Sign restriction approach to macro stress-testing of the Croatian banking system

NATAŠA ERJAVEC, PhD*
BORIS COTA, PhD*
SAŠA JAKŠIĆ, MA*

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Nataša ERJAVEC
University of Zagreb, Faculty of Economics and Business, J. F. Kennedy 6, 10000 Zagreb, Croatia
e-mail: nerjavec@efzg.hr

Boris COTA
University of Zagreb, Faculty of Economics and Business, J. F. Kennedy 6, 10000 Zagreb, Croatia
e-mail: bcota@efzg.hr

Saša JAKŠIĆ
University of Zagreb, Faculty of Economics and Business, J. F. Kennedy 6, 10000 Zagreb, Croatia
e-mail: sjaksic@efzg.hr

Abstract

The paper employs Uhlig's sign restriction approach to stress-testing of the Croatian banking system. The analysis is based on a standard monetary VAR comprising real economic activity, inflation and short-term interest rates augmented by the ratio of non-performing loans or return on average equity, both measures representing the aggregate banking sector. In spite of the selected indicator, the results suggest a strong sensitivity of the Croatian banking sector to macroeconomic shocks. The effects are the strongest for contractionary monetary policy shocks, followed by negative demand shocks while the effects of supply shocks turned out to be statistically insignificant. Since Croatia is a small open economy with banking the dominant financial sector, the results obtained could be interesting for policy makers in Croatia and other transition economies with similar characteristics.

Keywords: sign restriction, macroeconomic shocks, Croatia

1 INTRODUCTION

Croatia is a small open economy with banking the dominant financial sector and small participation of financial institutions or instruments other than bank loans. At the beginning of the year 2011 the Croatian banking sector consisted of 34 banks. The six largest banks accounted for 82.2% of total assets of the banking sector. As for the ownership structure, banks in foreign ownership accounted for 90.6% of the assets of the Croatian banking sector and only 1.4% of the assets related to state owned banks (CNB, 2011a). The assets of the banking sector are predominately related to credit activities (81%) and, in accordance with the asset structure, the revenue structure of the Croatian banking sector indicates that credit activities (interest from loans) are the dominant revenue of banks in Croatia (CNB, 2011b).

This paper investigates the dynamics of banking sector response to macroeconomic shocks in Croatia. The analysis is based on a standard monetary unrestricted VAR model comprising real economic activity, inflation and short-term interest rates augmented by a variable that represents the aggregate banking sector in Croatia. The aggregate banking sector is represented by two variables: ratio of non-performing loans (NPLR) as a measure of credit risk and return on average equity (ROAE) of the Croatian banking sector as a measure of profitability[1]. Furthermore, in order to take account of the fact that Croatia is a small open economy, a variable that represents the real economic activity of the European Union is added to the model as an additional exogenous variable. These macroeconomic and financial variables are a part of a standard macroeconomic stress-testing fra-

[1] In stress-testing scenarios profit and capital are considered as a buffer against risks and exposures (Cihak, 2007).

mework[2] whose objective is to assess the stability of the banking sector in the event of sudden macroeconomic shocks.

In addition to standard macroeconomic stress-testing procedures, the effects of shocks in this paper are estimated by using an agnostic sign restriction method proposed by Uhlig (2005). Based on the Bayesian estimation of a structural VAR, structural shocks are identified by imposing theoretically motivated short-run sign restrictions on impulse response functions. We identify a contractionary monetary policy shock, a negative demand shock and a negative supply shock. The same identification restrictions have been previously proposed by several authors such as: Farrant and Peersman (2005) for the euro area, the United Kingdom, Japan, Canada and the USA; Peersman and Straub (2006) for the USA and euro area; Eickmeier, Hofmann and Worms (2009) for Germany and the euro area; and Dovern, Meier and Vilsmeier (2010) for Germany. Dovern, Meier and Vilsmeier (2010) employ data on German banks' income and loss statements to model the interaction between the banking sector and the macroeconomy. Besides banking sector indicators (write-offs and return on average equity) other variables included in the model are: the real GDP, the consumer prices, the 3-months interest rate and USA GDP as an exogenous variable. The authors employ the sign restriction approach proposed by Uhlig (2005) for the identification of shocks. Their analysis indicates that both banking sector indicators are strongly affected by monetary policy shocks. On the other hand, the aggregate demand shocks have only limited effects while the aggregate supply shocks do not have a significant impact on banking sector indicators. Eickmeier, Hofmann and Worms (2009) analyze how bank lending responds dynamically to aggregate supply, demand and monetary policy shocks in Germany and the eurozone. The analysis is based on a standard VAR model comprising the variables real GDP, the price level and the short-term nominal interest rates. The stock of outstanding bank loans is employed as a banking indicator and the shocks are identified using the sign restriction approach. The authors find broadly similar results for both areas with a few important differences: the response of the banking indicator is more persistent in Germany, while in the eurozone only the response to a monetary policy shock turned out to be statistically significant. Farrant and Peersman (2005) employ the same set of sign restrictions in order to analyze the shock absorbing capacity of the real exchange rate for the eurozone, the United Kingdom, Japan, Canada and the USA. In addition to aggregate supply and demand shocks, the authors make a distinction between monetary policy shocks and pure exchange rate shocks. The authors find a substantial contemporaneous effect of both monetary policy and pure exchange rate shocks. Peersman and Straub (2006) use a VAR model with sign restrictions that are robust to model and parameter uncertainty to estimate the effects of monetary policy, preference, government spending, investment, price mark-up, technology, and labour supply shocks on macroeconomic variables in the USA and the

