

# Evidence of the Long-run Equilibrium between Money Demand Determinants in Croatia

B. Skrabic, and N. Tomic-Plazibat

**Abstract**—In this paper real money demand function is analyzed within multivariate time-series framework. Cointegration approach is used (Johansen procedure) assuming interdependence between money demand determinants, which are nonstationary variables. This will help us to understand the behavior of money demand in Croatia, revealing the significant influence between endogenous variables in vector autoregression system (VAR), i.e. vector error correction model (VECM). Exogeneity of the explanatory variables is tested. Long-run money demand function is estimated indicating slow speed of adjustment of removing the disequilibrium. Empirical results provide the evidence that real industrial production and exchange rate explains the most variations of money demand in the long-run, while interest rate is significant only in short-run.

**Keywords**—Cointegration, Long-run equilibrium, Money demand function, Vector error correction model.

## I. INTRODUCTION

STABLE money demand function is precondition for an effective monetary policy. Therefore, many empirical studies are devoted to investigate what are the main determinants of money demand function, and to examine if it is stable in long-run and short-run. The most frequent explanatory variables in money demand function are the economic activity variables, price levels, opportunity costs, and various other variables. For the variable of the economic activity, the most is used gross domestic product (GDP), gross national disposable income (GNDI), industrial production, consumption expenditure. The most frequently used proxies of opportunity costs are the money market interest rate, treasury bill interest rate, interest rate on savings and deposits. Price level (inflation) have been measured by the consumer price index (CPI), which is used as GDP deflator.

Among first researches of money demand function in Croatia have been provided by Anusic (1994), Sonje (1999), Babic (2000), and Erjavec and Cota (2002).

Anusic (1994) estimated univariate partial adjustment model (PAM), using ordinary least squared method, based on monthly data from January 1991 to November 1993. He concluded that the main determinants of the money demand during period of hyperinflation were inflation, real economic activity and lagged real money, whereas interest rate did not have significant influence on money demand [1].

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On the other hand Sonje (1999) has analyzed money demand in period after hyperinflation proving empirical evidence that inflation has no longer significant effect [10]. The essential element of antiinflationary program in 1993 was introduction of internal convertibility of national currency, which helped the previous inflation drastically reduced quantity of real money to be inducing a significant rise of supply through transferring of accumulated foreign exchange. Thus stopping not only indexation but bringing about the appreciation of the exchange rate as the basic indicator of inflatory expectations.

However, the main goal of Croatian monetary policy is adjusting to Maastricht's criteria of entering European Monetary Union (EMU) within inflation not greater then 1.5% of the average of three members of EMU with the lowest inflation rate.

Using seasonally adjusted variables Babic (2000) also found that inflation coefficient is insignificant at the 95% confidence level and very close to zero [6].

Erjavec and Cota (2002) have showed that money demand cannot be independent stimulus to the economic activity in the short-run in Croatia. 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 [7]. The VECM, used in their research, indicated that in the short-run variables interest rate and exchange rate stand out econometrically exogenous.

The structure of the paper is organized as follows. In the second section methodology approach and data used in analysis are described. In the third section interpretation of empirical results are given, while the fourth section summarizes the results of the research and provides conclusions.

## II. DATA AND METHODOLOGY APPROACH

Analyzing money demand in this paper we used monthly data from October 1994 to May 2006 with following variables:

- consumer price index (CPI)
- monetary aggregate (M1)
- real money demand ( $RM1=M1/CPI$ )
- real industrial production adjusted with producer price index, as a proxy of real output (RIP)
- interest rate on deposits in kuna (IRD)
- exchange rate of kuna per euro (ER)

Time series of real industrial production indices, as well as exchange rate were seasonally adjusted using multiplicative

method of moving average, because both series show periodic behavior on monthly basis over observed sample. All data excluding interest rate were transformed into natural logs. Observed data used in the analysis are shown on Fig. 1 and Fig. 2.

