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Does the Foreign Income Shock in a Small Open Economy DSGE Model Fit Croatian Data?

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Abstract

The paper compares theoretical impulse response functions from a DSGE model for a small open economy with an empirical VAR model estimated for the Croatian economy. The theoretical model fits the data well as long as monetary policy is modelled as a fixed exchange rate regime. The paper considers only a foreign output gap shock. A positive foreign shock increases domestic GDP and prices and decreases terms of trade, which is in compliance with theoretical assumptions. Interest rates behave differently than suggested by the estimated DSGE model, which could be explained with an unconventional interest rate transmission channel in Croatia.

Key words
DSGE, foreign income shocks, exchange rate, Croatia, gross domestic product, Eurozone

JEL classification
E32, F41

Introduction

Theoretical macroeconomic models are usually fitted for developed countries such as USA or Eurozone and are often modeled for closed economies. A very popular small open economy model is one by Galí and Monacelli (2005) who developed a small-scale dynamic stochastic general equilibrium model (DSGE) fitted for Canada. This paper compares theoretical results of a small open economy DSGE model by Galí and Monacelli (2005) with empirical results of a VAR model estimated for Croatia. In the paper empirical results are compared with different theoretical monetary policy rules. Focus of the paper is a foreign GDP shock and effects on the domestic real sector, inflation, interest rates and terms of trade.

Results show that the small open economy DSGE model fits Croatian data well as long as monetary policy is modelled as a pegged exchange rate regime. The empirical model confirms theory suggested increase in domestic output gap and inflation, as well as a decrease in terms of trade as a result of a positive foreign GDP shock. A response of nominal interest rate deviates from a theoretical model, which is not a surprise considering unconventional interest rate channel of the monetary transmission in Croatia. Three other monetary policy rules (domestic inflation targeting, domestic inflation-based Taylor rule, CPI inflation-based Taylor rule) cannot fit Croatian data that well.

Theoretical framework

Gali and Monacelli (2005) is a benchmark New Keynesian macroeconomic model with microeconomic foundations. In the model, the behavior of households and firms are rigorously modelled. Households choose a level of employment and consumption in order to maximize utility subject to a budget constraint and firms chose a level of economic activity which will maximize its profits subject to marginal costs and demand function for their products.

The labor market is perfectly competitive with rational households which means that first order conditions of utility function $U_t = E_t \sum_{t=0}^{\infty} \beta^t U_t(C_t, N_t)$, where C_t is consumption and N_t is labor, will represent labor supply and demand for total consumption and consumption of each differentiated good j. The good's market is imperfectly competitive with a continuum of j goods that are imperfect substitute, which results in a domestic goods and foreign goods downward slopping demand curve $C_{H,t(j)} = \left(\frac{P_{H,t(j)}}{P_{H,t}}\right)^{-\varepsilon} C_{H,t}$ and $C_{i,t(j)} = \left(\frac{P_{i,t(j)}}{P_{i,t}}\right)^{-\varepsilon} C_{i,t}$, where $P_{H,t}$ is a domestic price level.

Firms maximize its profits $\max_{\bar{P}_{H,t}} \sum_{k=0}^{\infty} \theta^k E_t\{Q_{t,t+k}[Y_{t+k}(\bar{P}_{H,t} - MC_{t+k}^n)]\}$ subject to sequence of domestic and foreign demand curves, where Q_t is nominal bond price, Y_t is output level, and MC_t is marginal cost. In other words, there is a monopolistic competition and firms will charge mark up $\frac{\varepsilon}{\varepsilon-1}$ over marginal costs, with ε representing demand elasticity. Having in mind that production function is Keynesian $Y_t(j) = A_t N_t(j)$, where A_t and N_t represent technology and labor respectively, marginal cost will be equal to unit labor cost $MC_t = \frac{W_t}{P_{H,t}} 1/A_t$, with W_t representing nominal wage. It means that prices are set as mark up over unit labor cost and the mark up is a function of elasticity of consumption demand functions.

As a result, price setting and wage setting relationship resemble WS-PS model with an exception that there is a labor supply curve instead of the wage-setting curve (no unions) and mark-up over marginal cost is derived from the slope of the demand curve for the good j.

