MONEY SUPPLY, GDP AND INFLATION: THE DYNAMIC ECONOMETRIC ANALYSIS OF MACRO-EQUILIBRIUM*

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The paper investigates some theoretical problems of the Hungarian economy. The fundamental question is, whether the Hungarian economy meets the requirements of a modern, developed market economy at the end of the transition period. In order to answer the underlying question the authors present several macroeconometric results, based on quarterly analysis of macroeconomic time series concerning the interrelations of GDP, money supply, velocity and inflation. No unanimous answer to the basic question is given, nontheless interesting findings for the relevance of some theoretical macromodels, the equilibrium–disequlibrium situation of the economy and the causal relations of some macrovariables are revealed.

KEYWORDS: Quantity theory of money; Disequilibrium analysis; Econometrics.

The study of the economic relations in the transition period is of both theoretical and practical importance. The two theoretical problems which require clarification are the following: *a*) has the transformation of the country into a market economy been completed, i.e. is the transitory stage over for the Hungarian economy; and *b*) is the emerging new system identical with the highly developed market economies, or should it be considered as something special, a 'third way' formation? The two questions are, of course, not independent from each other. It would hardly be possible to give comprehensive, and in many respects unquestionable answers, therefore it seems more useful to focus research on certain special areas and use the findings to facilitate the understanding of the nature of the new system. The present study follows this approach by attempting to analyse the equilibrium–disequilibrium of the macro level monetary processes with the help of empirical tools.

The determinant significance of the monetary processes did not become self-evident until after the transformation into the market economy. Attention was, however, focused mainly on the microeconomic processes in the finances and the money market rather than

* The study was written within the framework of the research programme No. T 019925, of the Hungarian Scientific Research Fund (OTKA) entitled. 'The econometric analysis of the macro-economic relations of transition.

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on the macro-level interrelationship between the monetary and real processes or the changes in the equilibrium. The authors of this study attempt to apply econometric tools to the analysis of this area, which has so far been less broadly investigated either from theoretical or practical (economic policy) aspects. The following three issues will be dealt with.

1. The relationship between the money supply and the GDP, with special regard to the fact that money can be active, i.e. used for the purposes of monetary policy, or can be passive, playing a neutral role in the shaping of macroeconomic processes.

2. The interrelation between the supply of money and the changes in the price level, the impact of the changes on the money supply on inflation, and the influence of inflation on the money demand and supply.

3. The changes in the money demand and supply, the study of the equilibrium on the money market, periods of disequilibrium on the money market: their changes in time and the macro-economic problems they refer to.

There are several factors making it quite difficult to perform the investigations proposed by the authors. The first and most important of these is the lack of a firm theoretical foundation which could serve as a basis for the analysis. This is the consequence of the transitional condition. The second difficulty is the lack of adequate, homogeneous data sets, and reliable, high quality macro-data, that could be the unquestionable starting point for the empirical study. Thirdly, the application of the econometric methods including testing raises various methodological problems. (Not to mention only the most obvious of these: our data-base contains not more than 40 observations, which makes the findings of the stochastic time series modelling less convincing. However, it can hardly be accepted that the 'optimal' size of the data-base does not allow macroeconomic modelling for at least twenty years to come.) In spite of all these difficulties we do believe that certain statements will prove to be true and some of the analyses will be useful in the future as well.

TESTING OF THE BASIC INTERRELATIONSHIPS AND THE SURVEY OF THE DATA

In this section we introduce the basic variables of the study, give a short description of their change in time in the period of transition and analyse their causal interrelations.

Quantity theory of money and the velocity

As a starting point for the analysis, the basic interrelationship of the quantity theory of money was used:

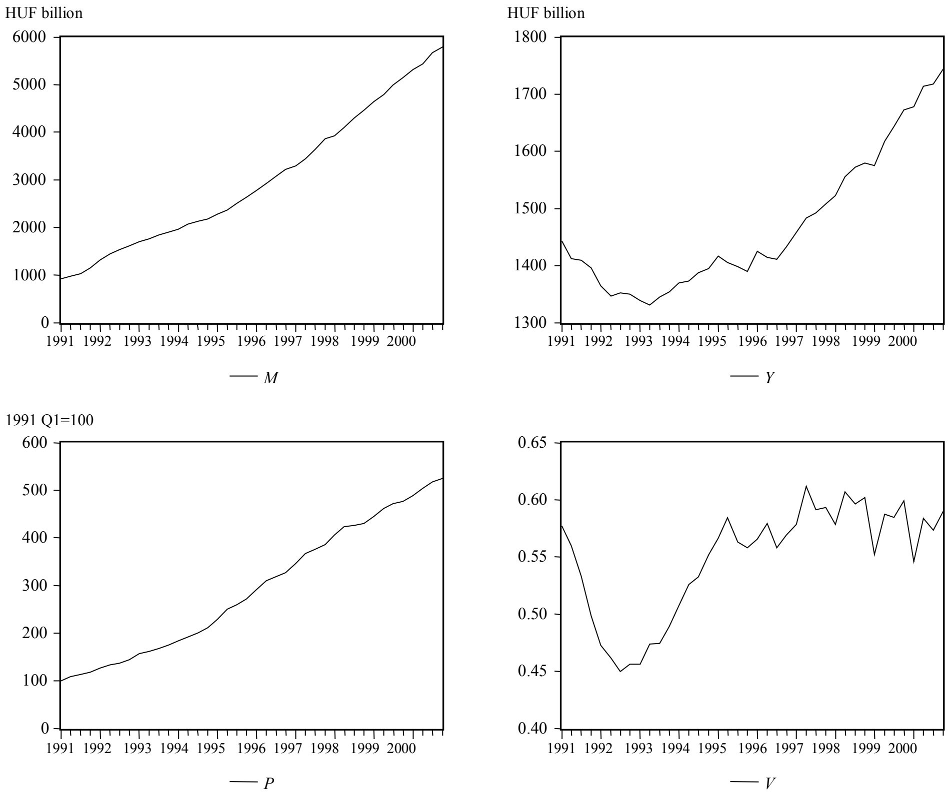
$$M \cdot V = P \cdot Y \qquad /1/$$

where M means the quantity of money, V is the velocity of money, P is the price level and Y represents real GDP. Following the conventions, the logarithms of the variables is given in lowercase letters, consequently the previous relationship /1/ can be transcribed as follows:

$$m - p = y - v \qquad /1a/$$

Several theoretical assumptions have been put forward to interpret the changes in the four variables. Monetarists say that the velocity of circulation remains constant – especially in the long run – and real GDP will change according to its potential growth path, consequently changes in money supply and price level are closely related. Keynesians state that the velocity cannot be considered as constant, and the adjustment of the price level is slow and comes with some delay, but the quantitative adjustment is much faster and more vigorous, therefore significant interrelation actually develops between money supply and the GDP. Which of the two theoretical assumptions can more appropriately be applied on the Hungarian conditions is hard to tell a priori, on a theoretical basis. The answer for this question can be attempted only after the analysis of macroeconomic data. For the period between 1991–2000, a relatively homogeneous quarterly data-set serves as a basis for the empirical studies.[3]

