Econometric Analysis of Monetary Transmission Channels in Croatia*

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Abstract

The aim of this paper is to explore the characteristics and functioning of monetary transmission in Croatia. Time series analysis (unit root test, VAR, Johansen cointegration procedure, Granger causality tests and error correction model) is used to estimate the influence of exchange rate, interest rate and narrow money on the real economic activity. The results of econometric analysis suggest that monetary policy in Croatia had a significant influence on the real activity through the direct monetary transmission and exchange rate channel. Furthermore, the results of statistical tests suggest that the interest rate channel is not active. The short-run interest rate inelasticity of Croatian economy combined with a strong exchange rate channel could present a great difficulty once Croatia joins the EMU, since the interest rate channel is the most important channel of monetary transmission in the EU, while the exchange rate channel will be eliminated upon adopting the euro. This could provoke a non-responsiveness of the Croatian economy to the EU monetary policy or it could make the monetary transmission asymmetric. However, high euroisation of the Croatian economy could facilitate the interest rate transmission once the euro is adopted.

Keywords: monetary policy, monetary transmission, time series analysis, transition economies, Croatia

JEL classification: B0, C2, E4, E5

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1 Introduction

This paper analyses the mechanisms of monetary transmission in Croatia. Monetary transmission is a system of functionally related variables explaining the influences that changes in money supply and money demand have on non-monetary variables. The primary element of monetary transmission is a shock to monetary equilibrium caused by changes in money supply which are the result of different measures in monetary policy or changes in money demand. Its final element is the re-establishing of monetary equilibrium through prices and real variables, which affects the national product (Baletić, 2004). The study of monetary transmission is of great importance for monetary authorities since a good knowledge of its characteristics allows them to stabilise unfavourable economic fluctuations in an efficient way and in due time as well as to favourably affect prices and the real activity. Furthermore, an insight into monetary transmission enables them to anticipate the effects of monetary policy measures, which is indispensable for implementing the inflation targeting regime introduced by several transition countries (the Czech Republic, Slovakia, Hungary and Romania).

The paper also addresses the problem of empirical research of monetary transmission mechanisms, i.e. exchange rate channel, interest rate channel and direct monetary transmission in Croatia. Bearing in mind that the structure of Croatian economy is somewhat similar to the small and open economies of Central and Eastern European (CEE) countries that are characterised by a developed bank system, an underdeveloped financial market and the presence of unofficial euroisation, the results should confirm the hypothesis that Croatia is similar to those countries regarding the activity of monetary transmission channels as well. Therefore, it is expected that, in addition to the direct monetary transmission, the exchange rate channel will be of the utmost importance in monetary transmission.

The characteristics of Croatia, such as the "fear of floating", the monetary policy aimed at maintaining stability of the exchange rate and a significantly higher level of euroisation additionally contribute to the assumption about the importance of the exchange rate channel in monetary transmission. On the other hand, high interest rate volatility on the money market, a lack of Croatian National Bank's (CNB) referent interest rate until 2005 and a great competition on the bank market in the last couple of years indicate there is a small probability that the interest rate channel will be active. The lack of CNB's referent interest rate and open market operations until 2005 are the characteristics that differentiate Croatian monetary system not only from most of the CEE countries, but also from the EU-15 countries where the interest rate channel is the dominant way of transmitting monetary policy impulses on prices and the real economic activity.

The results of empirical analysis conducted in this paper confirm that the interest rate channel and the direct monetary transmission play an important part in monetary transmission in Croatia, whereas the interest rate channel is not developed enough. Once Croatia joins the EMU, high euroisation and the bank system owned by banks from the EMU countries could help establish the interest rate channel. On the other hand, until Croatia enters the EMU, CNB's repo auctions are the first step in making the interest rate channel active.

At the very beginning of this paper, an overview of developments in the monetary sector as well as an outline of the main instruments of monetary policy for the period from 1990 to 2006 is given. Secondly, a brief review of monetary transmission characteristics in the EU and the CEE countries follows. Finally, the third part of the paper describes the econometric analysis of monetary transmission in Croatia consisting of three parts. First of all, a detailed description of the employed time series is provided, followed by unit root tests which examine whether the time series are stationary or nonstationary. The paper then tries to answer if there is a cointegration between the time series of the same order of integration. If such a relationship is proven to exist, the error correction model is established and subsequently included into the Granger causality test carried out in the third part of econometric analysis.

Finally, the paper concludes with a discussion on the implications that the empirical results might have on the implementation of monetary policy in Croatia.

2 Monetary Policy Developments in Croatia from 1990 to 2006

The process of gaining independence in Croatia was followed by the necessary institutional changes. The CNB became an independent central bank that introduced the Croatian currency and started implementing monetary policy in order to achieve its main goal – the stability of prices.[1]

Two major economic characteristics which have determined monetary policy in Croatia are the presence of inflation expectations tied to exchange rate movements and the high level of euroisation. Regardless of a successful implementation of the Stabilisation programme launched in 1993, it resulted in the "fear of floating".[2] Consequently, monetary policy instruments (*foreign exchange interventions and obligatory reserve requirement*) aimed at preserving the exchange rate stability[3] were used, thus ensuring the price stability. The control of exchange rate resulted in a relatively fixed kuna exchange rate, as compared to other transition countries[4], and a low annual consumer price inflation and core inflation (average annual consumer price and core inflation in the period from 1996 to 2005 was 3.5 and 2.6 percent respectively).[5]

The "fear of floating" has also been manifested in the growth of international reserves which have become larger than money supply. Therefore, Croatian monetary system can be referred to as a quasi currency board or "floating exchange rate with a life jacket" (Billmeier and Bonato, 2002; Reinhart and Rogoff, 2002). Table 1 provides an overview of changes in exchange rate, prices, monetary and other economic indicators.

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[1] *It is important to point out that the price stability as the primary goal of the central bank was clearly defined in 2001 by the Law on Croatian National Bank.*

[2] *The fear of a negative influence of exchange rate changes on prices and the rest of economy.*

[3] *To be more precise, the mentioned instruments control changes in the exchange rate within the implicit band that has never been officially announced. In his interviews to the media, the governor Rohatinski states that the CNB defends the exchange rate ranging from 7.30 to 7.60 HRK/EUR.*

[4] *Variablity of exchange rate and de facto exchange rate regimes are discussed in Reinhart and Rogoff (2002).*

