ECONOMETRIC ANALYSIS OF ASSET PRICE CHANNELS IN MONETARY TRANSMISSION – VECTOR MODELS APPROACH

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ABSTRACT

Monetary policy is implemented by central banks. Its primary objective in most central banks, including the Croatian National Bank, is maintaining price stability - the central bank supports low and stable inflation. Given that the monetary policy decisions of the central bank are transferred to the real economy, the bank needs to know the channels of operation of the monetary transmission mechanism. In Croatia, the use of the exchange rate as the operational goal of monetary policy prevails, which is characteristic of less developed and countries in transition with small and open economies. The aim of this research is to determine the statistical significance of the asset price channel in monetary transmission to the total Croatian economy. The impact of monetary measures on the real economy was examined by econometric analysis. An assessment of the corresponding vector models was performed and the existence of cointegration among the observed variables was examined using the Johansen procedure. The analysis was conducted on the basis of quarterly data for the period of twenty years, from January 2002 to January 2022. The real economy is approximated by the consumer price index. In addition to asset prices, the impact of monetary variables such as interest rates and exchange rate on the economy was analyzed. Based on the obtained results, as expected with regard to previous research on monetary transmission in the Republic of Croatia, the exchange rate channel has the most significant long-term impact on the real economy. The analysis of the obtained vector models shows the strengthening of the monetary transmission mechanism through the interest rate channel to the Croatian economy. Also, long-term impact of the asset prices on the growth of the Croatian economy proved to be statistically significant. Additionally, limitations and recommendations for future research were given.

Keywords: *econometric analysis, cointegration, monetary transmission mechanism, vector models*

1. INTRODUCTION

Like many post-transition economies, the Croatian economy is small, open and highly euroized. Namely, the Croatian financial system is not sufficiently developed, and since banks are the most active credit institutions in the payment system and in the financial market, it is characterized by a strongly developed banking system. These characteristics of the Croatian financial system and economy in the implementation of monetary policy require stability of the euro/kuna exchange rate as the primary goal of the Croatian National Bank. A review of previous research on the transfer of the Croatian National Bank's monetary policy to the economy has shown that monetary policy measures are predominantly transmitted through the exchange rate channel, while the effect through the interest rate channel is still weaker. The examination of the monetary transmission mechanism through asset channels (stock price, real estate price) will be carried out by estimating vector models while the long-term correlation between real and monetary variables will be examined by Johansen's cointegration testing procedure. Namely, cointegration analysis and VAR models (Vector AutoRegression model) are connected by the Vector Error Correction model (VECM). The operation of the monetary transmission mechanism will be observed through interest rates variables on interbank demand deposit trading, real effective exchange rate index of the kuna and the house price index and

the Zagreb Stock Exchange Equity Index, while the success of the monetary transmission channel will be monitored through the consumer price index.

2. LITERATURE REVIEW

In most research to date the effect of the monetary transmission mechanism has been examined by econometric analysis by vector models approach. In a study of the monetary transmission mechanism in Central and Eastern Europe Ganev et al (2002) stated that the main goal of the monetary policy of most transition countries in the beginning was the stability of national currencies (domestic stability of the national currency refers to the levels and stability of inflation while external stability refers to the adopted exchange rate regime). According to research by Egert and MacDonald (2009), who also investigated monetary transmission channels in Central and Eastern Europe, the transmission of monetary transmission through the exchange rate channel has lost importance over time while the interest rate channel has been strengthening and asset channels and the credit channel are weak. The research on the operation of the credit channel in Croatia was conducted by Ćorić (2008), and the size and ownership structure of banks proved to be limiting factors in the monetary transmission credit channel. Ivanov and Lovrinović (2008) investigated the monetary transmission mechanism through the property price channel (share price, exchange rate, real estate price) in the Republic of Croatia, which has gained significant importance given the strong credit expansion and emerging markets and all as a result of great global liquidity. Benazić (2009) concludes that the interest rate channel of monetary transmission exists, but that it is weak and that there is a significant role of the exchange rate in Croatian monetary transmission. The results of the research by Erjavec and Cote (2003) showed a neutral impact of money supply in the short run on economic activity and that monetary policy does not have a sufficient impact on sustainable economic development and price stability in the Republic of Croatia. In their research, Lang and Krznar (2004) showed that monetary policy in the Republic of Croatia was pro-cyclical, which is a characteristic feature of exchange rate targeting in small and open economies. Vizek (2006) came to the conclusion that the real sector was significantly influenced by monetary policy through regulating the money supply and the exchange rate, while monetary policy through the interest rate channel did not affect real economic activity. The results of Doležal's (2011) research showed that no monetary transmission channel had a strong impact on real economic activity and price levels in the short run, while the exchange rate channel had the strongest impact in the long run, the money supply had a slightly weaker impact and the interest rate had the weakest impact.