Figure 1. Time paths of the basic variables
(1991–2000, seasonally adjusted series)



[3] All these data available for the whole period can be found in the official publications of the Hungarian Statistical Office (except for the GDP, because quarterly GDP data are available only for the period 1996-2000). The GDP quarterly data for the period preceding 1996 were estimated from the annual data by *Viktor Várpalotai*. The detailed methodology of this estimation is given in *Várpalotai* (2000). With regard to the sensonality the variables are seasonally adjusted (except for the interest rate). The definitions and the observed time series of the variables can be found in the Appendix.

The first step was the exploration of the data generating processes (DGP) of the four basic variables. Three of them are observable (see the Appendix), while velocity of money is derived from /1/ as

$$V = \frac{P^d Y}{M},$$

where P^d is the quarterly GDP deflator. Since this GDP deflator was partly estimated from annual data, we mainly use quarterly consumer price index for P in the rest of this paper. The only exception is the real money, were the GDP deflator will be applied as M/P^d. The changes of the four variables over time are shown in Figure 1.

As the graphic representation of the basic variables suggests, these processes cannot be considered as stationary, so the level of integration was determined by means of hypothesis testing. The DGP of the basic variables was explored by the augmented *Dickey-Fuller* test (ADF). Table 1 shows the findings of the tests. The data-generating processes of the individual variables were specified separately (to find out whether they contained constant terms, or trends). The model was chosen on the basis of partial t-tests. Table 1 contains the test values calculated for the optimal model.

Table 1

ADF tests for the basic variables

Variable	Level	First difference	Second difference
M	-2.882	-2.674*	-6.506***
Y	-1.949	-4.631***	-6.338***
P	-2.760	-6.344***	-14.278***
V	-2.746	-3.246*	-5.537***

Note: The random walk null-hypothesis is to be rejected * at 10, ** at 5, and *** at 1 percent level.

Table 2

ADF tests for the logarithms of the basic variables

Variable	Level	First difference	Second difference
m	-2.438	-3.493*	-6.010***
y	-2.333	-4.464***	-6.428***
p	-2.323	-4.198***	-12.523***
v	-2.720	-3.121**	-5.552***

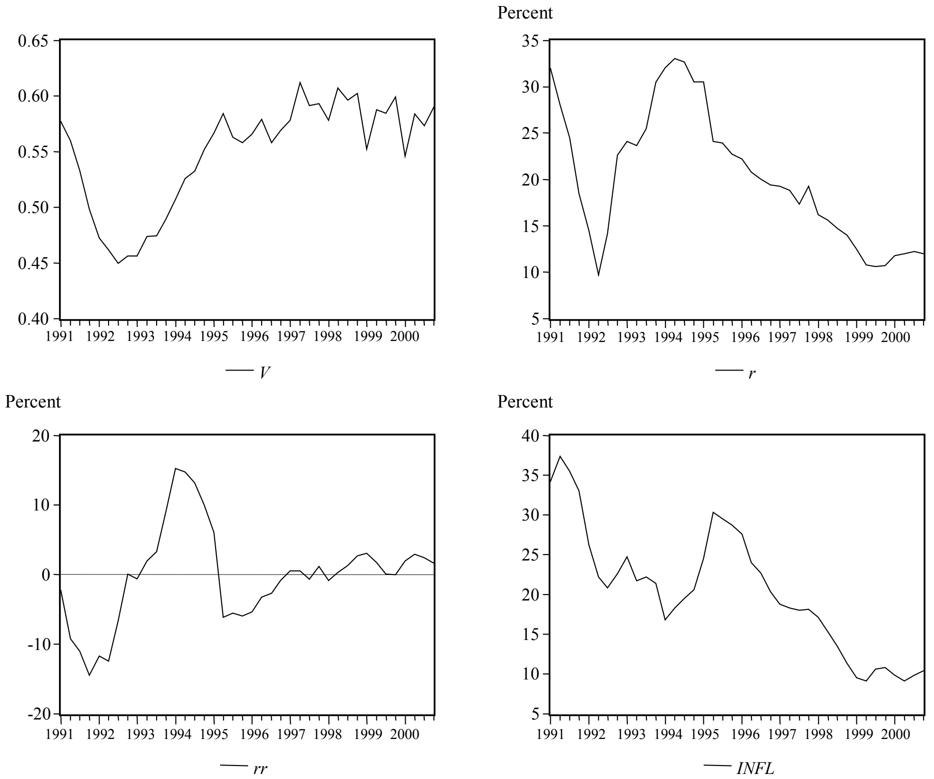
Note: The random walk null-hypothesis is to be rejected * at 10, ** at 5, and *** at 1 percent.

It can be seen that of the basic variables, the GDP and the consumer price index measured as the percentage of the first quarter of 1991 and representing price level, are most probably integrated of order 1. In the case of money supply and velocity, the null can be rejected only at a 10 percent level in the case of the first differences, i.e. the variables can be interpreted as integrated of order 2. This 'uncertainty' in the quantity of money is probably due to the structural break (the '*Bokros* package') experienced in the first quarter of 1995. It will be 'transferred' to the other variables as well, since the velocity was simply transformed using the other variables and equation /1/.

Since later, in the course of analysis, the original variables will be replaced with their logarithms (see, for example equation /1a/), the mentioned tests were performed for the transformed variables as well. Table 2 shows that the conclusions to be drawn from the tests are in perfect agreement with the statements made about the original variables.