[5] *These were the lowest inflation rates in the transition countries.*

Table 1 **Main Economic Indicators**

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Economic activity											
Real GDP (% changes)	6.8	5.9	6.8	2.5	-0.9	2.9	4.4	5.6	5.3	3.8	4.3
Industrial production (% changes)	0.3	3.1	6.8	3.7	-1.4	1.7	6.0	5.4	4.1	3.7	5.1
Unemployment rate (registered, %, pa)	14.5^{+}	16.4^{+}	17.5^{+}	17.2	19.4	21.3	22.0	22.3	19.1	18.0	17.9
GDP per capita (USD)	4,029	4,422	4,398	4,805	4,371	4,153	4,476	5,141	6,493	7,724	8,870
Prices and exchange rate											
Consumer price inflation (%, ep)	2.0	3.4	3.8	6.0	3.9	5.5	2.4	1.8	1.7	2.7	3.6
Core inflation (%, ep)	-	2.8	2.5	5.2	2.9	3.3	1.2	1.2	1.2	3.0	2.6
Exchange rate, HRK/EUR (pa)	6.75	6.80	6.96	7.14	7.58	7.64	7.47	7.41	7.56	7.50	7.40
Exchange rate, HRK/USD (pa)	5.23	5.43	6.16	6.36	7.11	8.28	8.34	7.86	6.70	6.04	5.95
Trade and capital flows											
Current account balance (% of GDP)	-7.5	-4.8	-12.5	-6.7	-7.0	-2.4	-3.2	-8.4	-7.3	-4.9	-6.3
Foreign Exchange Reserves (in million USD)	1,895	2,314	2,539	2,816	3,025	3,525	4,704	5,886	8,191	8,759	8,801
Foreign debt (in million USD)	3,809	5,308	7,452	10,738	10,142	11,282	11,870	15,679	24,759	24,759	30,219
Monetary indicators											
M1 (% changes, ep)	24.0	38.1	20.8	-1.5	2.4	30.1	31.5	30.2	9.8	2.0	12.3
M4 (% changes, ep)	39.3	49.1	38.3	13.0	-1.1	29.3	45.2	9.5	11.0	8.6	10.5
Total credits (% changes, ep)	18.6	3.1	44.4	22.4	-6.6	9.0	23.1	30.0	14.6	14.0	17.2
Household credits (% changes, ep)	35.4	39.5	93.5	38.4	8.6	21.0	29.3	43.0	27.7	18.7	20.3
Enterprise credits (% changes, ep)	21.2	2.6	35.6	17.1	-14.5	0.9	21.3	22.6	5.1	8.0	16.3
Interest rate on the money market (%, pa)	21.1	19.3	10.2	14.5	13.7	8.9	3.9	1.8	3.0	4.6	2.3

Note: $^{+}$Employed in army and police not included; Conventional abbreviations: pa - period average, ep - end of period, HRK - Croatian kuna, USD - US dollar, EUR - euro.
Source: Central Bureau of Statistics and Croatian National Bank.

The main instrument of monetary policy – foreign exchange intervention – has been implemented according to a discretionary decision of the CNB, with the aim of preserving the stability of the national currency and maintaining the liquidity of payments. Liquidity created by interventions on the foreign exchange market has been sterilised by the reserve requirement instrument in order to avoid the negative influence on prices and to improve the effectiveness of interest rate based monetary instruments (Lang and Krznar, 2004). The CNB used short-run treasury bills up to the mid-2005. Afterwards, instruments with active interest rates have been used in repo auctions. Then the CNB introduced a new instrument – open market operations – intended to manage money supply and implemented by repo and reverse repo auctions. Open market operations also have the task of establishing a referent interest rate on the money market which would alleviate a significant variability of interest rates and create the necessary conditions for the functioning of *interest rate channel*.

In order to better comprehend monetary transmission, it is also necessary to define, in addition to a description of Croatian monetary policy, how developments in the monetary and real sector have influenced the choice of monetary instruments and measures.

The process of gaining independence in Croatia was accompanied by the war which caused a 36 percent fall in output in the period from 1990 to 1993 (Lang and Krznar, 2004) and a monthly inflation that reached 38 percent in October 1993. The Stabilisation Programme launched in 1993 introduced the nominal exchange rate anchor. Thanks to the increased capital inflows from abroad, the exchange rate soon appreciated, reaching the level of 4.1 HRD/DEM. The CNB eliminated the appreciation pressures by intervening on the foreign exchange market, while the excess of liquidity was sterilised by an increase in the reserve requirement rate. As an additional instrument for managing liquidity, the CNB introduced voluntary and obligatory treasury bills from 1994 to 1998.

The problem of a liberalised entry of new banks into the bank market and a fast growth of small and medium sized banks culminated in the period from 1998 to 1999. Fourteen banks went bankrupt, while two large banks were recapitalised.

The banking crisis was followed by a short-run deceleration in economic activity (see Table 1) and strong depreciation pressures on kuna. However, inflation in this period did not respond to depreciation (Kraft, 2003). Furthermore, interest rates did not significantly respond to the crisis due to the agreement between banks to freeze the ceiling for overnight rate to 10 percent.

At the beginning of 2000, the Croatian Government started paying off its arrears that were one of the main causes of liquidity crunch. It also caused a weak monetary expansion, which resulted in the surplus of bank liquidity and encouraged economic growth. At the end of 2001, due to the conversion into euro, Croatia experienced a great inflow of foreign exchange into the banking sector. Kraft (2003) reports that around 3.3 billion euro, in circulation in Croatia at the time, were converted. Sixty percent of the amount was kept in banks, allowing for a stronger credit activity. After domestic savings were used, banks maintained the high rate of credit growth by foreign borrowing, thus generating a great increase in foreign debt. Croatian banks were restructured and privatised by being sold to foreign banks in 1999 and 2000, which allowed them an easy access to foreign funds. Given the dramatic growth of foreign debt (see Table 1), the CNB tightened the monetary policy in 2003. A ceiling of 16 percent on annual growth of bank credits was established. The penalty for exceeding the ceiling was the obligation to buy treasury bills of the CNB. The ceiling was abolished in 2004 since it was not able to control the credit expansion or foreign borrowing of Croatian banks. The CNB continued with a more restrictive monetary policy by introducing the marginal reserve requirement. Since the banks continued borrowing, the marginal reserve requirement was increased from the initial 24 to 55 percent in 2006.

Despite a great increase in the amount of lending and the expansion of domestic demand since 2000, price stability was nonetheless maintained. Due to a great import dependency of the Croatian economy, the increase in domestic demand is primarily manifested through an increase in current account deficit.

Monetary authorities have justified the "status quo" of monetary policy even after the inflation was successfully stopped (Kraft, 2003) by the fact that a high level of euroisation has been present in the Croatian economy. The national currency has become the medium of exchange, while the unit of account and the store of value functions have not become operational. As a consequence, the prices of more valuable goods have been expressed in a foreign currency. The same applies to savings (over 70 percent of savings are in a foreign currency). With the aim of rectifying the currency mismatch of liabilities and assets in the balance sheet, the banks have extended credits with a foreign currency clause, thus spreading exchange rate risks to households and enterprises. The government has also been under the influence of euroisation in the financial system since a significant amount of its domestic debt has had a foreign currency clause – as bonds traded on the capital market. Therefore, it is expected that the "fear of floating" will continue as well as the policy of a firm control of the exchange rate. Furthermore, the dominant effect of the *exchange rate channel of monetary transmission* is to be expected. However, Billmeier and Bonato (2002) and Kraft (2003) do not find a significant transmission of the exchange rate movement on prices in Croatia, which makes this study even more challenging.