3. MONETARY TRANSMISSION MECHANISM

Monetary policy is an integral part of national economic policy and is implemented by the central bank. Monetary policy is determined by its goals (Lovrinović, Ivanov, 2009, 203-204): high employment (when labor demand equals labor supply), economic growth (increase in gross domestic product), price stability (achieving low inflation rates between 2 % to 3% per year in the medium and long term with sustainable economic growth), stability of interest rates (increases transparency and stability of financial markets), stability of financial markets (efficient transfer of funds and avoidance of financial crisis) and stability in foreign exchange market (prevents changes of exchange terms related to the decline or increase in the value of the domestic currency against a foreign currency). Namely, the central bank manages the money supply and interest rates on the market by conducting monetary policy. Therefore, a developed financial system is crucial for the transfer of monetary policy to the economy. The transmission of monetary impulses to the economy takes place through the channels of the monetary transmission mechanism.

According to Benazić (2009, 18) and the specifics of the Croatian financial system, the channels of the monetary transmission mechanism can be divided into the transmission interest rate channel, the property price transmission channel, the exchange rate transmission channel and the credit transmission channel.

A brief description of the mechanisms through which transmission channels operate is given in Table 1.

The exchange rate channel
the effect of the exchange rate on exports and imports $\uparrow M \Rightarrow \downarrow r \Rightarrow \downarrow A \Rightarrow \uparrow E \Rightarrow \downarrow U \Rightarrow \uparrow Y \Rightarrow \uparrow GDP$
the effect of the exchange rate on the balance sheet $\uparrow M \Rightarrow \uparrow E \Rightarrow \uparrow D \Rightarrow \downarrow NW \Rightarrow \downarrow L \Rightarrow \downarrow I \Rightarrow \downarrow Y \Rightarrow \downarrow GDP$
The interest rate channel
$\uparrow M \Rightarrow \downarrow r \Rightarrow \uparrow I \Rightarrow \uparrow Y \Rightarrow \uparrow GDP$
The credit channel
acting on the balance sheet of economic entities and through bank loans $\uparrow M \Rightarrow \downarrow r \Rightarrow \uparrow K \Rightarrow \uparrow I \Rightarrow \uparrow C \Rightarrow \uparrow Y \Rightarrow \uparrow GDP$
The real estate prices channel
acting on the direct effect on household expenditure $\uparrow M \Rightarrow \downarrow r \Rightarrow \uparrow P_h \Rightarrow \uparrow H \Rightarrow \uparrow Y \Rightarrow \uparrow GDP$
impact on household welfare $\uparrow M \Rightarrow \uparrow P_h \Rightarrow \uparrow W \Rightarrow \uparrow C \Rightarrow \uparrow Y \Rightarrow \uparrow GDP$
acting on the balance sheet of commercial banks $\uparrow M \Rightarrow \uparrow P_h \Rightarrow \uparrow W \Rightarrow \uparrow C \Rightarrow \uparrow Y \Rightarrow \uparrow GDP$
The stock prices channel
impact on investment $\uparrow M \Rightarrow \uparrow P_s \Rightarrow \uparrow q \Rightarrow \uparrow I \Rightarrow \uparrow Y \Rightarrow \uparrow GDP$
acting on the balance sheet of the entrepreneur $\uparrow M \Rightarrow \uparrow P_s \Rightarrow \uparrow NW \Rightarrow \uparrow K \Rightarrow \uparrow I \Rightarrow \uparrow Y \Rightarrow \uparrow GDP$
effect on the population balance (liquidity of the household sector) $\uparrow M \Rightarrow \uparrow P_s \Rightarrow \uparrow value\ of\ financial\ assets \Rightarrow \downarrow Financial\ instability \Rightarrow \uparrow C_d \Rightarrow \uparrow H \Rightarrow \uparrow Y \Rightarrow \uparrow GDP$
acting on the well-being of the population sector $\uparrow M \Rightarrow \uparrow P_s \Rightarrow \uparrow W \Rightarrow \uparrow C \Rightarrow \uparrow Y \Rightarrow \uparrow GDP$
↑M – expansive monetary policy, r – interest rate, A – demand for financial assets, E – nominal exchange rate, U – import, D – debts of domestic sectors, NW – net value of domestic sectors, L – loans to domestic sectors, K – loans, C – consumption, Ps – stock price, q – Tobinov q, Cd- expenditure on durable goods (long-term expenditure including expenditure on furniture, household equipment and regular maintenance), H - expenditure on real estate (investment in land, flats, houses) or expenditure on housing, Ph - real estate prices (average price of dwellings sold per 1 m2), W - welfare, total disposable income, I - investments, Y - production, GDP – Gross domestic product