Let us examine now in more details the changes in the velocity (see Figure 2) The time sequences lead us to two conclusions (in addition to the fact that its expected value is not constant, as can be seen in the analysis of the order of integration): on the one hand, there was a significant decrease after the change of regime, due to the transformation crisis, and later, in the period of consolidation, it returned to the former level; and, on the other hand, its value got stabilised in the second part of the period under consideration (there were only small deviations).

Figure 2. Time paths of the velocity and its factors



What kind of factors can be related to the change in the velocity? First of all, the interest rate (*r*), because the trends in the costs of keeping money must have a decisive impact on the duration of keeping the money. On the other hand, the co-integration test has shown that although there is a relationship between the velocity of circulation and the nominal interest rate, or real interest rate (*rr*, nominal interest rate – rate of inflation), the direction of the relationship is not positive, but negative – in contrast with the expectations – and the error correction mechanism does not function properly either.

A more thorough look at Figure 2 will help us to find an acceptable explanation of this phenomenon. The figure shows quite clearly that both the nominal and the real interest rates decreased significantly in the early period of the transition; the decrease of the former came as a consequence of the economic and financial crisis, while the latter for the same reasons and because of the increasing inflation. Later, after 1992, both showed an increase, while inflation slowed down and this process continued until the end of 1994. Actually, up to this point the trend was the same as in the case of the velocity of money. After 1994, however, inflation highly increased again, while both interest rates fell significantly. This accelerated inflation was not caused by a setback in the performance of the economy, but by the change in the economic policy, therefore the velocity did not decrease again, but stabilised around the given level. This short historic overview leads to two conclusions: on the one hand, a distinction between the period before 1995 and the period after it will make the close relationship between velocity and interest rates even more obvious. On the other hand, considering that the changes in the real interest rate were not caused by the inflation, but by the nominal interest rate, one can suppose that the velocity is more strongly related to inflation than to the real interest rate.

Let us examine now, whether these two hypotheses can be supported by the estimates. The relationship between the velocity of circulation and the real interest rate was tested again using a dummy variable, and the following co-integrating equation was set up.

$$\hat{V} = 0.5799 + 0.00214 \cdot rr - 0.08364 \cdot DUM \quad ,$$

where *rr* is the real interest rate, *DUM* stands for dummy (the *t*-statistics were 4,05 and -16.47). Dividing the period into two parts the following equations were estimated

$$\hat{V} = 0.5799 - 0.08154 \cdot rr \qquad (1991-1995)$$

$$\hat{V} = 0.5799 + 0.00214 \cdot rr \qquad (1995-2000)$$

It can be seen that the real interest rate has different impacts in the two periods. This role, however, is not equally strong; the negative role between 1990–1995 was significantly stronger than the positive one played in the second period, that of stabilization.

The co-integrating relationship between the velocity and quarterly inflation is quite convincing, and the error correcting mechanism also operates adequately. As it was expected, the relationship is negative ($\hat{V} = 6849 - 3.2833 \cdot \Delta p$) and there was no need to divide the period into two parts.

The relationship of the three basic variables

After the analysis of the velocity the three further variables of the starting equation of the money supply /1/, i.e. the changes in the nominal money supply, the price level and the GDP will be examined. Since the velocity changes in time, it is not reasonable to assume a stationary combination of these variables. It may, therefore, be more useful to continue the analysis by setting up a VAR model, instead of co-integration.

The VAR estimates of the three variables are considered to be quite adequate and reliable. There is, however, a fundamental problem, which jeopardises further analysis, namely, that for each variable only its own lagged value was significant, the other two were not, with two unimportant exceptions. These were: the GDP lagged by one and two periods was significant for the money supply and the price level. On the whole, however, this does not alter the previous conclusion: the changes in the three variables do not give a coherent picture, consequently it may be more helpful to examine the pairvise relationships.

If we examine the relationship between the supply of money and the price level, it seems to be true that changes in money supply is an I(2) process, while those in price level is an I(1), but since the former was brought about by a structural break in the middle of the period under consideration, we can reasonably expect to discover a co-integrating relationship between them, even if certain restrictions are necessary. The estimated equation ($m = 3.447 + 0.799p$, $t = 23.11$) shows that the relation is positive and quite steady, the latter being also proved by the significant error correction equation. After the testing of the causal relation it can be established that the change in money supply may be more caused by the change in price level than by the opposite relation.

Table 3

Significance values of Granger causality test

X is not the cause of *Z*	Lags in the VAR model				
	1 period	2 period	3 period	4 period	5 period
$p \Rightarrow m$	0.0189	0.008	0.008	0.047	0.020
$m \Rightarrow p$	0.5829	0.7570	0.1141	0.3522	0.5286
$\Delta p \Rightarrow \Delta m$	0.2873	0.1668	0.5117	0.0504	0.0124
$\Delta m \Rightarrow \Delta p$	0.6217	0.6086	0.6266	0.5343	0.2452
$m \Rightarrow y$	0.0001	0.0001	0.0001	0.0001	0.2980
$y \Rightarrow m$	0.0632	0.0633	0.0379	0.4683	0.7174
$\Delta m \Rightarrow \Delta y$	0.0018	0.0116	0.0297	0.6207	0.5672
$\Delta y \Rightarrow \Delta m$	0.7209	0.3575	0.5136	0.4283	0.4996

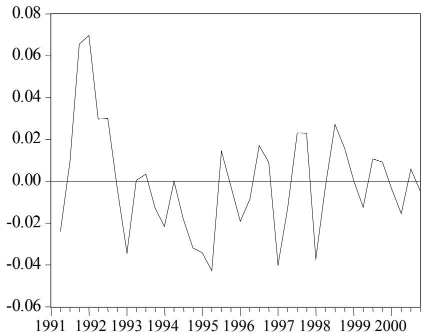
In the course of further analysis the dynamics of changes, i.e. the relationship between the increase in money supply and inflation is examined. The co-integrating regression is estimated as

$$\Delta\hat{m} = 0.01431 + 0.7837 \cdot \Delta p \,.$$

The estimated regression parameter can be interpreted in such a way that a 1 percent increase in the quarterly inflation brought about a 0.78 percent (quarterly) increase in money supply. In good agreement with the former statements (see Table 3) the direction of the causal relation remained the same, i.e. it is the inflation that causes increase in money supply and not the other way round (the increase in money supply causes inflation). This conclusion is drawn from the widely, but not generally accepted view that the inflation experienced in the transition period was basically generated not by the demand, but by the collapse of the supply side, and is to be considered as cost inflation originating in the structural transformation.