3 Characteristics of Monetary Transmission in the EU-15 and CEE Countries

We are going to start the overview of empirical research on monetary transmission in the EU with the paper by Peersman and Smets (2001). By applying the vector autoregression to synthetic data from the EU in the period from 1980 to 1998, the authors examine monetary transmission in the EU-15 countries. According to their findings, a temporary growth of the short-run interest rate is followed by the real appreciation of the exchange rate and a temporary fall in output. Prices do not immediately respond to monetary contractions; they start declining considerably only a couple of quarters after GDP. The decrease in output following the monetary shock is mostly considered to be the result of investment contractions that are three times higher than the GDP contraction and only to a lesser degree the result of personal consumption contraction.

Mojon and Peersman (2001) also use VAR to analyse monetary transmissions in the EU-15 countries. Their results are similar to the ones Peersman and Smets obtained for the synthetic EU-15 aggregates. Thus, the contractionary monetary policy shock causes a temporary fall in GDP that usually peaks four quarters after the shock in most countries, while the respective decline in prices takes place gradually. A greater effect of monetary shock on GDP is achieved through changes in investment and export, while the change of GDP is much smaller, due to the effects of monetary shock on personal consumption.

McAdam and Morgan (2001) improved the evaluation of monetary transmission in the EU by simulating AWM and NiGEM[6] models. The results of both models indicate that the dominant channel of transmitting monetary impulses to GDP is the one operating through interest rates. The main exception to this rule are the first year results obtained by the NiGEM model where the exchange rate channel dominates.

Van Els et al. (2001) analyse the monetary transmission mechanisms in the EU using a large structural macroeconomic model. They conclude that during monetary contractions, related to an interest rate increase of 1 percentage point, GDP decreases by 0.4 percent, which becomes evident only two years later. The exchange rate channel dominates in the first two years, whereas from the third year on the interest rate channel becomes dominant.

Ehrman et al. (2001) examined the role of banks in the process of monetary transmission in the EU-15 countries and demonstrated that the bank credit activity is significantly reduced after a monetary contraction both on the aggregate level of EU-15 and in individual countries. By analysing the bank micro data, the authors concluded that the response of more liquid banks to the monetary policy measures is weaker (thus implying active bank lending channel), although the same is not true for all the countries in the sample. A factor such as bank capitalisation is not relevant in explaining bank adjustment to monetary measures, contrary to the results from the USA.

[6] *Area Wide Model and National Institute for Economic and Social Research Global Model.*

Chatelain et al. (2001) examined the effects of monetary transmission on enterprise investment in the largest EU economies (Germany, France, Italy and Spain). They showed that the enterprise investment is elastic to changes of the user cost of capital, which implies the activity of interest rate channel.

Angeloni et al. (2001) concluded that the results of VAR models and large structural models are relatively similar, indicating that after an unexpected monetary contraction a temporary output contraction follows, reaching its peak after a year, whereas a decline in prices is much more gradual and takes place only after the first year. The authors emphasise that the model estimates point to the relevance of investments to the changes of GDP. This is the difference between the monetary transmission process of the EU-15 countries and the USA, where the measures of monetary policy affect GDP through the changes in personal consumption.

They also claim that the research so far has not been able to isolate the dominant channel of monetary transmission. Two important channels have been singled out – the credit channel and the interest rate channel (the role of credit channel in the monetary process of EU-15 countries being probably overrated).

Unlike in the EU-15 countries, empirical research of monetary transmission in the CEE countries was not intensive in the past. It has increased only after some countries joined the EU and in some cases introduced the regime of inflation targeting, which requires knowledge of the process of monetary transmission.

Ganev et al. (2002) examined the characteristics of interest rate channel and exchange rate channel for the following countries: Poland, Hungary, the Czech Republic, Slovakia, Slovenia, Romania, Bulgaria, Lithuania, Latvia and Estonia. First, they used the Granger test to prove that, in most countries, the exchange rate channel is stronger and more stable than the interest rate channel. Furthermore, using the impulse response function, the authors examined the effect of interest rate and exchange rate on output and prices. The results indicate that an increase in interest rates decreases inflation, while depreciation causes inflation and an increase in output.

Using VAR, Anzuini and Levy (2004) estimated the efficiency of monetary transmission in the Czech Republic, Poland and Hungary. The results imply that, despite a lower level of financial system development, macroeconomic variables of these three countries have identical reactions to the ones of the developed countries, but with a somewhat weaker intensity. After the monetary shock - namely, an increase of interest rate by 1 percentage point – a contraction in industrial production took place in these three countries, while a year after the shock, consumer prices were reduced. The contractionary shock in monetary policy causes an appreciation of national exchange rates. The authors concluded that the contribution of monetary shock to the variability in output is similar to the one in the EU, which confirms that, in case these countries entered the EMU, there would be no asymmetric effects of common monetary policy.

In his 2005 paper, using the structural VAR, Darvas also investigated monetary transmission in Poland, the Czech Republic and Hungary. He concluded that monetary transmission does not have the same effects on these three economies. Poland's economy responds to a contractionary monetary shock more than other economies, which is explained by the fact that it is a relatively less open economy where monetary policy was aggressively implemented. On the other hand, due to a high level of openness and adaptable monetary policy, Hungarian economy shows the weakest response to monetary policy shocks. While the effect of monetary policy on the real economy is the same in all three countries, i.e. it has the same sign, the changes in the level of prices after the contractionary monetary shock diverge.

Schmitz (2004) examined the characteristics of the bank credit channel in transition countries, using the annual data from the balance sheets of 261 banks in the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia. It shows that, by increasing the interest rate in the EU by 1 percentage point, loan growth is reduced by 1.8 percentage points in the current and by 2 percentage points in the following year. The author traced the causes of this phenomenon to the euroisation of transition countries and to the entry of banks from the EU into their bank markets. She also shows that foreign-owned banks respond to the changes in European monetary policy measures more strongly than domestic banks. Schmitz also confirmed that only the size of the bank influences monetary transmission through the credit channel, while liquidity and bank capitalisation have no role in it.

Using the Bayesian panel vector autoregression and data for six transition countries and seven EU-15 countries, Jarocinski (2004) examines the differences between monetary transmissions in these two groups of countries.

After one standard deviation monetary shock, both regions experienced an average currency appreciation from 1 to 2 percent lasting for a year and followed by depreciation. Similarly, monetary contraction in both groups causes a temporary contraction in output and a permanent reduction of prices. Although reactions to the unexpected monetary contractions are similar in all economies in the sample, the author perceives some systematic differences:

- reactions of macroeconomic variables to monetary contraction on average have smaller statistical significance in the transition countries;
- increase in interest rate and exchange rate appreciation after monetary contraction is more persistent in the CEE countries;
- short-run effects of monetary contraction on the price level is more significant in the EU countries, and
- decline in prices is pronounced in the CEE countries in the medium-term.

The author claims that generally weaker reactions of macroeconomic variables to changes in monetary measures in transition countries are a result of the inadequate development of their financial systems. On the other hand, sticky prices and a lower level of monetary policy credibility in transition countries, which do not have a long history of market economies, might be considered the cause of differences in price behaviour in the two groups of countries. The author concludes that monetary policy in transition countries, although not efficient enough in the short-run, is in the medium term completely capable of influencing the macroeconomic variables – in the same way as in the EU countries.

