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MACROECONOMIC GRANGER-CAUSAL DYNAMICS IN CROATIA: EVIDENCE BASED ON A VECTOR ERROR-CORRECTION MODELLING ANALYSIS

In the paper the causal relationships between money and other macroeconomic variables such as output, interest rate, prices and exchange rate in Croatia were analysed. The basic principle of Granger-causality analysis is to test whether past values of monetary variable help to explain current values of output. Multivariate causality tests were performed in a vector autoregression (VAR) model. The analysis also made use of the techniques - variance decompositions (VDCs) and impulse response functions (IRFs) - to unveil Granger causality in macroeconomic activity in a dynamic context. In the short-run variables interest rate and nominal exchange rate stand out econometrically exogenous. In the empirical period these variables were relatively the leading variables. They were initial receptors of exogenous shocks to the long run equilibrium. The causal relationships detected among the variables indicate that money supply is neutral in the short run.

Introduction

One of the main tasks in empirical macroeconomics is investigation of the relevancy of real and monetary shocks. In that sense the main interest is causal relationship between money and other macroeconomic variables such as output,

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interest rate, prices and exchange rate. Different schools of economic thought have postulated various relationships between money and other macroeconomic variables. Up until the real business cycle theory, the dominant thinking (except classical economists) was that an aggregate demand shock, such as monetary shocks, would have a positive effect on the real economic activity. That means, money would lead economic activity. The issues among the Keynesians, the monetarists, the new classicals and the new Keynesians were not whether monetary shocks had a positive effect on output but the nature and the transmission channels of these positive shocks. The Keynesians postulated that a positive monetary shock would increase both economic activity and price level through the interest rate and investment variables. The monetarists assume valid Keynesian transmission channel in the short run but in the long run they agree with classical economists that money is neutral to output. The new classical economists decomposed monetary effect into output and price effect on the basis of anticipated monetary expansion. They postulated that only unanticipated monetary expansion would result in an increase in output. The new Keynesians postulated non-neutrality of money, at least in the short run, because of rigidities in prices and wages, and market failures and imperfections. The real business cycle theory postulated relationship between money and output as the case of money supply endogenously responding to an increase in output. Banking sector responds to increased transaction demand for money by creating more inside money. Monetary expansion will have no positive effect on output. It will only raise interest rates and the price level. The real business cycle theory considers money supply as endogenous and output is determined exogenously, primarily by technology.

The causal chain (among money and other macroeconomic activity such as output, interest rates and price level) implied by the existing macroeconomic paradigms still remains ambiguous. The issue, therefore, as to the dynamic causal relationships (even in the Granger temporal[1] sense rather than in the structural sense) remains unresolved and is an empirical one.[2]

The basic principle of Granger-causality analysis (Granger, 1969) is to test whether past values of monetary aggregate help to explain current values of output. There are three different types of these tests: Simple Granger-causality tests, Multivariate causality tests and Granger-causality tests taking place in a vector autoregression (VAR).

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[1] Granger causality is defined as a presence of feedback from one variable to another. Granger non-causality is defined as absence of such feedback.

[2] Causality is a subject of great controversy among economists: see for example, Zellner (1988). Without going into the debate, we would like to state that the concept used here is in the stochastic or 'probabilistic' sense rather than in the philosophical or 'deterministic' sense. Also the concept used here is in the Granger 'temporal' sense rather than in the 'structural' sense.

Simple Granger-causality tests operate in a single equation with two variables and their lags (autoregressive-distributed lag models). It is tested whether the lags of the lagged money variables are equal to zero. If this hypothesis can be rejected, it is said that money causes output. In order to empirically resolve the issue of the direction of causation in a bivariate context, a lot of causality tests have been applied (Granger, 1969, Sims, 1972 and Geweke et all., 1983).

The studies applying these tests suffered from the following methodological deficiencies:

i) These standard tests did not examine the basic properties of the variables. If the variables are cointegrated[3], then these tests incorporating differenced variables will be misspecified unless the lagged error-correction term is included (Granger, 1988).

ii) These tests turn the series stationary mechanically by differencing the variables and consequently eliminated the long-run information embodied in the original level form of the variables. The error-correction model (ECM) derived from the cointegrating equations by including the lagged error-correction term reintroduces, in a statistically acceptable way, the long-run information lost through differencing. The error-correction term stands for the short-run adjustment to long-run equilibrium trends. The term also opens up the additional channel for Granger-causality so far ignored by the standard causality tests.

Multivariate causality tests include more variables beside money and output in the equation. The principle remains the same as in the case of simple Granger-causality tests, except that now the influence of other variables can affect the test results. For instance, it may be that the effect on output does in fact run via the interest rate. In a two variable test without interest rate variable this effect might erroneously be affected by money.

Finally, there are Granger-causality tests taking place in a vector autoregression (VAR). Here the multivariate model is extended to allow for the simultaneity of all included variables.

The purpose of this paper is to test the dynamic causal relationships among money and other macroeconomic variables such as output, interest rate, prices, and exchange rate for the small open economy such as Croatia. During the empirical period economic policy was inward oriented because of problems with transition process. In fact, problems with restructuring economy lead to inward oriented growth "strategy". The foreign exchange rate variable is incorporated in the analyses because of examination of the dynamic interactions of these variables with the foreign trade sector.

[3] Two or more variables are said to be cointegrated, i.e. they exhibit long-run equilibrium relationship(s), if they share common trend(s).