In spite of the revealed causality relations, we cannot be convinced that inflation is the only factor influencing the increase in money supply. Table 3 drawn up on the basis of co-integrating regression makes is quite clear that the high growth rate of the early 1990s cannot be attributed to the acceleration of inflation alone. The decrease in the velocity could also play a role in the increase of money supply, among many other things. A more detailed analysis of this issue would require a study of further money market factors, but this would be beyond the scope of the present study.

Figure 3. Residuals of the co-integrating regression between the increase in money supply and increase in quarterly inflation



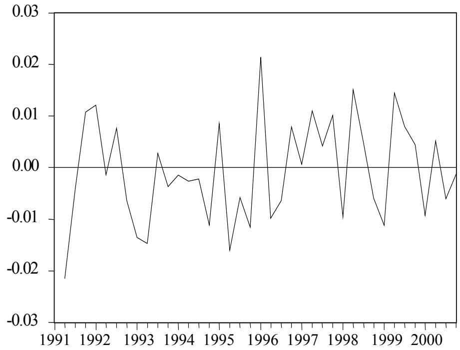
Let us turn our attention to the relation between money supply and real GDP. Testing the co-integration can be performed here as well, but with regard to our statement made earlier about money supply and price level. The test found only a weak co-integrating relation between the two variables, and the error correction mechanism does not work either. In principle these findings do not contradict any theoretical hypotheses, because the latter are usually concerned with the existence or non-existence of a relation between real money supply (instead of nominal money supply) and real output. This is also supported by the causality analysis, which has failed to produce any significant result (see Table 3).

We continue with the analysis of the relation between the increments. The co-integration test allows us to establish the following interrelationship:

$$\Delta\hat{y} = 0.0260 - 0.4352 \cdot \Delta m$$

and the relevant error correction mechanism is also correct. Figure 4 presents this relationship and shows satisfactory adjustment, i.e. well behaving residuals.

Figure 4. Residuals of the co-integrating regression between the increment in GDP and that of quarterly inflation



The negative relation between the two variables can be attributed to the fact that at the beginning of the decade production fell dramatically, leading to a very high inflation, and consequently to an increase in money supply. In the second half of the decade, however, consolidation resulted in increasing production, and a decrease in the growth of money supply and inflation. In the case of 1-3 lags the analysis of the causal relation between the rates of increase has shown beyond doubt that the rate of increase in money supply is actually the cause of the GDP's growth rate. Since there is a negative relation between the two variables, it can by no means be considered as a manifestation of the Keynesian stimulating monetary policy or of active money. What we have got here is rather the negative impact of inflation: high or increasing inflation enforces an increase in the growth of money supply, and, at the same time, impairs the conditions in real economy or makes them more uncertain. As a result, the increase in GDP is also slowed down.

The co-integrating relation is in agreement with equation /1/ and also with the relation established formerly between the velocity and inflation. Since $\Delta y - \Delta m$ is stationary, $\Delta v - \Delta p$ should be stationary as well, in terms of /1/. This requirement is not in contradiction with the co-integrating equation between the velocity and inflation given previously.

2. ANALYSIS OF THE DEMAND SIDE

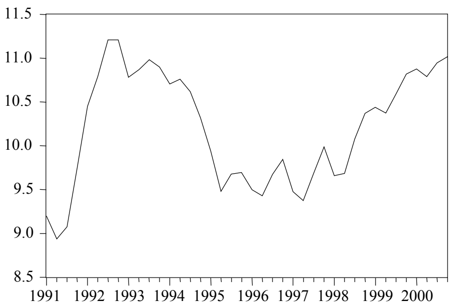
In this section analysing the demand side of two models, a traditional and the *Cagan*-type money demand model will be treated. An interesting question of this investigation is whether the adaptive or the rational expectations of inflation seem to be more plausible in describing the Hungarian economy.

The traditional money demand equation

We have so far examined the changes in nominal money supply as a basic variable and its relationships. From an economic point of view, however, the time series analysis of the real money supply is more important (*M/*P, or its logarithm *m-p*).[4] Figure 5 shows the changes in real money supply during the decade under examination.

[4] In this case – as a second exception – the quarterly deflator index is used as variable *P*.

Figure 5. Changes in the real money supply



Based upon the unit root test it can be stated that the changes in real money follow an I(1) process, (the ADF-test for the level of the variable being -2.740; the test value of the first difference is -4.509.) Therefore the changes in real money can be described by an ARMA (2, 1) model. Because the estimated roots of the dynamic process are less than one, the process is stationary. The complex roots, on the other hand, indicate a cyclical movement, though a cycle with a decreasing amplitude.

In terms of the traditional, simple Keynesian money demand function, real money demand depends on the nominal interest rates and real GDP, on the former in a negative way, on the latter positively, with respect to the speculative and transactional demand. In a general equation form:

$$\left(\frac{M}{P}\right)^D = f(Y, R) \qquad f_Y > 0, f_R < 0 \qquad /2/$$

If R is defined as a vector, which designates the yields of the alternative money holdings, then we might use the portfolio-theory approach. Fundamentally, R means short-term interest rates. It is a common assumption, that the money market is one of the most flexible ones, and therefore the market always clears, i.e. demand equals supply. It is to be stressed that in this approach this is a one-sided market adjustment, since the money demand is the only one which adjusts to the money supply. Moreover, there is another often used assumption, that money supply equals the quantity of money in circulation. Using these simplifications we get the following simple, and empirically testable formula:

$$\frac{M}{P} = f(Y, r) \qquad f_Y > 0, f_r < 0 \qquad /2a/$$

In equation /2a/ there is another hidden assumption, which states that the demand for money (the attitude of the actors of the market) remains unchanged even if the money supply changes. (This is the essence of the *Lucas*-critique, which is neglected by this assumption, and is totally avoided by the relation /2a/).

