Money Demand in an Open Transition Economy: The Czech Republic 1993–2001*

Luboš Komárek

Czech National Bank

Na Příkopě 28, 115 03 Praha 1, Czech Republic

Zlatuše Komárkova

University of Economics, Prague

W. Churchill square 4, 130 67 Prague 3

Martin Melecký

University of New South Wales, School of Economics

John Goodsell Building, Sydney NSW 2052, Australia

Abstract

This paper offers an internationalised view on the demand for money as applied to the Czech Republic. The traditional money demand function, consisting purely of domestic variables, is extended to include certain foreign determinants that likely affect the demand for money in a small open transition economy. In this respect both narrow and broad money are considered. Several estimation techniques are applied to increase robustness of acquired results. These are DOLS, DGLS, the Johansen method and ARDL. Stability of obtained estimates is tested to study the changes in the estimated relations during the transition period. Finally, estimates of the possible effects of money market disequilibria on prices and output is presented. We find on balance that international variables appear to be significant mainly in the context of broad money demand and the liquidity gaps significantly influence prices and output dynamics.

Keywords: Money Demand, Small Open Economy, Transition, Cointegration
JEL Classification: E65, F31, E41, C20

Corresponding author: Martin Melecky, E-mail: m.melecky@unsw.edu.au

* Authors are indebted to Lance Fisher and Geoffrey Kingston for helpful comments on the earlier version of this paper. This research was supported by a grant from the CERGE-EI Foundation under a program of the Global Development Network. Additional funds for grantees in the Balkan countries have been provided by the Austrian Government through WIIW, Vienna. All opinions expressed are those of the author(s) and have not been endorsed by CERGE-EI, WIIW, or the GDN.

Money Demand in an Open Transition Economy: The Czech Republic 1993–2001

1 Introduction

Demand for money is a very important concept in the history of economic thought and one of the most popular concepts in theoretical and empirical economics. The main objective of this paper is to present a somewhat internationalised view on the demand for money as applied to the Czech Republic from the beginning of the Czech market economy to the present. In this paper we extend the traditional money demand function, consisting purely of domestic variables, to include certain foreign determinants that can potentially affect the demand for money in a small open transition economy. We do so for both narrow and broad money.

The research on money demand is mostly conducted within the framework of a closed economy, as many authors argue that domestic determinants are superior to foreign or international ones. In other words, they argue that after accounting for domestic variables, there is limited scope for improving the explanatory power of such "domestic" money demand specifications. There are many papers on money demand of developed countries which use cointegration techniques, among them Hendry S. (1995), de Brouwer and Subbaraman (1993), Coenen and Vega (1999), Hayo (1999) and Hendry, Ericsson and Prestwich (1997). Nevertheless, there is a lack of an internationally available literature on the analysis of money demand in transition countries, especially those in Central Europe. We are aware of several papers on money demand applied to the Czech Republic. However, these either do not use cointegration techniques (Klacek and

Šmídková, 1995; Hanousek, Kubín, Tůma, 1995; and Kozel, 2000) or operate only within the framework of a closed economy (Arlt et al., 2001).

As foreign financial markets have been undergoing substantial deregulation over the last decade or two, additional investment opportunities have arisen and many residents of developed countries have changed their habits associated with portfolio allocation. There is, in addition, the phenomenon of dollarisation (D-markisation or Euroisation), something that often emerges in open economies in transition. Giovannini and Turtelboom (1992) provide an excellent review of the literature on currency substitution in its broad sense. Furthermore, several authors present particular views on world-wide dollarisation, e.g. Doyle (2000), but papers on dollarisation in transition economies are rather rarer – see Aarle and Van Budina (1995). These papers, however, do not approach the currency substitution phenomenon from the point of view of money demand. Even though papers on money demand incorporating determinants associated with currency substitution and/or capital mobility are rather rare, some researchers do cover this area (Vega, 1998 or McNown and Wallace, 1992).

We divide our paper into six main parts. In the second part, we review recent macroeconomic development in the Czech Republic. The third part discusses some methodological issues. The fourth and fifth parts deal with modelling of narrow and broad money demand in the Czech Republic. In the sixth part, we analyse the effect of money market disequilibria on the dynamics of prices, output and interest rates. Finally, we summarise our findings, discuss some implications and offer conclusions in the seventh part.

2 Overview of Macroeconomic Development

Most transition economies shared similar initial conditions and the process of transformation. Concerning the Czech Republic, periods of internal and external liberalisation have simultaneously occurred to generate convergence to more developed countries. Internal liberalisation has been brought about by price liberalisation resulting in a higher inflation environment, restructuring of industries, adoption of new tax systems, etc, while external liberalisation has been accomplished via trade liberalisation and, in particular, by external convertibility of national currencies and liberalisation of financial accounts. All these transformation problems can seriously obstruct the very effectiveness of monetary policy, on which the authorities heavily rely to achieve macroeconomic stability.