This study will be taken in a multivariate framework and within the environment of vector error-correction model (VECM). The analysis will also make use of the techniques - variance decomposition and impulse response functions - to unveil Granger causality in macroeconomic activity in a dynamic context.

The error-correction terms derived from the cointegrating vectors are obtained through Johansen's multivariate cointegrating testing procedure (Johansen, 1988, and Johansen and Juselius, 1990), which are than used as additional channel in order to identify Granger-causation. Since this procedure identifies multiple cointegrating relationships and hence error-correction terms, this is an issue of crucial importance in Granger-causality testing in a dynamic multivariate context.

Econometric methodology

The following sequential procedures will be applied:

Step 1: Cointegration and Granger causality

The cointegration technique pioneered by Engle and Granger (1987), Hendry (1986) and Granger (1986) made a significant contribution towards testing Granger causality. According to this technique, if two variables are cointegrated, finding of no causality in either direction, one of possibilities with the standard Granger and Sims tests, is ruled out. So long as two variables have a common trend, causality (in the Granger sense, not in the structural sense), must exist in at least one direction, (Granger, 1988, Miller and Russek, 1990). This Granger (or temporal) causality can be detected through the vector error-correction model derived from the long-run cointegrating vectors.[4]

[4] Being a system of unrestricted reduced form equations, the VAR model have been criticized by Cooley and Le Roy (1985). Runkle (1987) is a good example of the controversy surrounding this methodology. It is debatable whether the method of identification employed by the simultaneous structural model which often relies on many simplifying assumptions and arbitrary exclusion restrictions together with the related exogenous-endogenous variables classification (which are often untested), is superior to the identification procedure used in the VAR model. The critics of VAR, however, all agree that there are important uses of the VAR models. For example, McMillin (1988) points out that VAR models are particularly useful in the case of 'forecasting, analysing the cyclical behaviour of the economy, the generation of stylised facts about the behaviour of the elements of the system which can be compared with existing theories or can be used in formulating new theories, and testing of theories that generate Granger causality implications.'

Step 2: Vector Error-Correction Modelling (VECM) and Exogeneity

Engle and Granger (1987) demonstrated that once a number of variables (say x_t and y_t) are found to be cointegrated, there always exists a corresponding error-correction representation which implies that changes in the dependent variable are a function of disequilibrium in the cointegrating relationship (captured by the error-correction term) as well as changes in other explanatory variable(s). A consequence of ECM is that either Dx_t or Dy_t or both must be caused by e_{t-1} (the equilibrium error) that is itself a function of x_{t-1} and y_{t-1}. Intuitively, if x_t and y_t have a common trend, than the current change in y_t (say dependent variable) is partly the result of y_t moving into alignment with trend value of x_t (say independent variable). Through the error-correction term, the ECM opens an additional channel for Granger causality (ignored by standard Granger and Sims tests) to emerge. The statistical significance of the F-tests applied to the joint significance of the sum of the lags of each explanatory variable and/or the t-test of the lagged error-correction term(s) will indicate the Granger causality (or endogeneity of the dependent variable). The non-significance of both the t-test(s) as well as the F-tests in the VECM will imply econometric exogeneity of the dependent variable.

The F-tests of the 'differenced' explanatory variables give us an indication of the 'short-term' causal effects, strict exogeneity of the variables. On the other hand, the significance of the lagged error-correction term(s) will indicate the 'long-term' causal relationship.[5] The coefficient of the lagged error-correction term, however, is a short-term adjustment coefficient and represents the proportion by which the long-term disequilibrium (or imbalance) in the dependent variable is being corrected in each short period. The non-significance or elimination of any of the lagged error-correction terms affects the implied long-term relationship and may be a violation of theory. The non-significance of any of the 'differenced' variables which reflects only the short-term relationship, does not involve such a violation because, the theory typically has nothing to say about short-term relationships, (Thomas, 1993).

Step 3: Variance Decompositions (VDCs) and Relative Exogeneity

The VECM, F- and t- tests may be interpreted as within-sample causality tests. They can indicate only the Granger causality of the dependent variable within

[5] The lagged error-correction term contains the log-run information, since it is derived from the long-term cointegration relationship(s). Weak exogeneity of the variable refers to ECM-dependence, i.e. dependence upon stochastic trend.

the sample period. They provide little evidence on the dynamic properties of the system, the relative strength of the Granger-causal chain or a degree of exogeneity among the variables.

On the other hand, the variance decompositions (VDCs), by partitioning the variance of the forecast error of a certain variable into the proportions attributable to innovations (or shocks) in each variable in the system including its own, can provide an indication of these relativites.[6] VDCs may be termed as out-of-sample causality tests (Bessler and Kling 1985). The variable that is optimally forecast from its own lagged values will have all its forecast error variance explained by its own disturbances, (Sims, 1982)[7].

Step 4: Impulse response functions (IRFs)

The information contained in the VDCs can be equivalently represented by IRFs. Both are obtained from the MA representation of the original VAR model[8]. The IRFs are the dynamic response of each endogenous variable to a one-period standard deviation shock to the system.

Empirical results

Data

The database used for this study is a monthly time series sample of five variables: real output, money, interest rate, prices and exchange rate. The industrial product index was utilized as a proxy for real output (GDP), money stock (M1) for the money supply, the retail prices index for the price level (CPI), interest rates on credits for the interest rate (INT) and nominal effective exchange rate of the kuna index for exchange rate (NEX). The analysed period is 1994(10) to 2001(10). This period was chosen to include the years during which the country has adopted

[6] VDCs tells us the proportion of the movements in a variable due to it "own" shocks versus shocks to other variable.