Testing empirically formula /2a/ we used a dummy variable to separate the periods before 1995 from the period after, the same way as we did previously. The results of the

OLS estimates of the model including real money, real GDP and interest rate variables are the following:

$$(m - p^d) = 5.497 + 0.3384 \cdot y - 0.0065 \cdot r + 0.0743 \cdot DUM \ ,$$

where p^d is the quarterly GDP deflator. Though all the parameters are significant, it is difficult, however, to interpret the coefficient of y, because according to the conventional interpretation the value of the transactional money demand coefficient should be somewhere between 0.5–0.8 (depending on the changes in the velocity). The discouraging results (e.g. $R^2 = 0.44$, $D - W = 0.24$) indicate, that the traditional concept of the demand function cannot really be considered relevant to the Hungarian economy in the transition period.

Consequently, it might be expedient to release the basic assumptions used so far. First, we remove the assumption, that the behavioural rule determining the demand for money is independent from the supply of money. Accordingly, let us take a look at the following five equations:

$$\begin{aligned}
&(m-p)_t^D = a_0 + a_1 y_t - a_2 r_t + \varepsilon_t^D , \\
&y_t = \beta_1 y_{t-1} + \beta_2 \left[(m-p)_{t-1} - (m-p)_t^e \right], \\
&(m-p)_t^e = \alpha_1 (m-p)_{t-1} + \alpha_2 y_{t-1}, \\
&(m-p)_t^S = \alpha_1 (m-p)_{t-1} + \alpha_2 y_{t-1} + \varepsilon_t^S , \\
&(m-p)_t^D = (m-p)_t^S = (m-p)_t .
\end{aligned}$$

The first equation defines the traditional behaviour of money demand, the second one defines a *Lucas*-type supply function, the third – based on the rational expectations – assumes that the actors of the economy know the rule of money supply, which is formulated by the fourth equation. And finally, the fifth equation further maintains the assumption, that the equality of demand and supply automatically exists without time lag on the money market. From the five equations we can get the following reduced form:

$$(m-p)_t = a_0 + a_1 \beta_2 (1-\alpha_1)(m-p)_{t-1} + a_1 (\beta_1 - \beta_2 \alpha_2) y_{t-1} - a_2 r_t . \qquad /3/$$

We can take the following three relations as an alternative to the previous five equation model:

$$\begin{aligned}
&(m-p)_t^D = a_0 + a_1 y_t - a_2 r_t + \varepsilon_t^D , \\
&(m-p)_t^S = \alpha_1 (m-p)_{t-1} + \alpha_2 y_{t-1} + \varepsilon_t^S , \\
&\Delta(m-p)_t = \gamma \left[(m-p)_t^D - (m-p)_t^S \right].
\end{aligned}$$

In these equations, however, the condition of the immediate adjustment of demand and supply was ruled out, the parameter γ shows the velocity of adjustment.

Further reducing these three equations we can get the following formula:

$$(m-p)_t = \gamma a_0 + (1-\gamma\alpha_1)(m-p)_{t-1} + \gamma(a_1-\alpha_2)y_{t-1} - \gamma a_2 r_t \qquad /4/$$

The two reduced forms show very similar structures, though their parameters are obviously different. The common estimation of the two reduced forms is the following:

$$\left(m-p^d\right)_t = 1.9562 + 0.8293(m-p^d)_{t-1} - 0.07517 y_{t-1} - 0.0029 r_t + u_t \,.$$

The parameters are all significant, $R^2 = 0.92$ and $D-W = 1.83$. Unfortunately, the structural parameters cannot be obtained 'back' from the estimated reduced form (underidentified model). At the same time, however, with the testing of the stability of the parameters, we can answer, even if only indirectly, the question: weather the rule of money supply has changed over time. In our case the *Chow*-test – using the most probable 1995 Q1 breakpoint – shows instability, moreover, the distribution of the residual variable of the model is not normal. As a result, we cannot make any decisive statements about the rule of money supply.

Testing the Cagan-model

In Hungary in the period of transition there was a significant inflation, which had different levels and was very varied in nature, yet was continuously present. This in itself justifies, that we use the *Cagan*-type money demand model to determine the money demand function. The model is defined by the following very simple relation:

$$(m-p)_t^D = b - a\Delta p_{t+1}^e + u_t \,. \qquad /5/$$

The demand equation expresses the empirically observed behaviour, that as the expectations about inflation increase the demand for holding money decreases. Here *b is* constant, *u* is the random variable, indicating the shocks, caused by the changes in demand and the velocity, and the parameter *a* (since we work with log-variables) expresses the percentage decrease of money demand derived by 1 percent increase of the expected inflation.

We take two cases for defining the expectations: one is the adaptive, the other is the rational expectations. First, let us take a look at the *adaptive expectation*, which according to the widely accepted definition is:

$$\Delta p_{t+1}^e = \theta\Delta p_t + (1-\theta)\Delta p_t^e \,. \qquad /6/$$

For the sake of simplicity let us assume that money supply equals the quantity of money, and the adjustment of demand-supply can be defined by the simple form presented in the previous part:

$$(m-p)_t^S = (m-p)_t$$
$$\Delta p_t = \gamma\left[(m-p)_{t-1}^D - (m-p)_{t-1}^S\right].$$

If we assume that the adjustment is immediate and perfect, that is $\gamma \to \infty$, then based on the equations /5/ and /6/ we get the following reduced form:

$$(m-p)_t = \theta b + (1-\theta)(m-p)_{t-1} - a\theta\Delta p_t \ . \qquad /7/$$

The OLS estimates yielded relatively good results:

$$(m-p^d)_t = 1.1986 + 0.8505(m-p^d)_{t-1} - 0.3780\Delta p_t + u_t \,.$$

Because the model is just identified, the structural parameters can be determined exactly: $b = 8.0174$; $\theta = 0.1495$; $a = -2.5284$. Based on this, we can conclude on the one hand, that the last pieces of information play a relatively small role in the formation of adaptive expectations ('slow forgetting'), as opposed to the earlier expectations, on the other hand a 1 percent increase of the expectations about inflation will bring about a two and half percent decrease in the demand for money.

If the adjustment of demand supply is not perfect, then the following reduced form occurs:

$$\Delta p_t = \frac{\gamma\theta}{1+\gamma\theta a} b + \frac{1-\theta}{1+\gamma\theta a}\Delta p_{t-1} - \frac{\gamma}{1+\gamma\theta a}(m-p)_t + \frac{(1-\theta)\gamma}{1+\gamma\theta a}(m-p)_{t-1} \,. \qquad /8/$$

Based on the results of the corresponding OLS estimate the estimated reduced form is:

$$\Delta p_t = 0.6353 + 0.2200\Delta p_{t-1} - 0.1986(m-p^d)_t + 0.1221(m-p^d)_{t-1} + u_t \,.$$

Similarly to the previous case, this model is just identified, so we can determine the structural parameters, which are the following: $b = 8.30$; $\theta = 0.3852$; $a = -8.394$; $\gamma = 0.555$. Practically, only parameter *a* deviates significantly from the earlier estimates, which indicates, that if there is no immediate adjustment between demand and supply, just a gradual one (the adjustment parameter is less than 1), then as a compensation, the elasticity of demand of the inflationary expectations will be much higher.