[2] For instance see Kalirai and Schleicher (2002) and Blaschke et al. (2001). For a more detailed overview on macroeconomic stress-testing see Quagliariello (2009).

eurozone. In order to identify a broader set of shocks, the authors employ a larger set of variables.

The results of our study point out the importance of monetary policy for the stability of the Croatian banking sector; the effects of contractionary monetary policy shock on both variables are highly persistent even a couple of years following the shock. The main contribution of our paper to the existing literature focusing on macroeconomic stress-testing is the application of VAR methodology and the sign restriction procedure proposed by Uhlig (2005) in stress-testing of the Croatian banking system. As existing studies are restricted to large economies like Germany, USA and the eurozone, the results for a small open economy as Croatia might be of substantial interest. Furthermore, apart from the Croatian National Bank's Financial Stability Reports that perform stress-testing following the methodology of the International Monetary Fund[3], no complete macroeconometric study testing the fragility of the Croatian banking system has been carried out so far. The IMF approach is based on a single factor sensitivity test where the impact of a change in the key variable of interest[4] on banks' balance sheets is analysed. The drawback of this approach is that it does not account for the dynamics between banking and key macroeconomic variables, as opposed to the VAR methodology, which allows for interactions between variables and potential feedback effects from the financial markets and the real economy.

The paper is organized as follows: the next section presents a short description of the data set used in this study and lists the sources from which the data were obtained. The methodology applied is briefly described in section three. Section four presents the empirical results for both banking sector variables. Section five concludes with a brief summary of the main results and suggestions for further steps in research.

2 DATA

Macroeconomic variables used in this study are: growth rate of Croatian real GDP (GDPRH), growth rate of European Union real GDP (GDPEU), Croatian short-term interest rates (IRHR) and inflation in Croatia (INF). As an indicator of Croatian banking sector we consider two variables: changes in the ratio of non-performing loans[5] (DNPLR) and return on average equity (ROAE). The banking variables refer to the banking sector as an aggregate. The selected macroeconomic and financial variables are a part of a standard macroeconomic stress-testing fra-

[3] For a complete overview of the methodology see Cihak (2007).

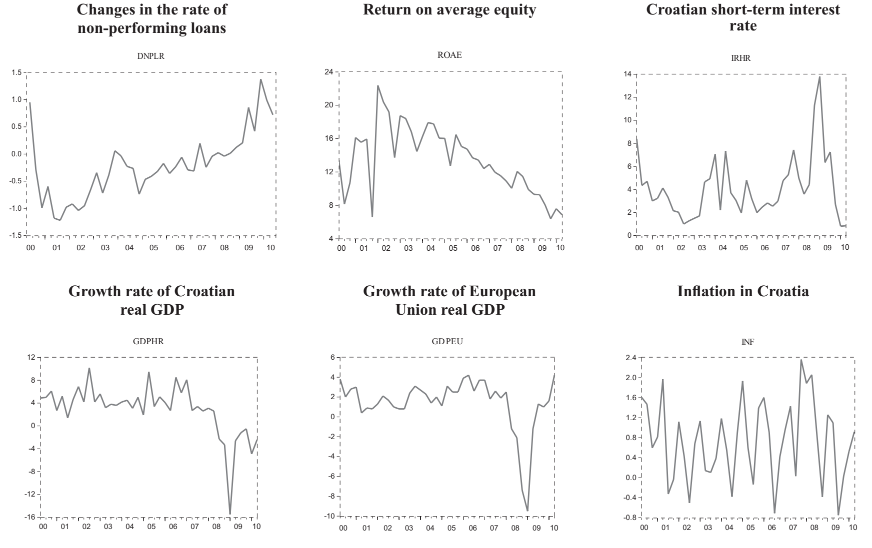
[4] Policy variables or macroeconomic variables such as output growth, exchange rate and interest rates are commonly used in these studies.