The discussed papers, examining monetary transmission in transition countries, show it is mostly dominated by the exchange rate channel with a presence of credit channel, while the interest rate channel is not developed well enough. Furthermore, reactions of macroeconomic variables to monetary shocks in transition countries are similar to those of the EU economies, although somewhat weaker and with longer time lags.

The following part of the paper uses empirical research to examine monetary transmission channels in Croatia and their influence on the real economic activity. Its findings will allow comparing monetary transmission in Croatia with monetary transmission in other CEE and EU-15 countries.

Given the structure of Croatian economy, it is expected that the results of this analysis will confirm that monetary transmission in Croatia does not significantly differ from the one in other transition countries, i.e. that the exchange rate channel is active, while the interest rate channel is underdeveloped.

4 Econometric Analysis of Monetary Transmission in Croatia

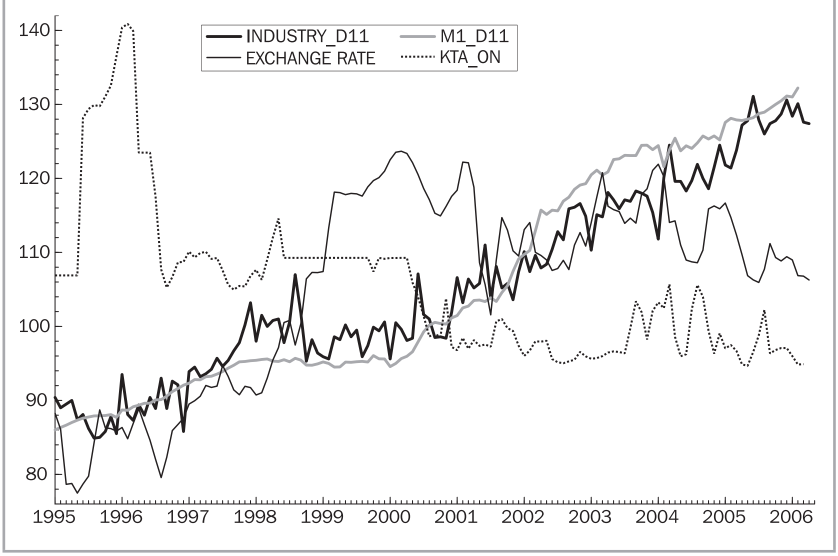
4.1 Stationarity of Time Series

The analysis of monetary transmission in Croatia refers to the period form January 1995 to April 2006. It uses monthly frequencies in logarithms of the following time series in levels and first differences:

- volume of the aggregate industrial production;
- monetary aggregate M1;
- interest rate on the money market, overnight credits;
- average HRK/EUR exchange rate at the end of the period.

Source for the data are the Central Bureau of Statistics monthly reports and the Croatian National Bank monthly bulletins. The dynamics of time series is presented in Figure 1.

Figure 1 **Monetary Indicators and Real Activity**



Note: Series are mean adjusted; INDUSTRY_D11 - seasonally adjusted industrial production; M1_D11 - seasonally adjusted monetary aggregate; EXCHANGE RATE - HRK/EUR exchange rate; KTA_ON - interest rate on the money market, overnight credits.
Source of the original data: Croatian National Bank and the Central Bureau of Statistics.

Time series of the industrial production are used for approximation of the total economic activity in the country. There are several reasons for that. Despite the fact that the share of industrial production – as compared with the total economic activity – has decreased in the last fifteen years, and despite the fact that industrial production does not reflect the total economic activity (in the last couple of years the manufacturing sector has participated in the total gross added value of the Croatian economy with approximately 28 percent and has hired a bit over one fifth of the total number of the employed persons), it is continually being confirmed that manufacturing cycles in the Croatian economy match the cyclical pattern of GDP (Bačić et al., 2004).

Manufacturing sector is connected with other sectors, and is cyclically the most sensitive part of the economy. Therefore, the short-run fluctuations of industrial production series are extremely well correlated with the changes in

GDP (Cerovac, 2005). Furthermore, data on industrial production is published every month, while data on GDP is published quarterly. The use of industrial production series thus allows a greater number of degrees of freedom necessary for statistical analysis.

Furthermore, in their analysis of monetary transmission in Croatia, Erjavec et al. (1999), Erjavec and Cota (2003), Lang and Krznar (2004) also use the industrial production series to approximate GDP.

Before we start using the Johansen method to check for cointegration and estimate the Granger causality test, we need to establish whether the above mentioned time series are stationary or nonstationary. Only a short glance at Figure 1 is revealing enough. The four time series in levels do not exhibit a mean reverting property, while the values of all series in first differences are approximately revolving around the mean, which leads us to the conclusion that all series are I(1). In order to determine the level of integration of the four variables, the augmented Dickey-Fuller unit roots test (ADF test) is used in addition to the graphic method.

The power of the unit root tests reduces if the series contain structural breaks (Ganev et al., 2002) – a phenomenon not unusual in transition countries. Due to structural breaks in a possibly stationary series, the null hypothesis on the existence of the unit root in the series may be rejected.

The paper tests the existence of structural breaks only after the Granger causality test by introducing a recursive estimation of the Granger test, from which the Chow test statistics is obtained. Since the results of Chow tests indicate a presence of structural breaks in HRK/EUR exchange rate and industrial production in 1998 (see Figure 4), the tests including the exchange rate were performed only for the period from October 1998 to April 2006. Chow tests of the remaining pairs of time series do not indicate the existence of structural breaks. The series are therefore estimated for the entire available period.