Considering the other type of expectations, the *rational expectations*, estimation of /5/ becomes very simple. Taking into account the definition of rational expectations:

$$\Delta p_{t+1} - \Delta p^e_{t+1} = \varepsilon_{t+1}$$

where ε is a white noise variable, inserting this into equation /5/, and assuming, that supply equals the real money supply and the adjustment is perfect, then we get the following form:

$$(m-p^d)_t + a\Delta p_t = b - a\Delta^2 p_{t+1} + u_t + a\varepsilon_{t+1} \,. \qquad /9/$$

Because inflation is an I(1) process, the growth rate of inflation is stationary, and if there is no demand shock, then the whole right hand side becomes stationary, conse quently the two elements of the left hand side must be co-integrated, with co-integrating coefficient *a*.

Estimating this relation we get the following co-integrating equation:

$$(m - p^d)_t = 8.1431 - 6.493\Delta p_t + u_t \ .$$

The parameters are very close to those, estimated in the model of the adaptive expectations. The error correction mechanism works well. Testing of the residuals showed, that they may follow a normal distribution with expectation close to 0, which means that the assumption of the rational expectations proved to be acceptable.

3. EQUILIBRIUM ANALYSIS OF THE MONEY MARKET

After examining the demand side of the Hungarian money market, let us take a look at the whole of the market, and the equilibrium relations dominating the market. This obviously requires that the money supply function should be defined, which – opposed to the demand function – possesses a significantly less theoretical base. After the specification of the supply function, for the analysis of the equilibrium we must choose one of the following two principles.

– According to the *equilibrium approach*, the money demand and supply move together in the long-run (do not necessarily coincide, but the difference between them is nearly constant), when either of these variables diverts from this equilibrium path – due to an incidental shock – the mechanisms (perhaps automatisms) which return the market into the state of equilibrium immediately switch on (error correction takes place). When some influence (e.g. price increase) evokes a change leading to an increase of inflation, then with the increase of supply the equilibrium will come about, and vice versa.

– The *disequilibrium approach* on the other hand assumes that the difference between demand and supply is not steady, not stationary (not constant), there are no forces on the market that might stimulate demand or supply to 'follow' each other. A certain adjustment variable (e.g. the real interest rate) continuously provides information about the earlier relations of demand and supply, it decreases when the supply is prevalent, and increases when the supply decreases.

From modelling point of view this means that:

a) we specify the money demand and money supply function (when specifying the demand function we obviously rely on our earlier argumentation);

b) we estimate – independently – the value of the target variable based on the demand and the supply function, then by testing the co-integration of the two estimated variables we analyse the equilibrium hypothesis;

c) after we have a satisfactory adjustment equation, we estimate the models in a disequilibrium approach and carry out a specification analysis;

d) Based on the fit of the model estimated at two different approaches and on the specification analysis, an assessment on the equilibrium–disequilibrium situation of the economy can be set.

The specification of the market model

Based on our earlier findings it becomes obvious that the study of the equilibrium situation requires the re-specification of the money demand and money supply functions. Our study with regard to the money demand function made it clear, that the demand for real money supply depends on the GDP, on the inflation as well as on the interest rate. Consequently, we specified the following demand function:

$$D_t^M = \alpha_0 + \alpha_1 y_t + \alpha_2 \Delta p_t + \alpha_3 r_t + \alpha_4 DUM + u_t^D \ ,$$

where D_t^M means the demand for money supply, DUM denotes the dummy variable, (introduced earlier for the quantification of the impacts of the 'Bokros-package'). From the point of view of equilibrium the intended and the actual demand coincide in the long-run, its value equals that of the supply, and the actual value of the real money supply (in our earlier models we used the notation $(m-p)_t$). It is to be mentioned, that we did not want to use a lagged endogenous variable in our model, because it could result in an 'over-adjustment' especially in a later disequilibrium model.

During the specification of the supply function we could not rely on theoretical considerations as we did before. With regard to the whole of the period it would not seem feasible to have a rule of money supply or a monetary policy with exclusive effect, so we considered the two most obvious factors as basic variables: the domestic interest rate influencing the money supply of the commercial banks, and the interest premium influencing the flow of foreign currency.[5] Based on all these findings the final form of the supply function is as follows:

$$S_t^M = \beta_0 + \beta_1 r_t + \beta_2 rp_t + \beta_3 DUM_t + u_t^S$$

where S_t^M corresponds to the quantity of supply, and rp_t represents interest premium.

In both the demand and the supply function we took the logarithms of real money supply, real-GDP, and the price level variables.

The estimation and the analysis of the equilibrium model

According to the equilibrium hypothesis, the demand for money and the supply of money was in dynamic equilibrium during the past decade on the Hungarian money market, the two sides of the market practically equalled the actual money supply, that is:

$$D_t^M = S_t^M = (m-p)_t$$

The results of the OLS estimates are the following (*t*-statistics are in brackets):

$$\underset{}{(m-p^d)_t} = \underset{(3.90)}{53190} + \underset{(2.12)}{0.379 y_t} - \underset{(-1.49)}{0.711 \Delta p_t} - \underset{(-2.64)}{0.005 r_t} + \underset{(3.39)}{0.083 DUM} + u_t^D \ ,$$

[5] The definition of interest premium and the referring data are displayed in the Appendix.

$$\left(m - p^{d}\right)_t = \underset{(315.6)}{8.026} - \underset{(-4.46)}{0.008} r_t - \underset{(-5.86)}{0.441} rp_t + \underset{(2.76)}{0.054} DUM_t + u_t^S \, .$$

The coefficient of determination of the demand function is 0.498; while the corresponding indicator of the supply function is 0.607. (It must be mentioned, that the values of the *Durbin-Watson* *d*-statistic – a generally accepted diagnostic test – are very low for both functions.)