[7] By construction, the errors in any equation in a VAR are usually uncorrelated. However, there could be contemporaneous correlations across errors of different equations. These errors were orthogonalized through Choleski factorization. The factorisation depends on the ordering of the variables. Variables that we do not expect to have any predictive value for other variables should be put first.

[8] MA representation of a model is simply the complete set of IRFs.

stabilization program[9]. All variables, except interest rate are in logarithms and are seasonally unadjusted.[10]

Integration and cointegration properties

The necessary but not sufficient condition for cointegration is that each of the variables should be integrated of the same order[11] (more than zero) or that all series should contain a deterministic trend, (Granger, 1986). A various set of unit root tests were applied to test the order of integration of the variables. To save space, only Dickey ADF test (Dickey-Fuller, 1979) and KPSS test (Kwiatkowski, Phillips, Schmidt and Shin 1992) are presented[12] in Table 1.

Table 1

TESTS OF THE UNIT ROOT HYPOTHESIS

a) Levels

Variable	ADF value Constant included	ADF value Constant and trend included	KPSS value H_0 stationary around a level	KPSS value H_0 trend stationary
LM1	-0,5810(13)	-2,5012(13)	0,6930**	0,12131*
LGDP	-3,4412**(1)	-2,3146(16)	2,6380***	0,0749
LCPI	0,7111(0)	-2,6467(0)	8,44376***	1,4403***
INT	-0,4963(0)	-2,3949(0)	5,9733***	0,3000***
LNEX	-0,5158(0)	-2,6393(0)	7,9224***	0,7362***

[9] Although Croatia introduced stabilization program by the end of 1993, the inclusion of the data before 1994(10) does not improve the analysis, because of the low quality of the data.

[10] All empirical work was performed with RATS and CATS statistical packages of Doan (1992).

[11] If a variable must be differenced *d* times before it becomes stationary, than it contains *d* unit roots and is said to be integrated of order *d*, denoted *I(d)*.

[12] The difference between these two tests is in the formulation of the null hypothesis. ADF test has a nonstationarity as a null hypothesis i.e. the null hypothesis is that the variable under investigation has a unit root. On the other hand, in the KPSS test we assume that the variable is stationary. It has been suggested (KPSS, 1992) that tests using stationarity as a null can be used for confirmatory analysis, i.e. to confirm our conclusion about unit root tests. If both tests fail to reject the respective nulls or both reject the respective nulls, we do have a confirmation

b) First Differences

First diff.	ADF value Constant included	ADF value Constant and trend included	KPPS value H_0 stationary around a level	KPPS value H_0 trend stationary
ΔLM1	-2,9091**(11)	-4,9104***(7)	0,33908	0,1370*
ΔLGDP	-6,5223***(11)	-10,8132***(1)	0,3299	0,1261*
ΔLCPI	-935,9979***(0)	-917,7099***(0)	0,3278	0,1321*
ΔINT	-24,0178***(0)	-23,6016***(0)	0,4240*	0,1586**
ΔLNEX	-891,3388***(0)	-871,0124***(0)	0,3285	0,1310*

*Notes: Δ is the first difference operator. ***,** and* indicate significance at 1%, 5% and 10%. . The critical values for ADF test are from Hamilton (1994) and for KPSS test from KPSS (1992). Letter L denotes log transformation.*
The strategy of adding lags to the ADF regression is based on the objective to remove any autocorrelation from the residuals, which is tested applying Lagrange Multiplier test. The appropriate number of lagged differences is determined by adding lags until LM test fails to reject no serial correlation of order 12 at 5% level. In square brackets after the test values, the length of included lags is given.

The results from Table 1 indicate that we cannot reject the presence of a unit root for any of the variable. Analysing the first differences of the variables, we cannot find evidence that the variables are not *I(1)*, i.e. the variables were found to be non-stationary in levels, but stationary after first-differencing, although some of the results are sensitive to the number of included lags.[13] So, in our study we treat all variables being *I(1)*.

To analyse the cointegration relationships among the variables we define a VAR(4) model of five variables (LGDP, LM1, INT, LCPI, LNEX) with constant term and 11 centred dummy variables, and lag length[14], *k=4*.

[13]Additionally PP (Phillips-Perron type, Phillips and Perron, 1988) tests were performed. PP tests are non-parametric unit root tests that are modified so that serial correlation does not affect their asymptotic distribution. PP tests confirm the above conclusion i.e. that all variables are integrated of order one with and without trends, and with or without intercept terms. The results are not reported here to conserve space. They can be obtained from the authors upon request.

[14] The results based on VARs and VDCs are generally found to be sensitive to the lag length used and ordering of the variables. A considerable time was spent in selecting the lag structure. Variables lag lengths were chosen by SC and HQ information criteria, lag lengths that reduce auto-correlation in the model, asymptotic c^2 values calculated by determinants of residual covariance matrices and log likelihood of different pairs of lag size. Also, common sense was applied to choose the lags by bearing in mind that although more lags were desirable, nevertheless excessive lags would exhaust our limited sample size.