[5] Changes in the rate of non-performing loans are used in the study as the original rate of non-performing loans series exhibited strong trends and is very persistent. Possible reason for such behaviour might be that non-performing loans (NPL) typically remain in banking books for some period of time. Hence the NPLs do not necessarily reflect the credit quality in certain period due to the fact that part of the NPLs might stem from before. Therefore, the employed specification turned out to be more appropriate in reflecting the actual credit quality.

mework (Kalirai and Schleicher, 2002; Quagliariello, 2009). The particular choice of the variables is motivated by variable selection in similar studies that use sign restriction approach for macroeconomic stress-testing of the banking sector (Dovern, Meier and Vilsmeier, 2010; Eickmeier, Hofmann and Worms, 2009). We do not employ the exchange rate as an endogenous variable in our study as the changes in the interest rates indirectly reflect the dynamics of the exchange rate (Hoggarth, Logan and Zicchino, 2005)[6]. Data availability restricted the analysis to the period from Q2/2000 to Q2/2010. Quarterly data for the growth rate of real GDP (annualized percentage change on the previous period) for Croatia and EU are taken as reported by Eurostat. The inflation in Croatia is calculated using data on CPI obtained from the IFS database. The source for the short-term interest rates (3-months money market interest rate) is the Zagreb Money Market. Banking variables (the ratio of non-performing loans and return on average equity) are obtained from the Croatian National Bank. The series are seasonally adjusted[7] and presented in graph 1.

Graph 1

Macroeconomic and banking variables from Q2/2000 to Q2/2010



Source: Eurostat, IFS, Croatian National Bank, Zagreb Money Market.

Both Croatian and EU GDP series seem to have a structural break in the first quarter of 2009 (graph 1). The break is likely to reflect the beginning of the recession period caused by the global financial crisis. To account for the presence of a struc-

[6] However, inclusion of the exchange rate as an additional endogenous variable could be a point for further research.

[7] Seasonal adjustment is performed using the TRAMO/SEATS method within DEMETRA statistical program.

tural break, an impulse dummy variable for the first quarter of 2009 was additionally included in the model.

As a result of a structural break, the descriptive statistics for the variables (table A1 in appendix) show the rejection of the null hypothesis of the normality for both GDP-growth variables and interest rate. Furthermore, on the basis of the unit root ADF tests results (table A2 in appendix) the null of a non-stationarity can be rejected in all cases[8].

3 METHODOLOGY

The interaction between the banking sector and the macroeconomy was studied using VAR methodology. The standard VAR model in its reduced form can be written as[9]:

$$Z_t = \Theta_1 Z_{t-1} + \ldots + \Theta_k Z_{t-k} + u_t, \quad u_t \approx \mathrm{IN}\,(0, \Sigma), \tag{1}$$

where Z_t is a $n \times 1$ vector of n endogenous variables, Θ_i represents coefficient matrices of size $n \times n$, k is a lag length, and u_t is the vector of error terms with variance-covariance matrix Σ.

After estimating the parameters of a reduced model (1) we are interested in identifying the economically meaningful structural shocks and in analysing the impulse responses of the individual variables to these shocks. In order to perform that, the vector of prediction errors u_t from model (1), has to be transformed into the vector of structural innovations w_t, assumed to be orthogonal. This defines a one-to-one mapping from a vector of orthogonal structural shocks w_t to the reduced form residuals u_t:

$$u_t = Aw_t. \tag{2}$$

In order to find a matrix A that uniquely solves equation (2) (up to an orthogonal transformation) we have to impose $n(n-1)/2$ restrictions on matrix A. These restrictions emerge from the orthogonality assumption of structural shocks $w_t (E\,[w_t w_t'] = I)$ and the covariance structure (symmetry) of the variance-covariance matrix Σ which can be decomposed as:

$$\Sigma = \mathrm{E}\,[u_t u_t'] = AE\,[w_t w_t']\,A' = AA'. \tag{3}$$

[8] To be more precise, the results of ADF unit root tests were the trend stationarity of return on average equity, stationarity around zero for the growth rate of EU-27 GDP and no unit root for other variables (changes in the rate of non-performing loans, Croatian GDP growth, interest rate and inflation).

[9] The model can additionally incorporate an intercept, a time trend, dummy variables or additional exogenous variables which are excluded from the model for notation simplicity.

There are many ways to perform factorisation of a positive definite matrix $\Sigma = AA'$, e.g. Cholesky decomposition, eigenvalue–eigenvector decompositions or structural decompositions proposed by Bernanke (1986) and Sims (1986).

In this study we applied the "pure-sign-restriction approach" proposed by Uhlig (2005). In this approach, which is based on a Bayesian method, the identification of the VAR is achieved by imposing sign restrictions on the impulse responses of a set of variables. The structural shocks w_t are obtained from u_t by imposing identifying restrictions, which are incorporated in matrix A. Uhlig (2005, Proposition A.1) shows that any impulse vector a can be represented as:

$$a = A\alpha, \tag{4}$$

where α is a n-dimensional vector of unit length and A is the lower triangular Cholesky factor of $\Sigma = AA'$. To identify a structural shock we first obtain the OLS estimates of coefficient matrices Θ_i in the VAR. For a given impulse vector α, the vector of impulse responses of n variables at horizon K (r_k) can be calculated as:

$$r_K = [I - \Theta(\mathrm{B})]^{-1} a, \tag{5}$$

where $\Theta(\mathrm{B})$ is a lag polynomial[10].

Sign restrictions can be imposed on $m \leq n$ variables up to horizons $\tau=0,1,...K$. Identification of the model is then achieved by simulation.