Figure 2 **Selected Time Series in Levels and First Differences**

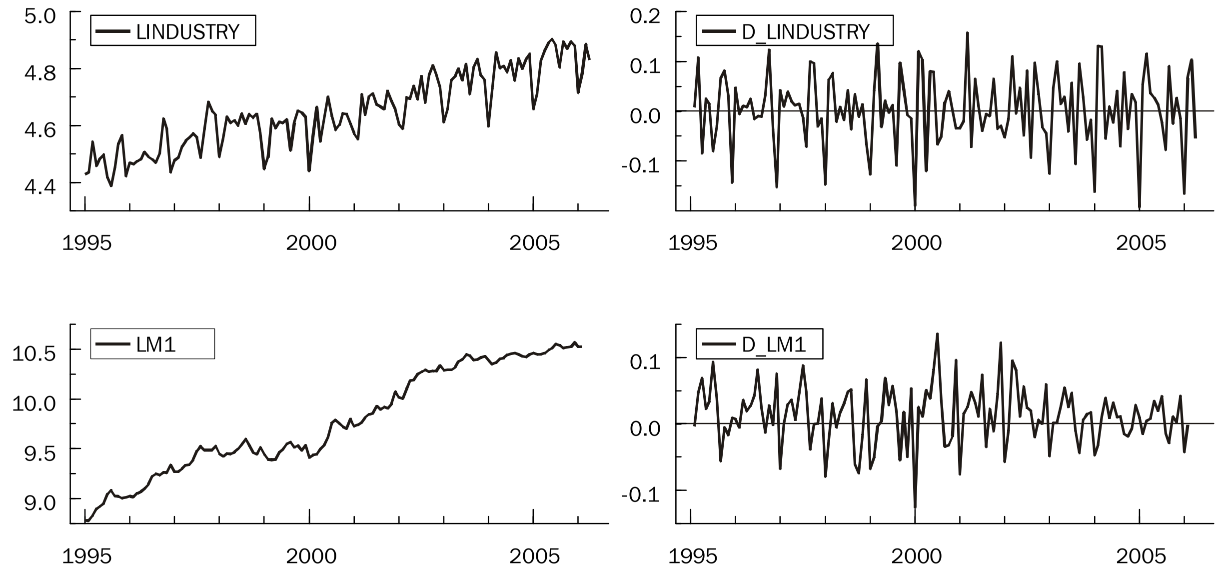
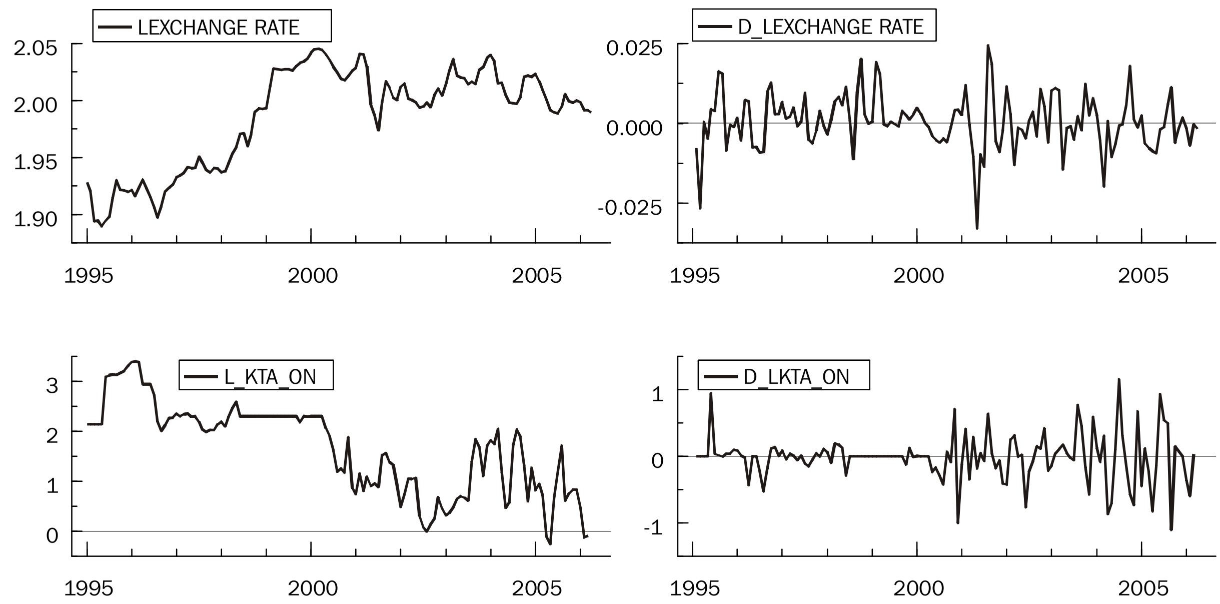


Figure 2 **Continued**



Note: LINDUSTRY - logarithmic value of the industrial production; D_LINDUSTRY - first difference of the logarithmic value of the industrial production; LM1 - logarithmic value of monetary aggregate M1; D_LM1 - first difference of logarithmic value of monetary aggregate M1; LEXCHANGE RATE - logarithmic value of HRK/EUR exchange rate; D_LEXCHANGE RATE - first difference of logarithmic value of HRK/EUR exchange rate; L_KTA_ON - logarithmic value of interest rate on the money market; D_LKTA_ON - first difference of logarithmic value of interest rate on the money market; seasonally unadjusted series.

Source of the original data: Croatian National Bank and the Central Bureau of Statistics.

Table 2 shows the results of ADF tests in levels, while Table 3 shows the results in first differences. The test results indicate the same conclusions as the graphical analysis. The test results show that all time series are nonstationary in levels and stationary in first differences, which means that they are integrated of order I(1).

Table 2 **ADF Unit Root Test – in Levels**

Name of the variables	Time lag	t-value (ADF)	Beta	Sigma	t-value (lag)	p-value (lag)	AIC
Industrial production	9	-2.124	0.68224	0.03398	1.983	0.0502	-6.593
Monetary aggregate M1	9	-2.084	0.94482	0.02662	2.898	0.0047	-7.079
HRK/EUR exchange rate	11	-1.800	0.77694	0.008065	1.765	0.0857	-9.352
Interest rate	11	-2.541	0.78844	0.3272	1.725	0.0878	-2.050

Note: ADF - augmented Dickey-Fuller test; trend included, constant and seasonal dummy variables; optimal time lag is determined by Akaike's information criterion: all series are in logarithms and are not seasonally adjusted; the unit root test for HRK/EUR exchange rate for the period from October 1998 to April 2006.
Source: Author's calculations.

Table 3 **ADF Unit Root Test – in First Differences**

Name of the variables	Time lag	t-value (ADF)	Beta	Sigma	t-value (lag)	p-value (lag)	AIC
Industrial production	8	-4.983**	-0.4705	0.03454	-1.657	0.1007	-6.569
Monetary aggregate M1	0	-9.913**	0.037227	0.02770	-	-	-7.063
HRK/EUR exchange rate	2	-5.601**	-0.39618	0.008124	1.449	0.1542	-9.408
Interest rate	7	-4.781**	-0.58092	0.3331	2.546	0.0124	-2.042

Note: ADF - augmented Dickey-Fuller test; trend included, constant and seasonal dummy variables; optimal time lag is determined by Akaike's information criterion: all series are in logarithms and are not seasonally adjusted; the unit root test for HRK/EUR exchange rate for the period from October 1998 to April 2006;
*** null hypothesis on the existence of unit root rejected at the 1 percent significance level.*
Source: Author's calculations.

4.2 Cointegration of Time Series

Once it was established that all time series to be used in testing Granger causality are stationary in first differences, it remains to be seen whether the above mentioned series are cointegrated. Using the cointegration results, statistical analysis can be continued in one of the two following ways:

- in case there is a long-run equilibrium between the two series, Granger causality test – augmented for the error correction term (error correction model) – is estimated in first differences;
- in case the cointegrating vector for the two time series does not exist, Granger causality test is estimated in first differences.

In order to determine cointegration relation between the two variables, Johansen procedure is used (Johansen, 1988; Johansen, 1991; Johansen and Juselius, 1992). It should be noted that the time series are relatively short (8 years for the pair of variables HRK/EUR exchange rate and industrial production; and 12 years for the other two pairs). This is the biggest shortcoming in the implementation of this method for transition countries. The method is nevertheless used in various analyses of transition countries and is more appropriate than, for example, Engle-Granger method which suffers from serious inadequacies (Enders, 1995). The Johansen procedure will be used to test the existence of the long-run relation in the following three series:

- industrial production and monetary aggregate M1 => **direct monetary transmission**;
- industrial production and HRK/EUR exchange rate => **exchange rate channel**;
- industrial production and interest rate => **interest rate channel**.