For determining the number of cointegrating vectors the Johansen's reduced-rank procedure was employed (Johansen, 1988, and Johansen and Juselius, 1990), Table 2.[15]

Table 2

JOHANSEN'S TEST FOR THE NUMBER
OF COINTEGRATING VECTORS

H_0: r =	p-r	λ_{max}	λ_{trace}	λ
0	5	33,51*	76,36*	0,3388
1	4	23,61	42,85	0,2528
2	3	11,04	19,24	0,1274
3	2	8,18	8,19	0,0961
4	1	0,01	0,01	0,0002

BETA (transposed)

LM1	LGDP	INT	LCPI	LNEX
1.000	-9.710	-0.052	4.059	-3.261

Testing restriction on beta:

The LR test, CHISQ(1) = 0.88 , p-value = 0.35

BETA (transposed)

LM1	LGDP	INT	LCPI	LNEX
1.000	-6.302	0.000	1.845	-1.420

Note: '*' indicates a rejection of the Null at 10 %. The critical values are from Osterwald-Lenum, (1992).

[15] For the Johansen procedure, there are two test statistics for the number of cointegrating vectors: the trace (λ_{trace}) and the maximum value statististics, ($\lambda_{\max}$). In the trace test, the null hypothesis is that the number of cointegrating vectors is less than or equal to *r*, where *r* = 0 to 5. In each case the null hypothesisis is tested againest the general alternative. The maximum eigenvalue test is similar, except that alternative hypothesis is explicit. The null hypotheisis *r=0* is tested againest the alternative that *r=1*, *r=1* againest *r=2* etc.

The cointegration test, which was the precondition for estimating VECM, was performed under the assumption that there are linear trends in the data, so the model allows the nonstationary relationships in the model to drift. From the results in Table 2 we can conclude that there exists one significant cointegrating vector, $\hat{\beta}_1$, i.e. that these five variables are bound together by long-run equilibrium relationship[16].

The number of cointegrating vectors found in Table 2 results in a corresponding number of residual series, and hence error-correction terms (ECTs), which can be embodied as exogenous variables appearing in their lagged-levels as part of the vector error-correction model (VECM), Table 3.

Table 3

TEMPORAL CAUSALITY RESULTS BASED ON VECTOR ERROR-CORRECTION MODEL (VECM) FOR M1 MODEL

Dependent variable	ΔLGDP	ΔLM1	ΔINT	ΔLCPI	ΔLNEX	ECT_{t-1}
	F-statistics (signif levels)					t-statistics
ΔLGDP	-	0,5090	0,5839	0,8642	0,2552	3,3354***
ΔLM1	0,5699	-	0,0189**	0,5347	0,7486	1,4700
ΔINT	0,9125	0,1648	-	0,5255	0,3376	-1,0775
ΔLCPI	0,0319**	0,1586	0,8100	-	0,1841	-1,7520*
ΔLNEX	0,6087	0,8934	0,6323	0,1699	-	-0,1721

Notes: All variables are in the first differences (denoted by Δ) with the exception of lagged error-correction term ECT generated from Johansen's cointegration test conducted in Table 2. The cointegrating vector is normalised on LM1 with the imposed restriction that interest rate variable do not enter cointegration relationship, Table 2. The residuals were also checked for stationarity by way of unit-root testing procedures applied earlier and inspection of their autocorrelation functions respectively. Diagnostic tests (not reported here, but available upon request) conducted for various orders of serial correlation, normality, heteroscedascity were found to be satisfactory.
***, ** and * indicate significance at the 1%, 5% and 10% levels.

Although cointegration indicates presence or absence or Granger-causality, it does not indicate the direction of causality between variables, which will be done

[16] Additionally, test of a joint hypothesis of both the rank order and the deterministic components based on so-called Pantula principle, (Johansen, 1992) was performed. The result was one cointegrating vector and a model with deterministic trends in the levels of the data. When testing the hypothesis on Cointegrating vector that interest rate variable is zero, we can reject the hypothesis (p-value=0,35) on the usual level of significance. Thus we continue the analysis under that restriction.

by analysis of results, based on estimating VECM (Table 3). The significance of the F-statistics for the lag values of the independent variables presented in Table 3 indicate that there is a unidirectional short-run causal effect running from LGDP to LCPI and INT to LM1. The significance of the error correction term shows that the burden of short-run endogenous adjustment (to the long term trend) to bring the system back to its long-run equilibrium has to be taken by LGDP and LCPI variable. The VECM tends to indicate that in the short-run variables interest rate and nominal exchange rate stand out econometrically exogenous, as evidenced in the statistical significance of the t-test of the lagged error correction term or F-tests of the independent variables. In the empirical period these variables were rigid, so they were relatively the leading variables. Interest rate and exchange rate were initial receptors of exogenous shocks to the long run equilibrium.

The causal relationships detected among the variables indicate that money supply is neutral in the short run. The monetary policy cannot be efficient in stabilization of the price level in the Croatian economy.

The F-test and t-test on VECM may be interpreted as within-sample causality tests since they only indicate the Granger-exogeneity or endogeneity of the dependent variable within the sample period. They do not provide us with the dynamic properties of the system or relative strength of the variables beyond the sample period. In order to analyse the dynamic properties of the system, the forecast error variance decompositions (VDCs) and impulse response functions (IRFs) were computed. So, the results of the relative contribution of the explanatory variables in explaining the variation in the dependent variable in the post-sample period are presented through Table 4 and Figure 1.[17]

The results tend to confirm the conclusion obtained by within sample VECM analysis. In the case of interest rate after 12-month horizon, 73% of the forecast error variance is explained by its own shocks, and in the case of nominal exchange rate 67%. Furthermore, the real output and money also explain most of its own forecast error variance, 78% and 71%, respectively.

