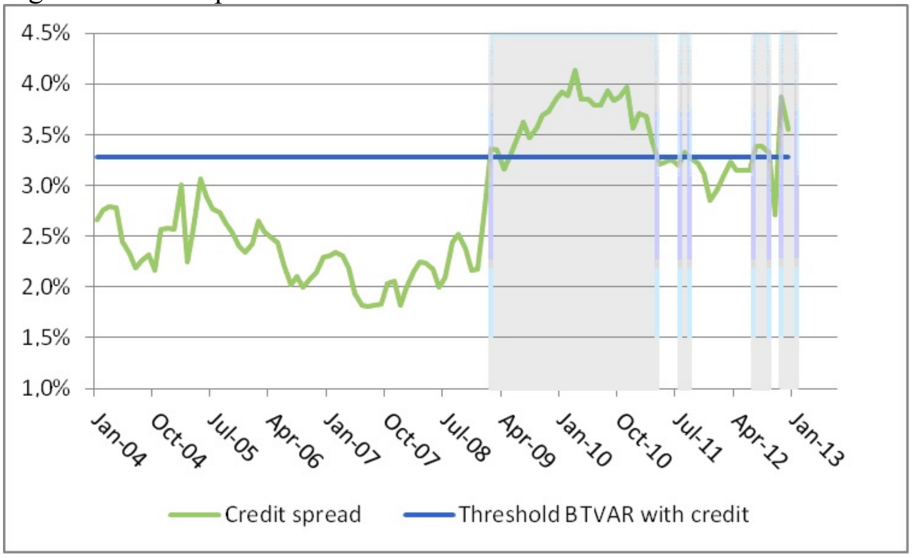


Figure 2: Credit spread and estimated threshold from BTVAR with NPLs.

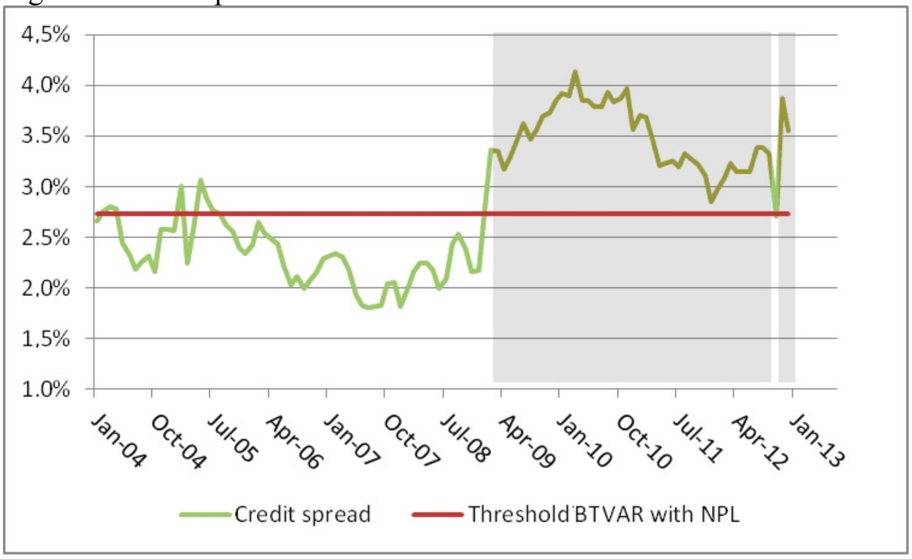


Figure 3: Impulse response functions from real sector variables to credit.

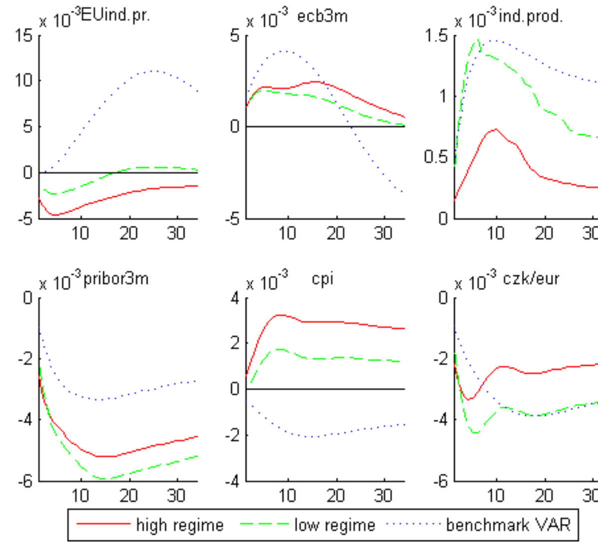


Figure 4: Impulse response functions from real sector variables to non-performing loans.