To determine whether the pairs of time series are cointegrated in the Johansen procedure, $\lambda trace$ and λmax statistics tests are used to determine the number of cointegrating vectors between variables. In our case, the maximum number of cointegrating vectors is 2.

Table 4 shows the results of Johansen procedure for determining the number of cointegrating vectors between the three selected pairs of series denoting the three channels of monetary transmission. The table shows only the results of λ*trace* statistics because it can unambiguously determine the number of cointegrating vectors in the estimated VAR. It is obvious that there are long-run equilibrium relations (one cointegrating vector) in all three cases, i.e. between industrial production and monetary aggregate M1; industrial production and HRK/EUR exchange rate[7]; industrial production and interest rate.

Based on these results, Table 5 shows the estimate of cointegration equation parameters for all the three pairs of series that are to be used in the calculation of error correction term. Furthermore, adjustment parameters for deviations from the long-run equilibrium defined by cointegration relation (error correction model) as well as the results of Chi^2-test (used to test the restriction that the adjustment parameter for the given variable in the error correction model equals 0) are presented. In case the null hypothesis of Chi^2-test is accepted, the given variable is considered to be weakly exogenous, i.e. lacking the ability to adjust in the short- run to deviations from the long-run equilibrium.

Table 5 implies that nominal rigidities in Croatia are relatively large. Namely, monetary aggregate M1 and HRK/EUR exchange rate seem to be weakly exogenous since in the short-run they do not react to deviations from the long-run equilibrium defined by relationships between industrial production and monetary aggregate M1 and between industrial production and HRK/EUR exchange rate. By testing the restrictions on adjustment parameters of monetary aggregate M1 and HRK/EUR exchange rate, the assumption was found to be true. Thus, only industrial production in the short-run adjusts to deviations from the long-run path of monetary aggregate M1 and industrial production, while monetary aggregate M1 is weakly exogenous.

The same conclusion is valid in case of industrial production and HRK/EUR exchange rate, where the latter is weakly exogenous. Such a result is not surprising

[7] *Estimated for the period from October 1998 to April 2006.*

since monetary policy is mostly based on rather strict exchange rate management within a relatively narrow band, thus causing an increase in nominal rigidities.

Table 4 **Determining the Number of Cointegrating Vectors**

	Direct monetary transmission			Exchange rate channel			Interest rate channel		
Maximum range	**Eigen value**	**λ trace**	**p-value**	**Eigen value**	**λ trace**	**p-value**	**Eigen value**	**λ trace**	**p-value**
0	0.229	38.71**	0.00	0.539	64.9*	0.000	0.151	29.04*	0.017
1	0.035	4.65	0.65	0.0760	6.014	0.469	0.056	7.59	0.30

Note: variables are in logarithms, optimal number of time lags is determined by Akaike's information criterion; cointegration space includes trend; VAR estimate includes constant and seasonal dummy variables; Johansen cointegration for HRK/EUR exchange rate is carried out for the period from October 1998 to April 2006;
*** null hypothesis rejected at the 1 percent significance level; * null hypothesis rejected at the 5 percent significance level.*
Source: Author's calculations.

Table 5 **Cointegration Equation Parameters, Error Correction Model and Weak Exogenity of Variables**

	Cointegration equation	ECM	Weak exogeneity (Chi²-test)
Direct monetary transmission			
Industrial production	1	-0.703	28.198**
M1	-0.146	-0.098	1.0186
Trend	-0.001	-	-
Exchange rate channel			
Industrial production	1	-1.0675	51.86**
HRK/EUR exchange rate	0.01493	0.0363	1.452
Trend	-0.0037	-	-
Interest rate channel			
Industrial production	1	-0.351	6.65**
Interest rate	-0.024	3.276	7.48**
Trend	-0.003	-	-

*Note: ECM – Error Correction Model; variables are in logarithms; cointegration space includes trend; value in brackets is p-value; Johansen cointegration for HRK/EUR exchange rate carried out for the period from October 1998 to April 2006; ** null hypothesis rejected at the 1 percent significance level.*
Source: Author's calculations.

In case of the interest rate channel, i.e. the long-run path of industrial production and the interest rate on the money market, it is shown that both variables are in the short-run capable of adjusting to deviations from the long-run path.[8]

Since the cointegrating vector was determined in all three cases, it can be concluded that all variables are stationary in first differences. Granger causality will be estimated in first differences, but a term will be added to the Granger test representing error correction. The term is based on elements of cointegration equation from Table 5.

4.3 Granger Causality Test and Error Correction Model

Granger (1969) created the causality test in order to solve the problem of forecasting one variable by determining the relation to another variable. The test determines whether a variable "y" has statistically significant information about the variable "x", with an existence of a time lag of "x". If this is not the case, then "y" does not cause "x", according to Granger. In this paper, the Granger causality test is used to estimate the way that changes in the movement of monetary aggregate M1, HRK/EUR exchange rate and the changes in interest rates on the money market affect the industrial production used in turn to approximate GDP. However, in order to use the Granger causality test, we need to augment it by the error correction model. The necessity to augment the Granger causality test arises from the results of cointegration analysis. Namely, the cointegration of two or more time series means that there is a long-run equilibrium relationship between them allowing only temporary deviations from the long-run equilibrium, after which a new equilibrium is established. The speed of the short-run adjustment to the long-run equilibrium between variables is estimated using the added term in the model that represents error correction, while the model itself is called the error correction model. Thus, in

[8] *Weak exogeneity of monetary aggregate M1 and HRK/EUR exchange rate with respect to industrial production is a precondition for the two series to be treated as independent variables in the Granger causality test augmented for the error correction model. Precondition of weak exogeneity of the independent variable in relation to the dependent variable is not met in the Granger causality test in which the interest rate is an independent variable, while industrial production is a dependent variable.*

case two or more series are cointegrated, their estimation using the Granger test in first differences should be done again in such a way as to include the error correction term (error correction model).

Such a model of Granger causality, augmented for error correction (error correction model) has the following form (Granger et al., 2000):

$$\Delta Y_t = c_1 + \sum_{i=1}^{p} \alpha_i \Delta Y_{t-i} + \sum_{i=1}^{p} \beta_i \Delta M_{t-i} + \delta_1 (Y_{t-1} - \gamma_1 M_{t-1}) + u_t \qquad (1)$$

$$H_0 : \beta_1 = \beta_2 = ... = \beta_p = 0$$

where δ_1 is a parameter representing speed and direction of adjustment of the dependent variable to temporary deviations of the long-run equilibrium, γ_1 is an element of a cointegrating vector, obtained by the previous estimate of the cointegration model whereas Y_{t-1} is the value of endogenous variable of industrial production and M_{t-1} represents exogenous variables – monetary aggregate M1 – HRK/EUR exchange rate – interest rates on the money market from the previous time period. The elements of the error correction model (γ_1, Y_{t-1} and M_{t-1}) are combined with data in order to obtain a stationary linear combination that enters the model as the final term with one time lag included. Either a constant or a trend or both enter the error correction model, assuming they were used as elements of cointegrating vector (space) estimation. Statistical significance of δ_1 coefficient as well as its sign, together with the sign of γ_1 coefficient show that industrial production responds to deviations of the stationary long-run path (Rousseau and Vuthipadorn, 2003).