[17] As pointed out earlier the results of VDCs may be sensitive to the ordering of the variables. But, in our study the residuals were close to being uncorrelated, so the results were not sensitive to alternative ordering of the variables.

Moreover, the results from different orderings show no significant difference. So the innovations were orthogonalized in the following order: {LGDP, LM1, INT, LCPI, LNEX}.

Table 4

DECOMPOSITION OF VARIANCE: ORDERING
(DLGDP, DLM1, DINT, DLCPI, DLNEX)

Percentage of forecast variance explained by innovations in:						
Mn.	Relative variance in:	ΔLGDP	ΔLM1	ΔINT	ΔLCPI	ΔLNEX
1	ΔLGDP	100.0000	0.00000	0.00000	0.00000	0.00000
4		82.36819	4.88196	5.63216	0.53424	6.58346
8		79.12883	5.17128	5.87335	1.67500	8.15155
12		78.56236	5.20549	5.96502	1.89804	8.36909
1	ΔLM1	3.62180	96.37820	0.00000	0.00000	0.00000
4		8.71994	73.08862	15.18579	1.91124	1.09441
8		9.55193	71.65271	15.11684	2.15273	1.52580
12		9.62927	71.49814	15.08082	2.17219	1.61958
1	ΔINT	0.74582	1.74216	97.51202	0.00000	0.00000
4		6.09132	6.67540	77.61472	3.93973	5.67882
8		8.98373	6.97207	73.96589	4.00019	6.07812
12		9.41688	6.97822	73.35071	4.03871	6.21548
1	ΔLCPI	2.88046	0.17311	0.25085	96.69557	0.00000
4		30.44899	5.03432	1.62382	59.24901	3.64386
8		31.06280	5.52821	2.42685	55.58880	5.39335
12		31.02097	5.52229	2.42916	55.22774	5.79984
1	ΔLNEX	4.25601	16.24367	1.73137	0.04845	77.72050
4		5.40874	14.84061	3.20494	8.69819	67.84752
8		5.63875	14.48380	3.89891	8.66662	67.31193
12		5.74844	14.45247	3.96590	8.67172	67.16147

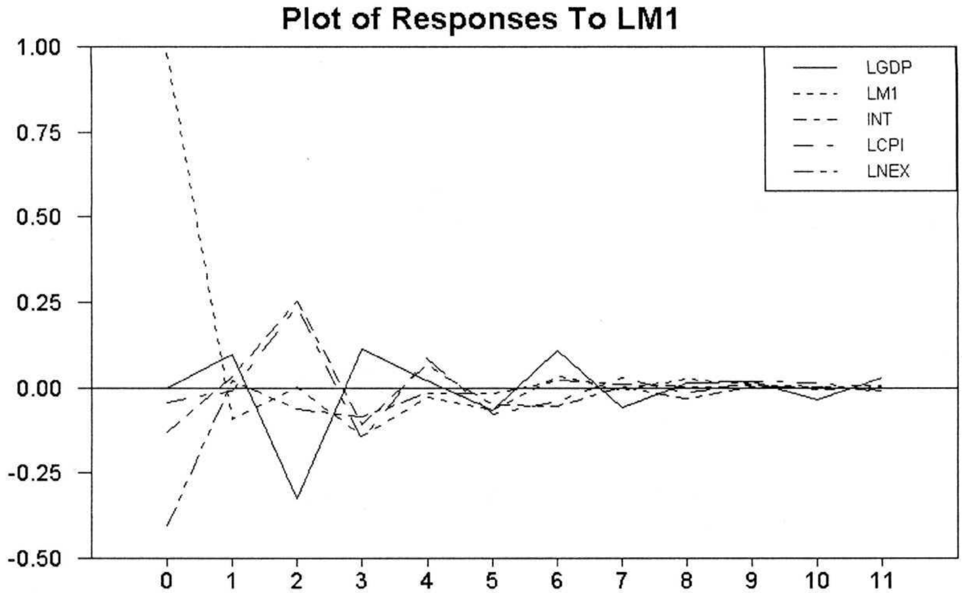
Notes: Figures in the first column refer to the time horizons (i.e. number of months). Several alternative orderings of these variables were also analysed, i.e. monetary variables appearing prior to output variable but such alternations did not change the results to any substantial degree. This is possibly due to the variance-covariance matrix of residuals being near diagonal, obtained through Choleski decomposition in order to orthogonalise the innovations across equations.