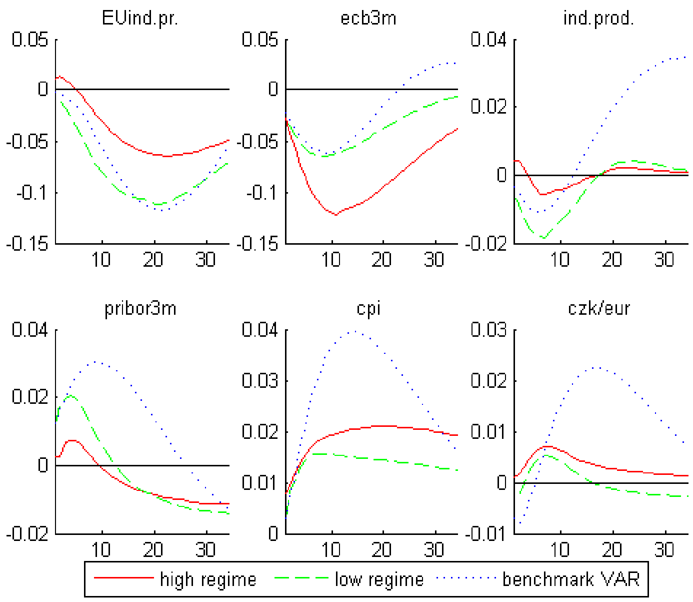


Figure 5: Impulse response functions from credit to real sector variables.

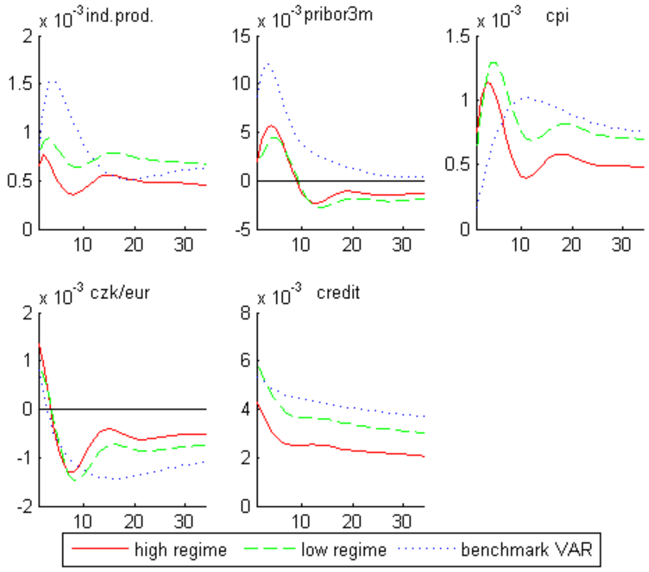


Figure 6: Impulse response functions from non-performing loans to real sector variables.