The sign restriction approach is based on the simultaneous OLS estimation of the reduced VAR model and the impulse vector. It is performed in several steps. First, we estimate the VAR and obtain OLS estimates of the parameters; $\hat{\Theta}_1, \hat{\Theta}_2,..., \hat{\Theta}_k$. After that we repeatedly draw possible impulse vectors α and calculate the impulse response functions at horizons $\tau=0,1,...K$ for all variables in the model. If all these impulse responses satisfy the sign restrictions for all relevant horizons $\tau=0,1,...K$ we keep the draw, otherwise we discard it[11]. We repeat the previous steps until we have 1,000 appropriate draws. Finally, using the draws kept we calculate the means of the impulse responses and one standard deviation band (the 16th and the 84th percentile)[12].

[10] In terms of lag polynomial model (1) can be written as $Z_t = \Theta(B)Z_{t-1} + u_t$, where $\Theta(B) = \Theta_1 + \Theta_2 B^1 + ... + \Theta_k B^{k+1}$.
[11] VAR parameter draws, which do not permit any impulse vector to satisfy the imposed sign restrictions, receive zero prior weight, and VAR parameter draws, which easily permit satisfaction of the sign restrictions, receive more weight (given by the Normal-Wishart prior), Uhlig (2005).
[12] For a more detailed exposition of the sign restriction method, see Fry and Pagan (2005), Peersman and Straub (2006) and Uhlig (2005).

Although the Uhlig sign restriction approach has several advantages[13], maybe the most important one is that this approach does not impose the strong *a priori* long-run or zero restrictions that are often used in structural VAR modelling. The methodology only makes explicit use of restrictions that researchers often use implicitly, Uhlig (2005). For instance, in our study we only impose the weak prior beliefs that prices should not rise following a surprise rise in interest rates, without any *a priori* theoretical assumption about the banking variable responses to the macroeconomic shocks.

4 EMPIRICAL RESULTS

The empirical analysis is based on a VAR model incorporating four endogenous variables: Croatian GDP growth (GRRH), interest rate (IRHR), inflation in Croatia (INF), a variable representing the aggregate banking sector and an exogenous variable GDP growth for the European Union (GREU). As a banking sector indicator, we employ changes in the ratio of non-performing loans (Model 1) and return on average equity (Model 2). The lag length is selected according to standard likelihood ratio tests and information criteria (Akaike information criterion with small sample corrections – AIC and Schwarz information criterion, SIC) which turned out to be one for both models (table A3 in appendix).

The impulse response functions are estimated from VAR models. We identify the shocks using a set of sign restrictions imposed on impulse responses. Specifically, we assume that a contractionary monetary policy shock does not lead to increases in prices and GDP or decreases in the interest rates for one quarter following a shock. As a result of a negative demand shock GDP, the prices and the interest rates are assumed to decrease. On the other hand, in response to the negative supply shock GDP is assumed to decrease and prices to increase while the interest rate is left unrestricted since its sign is not clear *a priori* from economic theory.

Since the aim of our paper is to provide a perspective on the responses of banking variables to macroeconomic shocks, sign restrictions are imposed on macroeconomic variables only. The effects of macroeconomic shocks on banking variables are left agnostically open (unrestricted) by design of the identification procedure, which is named "agnostic" for that reason, as stated by Uhlig (2005). Although affected by imposed *a priori* sign restrictions, the findings referring to macroeconomic variables are interesting too. Thus, we additionally report the responses of the macroeconomic variables to the analysed shocks. The imposed sign restrictions are summarized in table 1. The restrictions are imposed on the contemporaneous and one-quarter ahead reactions of the variables.

[13] For instance, the results are insensitive to decomposition of the residual covariance matrix or variable ordering in the VAR as in a conventional Cholesky decomposition, the parameters of reduced VAR model are simultaneously estimated with the impulse vectors, Uhlig (2005).

TABLE 1
Sign restrictions

	GDP growth	Inflation	Interest rate	Banking variable
Contractionary monetary shock	↓	↓	↑	?
Adverse demand shock	↓	↓	↓	?
Adverse supply shock	↓	↑	?	?

Note: Restrictions are imposed on the contemporaneous and on the first quarter following the shock. "?" indicates no restriction.

For each variable, we plot means of the sample impulse responses to macroeconomic shocks one standard deviation in size, i.e. a contractionary monetary policy shock, an adverse aggregate demand shock and an adverse aggregate supply shock. Additionally, in order to verify the significance of our results, we report the 16th and the 84th percentile for the sample of impulse responses.