On the demand side income is equal to the sum of consumption and trade balance $Y = C_t + NX_t$, where trade balance is implicitly defined as $nx_t \equiv 1/Y(Y_t - \frac{P_t}{P_{H,t}C_t})$ and Government consumption and investment (as well as physical capital in production function) are omitted due to simplicity. In the same way as in intermediate macroeconomic models, PPP assumption is assumed for the exchange rate determination $P_{H,t} = P_{F,t}$ and uncovered interest parity holds as in classical Mundell-Fleming model. The only difference is that terms of trade are a function of current and anticipated real interest rate differential.

Log-linearisation (or logs) of the first order conditions will result with a function for real wage (small letters denotes logs, hats deviations from steady states) $w_t - p_t = \sigma c_t + \varphi n_t$ Euler equation will result in $c_t = E_t\{c_{t+1}\} - 1/\sigma(r_t - E_t\{\pi_{t+1}\} - \rho)$, marginal costs function is $mc_t = -\nu + w_t - p_{H,t} - a_t$, production function is $y_t = a_t + n_t$, price setting curve is $\bar{P}_{H,t} = \mu + (1-\beta\theta)\sum_{k=0}^{\infty}(\beta\theta)^k E\_t(mc_{t+k} + p_{H,t})$, domestic inflation is defined as $\pi_{H,t} \equiv p_{H,t} - p_{H,t-1}$ and CPI inflation is defined as $\pi_t \equiv \pi_{H,t} - \alpha\Delta s_t$, where the terms of trade are $s_t = e_t + p_t^* - p_{H,t}$.

In the equilibrium, the New Keynesian dynamic IS curve is defined in terms of output gap as $x_t = E_t\{x_{t+1}\} - \frac{1}{\sigma_\alpha}\left(r_t - E_t\{\pi_{H,t+1}\} - \overline{rr}_t\right)$ where x_t represents output gap, Phillips curve is defined as $\pi_{H,t} = \beta E_t\{\pi_{H,t+1}\} + \mathrm{K}_{\alpha x_t}$ and natural real interest rate is $\overline{rr}_t = \rho - \sigma_{\alpha\Gamma(1-\rho_\alpha)a_t} + \alpha\sigma_{\alpha(\Theta+\Psi)E_t}\{\Delta\, Y_{t+1}^*\}$.

The model allows the comparison of the dynamic response of the economy to technological shocks and/or shock of world income based on four different designs of monetary policy in the model. Monetary policy designs are named as: domestic inflation targeting (DIT), domestic inflation-based Taylor rule (DITR), CPI inflation-based Taylor rule (CITR) and exchange rate peg (PEG). Behavior of central bank is defined with strict inflation targeting (DIT-optimal policy) $x_t = \phi_\pi \pi_{H,t} = 0$, Taylor rule for domestic inflation (DITR) $r_t = \rho + \phi_\pi \pi_{H,t}$ and Taylor rule for CPI targeting (CITR) $r_t = \rho + \phi_\pi \pi_t$ and exchange rate peg (PEG) $e = 0$.

We calibrate parameters in the model following Galí and Monacelli (2005) specification of a small open economy. They calibrate parameters for Canadian economy. For a model calibrated for Croatian economy refer to Palić (2015). Parameters used in a model are shown in the table 1.

Table 1. Calibrated parameters in estimated DSGE model

σ	ρ	τ	α	θ	β	κ	ω	ξ	ϕ_π	ρ_a	ρ_y
1.0	0.0101	1.0	0.4	0.0	0.99	0.3433	-0.1277	0.0	1.5	0.66	0.86

Methodology and data

A methodological framework for empirical research is based on theoretical assumptions of the Galí and Monacelli (2005) small open economy model. We estimate a five variable VAR model which facilitates the modelling of the impact of foreign income shocks on the domestic output gap, nominal interest rate, CPI inflation, and terms of trade. It also enables modelling of simultaneous interrelationships between variables which are treated endogenously. VAR model in a reduced form can be written as:

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + \cdots + A_p Y_{t-p} + e_t \tag{1}$$

where Y_t is a vector of endogenous variables, $A_i (i = 1, \ldots, p)$ are $(K \times K)$ parameter matrices, error process $e_t = (e_{1t}, \ldots, e_{Kt})$ is a K-dimensional zero mean white noise process with covariance matrix $E(e_t e_t') = \sum_e$, that is, $e_t \sim (0, \sum_e)$, and p is a number of lags in the model. The basic specification of the model is represented by the following vector of endogenous variables, with the corresponding Cholesky ordering of variables:

$$Y_t = (GAP\_EZ_t, GAP_t, IR_t, PI_t, TOT_t)' \tag{2}$$

where GAP_EZ_t represents the foreign output gap, GAP_t is the domestic output gap, IR_t is the domestic nominal interest rate, PI_t represents the inflation rate and TOT_t represents terms of trade. The ordering of variables in vector Y_t is based on economic theory, assuming foreign output gap can affect other variables in a first period but not vice versa. Interest rate follows the output gap and terms of trade follow the level of the inflation rate. However, results are robust even under alternative orderings of variables, which is available upon request.

Quarterly data covers the period from 1995:Q1 to 2015:Q2. The foreign country used as a benchmark for the foreign output gap is Eurozone, given that the majority of trade, investment and other economic linkages of Croatian economy originate from the Eurozone. Time series for the Eurozone output gap has been obtained by employing the Hodrick and Prescott (1997) filter on the seasonally adjusted real GDP time series for Eurozone, downloaded from Eurostat, to separate the cyclical from the trend component. The same method was used to obtain the domestic output gap series. Croatian real GDP data was obtained from both the Eurostat and the IMF's International Financial Statistics (IFS) database. Domestic nominal interest rates are represented by domestic overnight money market rates, obtained from IFS and the Croatian National Bank statistical database. The time series of CPI inflation is represented by the year-on-year percentage change in the consumer price index (CPI) for Croatia, downloaded from IFS. Finally, CPI-based real effective exchange rate (REER) is proxy for the terms of trade, obtained from IFS. In order to match terms of trade defined in the theoretical model, the REER time series was multiplied by -1, so that increase represents real depreciation and vice versa.

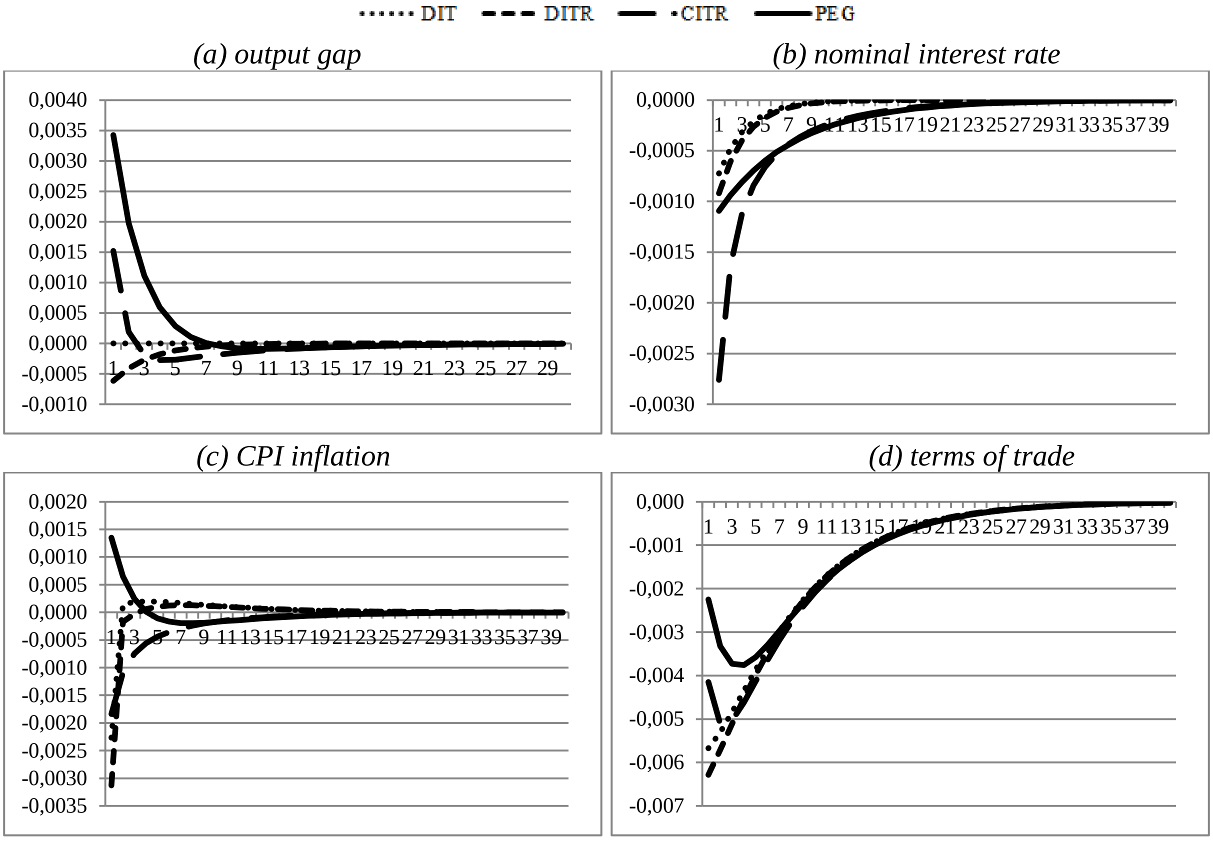
Time series indicating seasonal behaviour have been seasonally adjusted using the *Census X12* procedure. Stationarity of time series has not been tested given the requirements of the theoretical model. Specifically, to make the impulse responses derived from the empirical model comparable to those obtained from the theoretical model, variables in the VAR model mimic theoretical equations.