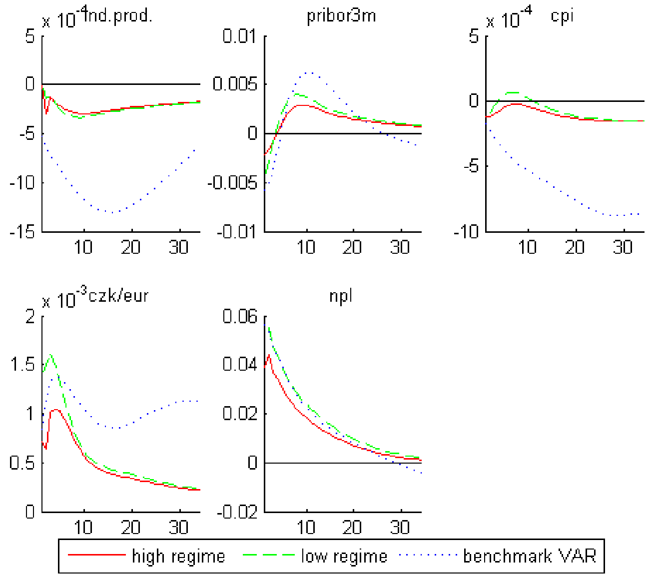
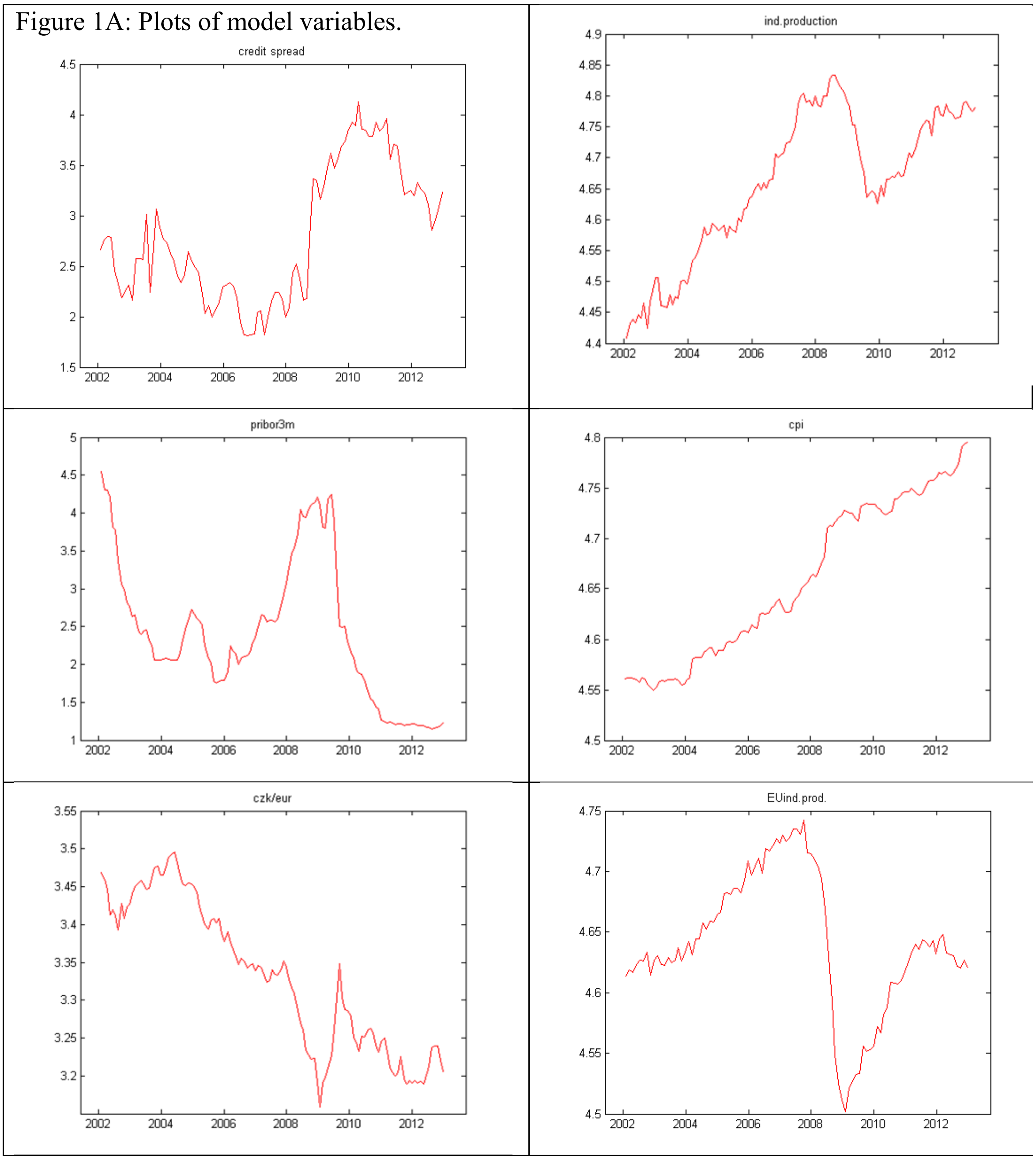


Figure 1A: Plots of model variables.