4.1 EMPIRICAL RESULTS FOR THE MODEL USING THE RATE OF NON-PERFORMING LOANS (MODEL 1)

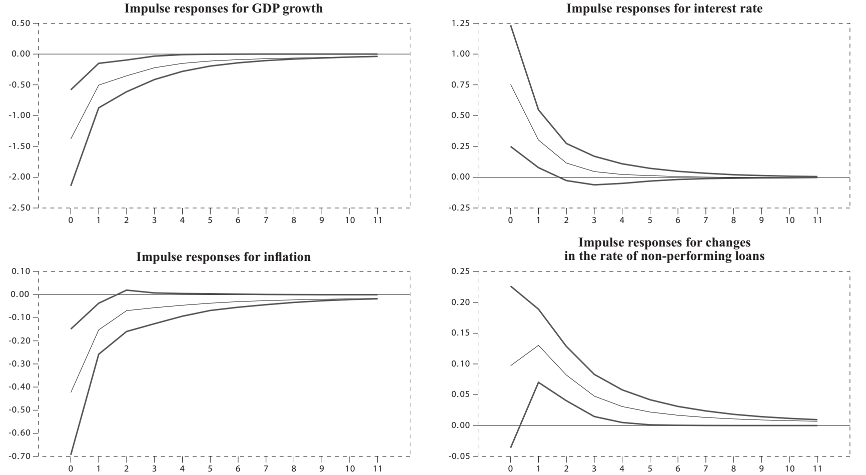
In this section, we present the results obtained by analysing Model 1 with banking variable changes in the ratio of non-performing loans (DNPLR). Graph 2 shows the impulse responses to a contractionary one standard deviation monetary policy shock.

The response of the system to a contractionary monetary policy shock (graph 2) shows that on impact the credit quality deteriorates. In response to the monetary policy shocks, changes in the ratio of non-performing loans increase instantaneously by almost 10 basis points. After a quarter, the impact increases to 13 basis points, which is about 63% higher compared to the sample average and declines gradually. Croatian GDP growth initially drops by 1.38 percent (48% compared to the sample average). After that considerable decrease, the effect of a contractionary monetary shock to GDP growth fades out within a year. The interest rates rise on impact by 75 basis points (18% higher compared to the sample average) and in about two quarters the effect of the shock diminishes. After the initial drop by 42 basis points (56% compared to the sample average) the response of the inflation rate to the contractionary monetary policy shock fades out within a year.

Graph 3 shows the impulse responses to an adverse one standard deviation supply shock. As a result of an adverse supply shock, changes in the ratio of non-performing loans increase about 5 basis points (24% compared to the sample average) but fade out quickly within the following two quarters. Croatian GDP growth rate initially drops by about 1% (34% compared to the sample average), the interest rate increases by 76 basis points (18% higher compared to the sample average) and the inflation rate rises by 38 basis points (52% compared to the sample average). Positive response of the interest rate to a supply shock can be viewed as the reaction of the central bank to the increase in prices. To meet the proclaimed goal of price stability, in response to increase in prices central bank raises interest rates. However, the responses are not only smaller in magnitude than the two other types of shocks but also statistically insignificant.