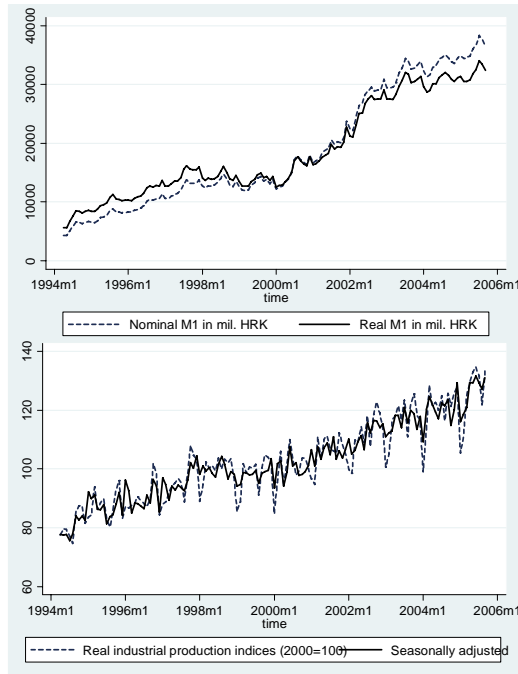


Fig. 1 Nominal and real M1 in mil. HRK with observed and seasonally adjusted real industrial production indices

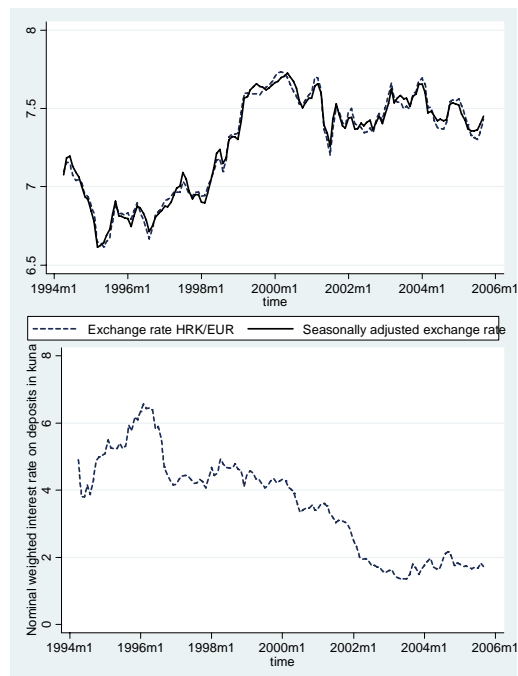


Fig. 2 Observed and seasonally adjusted exchange rate with nominal weighted interest rate on deposits in kuna

According to Fig. 1 and Fig. 2 we can assume nonstationary processes. Hence, Augmented Dickey-Fuller (ADF) unit-root test for the order of integration was conducted. The ADF test was performed by considering trend and constant, and in all cases the unit-root hypothesis could not be rejected. Additional ADF tests on first differences find that all time series are integrated of order one  $I(1)$ . Results of unit-root tests are given in Table I.

TABLE I  
ADF UNIT-ROOT TESTS IN LEVELS AND FIRST DIFFERENCES

Variables <sup>a</sup>	t-value (with trend)	t-value (without trend)
LRM1	-2.013	-2.013
LRIPSA	-2.461	-0.917
LERSA	-1.653	-1.648
IRD	-2.988	-0.329
D(LRM1)	-3.928**	-4.354*
D(LRIPSA)	-7.634*	-7.616*
D(LERSA)	-8.107*	-8.081*
D(IRD)	-10.203*	-10.215*

<sup>a</sup> Null hypothesis that time series variable has a unit-root can be rejected at 1% level (\*) or at 5% level (\*\*).

Consequently, the possible cointegration among all variables cannot be conducted within multivariate regression framework, since it does not allow for feedback effects. In this respect VECM(k-1) model is used. Reparameterized form of the initial VAR(k) is defined as:

$$\Delta y_t = \sum_{i=1}^{k-1} \Gamma_i \Delta y_{t-i} + \Pi y_{t-k} + \varepsilon_t, \quad (1)$$

where  $y_t$  is a  $n \times 1$  vector of endogenous variables, i.e.

$y_t = [LRM1 \ LRIPSA \ LERSA \ IRD]^T$ ,  $\varepsilon_t$  a  $n \times 1$  vector of stochastic disturbances. The rank  $r$  of matrix  $\Pi$  gives the statistical properties of the VAR. Full rank  $r = n$  implies that VAR is stationary. Rank  $r = 0$  implies that VAR is nonstationary with no cointegrating equations. Reduced rank  $0 < r < n$  means  $r$  cointegrating equations. Matrix  $\Pi$  can be decomposed as  $\Pi = \alpha\beta^T$ , where  $\alpha$  is  $n \times r$  matrix of speed of adjustments and  $\beta$  is an  $n \times r$  matrix of parameters which determines the cointegrating relationships. The columns of  $\beta$  are interpreted as long-run equilibrium relationships between the variables. Matrix  $\alpha$  determines the speed of adjustment towards this equilibrium. Values of the  $\alpha$  close to zero imply slow convergence.