The optimal number of lags in the VAR model has been determined by the minimization of the Akaike information criterion, which stated that one lag is optimal for estimation. Residuals from estimated models have been tested for autocorrelation using the multivariate serial correlation test (Hosking Q-statistics). The results, available upon request, indicate that the null hypothesis of no serial correlation cannot be rejected. Confidence intervals in impulse response functions (IRFs) have been obtained using Monte Carlo bootstrapping method with Cholesky factorization. The impulse response functions from the theoretical model were obtained using *Dynare* software in *MATLAB*.

Results

In their small open economy model, Galí and Monacelli (2005) examine the impact of a foreign income shock on various macroeconomic variables in four different monetary regimes: domestic inflation targeting regime (DIT), domestic inflation-based Taylor rule regime (DITR), CPI inflation-based Taylor rule regime (CITR) and pegged exchange rate regime (PEG). The quantitative and qualitative aspects of responses of variables to a foreign income shock varied depending on the monetary regime. Figure 1a displays how the influence of a shock in foreign income on the domestic business cycle is most pronounced in the case of a pegged (fixed) exchange rate while the opposite is true in the case of terms of trade (Figure 1d). Differences in responses of CPI inflation are also noticeable, as in the case of the pegged regime inflation increases initially after a positive shock in foreign income, after which it starts to decrease; while in other three regimes the effect is opposite.

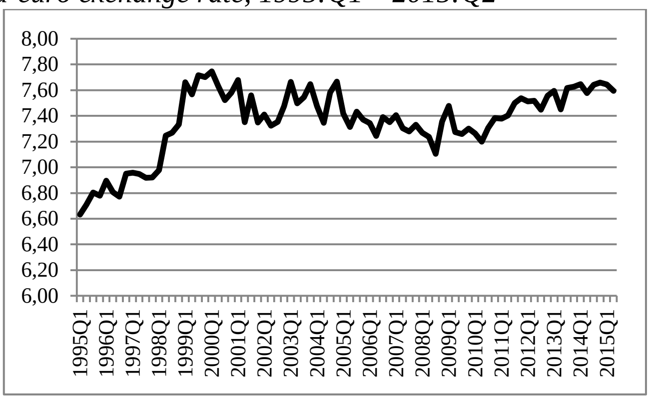
Figure 1: Impulse response functions of selected variables to a foreign income shock under different monetary regimes, theoretical model



Source: authors' calculations based on Galí and Monacelli (2005)

Croatia operates a crawl-like regime, where the exchange rate is not fixed, but the currency (kuna) is not allowed to deviate too much from the anchor (euro). Figure 2 reveals how kuna depreciated nearly 15 percent vis-à-vis the euro between 1995 and 2000. However, from that point on, the kuna-euro exchange rate remained stable, with fluctuations ranging mainly between $\pm$ 3 percent around the period average. Thus, the impulse responses from the empirical VAR model should offer an interesting insight into the mechanics of foreign macroeconomic spillover effects in Croatia, i.e. whether the foreign income shocks result in domestic movements that fit the theoretical predictions.