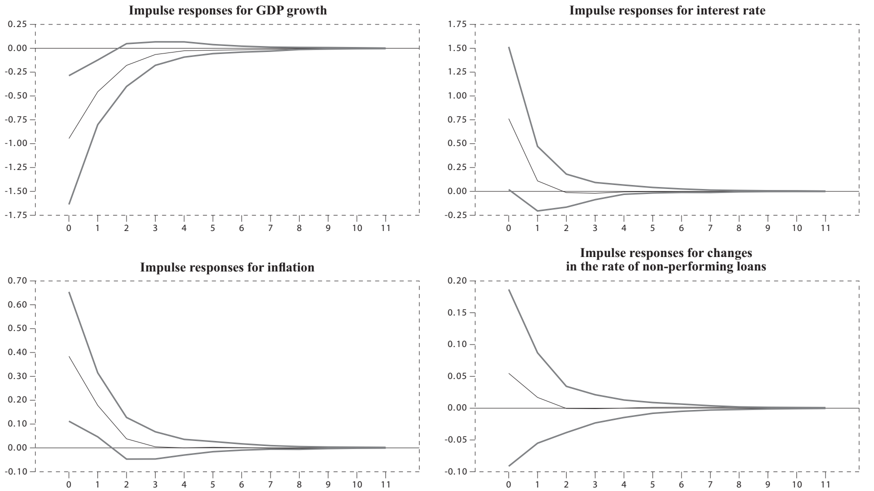
Graph 2

Model 1: Impulse responses to a contractionary monetary policy shock



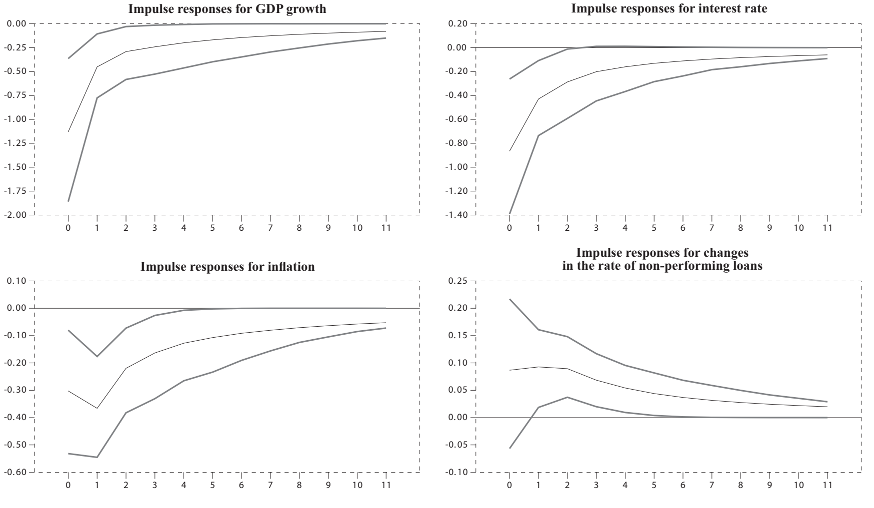
Graph 3

Model 1: Impulse responses to an adverse supply shock



The results with respect to an adverse one standard deviation demand shock (graph 4) show that the demand shock increases changes in the ratio of non-performing loans instantaneously by 8 basis points (39% compared to the sample average). The responses of macroeconomic variables and changes in the ratio of non-performing loans to an adverse demand shock are more persistent than for a contractionary monetary and an adverse supply shock. Croatian GDP growth rate is dampened by 1.1% (39% lower compared to the sample average), the interest rate decreases by about 86 basis points (21% compared to the sample average) and the inflation rate initially drops by 30 basis points (44% compared to the sample average).

GRAPH 4
Model 1: Impulse responses to an adverse demand shock



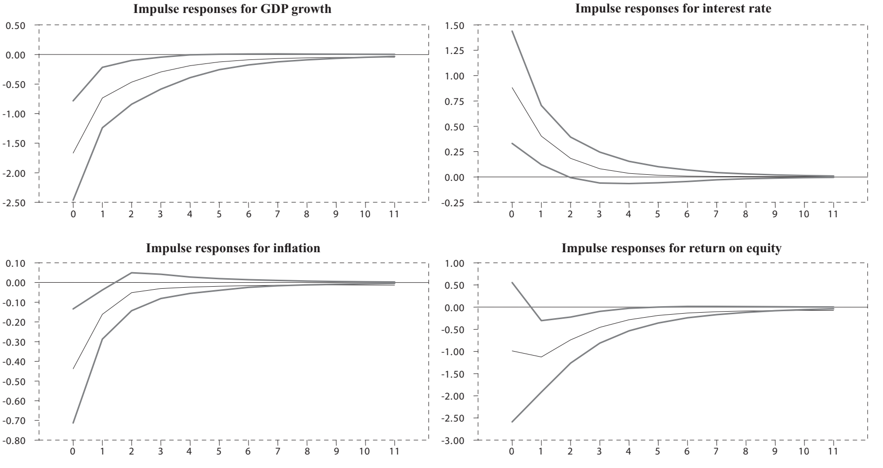
The obtained results suggest that, on impact, all the analysed shocks deteriorate the credit quality and hence increase the credit risk. The monetary policy shock and demand shock have a significant and more persistent impact on an increase of changes in the ratio of non-performing loans in comparison to the aggregate supply shocks, which fade out quickly and are statistically insignificant. Therefore, the results lead to the conclusion that the Croatian banking sector is more sensitive to monetary policy and aggregate demand shocks and less sensitive to aggregate supply shocks.

Surprisingly, graph 4 shows that the response of changes in the ratio of non-performing loans to a demand shock is persistent in spite of easing of monetary policy (a decrease in interest rates) after the shock. A slowdown in economic activity caused by a demand shock would be expected to give an impetus to the central bank to decrease interest rates in order to stimulate economic recovery. Under such circumstances, the ratio of non-performing loans is expected to decrease as well. However, the results of our analysis tell a different story: in spite of the decrease in interest rates as a response to decline in economic activity, the ratio of non-performing loans remains persistent even three years after the shock. On the other hand, the responses of macroeconomic variables to the analysed shocks fade out quickly (within a year), regardless of the persistent behaviour of the rate of non-performing loans.

4.2 EMPIRICAL RESULTS FOR MODEL WITH RETURN ON AVERAGE EQUITY (MODEL 2)

The same analysis is performed for Model 2, the one lag VAR model in which the banking sector is represented by variable return on average equity. Graph 5 presents the impulse responses to a contractionary one standard deviation monetary policy shock.