Johansen procedure is used for cointegration testing. Johansen derives a test on the number of characteristic roots that are different from zero by considering the two following statistics: the trace eigenvalue statistic ( $\lambda_{trace}$ ) and maximum eigenvalue statistic ( $\lambda_{max}$ ) [11]. In trace test, the null hypothesis is that the number of cointegration vector is less or

equal to  $r = 0$  to  $n$ . In each case the null hypothesis is tested against a general alternative. The maximum eigenvalue statistic tests that the number of distinct cointegrating vectors is  $m$  against the alternative of  $m+1$  cointegrating vectors. Results of the Johansen's cointegration tests are presented in Table II.

TABLE II  
JOHANSEN COINTEGRATION TESTS

Maximum rank <sup>a</sup>	Eigenvalue	Trace statistic	Eigenvalue	Max-Eigen statistic
0	52.542*	0.235	0.235	35.01*
1	17.532	0.0953	0.0953	13.126
2	4.41	0.026	0.026	3.473
3	0.936	0.007	0.07	0.936

<sup>a</sup> Test statistics indicates one cointegrating equation at the 5% level (\*)

From Table II rejection of null hypothesis is evident at the 5% level, i.e. trace statistic and max-eigenvalue statistic indicates one cointegrating vector.

### III. EMPIRICAL RESULTS

Before estimation of VECM model with associated cointegrating vector it is necessary to select optimal lag length of initial VAR. Therefore, different information criteria's were computed for different time lags [8]. Results of order selection criteria are given in Table III.

TABLE III  
VAR LAG ORDER SELECTION CRITERIA'S

Lag <sup>a</sup>	Likelihood Ratio	Final predict. error	Akaike info. criterion	Schwarz info. criterion	Hannan-Quinn info. criterion
0	NA	5.18e-08	-5.423466	-5.334789	-5.387435
1	1156.05	5.94e-12	-14.49844	-14.05506*	-14.31828*
2	30.9164	5.89e-12*	-14.50801*	-13.70993	-14.18373
3	27.042*	5.98e-12	-14.49308	-13.34028	-14.02467
4	19.1653	6.49e-12	-14.41613	-12.90864	-13.80361

<sup>a</sup> The asteriks indicates lag order selected by the criterion.

The lag length of VAR was chosen  $k = 2$  according to FPE and AIC criteria's, because diagnostic tests of vector autoregression models of order one and order three, according to other criteria's, were not satisfied. Estimated VECM(1) system with one cointegrating vector is given in matrix notation:

$$\begin{bmatrix} \Delta LRM1_t \\ \Delta LRIPSA_t \\ \Delta LERSA_t \\ \Delta IRD_t \end{bmatrix} = \begin{bmatrix} -0.0711 \\ 0.1641 \\ -0.0048 \\ -0.0205 \end{bmatrix} \cdot \begin{bmatrix} 1.0000 \\ -3.2579 \\ 1.3544 \\ 0.0569 \\ 2.4329 \\ 1 \end{bmatrix}^T \cdot \begin{bmatrix} LRM1_{t-1} \\ LRIPSA_{t-1} \\ LERSA_{t-1} \\ IRD_{t-1} \end{bmatrix} + \begin{bmatrix} 0.0178 & -0.0784 & 0.0366 & -0.0574 \\ -0.1331 & -0.2139 & 0.7371 & -0.0242 \\ -0.0007 & -0.0013 & 0.2780 & -0.0031 \\ 0.3825 & 0.0661 & 0.8783 & 0.1304 \end{bmatrix} \cdot \begin{bmatrix} \Delta LRM1_{t-1} \\ \Delta LRIPSA_{t-1} \\ \Delta LERSA_{t-1} \\ \Delta IRD_{t-1} \end{bmatrix} + \begin{bmatrix} 0.0089 \\ 0.0048 \\ 0.0003 \\ -0.0267 \end{bmatrix} \quad (2)$$

From VECM(1) system (2) estimated money demand function has following form:

$$\begin{aligned} \Delta LRM1_t = & -0.07111 \cdot (LRM1_{t-1} - 3.2578 \cdot LIRDSA_{t-1} + \\ & + 1.3544 \cdot LER_{t-1} + 0.0569 \cdot IRD_{t-1} + 2.4329) + \\ & + 0.0178 \cdot \Delta LRM1_{t-1} - 0.0784 \cdot \Delta LIRDSA_{t-1} + \\ & + 0.0366 \cdot \Delta LER_{t-1} - 0.0574 \cdot \Delta IRD_{t-1} + 0.0089 \end{aligned} \quad (3)$$

Tests of t-statistics of estimated coefficients are presented in Table IV and Table V.