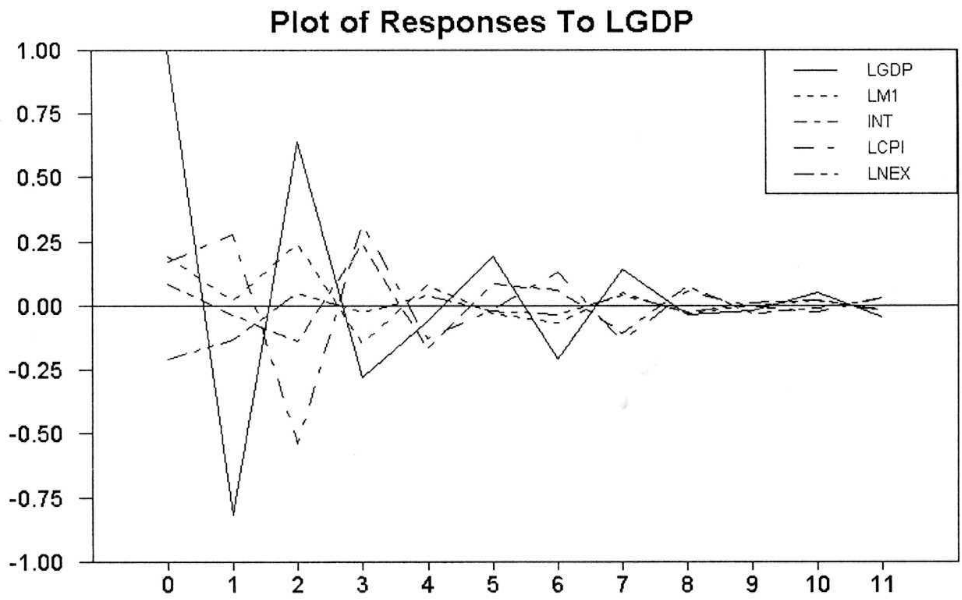
M1 accounts for 5% of the variation in the forecast error of GDP, while NEX contributes of 8%. After one year GDP accounts for 9.6% of the variation in the forecast error of M1. About 15% (even after the first quarter) of M1 forecast error variance is explained by the innovations in interest rate variable. M1 and CPI contribute 14% and 9% for the variation in the forecast error of NEX, respectively. Real output (even after the first quarter) explains about 30% of the variance of prices and about 55% are due to its own shocks. This further supports the hypothesis that there is causal effect from GDP to CPI.

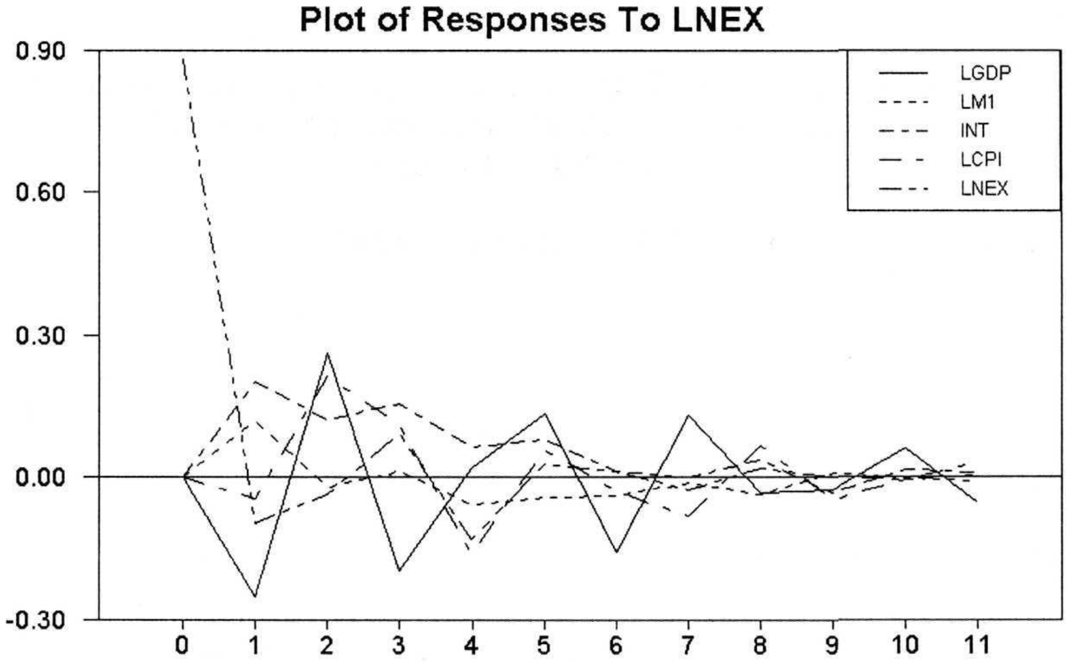
The IRFs, Figure 1, tend to suggest that one-standard deviation shock to money relatively has no effect to other variables. A shock to output variable significantly effects price variable. The impulse response functions of the price variable fluctuate in the entire period, but the effect is statistically significant only in the first quarter with the maximum negative value in the two-month's horizon.