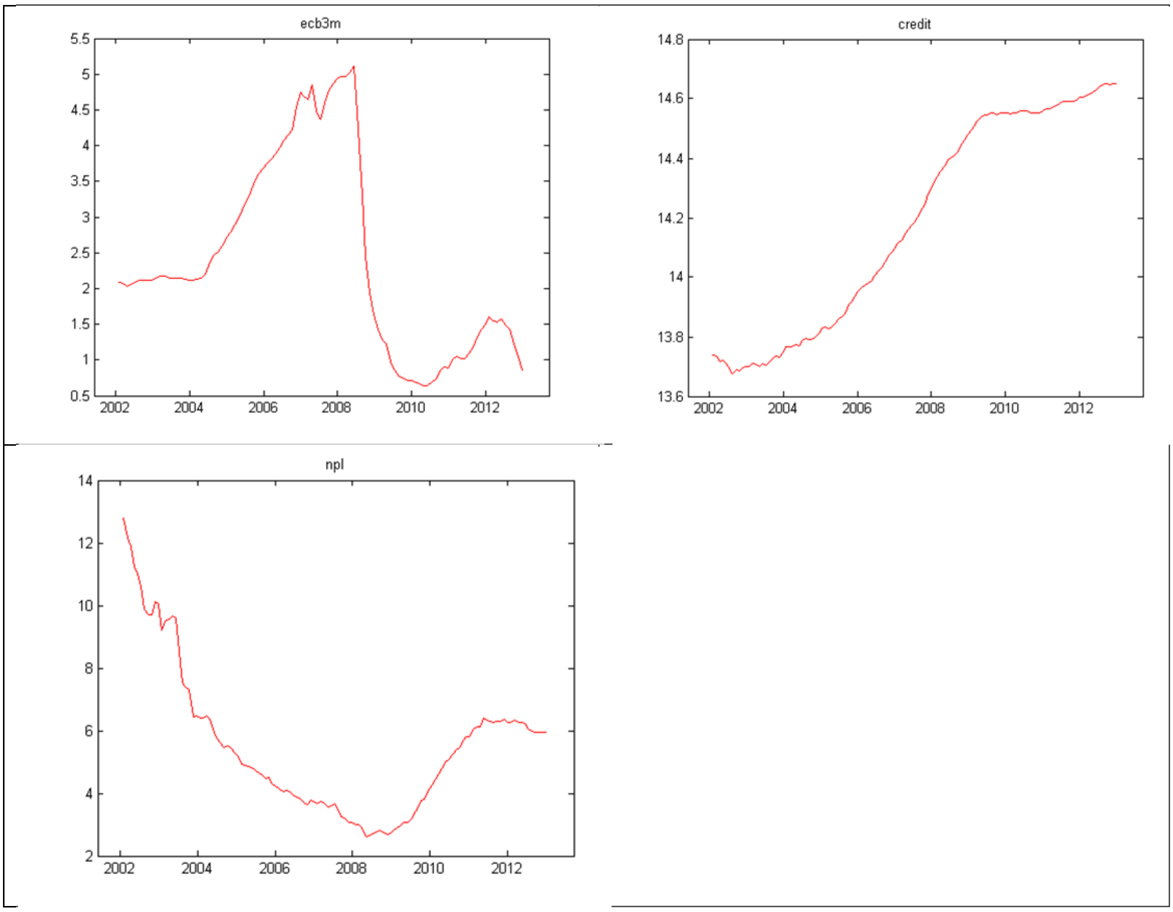


Table 1A Peak responses of credit and npl to shocks from industrial production and interest rate.

	from industrial prod. (1% change)		from pribor3m (10 bps change)	
	credit	npl	credit	npl
Benchmark	0.017%	-0.13 bps	-2.90%	28.8 bps
High	0.009%	-0.07 bps	-4.92%	7.68 bps
Low	0.017%	-0.25 bps	-5.79%	19.2 bps

Table 1B Peak responses of industrial production and interest rate to shocks from credit and npl.

	from credit (1% change)		from npl (1 pp change)	
	industrial prod.	pribor3m	industrial prod.	pribor3m
Benchmark	0.29%	2.43 bps	-1.66%	8.62 bps
High	0.15%	1.17 bps	-0.33%	5.31 bps
Low	0.19%	0.98 bps	-0.33%	3.98 bps