Figure 2: Nominal kuna-euro exchange rate, 1995:Q1 – 2015:Q2

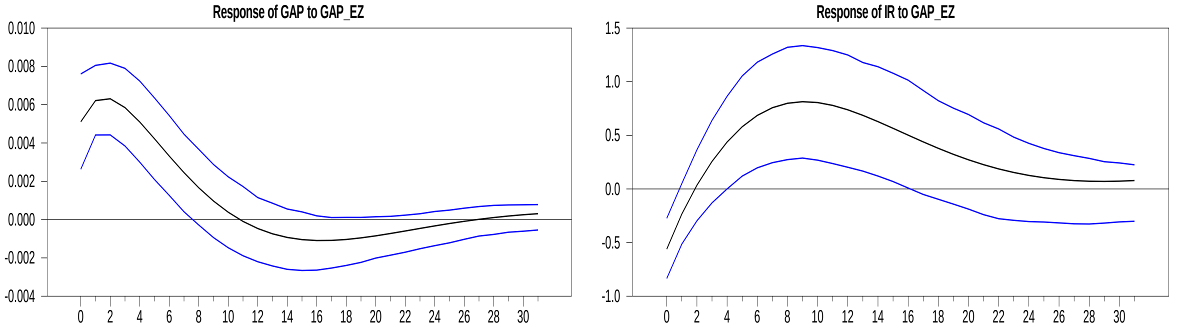


Source: Eurostat

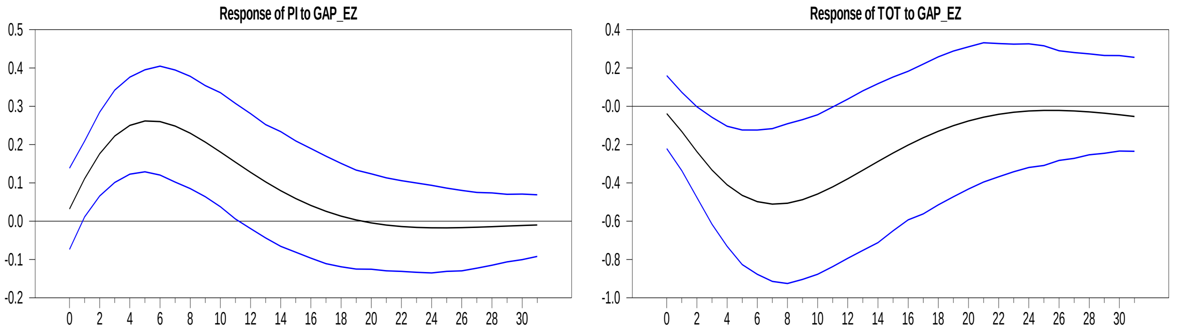
Figure 3 reveals the impulse response functions obtained by estimating a five variable VAR model on Croatian data. Right away it is evident that the impulse response functions are very similar to those from the theoretical model with a pegged exchange rate. A positive income shock in the Eurozone results in a significantly strong increase in the domestic output, with the effect lasting for seven quarters (Figure 3a), basically mirroring a theoretical impulse response function from Figure 1a. This reflects a high level of economic integration between Croatia and the Eurozone, with the swift transmission of business cycles from abroad to the domestic economy (Jovančević et al. 2012), with the exchange rate failing to act counter-cyclically as it remained fairly stable throughout the period.

Figure 3: Impulse response functions of selected variables to a foreign income shock, empirical model

(a) output gap *(b) nominal interest rate*



(c) CPI inflation *(d) terms of trade*



Source: authors' calculations

The response of the domestic nominal interest rate to a foreign income shock is the only variable for which the empirical IRF differs from the theoretical one. Although the initial reaction is negative in both models, the response of the interest rate turns positive after five quarters (Figure 3b), possibly reflecting the fact that the interest rate channel of the monetary transmission mechanism in Croatia does not work in a conventional manner (see e.g. Vizek, 2008).