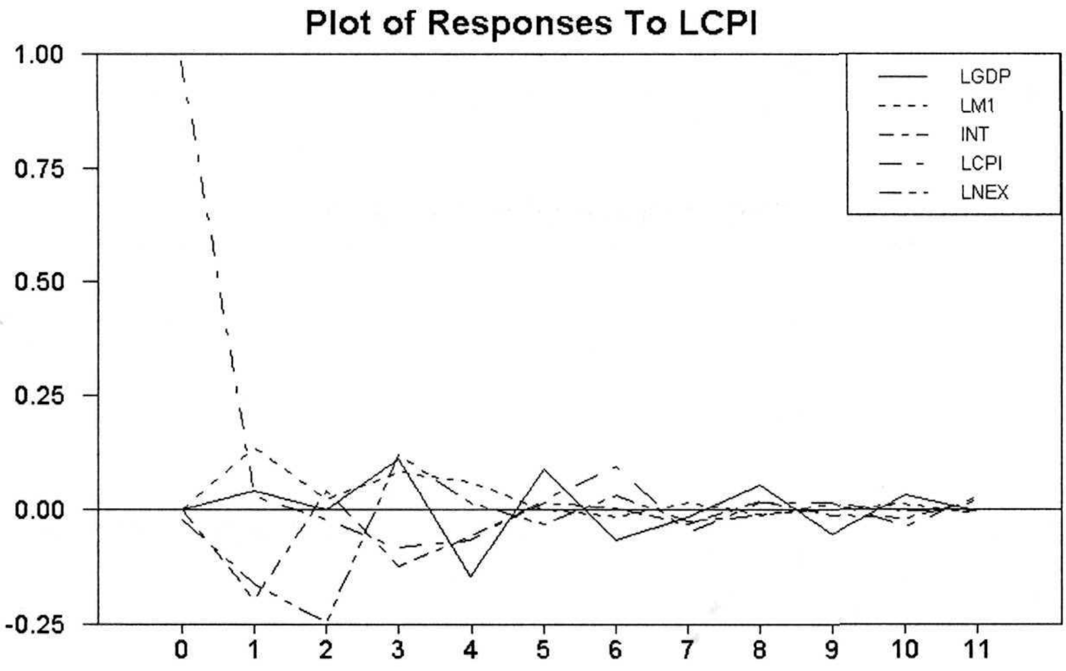
Figure 1

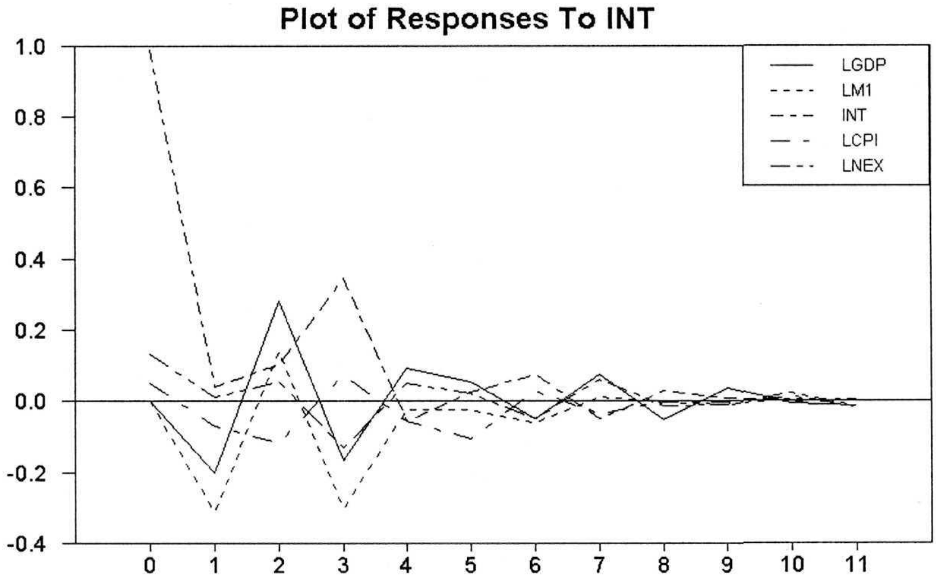
IMPULSE RESPONSES OF ALL VARIABLES TO A ONE-STANDARD DEVIATION SHOCK TO **LM1, LGDP, LNEX, LCPI** AND **INT** VARIABLE






Plot of Responses To LNEX
0.90
0.60
0.30
0.00
-0.30
0
1
2
3
4
5
6
7
8
9
10
11
LGDP
LM1
INT
LCPI
LNEX


Plot of Responses To LCPI
1.00
0.75
0.50
0.25
0.00
-0.25
0
1
2
3
4
5
6
7
8
9
10
11
LGDP
LM1
INT
LCPI
LNEX



The exchange rate variable and prices have no statistically significant effect on the other variables. One-standard deviation shock to interest rate variable influence slightly the money variable, but has no effect to other variables.

Our finding suggests that interest rate, exchange rate and output leads (more or less) money supply and prices. It is closer to the real business cycle theory than with the other macroeconomic doctrines.

Conclusion

The main task in this empirical macroeconomic work is investigation the causal relationship between money and other macroeconomic variables such as output, interest rate, prices and exchange rate in Croatia. Different schools of economic thought have postulated various relationships between money and other macroeconomic variables. But the causal chain implied by the existing macroeconomic paradigms still remains ambiguous and the issue remains unresolved and are an empirical one.

The basic principle of Granger-causality analysis is to test whether past values of monetary aggregate help to explain current values of output. The multivariate Granger-causality tests were performed in a vector autoregression (VAR) model. So, we included additional variables, beside money and output, in the model, allowing for the simultaneity of all included variables. The methodology employed here uses variance decomposition and impulse response functions to capture out-of-sample Granger causality in macroeconomic activity in a dynamic context.

The empirical results of this study show that money supply cannot be independent stimulus to the economic activity in the short run in Croatia. Money is neutral in the short run and monetary policy cannot contribute towards price stability in the Croatian economy. The variation in price level is mainly caused by its own lagged values and from real output. Granger causality from real output to price level means that the excess aggregate demand generated by the increase in income is not absorbed by the expansion in the aggregate supply in the economy.

The direction of the Granger causality was detected through the vector error correction model (VECM). The VECM indicates that in the short-run variables interest rate and exchange rate stand out econometrically exogenous. In the empirical period these variables were relatively the leading variables. They were initial receptors of exogenous shocks to the long run equilibrium.

In order to analyse the dynamic properties of the system, the forecast error variance decompositions (VDCs) and impulse response functions (IRFs) were computed. The results of the relative contribution of the explanatory variables in explaining the variation in the dependent variable in the post-sample period tend to confirm the conclusion obtained by within sample VECM analysis.