Table 1: Transmission channels and mechanisms of action
(Source: Benazić, 2009., 18-26)

4. REGRESSION MODELS

The first form of VAR (Vector AutoRegression model) model was given by Sims in 1980 (general unrestricted VAR model) which does not assume any restrictions on parameters and treats all variables symmetrically, ie variables are not pre-classified into dependent and independent. Namely, VAR models are generalizations of dynamic models of time group series defined on the basis of one equation.

The analysis of VAR models is used in testing economic theories that assume certain forms of correlation or causality between economic variables and in analyzing the dynamics of phenomena in previous periods. The interpretation of the VAR model uses the results of an innovation analysis consisting of an Impulse Response Function (IRF) and Decomposition of Variance (DVC) analysis. The impulse response function shows the response intensity of each dependent variable to the unit shock of other variables in the model, and is presented with a confidence interval to determine a statistically significant response to shock and the actual sign of the response. Since the variance decomposition represents the variance partition of the individual variable prognostic error into the parts associated with all variables, it is possible to analyze the share of variation in the observed variables of individual variables in the model. (Bahovec, Erjavec, 2009., 339-348,), Enders, 2010., 299-301, Jovančević, Arčabić, Globan, 2012.) VAR model can be expressed as

$$Z_t = a_0 + \sum_{i=1}^{k} a_i Z_{t-i} + e_t \tag{1}$$

where a_0 is deterministic term, Z_t is vector variables, e_t is error term. Stability VAR model requires that all parameters of the characteristic polynomial be within a unit circle (Bahovec, Erjavec, 2009., 362)

Johansen's cointegration testing procedure examines the long-term correlation between the observed variables. Vector Error Correction Model (VECM) links VAR models and cointegration analysis and can be expressed as (Bahovec, Erjavec, 2009., 370)

$$\Delta Z_t = \sum_{i=1}^{k-1} \Gamma_i \Delta Z_{t-i} + \Pi Z_{t-k} + e_t \tag{2}$$

where Z_t is vector variables, ΔZ_t is vector difference variables, e_t is error term. By estimating matrix parameters $\hat{\Gamma}_i$ and $\hat{\Pi}$ the model connects short-term ($\sum_{i=1}^{k-1} \Gamma_i \Delta Z_{t-i}$) and long-term dynamics (ΠZ_{t-k}).

Vector models require the stationarity of the variables included in the model, and the stationarity test is performed using the Unit Root Test. In this study, the results of the ADF (Augmented Dickey-Fuller test), PP (Phillips-Perron test) and KPSS (Kwiatkowski, Phillips, Schmidt, Shin) tests were used to examine the stationarity of the observed variables. The null hypothesis of the ADF and PP test is about the existence of a single root (non-stationary process) and the alternative hypothesis is about the non-existence of a single root (the process is stationary) while in the KPSS test it is the opposite. The general form of the Dickey-Fuller regression equation is:

$$\Delta Y_t = a_0 + \gamma \cdot Y_{t-1} + \alpha_2 t + e_t \tag{3}$$

where a_0 is constant, $\alpha_2 t$ is trend, and the test quantity on the basis of which the test is performed is defined by $t = \frac{\hat{\gamma}}{SE(\hat{\gamma})}$. (Bahovec, Erjavec, 2009., 262-279, Arčabić, 2022.)