The parameters of the models basically meet the theoretical expectations, with only one exception, this is the negative sign of the interest premium. According to the logic of the uncovered interest parity, the higher the interest premium is the more foreign currency will flow into the country, and after the exchange it will increase the quantity of money, that is the money supply. If, however, the monetary authorities follow a strict and consistent sterilising policy, that is they compensate for the foreign currency flow by withdrawing corresponding amounts of money from the internal market, then we can easily get a negative coefficient, because the withdrawal of money usually affects the 'active' money, while the foreign currency represents 'passive' money after the exchange (see for example the privatisation purchases). Based on the estimation of the money supply function we can conclude that during the period examined, the Hungarian National Bank followed a consequent sterilising policy.

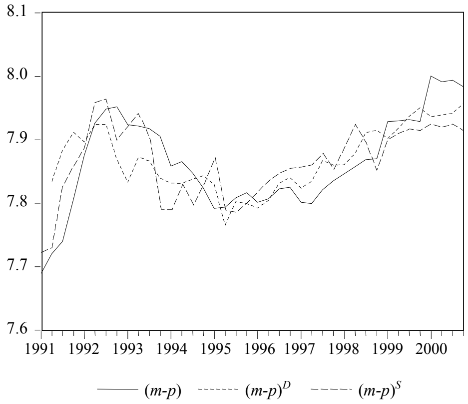
Based on OLS estimates we carried out the ex-post forecasts of the variables of the two equations, which seem to be co-integrated at a 5 percent significance-level (the value of the *Johansen* LR-test function is 17.546).

According to the co-integrating regression

$$\left(m - p\right)_t^D = -1.878 + 1.238\left(m - p\right)_t^S$$

where the superscripts indicate, which function the forecasts derive from. Figure 6 shows the changes in estimated demand and supply, and the actual real value of money supply.

Figure 6. The time sequence of money demand and money supply



The figure supports that demand and supply change together, so based on our findings we can assume, that the market was in equilibrium in the long-term, the error correcting mechanism prevailed itself.

The analysis of the disequilibrium model with regard to money markets

The essence of the disequilibrium concept is, that the market does not ‘clear itself’, that is – as we called it earlier there is no error correction – the actual transactional quantity (in our case the real money supply) is determined by the short side of the market at all times. The specification of the disequilibrium model resembles that of the equilibrium model described earlier, but differs from it in some – conceptual – questions. The model used by us is:

$$D_t^{\hat{M}} = \alpha_0 + \alpha_1 y_t + \alpha_2 \Delta p_t + \alpha_3 r_t + \alpha_4 DUM + u_t^D$$
$$S_t^{\hat{M}} = \beta_0 + \beta_1 r_t + \beta_2 rp_t + \beta_3 DUM_t + u_t^S$$
$$(m-p)_t = \min\left(D_t^{\hat{M}}; S_t^{\hat{M}}\right)$$
$$\Delta rr_t = \gamma\left(D_{t-1}^{\hat{M}} - S_{t-1}^{\hat{M}}\right)$$

where $D_t^{\hat{M}}$ and $S_t^{\hat{M}}$ mean the intended demand for money supply and the supply of money respectively. The latter – in case of the disequilibrium model – might not necessarily correspond to the actual supply. The model is completed by the minimum condition and a so-called adjustment equation, in which we assume that changes in the real interest rates are functions of the excess demand of the previous period. (Depending whether this equation contains a random variable we have to use different methods for estimating the parameters of the model).[6] The maximum likelihood estimates are as follows:

Parameter	Estimate	Estimated standard error
α_0	6.980	3.712
α_1	0.143	0.503
α_2	-1.373	1.246
α_3	0.005	0.003
α_4	-0.104	0.078
σ_{u^D}	0.077	0.011
β_0	7.987	0.073
β_1	-0.149	0.415
β_2	-0.005	0.004
β_3	-0.047	0.056
σ_{u^S}	0.063	0.020
γ	39.852	13.907
log *L*	-46.569	

[6] Given that both equations contain the same explanatory variables, construction of the likelihood function is not trivial. The details of this problem are beyond the scope of this study (see *Quandt*; 1988 and *Rappai*; 1989).

It can be seen, that the parameters show only a slight deviation from the values estimated earlier by the OLS method. Some of the striking differences are the result of the large standard errors which make even the signs uncertain. All this indicates that the empirical verification of the disequilibrium hypothesis is based on very precarious grounds.

Figure 7. The intended demand for and supply of money, and the changes in money supply

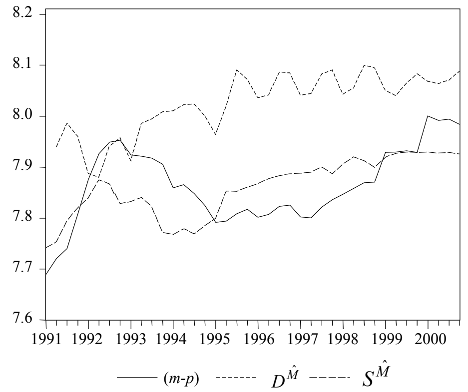


Figure 7 shows the changes in estimated intended demand, and supply having a disequilibrium conception, as well as the actual real money supply. We can see, that in the past decade under examination the intended demand continuously and significantly exceeded the intended supply, and – due to the effectiveness of the short side of the market – the actual real money supply as well. Nontheless it is true, that the 'excess demand' shows a decreasing tendency over time, but even then it cannot justify sufficiently the dynamic changes and the interrelation of money demand and money supply. Based on these findings, the disequilibrium hypothesis with regard to the period between 1991–2000 cannot be considered statistically verified.

4. CONCLUSION

Since the observation period is too short, the results allow us to draw conclusions of only limited validity. Nevertheless, the results of a many-sided model analysis provide the possibility to make a few careful and not too rigorous conclusions.

1. From the point of view of monetary processes the period between 1991–2000 cannot be regarded homogeneous. The Bokros-package of March 1995 has a relevance here from two aspects: on the one hand, the artificial acceleration of inflation, and on the other hand, the changing of the exchange rate mechanism. Its impacts can be well experienced during the modelling of the different monetary processes.

2. According to the evidence gained from our empirical analyses, the changes in the velocity of money in the transition period can be explained by the inflation rather than the changes in interest rates. This specific situation could arise, because the change in real interest rate (despite its high value) was basically determined not by the inflation, but by the change in the nominal interest rate.