Table 6 shows the results of Granger causality test augmented for the error correction model. It shows separately the adjustment parameter and its p-value, R^2 value, diagnostic tests for determining the existence of serial correlation, heteroskedasticity and the normality of residuals as well as the Wald test (exclusion test) used to test the null hypothesis that the exogenous variable – money aggregate M1 – HRK/EUR exchange rate – interest rate on the money market, do not cause industrial production.

Table 6 **Granger Causality Test in First Differences - Augmented for Error Correction Model**

Monetary transimission channel	**Number of included time lags**	**ECM**		**R²**	**AR-test**	**ARCH-test**	**Normality test**	**Wald test**
		Coefficient	p-value		**F-stat.**	**F-stat.**	**Chi²-stat.**	**F-stat.**
M1 - Industrial production	3	-0.745	0.000	0.791	1.48 [0.18]	1.095 [0.37]	1.320 [0.52]	3.466* [0.018]
HRK/EUR exchange rate - Industrial production	9^{+}	-3.95517	0.000	0.7328	2.36 [0.052]	1.32 [0.272]	0.342 [0.842]	2.798* [0.039]
Interest rate - Industrial production	4	-0.203	0.060	0.771	0.913 [0.49]	0.962 [0.46]	1.458 [0.48]	1.770 [0.14]

*Note: ECM – Error Correction Model; variables are in logarithms and are not seasonally adjusted, the model includes seasonal dummy variables; the value in brackets is p-value; the number of included time lags corresponds to the optimal number of time lags used in estimating cointegration relations; + the number of time lags is augmented due to the fact that diagnostic tests have indicated a presence of a serial correlation; Johansen cointegration for HRK/EUR exchange rate carried out for the period from October 1998 to April 2006; * null hypothesis rejected at the 5 percent significance level.*
Source: Author's calculations.

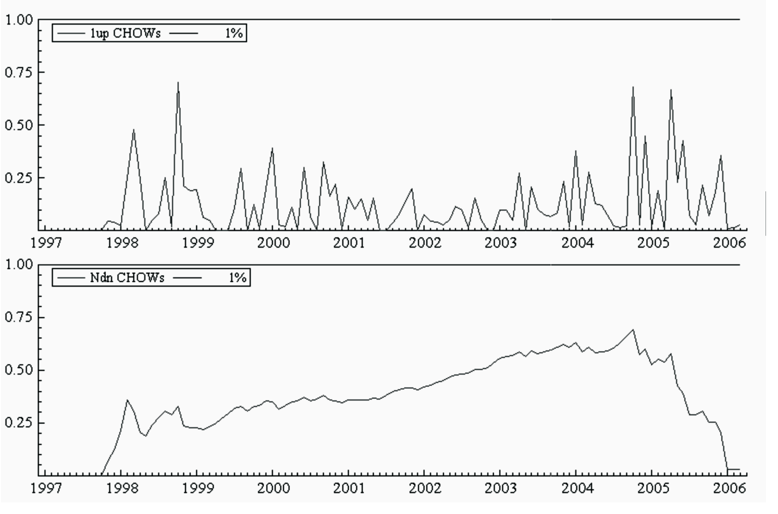
All three models have a very good explanatory power and pass all the diagnostic tests. The conclusion obtained from the conducted Wald test is that, according to Granger, monetary aggregate M1 and HRK/EUR exchange rate both cause industrial production.

It is important to mention that the Granger causality test for industrial production series and for HRK/EUR exchange rate was conducted in the period from October 1998 to April 2006, whereas the remaining two pairs of series were estimated with the complete data sample. The reason for this becomes obvious once Figures 3, 4 and 5 are studied. They show the results of one-step and break-point Chow tests. The one step and break-point Chow tests clearly show that the Granger test, conducted for the exchange rate channel on the complete sample, had structural breaks at the very beginning of 1998 and by the end of the summer of the same year, when Croatia was experiencing a banking crisis. It was precisely because of this that unit root tests for HRK/EUR exchange rate, cointegration analysis and the Granger causality test for industrial production started being applied in October 1998.

The lower graph in Figures 3, 4 and 5 shows that all three models have a constant value of coefficients, related to explanatory variables. Such a conclusion is valid for the series of HRK/EUR exchange rate and industrial production, which means that the estimates of model coefficients would have been constant for the entire period, even if the Granger causality test had been conducted for the entire period available. However, in order to conduct a valid analysis, the testing period for the exchange rate channel was reduced.

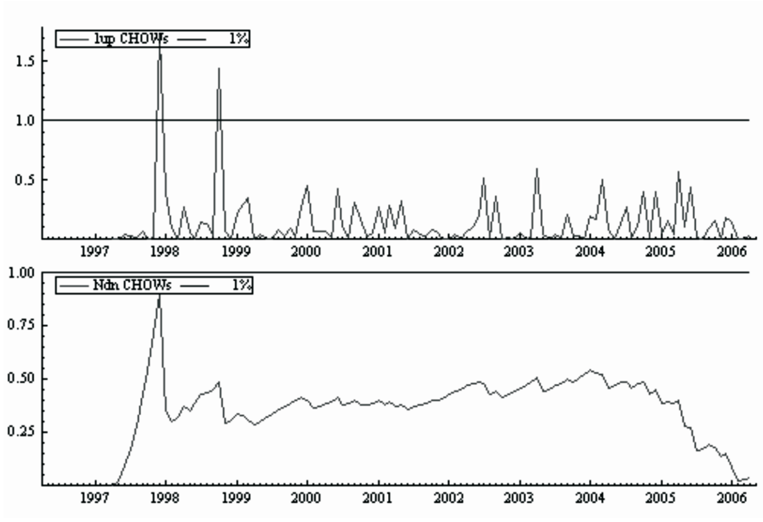
The results of the Granger causality test show that monetary policy in Croatia affects the real sector through the exchange rate channel and direct monetary transmission, whereas the interest rate channel is inactive.