Furthermore, in the application of vector models, it is important to select the offset length k for the selection of the optimal length using multivariate information criteria that measure how well the model describes the data. The best known are the Akaike criterion (AIC), the Schwarz (SBC) criterion and the Hannan-Quinn (HQ) criterion, and are defined

$$\begin{aligned} AIC &= -2\ln(L) + 2M \\ SBC &= -2\ln(L) + Mln(T) \\ HG &= -2\ln(L) + 2Mln(\ln(T)) \end{aligned} \tag{4}$$

where L is the maximum likelihood function of the estimated model, M is the total number of estimated parameters ARMA (p, q) model and T is the number of data used in the estimation. If the relation errors are normally distributed then the expression (4) reads

$$\begin{aligned} AIC &= Tln(\frac{2\pi \cdot SR}{T} + 1) + 2M \\ SBC &= Tln(\frac{SR}{T}) + Mln(T) \\ HG &= Tln(\frac{SR}{T}) + 2Mln(\ln(T)) \end{aligned} \tag{5}$$

where *SR* is the sum of the residual deviations squares of the estimated model. A better model is the one for which the value of information criteria is lower. The mildest information criterion is the AIC criterion because it selects the models with the largest number of parameters while the SBC is the most rigorous because it selects the models with the least number of parameters. The optimal model is considered to be the one with the lowest value of the indicator but provided that it satisfies all diagnostic tests. Namely, choosing too many shifts leads to the loss of degrees of freedom, while choosing too few shift lengths increases the probability of autocorrelation of relation errors. (Bahovec, Erjavec, 2009., 295-296, 380-381)

5. RESULTS

The consumer price index was used in the research as an approximation of the real economy. Namely, the consumer price index as a real variable was observed by numerous authors in their research on monetary transmission such as Peersman and Smets (2001), Ganev et al (2002), Erjavec and Cota (2003), Lovrinović and Benazić (2004), Doležal (2011). In the research, interest rates on interbank demand deposit trading, real effective exchange rate of the kuna and the house price index and the Zagreb Stock Exchange Equity Index were taken as monetary variables, ie variables through which monetary measures are transferred to the economy. All indices were taken with the base year 2015. The time period from the first quarter of 2002 to the last quarter of 2021 was analyzed, and all data were taken from the official website of the Croatian National Bank, the Croatian Bureau of Statistics and Zagreb Stock Exchange. Furthermore, all variables are seasonally adjusted to eliminate seasonal effects and they are logarithmic except for the interest rate to stabilize variance. The stationarity of the variables was examined using unit root tests which showed that all variables were integrated of order 1, I (1), ie all variables were nonstationary in levels and stationary in first differences. A graphical representation of the original variables and their first differences is given in Figure 1.