TABLE IV  
COINTEGRATING VECTOR COEFFICIENTS

Variables <sup>a</sup>	Coefficient	Standard error	t-value
LRM1(-1)	1		
LRIPSA(-1)	-3.2578	0.3931	-8.2578*
LERSA(-1)	1.3544	0.5532	2.4483**
IRD(-1)	0.0569	0.0312	1.8239
C	2.4328		

<sup>a</sup> Null hypothesis that estimated coefficient is equal to zero can be rejected at 1% level (\*), at 5% level (\*\*) or at 10% level (\*\*\*).

According to cointegrating coefficients in the long-run it can be expected 3.26% increase of real money demand if real industrial production increases for 1%. On the other han, 1% increase of exchange rate would decrease money demand for 1.35% in the long-run. Finally, the increase of interest rate of 1% would cause 0.06% decrease of real money demand.

TABLE V  
VECM(1) SYSTEM COEFFICIENTS

Variables <sup>a</sup>	Coefficient	Standard error	t-value
$\alpha$	-0.0711	0.0344	-2.062***
D(LRM1(-1))	0.0178	0.0936	0.1910
D(LRIPSA(-1))	-0.0784	0.0991	-0.7911
D(LERSA(-1))	0.0366	0.4925	0.0744
D(IRD(-1))	-0.0574	0.0217	-2.6433**
C	2.4328	0.0039	2.2849

<sup>a</sup> Null hypothesis that estimated coefficient is equal to zero can be rejected at 1% level (\*), at 5% level (\*\*) or at 10% level (\*\*\*).

In the short-run only the interest rate has significant influence on changes of real money demand, while other variables do not affect money demand in short-run. Moreover, parameter  $\alpha$  in Table V has expected negative sign, which determines the speed of adjustment towards equilibrium. Model demonstrate equilibrium correction mechanism, and take about 14 months to restore equilibrium after shock of money demand.

In a cointegrated system, if variable does not respond to the discrepancy from the long-run equilibrium relationship, it is weakly exogenous. Hence, if the speed of adjustment parameter  $\alpha$  is zero, the observed variable is weakly exogenous. The practical importance is that a weakly exogenous variable does not experience the type of feedback used in VAR. Weak exogeneity tests are presented in Table VI.

TABLE VI  
WEAK EXOGENEITY TESTS

Variable <sup>a</sup>	LRM1	LRIPSA	LERSA	IRD
$\chi^2(1)$	3.6433	18.100	0.5979	0.0166
p-value	0.0562***	0.0002*	0.4466	0.8972

<sup>a</sup> Null hypothesis that speed of adjustment is equal to zero can be rejected at 1% level (\*), at 5% level (\*\*) or at 10% level (\*\*\*).

From Table VI it is evident that exchange rate and interest rate are weakly exogenous variables. As the real industrial production is not weakly exogenous, we can expect strong speed of adjustment, i.e. after shock of money demand we can expect the restore of industrial production to its equilibrium for about 6 months.

The model is also checked for serial correlation, normality and heteroscedasticity. Residual heteroscedasticity White test ( $\chi^2 = 111.934$ , p-value 0.1951) indicates no heteroscedasticity in the system. Moreover, Lagrange Multiplier (LM) test showed there is no serial correlation between residuals at any lag, including up to lag 6. However, based on joint Jarque-Bera (JB) test multivariate normality of residuals is rejected at p-value less than 1%. All results are obtained using EViews software.

#### IV. SUMMARY WITH CONCLUSIONS

For money demand function estimation in Croatia variables as real industrial production, exchange rate HRK/EUR and interest rate on deposits in kuna are used. Unlike previous researches inflation is excluded from the model as statistically insignificant variable. This is consistent with stable prices policy as a result of accession of Croatia to the European Union, which is the main goal of Croatian National Bank.

Long-run money demand function is estimated indicating slow speed of adjustment of removing the disequilibrium within VECM framework. Empirical results provide the evidence that real industrial production and exchange rate explains the most variations of money demand in the long-run, while interest rate is significant only in short-run. However, the major effect on money demand is due to real industrial production as a proxy of real output. Moreover, it was found that exchange rate and interest rate are weakly exogenous variables.

For further research different interest rates from money market may be included in explaining money demand in short

and long-run.

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