The interest rate, exchange rate and output leads money supply and prices, so monetary policy alone is insufficient to achieve sustainable economic growth with price stability and external equilibrium. The Granger-causal chain implied by our evidence is consistent more with real business cycle theory than with other major macroeconomic paradigms.

LITERATURE

1. Bessler, D. and J. Kling, (1985). A Note on Tests of Granger Causality, *Applied Econometrics, 16,* 335-342.
2. *Bulletin,* National Bank of Croatia, various numbers.
3. Cooley, T. and S. Le Roy (1985). A Theoreretical Macroeconomics: a Critique, *Journal of Monetary Economics, 16,* 283-308.
4. Dickey, D.A. and W.A. Fuller (1979). Distributions of the Estimators for Autoregressive Time Series with Unit Root, *Journal of the American Statistical Association*, 74, 427-431.
5. Doan, A. T. (1992). *User's Manual: RATS, Version 4.2.*

6. Engle, R. and C. Granger. (1987). Cointegration and Error Correction: Representation, Estimation and Testing, *Econometrica, 55,* 251-276.
7. Granger, C.W.J. (1969). Investigating Causal Relations by Econometric Models and Cross-spectral Methods, *Econometrica 37*,24-36.
8. Granger, C.W.J. (1986). Developments in the Study of Cointegrated Economic Variables, *Oxford Bulletin of Economics and Statistics,48*,213-228.
9. Granger, C.W.J. (1988). Some Recent Developments in a Concept of Causality, *Journal of Econometrics 39,* 199-211.
10. Geweke, J.R., R. Meese and W. Dent. (1983) Comparing Alternative Tests of Causality in Temporal Systems: Analytic Results and Experimental Evidence. *Journal of Econometrics, 21*, 161-194.
11. Hamilton, J. D. (1994). *Time series analysis,* Princeton: Princeton University Press
12. Hendry, D. (1986) Econometric Modelling with Cointegrated Variables: An Overview, *Oxford Bulletin of Economics and Statistics, 48,* 201-212.
13. Johansen, S. (1988). Statistical Analysis of Cointegration Vectors, *Journal of Economic Dynamics and Control,* Vol. 12, pp. 231-54.
14. Johansen, S. (1992). Determination of the Cointegration Rank in the Presence of a Linear Trend, Oxford, *Bulletin of Economics and Statistics, 54,* 383-397.
15. Johansen, S. and K. Juselius (1990). Maximum Likelihood Estimation and Inference on Cointegration - with Application to the Demand for Money, *Oxford Bulletin of Economics and Statistics, 52,* 211-244.
16. Kwiatkowski D., P.C.B. Phillips, P. Schmidt and Y. Shin (1992). Testing the Null Hypothesis of Stationary against the Alternative of a Unit Root, *Journal of Econometrics, 54, 159-178.*
17. McMillin, W. D. (1988). Money Growth Volatility and the Macroeconomy, *Journal of Money, Credit and Banking 20,* 319-335.
18. Miller, S. and F. Russek (1990). Cointegration and Error Correction Models: The Temporal Causality Between Government Taxes and Spending, *Southern Economic Journal, 57,* 221-229.
19. Osterwald-Lenum, M. (1992), A Note with Fractiles of the Asymptotic Distribution of the Maximum Likelihood Cointegration Rank Test Statistic, *Oxford Bulletin of Economics and Statistics,* 54, 461-72.
20. Phillips, P.C.B. and P. Perron (1988). Testing for a Unit Root in Time Series Regression, *Biometrika, 75,* 335-346.
21. Runkle, D. (1987). Vector Autoregression and Reality, *Journal of Business and Economic Statistics, 5, 437-454*.

22. Sims, C.A. (1972). Money, Income and Causality, *American Economic Review 62,* 540-542.
23. Sims, C.A. (1982). Police Analysis with Econometric Models, *Brookings Papers on Economic Activity,1,* 1367-1393.
24. Thomas, R.L. (1993) *Introductory Econometrics*: *Theory and Applications*, Longman, London.
25. Zellner, A. (1988). Causality and Causal Laws in Economics. *Journal of Econometrics, 39,* 7-21.

MAKROEKONOMSKA GRANGER-UZROČNA DINAMIKA U HRVATSKOJ: ISTRAŽIVANJE TEMELJENO NA ANALIZI MODELA VEKTORSKE KOREKCIJE POGREŠKE

Sažetak

U radu se prikazuje uzročni odnos između novca i drugih makroekonomskih varijabli: outputa, kamatne stope, cijena i tečaja u Republici Hrvatskoj. Analiza Grangerove uzročnosti temelji se na testiranju hipoteze da li prošle vrijednosti monetarne varijable pomažu u objašnjavanju tekuće vrijednosti outputa. Provedeni su multivarijatni testovi Grangerove uzročnosti, a analiza je napravljena u okviru vektorskog autoregresijskog modela (VAR). U analizi su korištene metode dekompozicije varijance (VDCs) i funkcije impulsnog odziva (IRFs) kako bi se ispitala Grangerova uzročnost između varijabli. U kratkom su se roku kamatna stopa i tečaj pokazale kao ekonometrijski egzogene, odnosno vodeće varijable. One su bile i početni primatelji egzogenih šokova prema dugoročnoj ravnoteži. Uzročne veze otkrivene među varijablama pokazale su da je novčana masa neutralna u kratkom roku.