Graph 5
Model 2: Impulse responses to a contractionary monetary policy shock

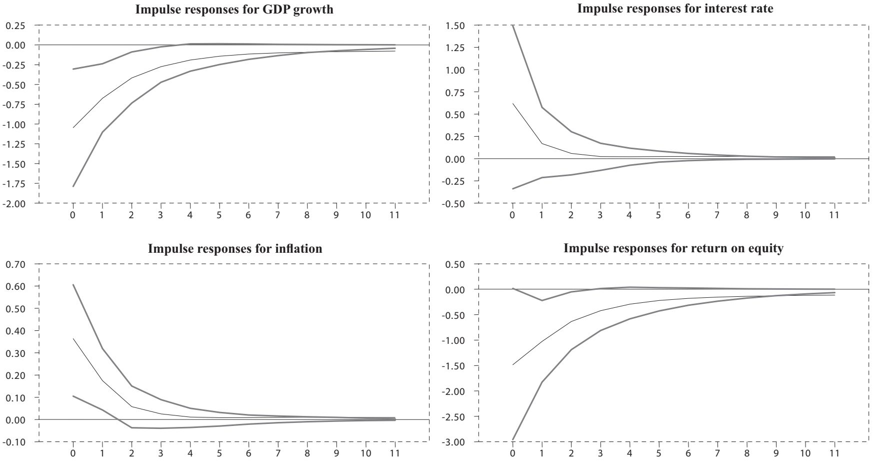


The response of the system to a contractionary monetary shock, graph 5, shows that on impact return on average equity decreases by almost 150 basis points (7% compared to the sample average). The magnitude of the response declines over the subsequent periods. However, the impact is still significant over a couple of years. Regarding the responses of the macroeconomic variables to monetary policy shocks, GDP growth decreases instantaneously by 1.7% (57% compared to the sample average) and inflation rate decreases by 43 basis points (60% compared to the sample average). After the initial increase by 88 basis points (21% compared to the sample average), the effect of monetary shock on interest rates fades in the following periods, just like the effects on other macroeconomic variables.

Graph 6 shows the impulse responses to an adverse one standard deviation supply shock. As a result of an adverse supply shock, return on average equity decreases by almost 100 basis points (11% compared to the sample average) instantaneously. In the following quarters the effect of a supply shock on the profitability of the banking sector decays. Compared to changes in the rate of non-performing loans, the effects on return on average equity are large in magnitude. A supply shock affects the macroeconomic variables as well: on impact, GDP growth decreases by 1% (36% compared to the sample average), inflation rate increases by 36 basis points (49% compared to the sample average) and interest rates increase by 61 basis points (15% compared to the sample average). The effects of the supply shock to the macroeconomic variables gradually diminish over the following quarters (within a year).

Graph 6

Model 2: Impulse responses to an adverse supply shock

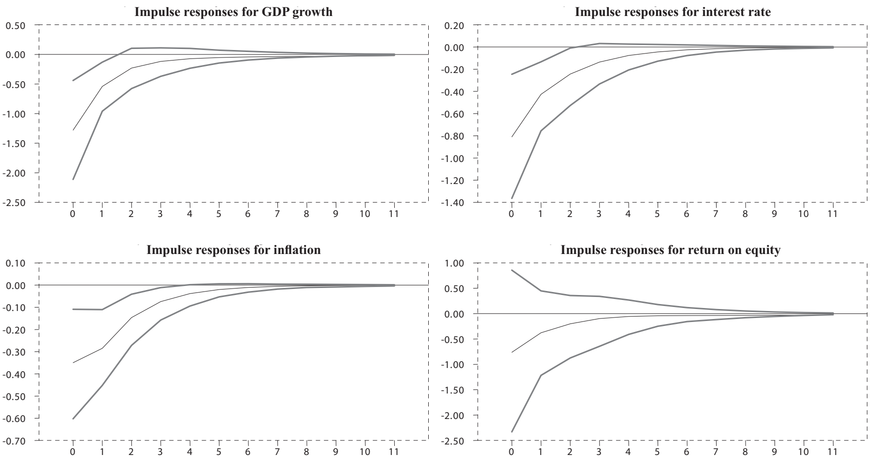


The results with respect to an adverse one standard deviation demand shock (graph 7) show that after an initial decrease by 80 basis points (6% compared to the sample average), the effects of the shock on return on average equity fade within a year. The same applies to the macroeconomic variables. After the initial decrease in GDP growth by 1.3% (44% compared to the sample average), in the inflation rate by 35 basis points (48% compared to the sample average) and interest rates by 81 basis points (19% compared to the sample average), the effect of the demand shock diminishes within a year.

The results obtained for Model 2 are similar to those previously obtained for Model 1. As in the case of changes in the rate of non-performing loans, a contractionary monetary policy shock has the largest impact on the return on average equity. Demand shocks, although significant in the periods following the shock, fade out within a year. The effects of supply shocks on return on average equity are bigger in magnitude and more persistent than in Model 1 with changes in the ratio of non-performing loans as a banking indicator. Once again, the results highlight the importance of monetary policy and demand shocks to the Croatian banking sector.

Graph 7

Model 2: Impulse responses to an adverse demand shock



5 CONCLUSION

The paper investigates the impact of macroeconomic shocks on the Croatian banking sector. That is to say, we analyse the responses of financial indicators to a contractionary monetary policy shock, an adverse aggregate demand and an adverse aggregate supply shock. We estimate a monetary VAR model comprising real economic activity, inflation, short-term interest rates and a variable that is an indicator of the aggregate banking sector. The aggregate banking sector in Croatia is represented by two variables: changes in the ratio of non-performing loans and return on average equity. The fact that Croatia is a small open economy is accounted for by an additional exogenous variable that represents the real economic activity of the European Union. In addition to the VAR stress-testing procedures, the paper takes advantage of the sign restriction approach proposed by Uhlig (2005) in identifying the effects of macroeconomic shocks. The estimated impulse response functions suggest that all shocks lead to an increase of credit risk (measured by changes in the rate of non-performing loans) and a decrease of Croatian banking sector profitability (return on average equity).