Figure following on the next page

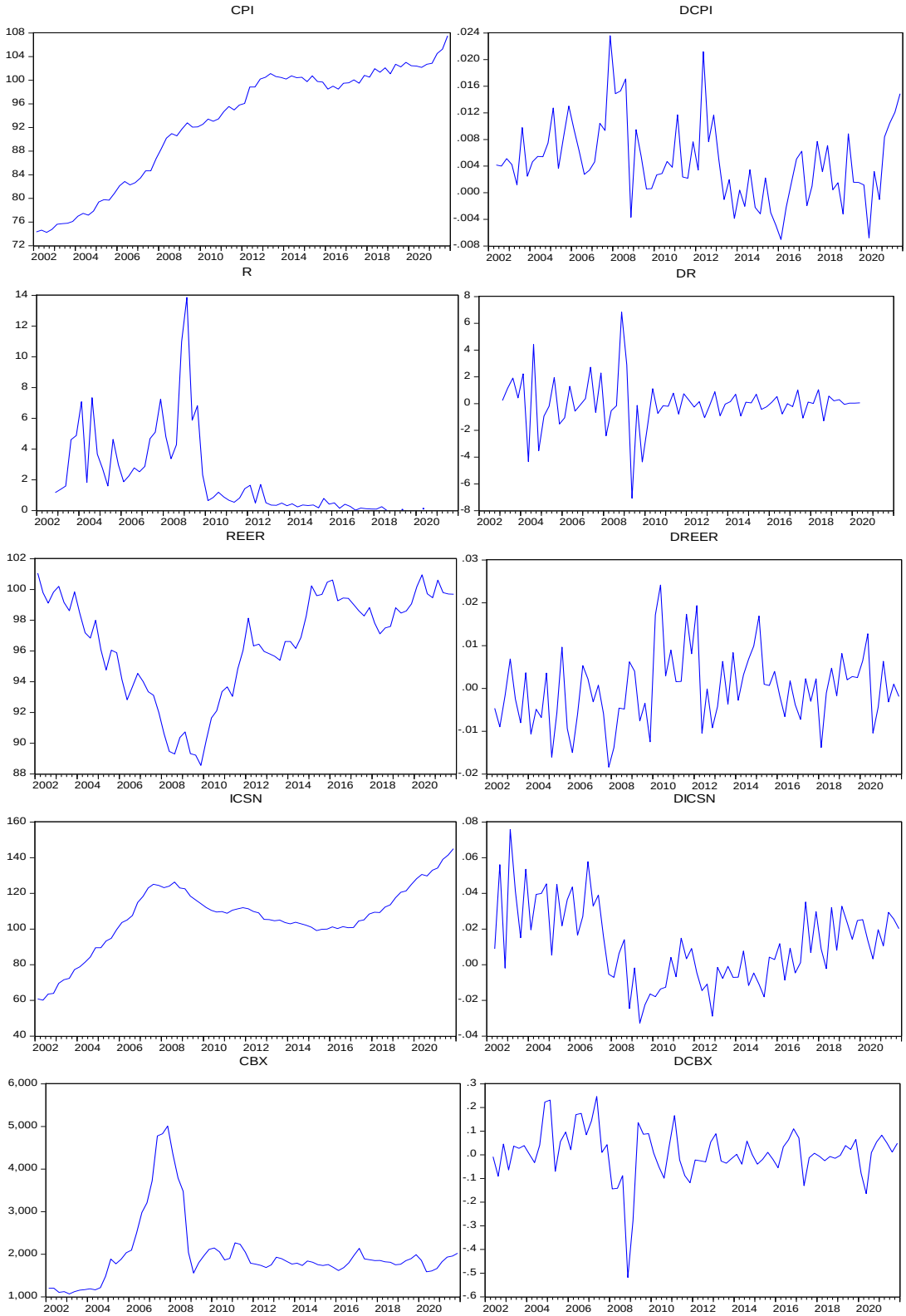

Figure 1: Graphical representation of the original variables and their first differences (Source: author`s calculation)

Differentiation of variables removed the existence of the trend, so only a constant was included in the model. Based on the AIC information criterion, a two lags VAR model was selected, which proved to be stable. The results of the information criteria are given in Table 2, and the stability of the VAR model is shown in Figure 2.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	547.3846	NA	3.00e-14	-16.94952	-16.78086	-16.88307
1	600.1939	95.71695	1.26e-14	-17.81856	-16.80658*	-17.41989*
2	632.6075	53.68492*	1.01e-14*	-18.05023*	-16.19494	-17.31934
3	653.2537	30.96935	1.21e-14	-17.91418	-15.21557	-16.85106
4	675.5928	30.01824	1.41e-14	-17.83103	-14.28911	-16.43569
5	703.2769	32.87483	1.46e-14	-17.91490	-13.52967	-16.18734
6	728.7519	26.27108	1.75e-14	-17.92975	-12.70120	-15.86996

Table 2: VAR Lag Order Selection Criteria
(Source: author`s calculation)

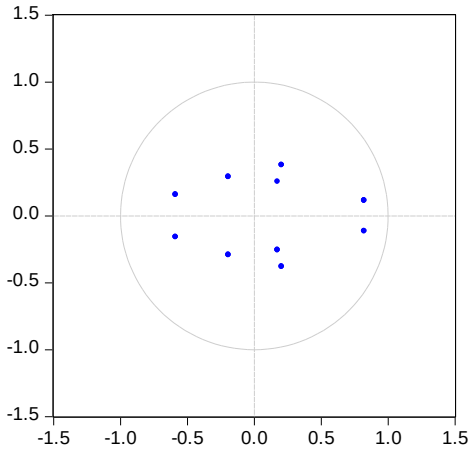

Figure 2: Roots of Characteristic Polynomial VAR model
(Source: author`s calculation)

The correlation of variables in the long run was examined by Johansen's procedure since long-term correlation between variables may exist even though the variables in the levels are nonstationary but their linear combination can be stationary. The highest eigenvalue test was used to select the number of cointegration vectors, which showed that the variables were cointegrated with one cointegration vector. The test results are presented in Table 3.