Figure 3 **Chow Tests for Direct Monetary Transmission**



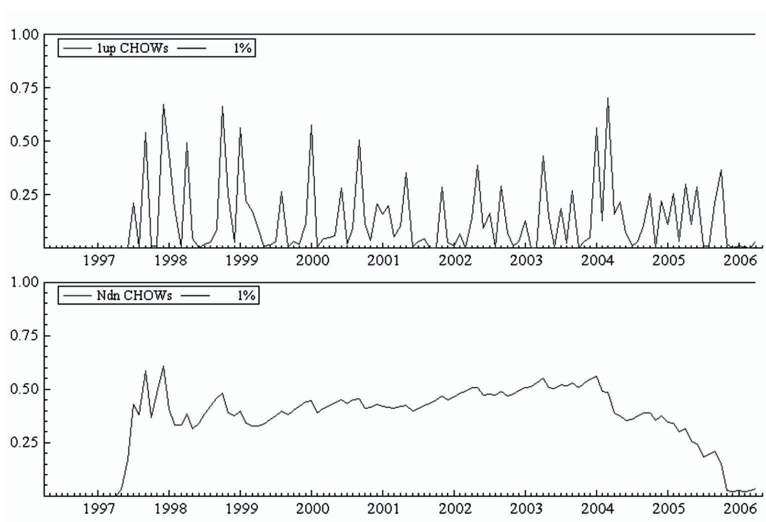
Source: Author's calculations.

Figure 4 **Chow Tests for Exchange Rate Channel**



Source: Author's calculations.

Figure 5 **Chow Tests for Interest Rate Channel**



Source: Authors' calculations.

Adjustment coefficients (ECM) in the Granger causality test are statistically significant for all three models and have a corresponding, negative sign. By comparing them, it can be concluded that industrial production shows a significant short-run adjustment to the long-run changes within all three models. It is most sensitive to the long-run changes in the exchange rate movements, and least sensitive to the long-run changes in interest rate movements. Adjustment parameters for industrial production, obtained directly after the cointegration analysis (Table 5) are pretty similar and comparable, as expected. All signs are the same, and according to the error correction model from Table 5, industrial production is also highly sensitive to the long-run movements of exchange rate. It shows the weakest level of the short-run adjustment after a long-run change in the movement of interest rate on the money market.

Finally, considering the papers that examine the monetary transmission channel in Croatia, it is essential to compare their results with the results of statistical research presented in this paper. By estimating the relation between monetary aggregate M1 and industrial production, obtained by the Granger causality test augmented for the error correction model, the existence of the mentioned direct channel is indicated. The results are opposite to those obtained by Erjavec et al. (1999), who used a different methodology – in the period when Croatian banking system was experiencing deep structural crises which could have well affected the reliability of the statistical analysis. Similarly, the results of statistical analysis used in this paper confirm the exchange rate pass through to the real activity, i.e. to industrial production, contrary to the results reached by Erjavec and Cota (2003), also using a different methodology. However, the work of Balazs and Morales (2005), not dealing directly with the examination of monetary transmission, shows that the exchange rate variability in the Croatian case significantly affects the export activity (with a time lag up to 12 month). It is actually another confirmation of the conclusion reached in this paper – exchange rate movement significantly affects the real activity of the Croatian economy. On the other hand, the results of this paper support the conclusions reached by Erjavec and Cota about inactivity of the interest rate channel of monetary transmission.

The results by Billmeier and Bonato (2002) and Kraft (2003) match the results of this paper and could therefore serve as a solid base for testing the hypothesis that the exchange rate pass-through is partly carried out by changes in producer prices, and partly by the adjustment of economy through the real economic activity.

5 Conclusion

Using the results obtained by statistical analysis in the previous part of the paper, the following conclusions can be made:

- monetary policy in Croatia has significantly affected the real sector through the control of money supply and exchange rate;
- monetary policy in Croatia does not affect the real economic activity through the interest rate channel;
- exchange rate channel and direct monetary transmission successfully transmit the impulses of monetary measures to the real sector;
- economy is not elastic enough to the movements of interest rate on the money market.

By studying the overview of monetary transmission mechanisms in the transition countries (CEE countries), it can be easily concluded that the exchange rate channel and credit channel, together with the direct monetary transmission are of the utmost importance in the monetary transmission. The reasons for this are explained by observing the properties of the transition countries' economic structures (small and open economies, developed banking system and underdeveloped financial market as well as presence of unofficial euroisation).

This paper confirms that Croatia, similar to the CEE countries in the mentioned structure, is no exception when it comes to the monetary transmission channel, either. The exchange rate channel and direct monetary channel play an important role in the monetary transmission in Croatia, while the interest rate channel is not developed well enough.

The results of cointegration analysis point to the fact that exchange rate policy could have a weak influence on the cyclic movement of economy. Thus, a long-run depreciation of kuna to euro of 1 percent causes decrease in the industrial production by 0.0149 percent in the long-run, while a long-run appreciation of kuna causes expansion in the industrial activity.[9] This result explains that the relationship between exchange rate and industrial production is not in accordance with basic economic principles (kuna depreciation will not have the expected expansionary effect on the industrial production). Such behaviour of industrial activity is characteristic of economic systems such as Croatia's, in which monetary policy is based on nominal exchange rate anchor (BIS, 1998). This relation between exchange rate and industrial production should, however, be brought into a wider context. Namely, monetary policy in Croatia is basically reduced to the regime of targeting exchange rate within the band of only ±2 percent (Reinhart and Rogoff, 2002). Thus, any influence of long-run changes of exchange rate movements to the industrial activity remains limited. A weak reaction of the industrial production of 0.0149 percent to long-run changes in exchange rate by 1 percent confirms that the influence of monetary policy to the real activity is limited.

Finally, since monetary transmission to real sector is in the EU usually done through the effects of interest rate on investment, the indicated insensitivity of the economy to the changes in interest rates might cause a huge problem once Croatia joins the EMU. Additional problem presents the fact that, starting from that point, the exchange rate channel, which so far has been of great importance in Croatia, will be eliminated. The conclusion is that, by entering the EMU, Croatia will lose its own monetary policy so that its economy, due to an inactive interest rate channel, will probably not respond to measures of European monetary policy strongly enough or will respond in an asymmetrical way. If the transmission mechanisms are different, then a common monetary policy might increase the existing discrepancies in business cycles which in the end would mean that by changing the interest rate, as a consequence of inflation shock, inflation differential might actually be increased instead of being decreased. When the common monetary policy is not efficient in smoothing the

[9] *The same conclusion was reached by Lang and Krznar (2004).*

cyclical fluctuations and fiscal policy is not capable of annihilating the effects of asymmetrical monetary transmission, monetary divergence between a certain country and the rest of the Union is possible.

Thus, establishing a referent interest rate through repo auction is a good way for the CNB to start creating preconditions for implementing an active interest rate channel. Namely, open market operations were introduced in 2005, and have been carried out since, which should have contributed to the stabilisation of the money market interest rate, which might in the end increase the importance of interest rate channel in Croatia. Open market operations should result in the establishment of interest rate corridor and a referent interest rate to which the economy would probably respond with more elasticity. The reason is that such an interest rate will better reflect the stance of monetary policy of the country.

On the other hand, due to the extremely high level of euroisation of the economy, Croatia has a small competitive advantage over other CEE countries in entering the EMU. The euroisation, (other than partly conditioning the introduction of euro in case of a small open economy), alleviates the shock of the very introduction of euro since the agents are already used to the currency. Also, the euroisation might enable a faster and a more complete transmission from a referent ECB interest rate to the domestic interest rate (establishing the interest rate channel), a process so far very difficult – precisely because most of the financial assets are denominated in euro or linked to euro by a currency clause.

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