The results referring to the stress-testing of the Croatian banking sector indicate the importance of monetary policy for both banking indicators. The effects of contractionary monetary policy shocks on the banking sector are highly significant and persistent over a couple of years following the shocks for both banking sector indicators. The aggregate demand shock induces stress in the Croatian banking system as well. The effects of a demand shock are more pronounced and more persistent for changes in the rate of non-performing loans than for return on average equity. Furthermore, the results show that the effects of the supply shocks are statistically insignificant. The impact of supply shock is also smaller in magnitude than those of monetary policy or demand shocks.

The analysis performed shows that in spite of potential shocks, the Croatian banking sector has enough capacity to recover from adverse movements in macroeconomic variables, which is associated with the shock-absorbing capacities of its banking system. At the beginning of the year 2011, Croatia's banking sector, which is dominated by foreign ownership, was still highly profitable and strongly capitalised, yielding return on average equity of 6.6% while the capital-to-assets ratio had been stable at the relatively high level of about 14% since 2009. Furthermore, stress tests under the shock scenario[14] performed by the Croatian National Bank show that the banking industry would still be highly capitalised with a capital adequacy ratio at 17.4%. However, a few smaller banks (nine banks holding around 3.5% of banking sector assets) could experience problems due to their capital adequacy ratio falling below the 12% prescribed by the Croatian National Bank (CNB, 2011b).

As an extension of our analysis, possible further steps could include expanding the analysis to a broader set of variables in order to enable the identification of more shocks. However, this is not a feasible solution due to the small number of available observations, as sufficient historical data are often unobtainable. Changes in the methodology or regulatory policy pose an additional problem regarding data quality, and limit the usefulness of the data in the empirical analysis. Therefore, the research could be headed in the direction of employing more appropriate proxies for the identification of the macroeconomic shocks analysed. For instance, the exchange rate could perhaps be a better proxy for identifying the monetary policy shock in Croatia than interest rates, as the Croatian National Bank pursues a tightly managed float. Another possible route is to make a distinction between monetary policy shocks and pure exchange rate shocks to distinguish the part of the exchange rate fluctuations that might be explained as a reaction to relative monetary policy shocks.

[14] The shock scenario refers to a combination of unlikely but plausible shocks reflecting the impact of unfavourable economic developments. To be precise, the performed stress test under the shock scenario assumes a 0.5% GDP decline and a 10% depreciation of the kuna against the euro.

APPENDIX

Table A1
Descriptive statistics of the variables

Variables	Mean	Standard deviation	Jarque–Bera normality test
Changes in the rate of non-performing loans	-0.208604	0.601225	2.4646 (0.2916)
Return on average equity	13.4552	3.9810	0.8062 (0.6682)
Croatian GDP-growth	2.9073	4.4419	75.4682 (0.0000)
EU GDP-growth	1.4171	2.6697	141.3361 (0.0000)
Interest rate	4.1474	2.7483	28.7958 (0.0000)
Inflation	0.7339	0.8012	1.0011 (0.6062)

Note: Figures in parenthesis are the p-values corresponding to Jarque–Bera normality test statistics.

Source: Authors' calculation.

Table A2
The results of Augmented Dickey-Fuller test – variables in levels

Variables	None	Constant	Trend and constant
Changes in the rate of non-performing loans	-3.5004 (0.0009)	-3.1616 (0.0298)	-3.5557 (0.0466)
Return on average equity	-1.7925 (0.0697)	-2.5375) (0.1143)	-5.1380 (0.0008)
Croatian GDP-growth	-2.7523 (0.0071)	-3.2080 (0.0268)	-4.2532 (0.0088)
EU GDP-growth	-2.3022 (0.0223)	-2.6028 (0.1006)	-2.4216 (0.3636)
Interest rate	-2.2764 (0.0237)	-3.5201 (0.0123)	-3.6071 (0.0415)
Inflation	-3.6053 (0.0006)	-5.5132 (0.0000)	-5.4298 (0.0003)

Note: Figures in parenthesis are the p-values corresponding to Augmented Dickey-Fuller test statistics. The optimal number of lags is chosen according to LM test for residual serial correlation of order 12 by adding lags until LM test fails to reject no serial correlation at 5% level.

Source: Authors' calculation.

Table A3

The results of VAR lag selection criteria

Variables	**VAR lag select criteria**				
	Lags	AIC	SBC	LR	Test p-value
Changes in the rate of non-performing loans DNPLR	1	12.40204*	13.32673*		
	2	13.23115	14.09784	41.3948	0.0005
	3	14.82734	14.90458	40.7433	0.0006
	4	17.23080	15.03545	65.7760	0.0000
	Lags	AIC	SBC	LR	Test p-value
Return on average equity ROAE	1	17.38909*	18.26138*		
	2	17.66775	18.62982	61.8003	0.0000
	3	19.34933	19.81817	30.5313	0.0154
	4	20.94492	19.79856	76.7183	0.0000

Note: Akaike information criterion (AIC) with small sample corrections, Schwarz information criterion (SIC), likelihood ratio test (LR Test) and corresponding p-value for LR test.

Source: Authors' calculation.

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