3. Our research rendered it possible that in the Hungarian economy, money did not play an active, but rather a passive role in the period of transition. Our model-estimates confirm that the increase and at a later stage the decrease of inflation was caused by the decrease and the stabilization of real output (GDP) (with the exception of 1995, when inflation was artificially accelerated). The nominal money supply (with a short time-lag) basically adjusted to the changes of inflation.

4. Effectiveness of the two-factor, containing GDP and interest rate money demand function – when it is assumed that the demand of money adjusts immediately and perfectly to the quantity of money (which is equal to the money supply as well) – cannot be proven by empirical investigations. We can get far better results if we overrule the assumption that quantity of money = money supply, and the immediate adjustment of demand supply (money supply = money demand), and we transform the money demand function accordingly.

5. The *Cagan*-type money demand function provided surprisingly good results, with both adaptive and rational expectations. This might come as a surprise, because though the level of inflation in the Hungarian economy was quite significant throughout the period under consideration, yet there was no real danger of a hyperinflationary situation (that is why the *Cagan*-model was originally developed for). One explanation of this fairly good result could be, that the expectations about inflation played an important role in the changes of the domestic inflation process.

6. With respect to the mutual relations between the demand for money and the supply of money and to the balanced situation of the money market, the findings of our tests firmly suggest that we accept the equilibrium hypothesis against the disequilibrium hypothesis. Our estimates suggest, that the demand for money and the supply of money adjusted to each other relatively fast and well through the determining factors, and accordingly, significant disequilibrium did not occur during the whole period.

APPENDIX

Observed time series

Year/quarter	Variables						
	M2	GDPC	GDF	CPI 4	INFL	INTEREST	IPREM
1991 Q1	914.7	592.0	1363.0	100.00	34.2	31.94	23.06
1991 Q2	963.5	614.2	1398.4	109.17	37.3	28.05	28.47
1991 Q3	1018.1	623.6	1418.6	113.64	35.5	24.51	13.05
1991 Q4	1183.0	674.0	1481.9	117.66	33	18.49	16.78
1992 Q1	1311.8	666.6	1289.7	126.23	26.2	14.49	17.68
1992 Q2	1422.2	703.3	1333.3	133.46	22.2	9.72	10.11
1992 Q3	1519.8	724.8	1361.7	137.33	20.8	14.14	0.72
1992 Q4	1666.5	795.2	1433.9	144.26	22.6	22.61	-0.15
1993 Q1	1687.6	802.0	1265.3	157.38	24.7	24.10	-7.63
1993 Q2	1743.1	856.6	1318.2	162.37	21.7	23.65	-11.54
1993 Q3	1819.8	890.0	1353.5	167.81	22.2	25.46	-5.27
1993 Q4	1967.1	986.7	1438.2	175.11	21.4	30.44	10.41
1994 Q1	1957.5	1015.2	1294.3	183.83	16.8	32.03	7.68

(Continued on the next page.)

(Continuation.)

Year/quarter	Variables						
	M2	GDPC	GDF	CPI 4	INFL	INTEREST	IPREM
1994 Q2	2041.3	1093.6	1359.2	192.10	18.3	33.07	-3.30
1994 Q3	2102.4	1138.2	1396.8	200.52	19.5	32.66	4.71
1994 Q4	2246.0	1258.1	1480.7	211.18	20.6	30.54	1.07
1995 Q1	2262.8	1298.4	1338.8	228.84	24.5	30.54	-8.24
1995 Q2	2343.1	1380.5	1391.5	250.30	30.3	24.13	9.97
1995 Q3	2481.1	1407.8	1407.7	259.69	29.5	23.94	11.07
1995 Q4	2715.4	1527.3	1476.0	271.76	28.7	22.73	9.64
1996 Q1	2759.3	1577.1	1346.7	292.03	27.6	22.24	6.67
1996 Q2	2891.1	1692.8	1401.2	310.43	24	20.76	5.44
1996 Q3	3043.0	1717.0	1420.3	318.63	22.7	20.02	4.16
1996 Q4	3318.0	1907.1	1521.0	326.97	20.3	19.41	3.53
1997 Q1	3268.8	1910.5	1377.8	346.87	18.8	19.28	3.34
1997 Q2	3399.0	2101.2	1468.5	367.21	18.3	18.80	3.43
1997 Q3	3593.4	2147.5	1501.6	376.01	18	17.34	2.05
1997 Q4	3975.3	2381.5	1601.5	386.14	18.1	19.27	4.17
1998 Q1	3901.2	2276.6	1438.4	406.18	17.1	16.21	1.99
1998 Q2	4050.1	2479.0	1540.5	423.40	15.3	15.62	-5.26
1998 Q3	4242.8	2548.1	1582.7	426.38	13.4	14.71	2.98
1998 Q4	4593.4	2783.7	1676.9	429.81	11.3	14.00	14.07
1999 Q1	4618.2	2567.4	1487.8	444.78	9.5	12.51	6.01
1999 Q2	4733.1	2802.7	1601.4	461.92	9.1	10.78	6.87
1999 Q3	4930.7	2906.3	1654.4	471.54	10.6	10.64	5.58
1999 Q4	5310.2	3212.1	1775.1	476.23	10.8	10.73	5.85
2000 Q1	5282.6	2913.3	1585.4	488.38	9.8	11.78	1.69
2000 Q2	5370.5	3166.2	1696.6	503.95	9.1	12.00	2.47
2000 Q3	5595.1	3237.5	1728.2	517.73	9.8	12.20	0.89
2000 Q4	5968.3	3563.6	1851.4	525.71	10.4	12.00	3.51

Note. Signs and abbreviations used:
M2 – M2 money supply (HUF billion).
GDPC – Quarterly GDP in current prices (HUF billion).
GDF – Quarterly GDP in 1995 constant prices (HUF billion).
CPI 4 – Quarterly consumer price index (1991Q1=100).
INFL – 12 month consumer price index – CPI.
INTEREST – Average yield of three month discount treasury bills, computed for annual level.
IPREM – Interest premium, computed from the relation of the so-called non-covered interest parity, $rp = r - r^f - \Delta e / e$,

where r^f means the interest rate of the world market, $\Delta e / e$ means the rate of devaluation of the domestic currency.

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