The response of CPI inflation in Croatia to a foreign income shock is the most indicative one. Figure 3c displays how CPI inflation increases after foreign income increases, and the reaction becomes statistically positive two quarters after the shock, as the prices cannot adjust immediately (Arčabić, forthcoming). The reaction dies out ten quarters after the shock. If we look at the theoretical IRFs from Figure 1c, it is evident that this empirical reaction is very similar to that of the inflation in a pegged exchange rate framework. After expansion and income growth in the Eurozone, prices of foreign products increase and if the exchange rate remains stable, the result is an increase of CPI inflation, given that foreign goods constitute a significant portion of the consumer basket in Croatia (Palić, 2015).

Quite similarly, the empirical reaction of terms of trade (approximated by the real effective exchange rate) to a foreign income shock (Figure 3d) corresponds almost one-for-one to the IRF from the Galí and Monacelli (2005) model (Figure 1d). The domestic price growth tends to overshoot the initial growth in foreign prices, which leads to the worsening of terms of trade, i.e. a real appreciation.

From the quantitative perspective, the variable that reacted most intensively to a foreign income shock in the pegged regime's theoretical framework was the domestic output gap (Figure 1). The empirics confirm this finding, as Table 2 reveals that a foreign income shock determines 25 percent of a variance in domestic output gap, while for the interest rate, inflation, and terms of trade, respectively, this share is lower. It is interesting to note that the foreign income shock explains a bigger proportion of CPI inflation variance than the domestic income shock, possibly indicating a large influence of the foreign goods component in the consumer basket in Croatia. On the other hand, the opposite holds for terms of trade, whose variance is more influenced by domestic rather than foreign income shocks.

Table 2. Variance decomposition of selected variables, empirical model

		Contribution of shocks to variance, after 16 quarters				
		GAP_EZ	*GAP*	*IR*	*PI*	*TOT*
Variable	*GAP*	25.3	60.2	1.9	10.0	2.6
	IR	18.1	4.5	73.2	3.3	0.9
	PI	15.6	8.8	10.3	53.4	11.9
	TOT	10.3	21.7	10.5	5.7	51.8

Source: authors' calculations

Taking all into consideration, the results suggest that the small open economy model as designed and calibrated by Galí and Monacelli (2005) fits well with Croatian data, especially for the monetary regime with a pegged exchange rate.

Conclusion

The paper shows Croatian economy could be theoretically modelled as a small open economy DSGE model in the fashion of Galí and Monacelli (2005). Responses of the output gap, inflation and terms of trade fit well with theoretical conclusions as long as monetary policy is modelled as pegged exchange rate regime.

If the model resembles the data well, we can get a deeper understanding of mechanisms and variables which transmit the foreign shock, as well as get the insight into shock propagation mechanisms. What is even more important, if foreign demand shocks significantly affect domestic GDP as it has been shown in Arčabić (forthcoming), Palić (2015) and Dumičić et al. (2015), we can conclude that output fluctuations in Croatia are demand driven. This would mean that fluctuations do not represent equilibrium states of the economy which are driven by optimal decisions made by economic agents, but are rather disequilibrium states which could (and should?) be moderated by counter-cyclical economic policy.

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References

Arčabić, V. (forthcoming) Technology, Employment, and the Business Cycle in Post-transition Countries of the EU. *Post-communist Economies*, forthcoming

Dumićić, K., Palić, I. & Šprajaček, P. (2015) The role of external shocks in Croatia: block exogeneity SVAR approach. *Journal of Economic and Social Development* (1849-6628) 2(1); pp. 44-54

Galí, J., & Monacelli, T. (2005). Monetary policy and exchange rate volatility in a small open economy. *The Review of Economic Studies*, *72*(3), 707-734.

Hodrick, R. J., & Prescott, E. C. (1997). Postwar US business cycles: an empirical investigation. *Journal of Money, credit, and Banking*, 1-16.

Jovančević, R., Arčabić, V. & Globan, T. (2012) Prijenos poslovnih ciklusa zemalja Europske unije na Republiku Hrvatsku. *Ekonomski pregled*, 63 (1-2), pp. 3-21

Palić, I. (2015) *Ekonometrijska analiza i kalibracija dinamičkih stohastičkih modela opće ravnoteže gospodarstva Hrvatske*. Unpublished doctoral thesis. Faculty of Economics and Business, University of Zagreb

Vizek, M. (2008). Econometric analysis of monetary transmission channels in Croatia. *Croatian Economic Survey*, (10), 11-44.