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.498093	46.18578	33.87687	0.0011
At most 1	0.326329	26.46585	27.58434	0.0690
At most 2	0.242594	18.61632	21.13162	0.1085
At most 3	0.153366	11.15462	14.26460	0.1466
At most 4	0.044487	3.048981	3.841466	0.0808

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Table 3: Unrestricted Cointegration Rank Test (Maximum Eigenvalue)
(Source: author`s calculation - EViews)

The cointegration vector is given by the equation:

$$ICP = -0{,}02 * IR + 0{,}64 * REER + 0{,}39 * ICSN - 0{,}01 * CBX + 0{,}16 \quad (6)$$
$$(0{,}00) \quad (0{,}21) \quad (0{,}05) \quad (0{,}02)$$
$$[9{,}27] \quad [-3{,}11] \quad [-7{,}57] \quad [0{,}06]$$

where the standard errors are in parentheses and the corresponding t-values are in square brackets. Based on the obtained equation, the long-term negative impact of the interest rate realized in the trade of deposits on the interbank market on the consumer price index is visible, which is in line with economic theory. This impact is weak, namely, the growth of interest rates in trade in deposits on the interbank market leads to a fall in consumer prices by an average of 0.02%, ceteris paribus. The exchange rate channel still has the most significant impact in the long run in monetary transmission. Furthermore, the long-term impact of the house price index on real economic activity is statistically significant and positive, which is in line with the theory, while the long-term impact of the Zagreb Stock Exchange index in the model is not statistically significant.

The results of the corresponding VEC model are shown in Table 4. (values in brackets are the corresponding t - values).

Variable	VEC Model
ECT	-0,0489 [-2,70]
ΔICP_{t-1}	0,4170 [3,21]
ΔIR_{t-1}	0,0004 [0,92]
$\Delta REER_{t-1}$	0,6010 [0,69]
$\Delta ICSN_{t-1}$	-0,0457 [-1,06]
ΔCBX_{t-1}	-0,0131 [-1,82]
C	0,0031 [2,92]

Table 4: The results of VEC model
(Source: author`s calculation - EViews)

According to the theory, ECT, a member of the error correction, is negative and statistically significant in the model, and indicates that the consumer price index corrects 4.89% of the total long-term deviation from imbalance in one quarter. Additionally, two dummy variables were considered in the model to examine the impact of the financial crisis and the Covid-19 pandemic. However, since both dummy variables did not prove statistically significant, they were excluded from the model. The estimated model proved to be adequate since the estimated residual deviations are stationary and there is no problem of autocorrelation. The coefficient of determination R^2 shows that 31% of the dependent variable varaince is explained with this model.

6. CONCLUSION

A cause-and-effect relationship between the observed variables was performed by estimating the appropriate vector models. The research looked at interest rate variables realized in interbank deposit trade, the real effective exchange rate index of the kuna, the house price index, and the stock exchange index of the Zagreb Stock Exchange as variables through which monetary policy is transferred to the economy while the success of the transfer is observed through the consumer price index. Based on the obtained results, as expected with regard to previous research on monetary transmission in the Republic of Croatia, the exchange rate channel has the most significant impact on the real economy in the long run.

Furthermore, the analysis of the obtained vector models shows the strengthening of the monetary transmission mechanism through the interest rate channel to the Croatian economy. Also, in the long run, the impact of the house price index on the growth of the Croatian economy proved to be statistically significant. Several limitations have been identified in this study, such as the lack of feasibility of all monetary transmission assumptions due to the problem of including a large number of variables, and one of the limitations is the sample size, ie the number of years taken into consideration, which all may result in inadequate estimates. Based on the data (Figure 1), the impact of the financial crisis (2008-2009) and the impact of the COVID economic crisis are visible. Thus, there are structural fractures in time series. In the ECM model, the introduction of dummy variables did not prove statistically significant.

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