The overall picture of the Czech Republic seems to be rather changeable. After the initial transitory turmoil, real economic activity increased sharply and then turned down. The first period (1993 to 1997) can be described as a period of growing overheating, inflationary pressures and external disequilibrium. The second period (1997 to 1999) was characterized by deep recession, disinflation and rising unemployment, whereas the third one (1999 to now) as a period of stabilisation and strong convergence to the European Union.

The development of external conditions was as follows. The initial political reorientation and the break-up of traditional markets in Eastern Europe caused notable swings in the external position of the Czech Republic, especially in the trade balance. Additionally, new orientation to developed countries of the European Union evoked a change in the commodity structure that resulted in a decrease of exported products with a high degree of manufacturing. The structure

of imports in manufacturing changed only slightly, but imports of products with a relatively lower added value increased substantially.

The current account of the balance of payments was positive from 1991 to 1993 but moved to deficit in 1994. In 1998 the Czech economy left the general "risk level" of extremely high current-account-deficit-to-GDP ratios. Relatively stable development in this respect is now expected. The development of the financial account of the balance of payment was opposite to that of the trade balance, i.e. negative only from 1991 to 1992. In addition, it appears that the financial account has mostly offset the current account deficit. The productive part of foreign direct investment (FDI) has been increasing over time improving the production capacity of the domestic economy.

At the end of 1990 there has been nearly 100-percent decline in nominal value of Czech koruna (CZK) against key currencies due to three successive devaluations. After the last devaluation, the CZK/USD exchange rate was set at 28 CZK/USD, whereas the purchasing power parity estimates were approximately 12 CZK/USD. The Czech koruna was pegged to a basket of five currencies in January 1991. After the break-up of Czechoslovakia (1st January 1993) the CZK was (in March 1993) pegged to a basket containing the German mark (DEM) with a weight of 65 % and the US dollar (USD) with weight 35 %. These weights were set to reflect relative importance of both currencies in foreign trade. From 1990 to 1997, the nominal exchange rate was fixed and a significant inflation differential developed, as the result of the transformation process, at the same time. The real exchange rate adjustment in this fixed nominal exchange rate regime had to be done through the short-term capital inflow, excessive money stock growth and the growing trade balance deficit. As a consequence of this development, a speculative

attack on the currency occurred in May 1997. The Czech National Bank is applying a managed free float regime from the end of May 1997 till now.

3 Model Specification

M1 Aggregate

The construction of the model for narrow money takes into account the dominant role of transaction demand for money, nevertheless we control for the effect of the own rate of return on M1 money and its opportunity cost (return on its closest substitute). We emphasise the focus on a transaction money demand when extending the framework to a small open economy in transition.

In accordance with our interest, the estimated model of narrow money demand takes the form described by equation (1):

$$m1_t = \beta_1 ppi_t + \beta_2 ipp_t + \beta_3 i_r + \beta_4 r_r + \beta_6 inf_t + \beta_7 re_r + \beta_8 fdi_r + \varepsilon_t \qquad (1)$$

where $m1$ is the M1 monetary aggregate, ppi is the producer price index (PPI), ipp is the index of industrial production (IPP), i denotes the interest rate on sight deposits, r the interest rate on short-term time deposits, re the real exchange rate and fdi foreign direct investment, and ε is the residual term. All variables are in logs except for interest rates which are in levels (per cent). β_1 to β_8 are estimated coefficients. Where relevant, when estimating the model we initially assume that all domestic variables are endogenous and foreign variables exogenous.

M2 Aggregate

Now, the speculative motive dominates regarding the demand for broad money. Generally, agents have a range of possibilities where to distribute their wealth and broad money is one asset within the common spectrum. Institutions of

the particular economy determine the variety and span of the plausible range. A money demand function then describes the agents' decision-making process regarding whether to hold their wealth as money.

The spectrum of available assets is more limited in the Czech Republic compared to developed countries. This is mainly due to less developed financial markets (especially for stocks and bonds) and considerable difficulty for many agents to access some markets (especially the markets for treasury bills and government bonds). Also, mutual funds of Czech assets are underdeveloped. This undesirable situation is primarily due to problems associated with asymmetric information and a poor regulatory and legislative base for effective functioning of financial intermediation, especially through financial markets (see Mishkin, 2001).

Therefore we assume, under recent conditions, that the typical agent's portfolio consists, in the context of a closed economy, of broad money, real assets and credits. We assume that agent's portfolios do not only consist of assets but also of liabilities. Thus we take into account one of the most important transmission channels in transitional countries, i.e. the credit channel. Agents increase their borrowing in response to lowering interest rates on credits and vice-versa. This increased demand for credits affects positively holdings of broad money, since agents use these funds to purchase consumption or capital goods. Additionally, lower interest rates on credits may result in a situation when agents tilt their consumption more to the present. The opportunity cost of holding money with respect to real assets is approximated here by inflation (see e.g. Sriram, 1999). We also take into account the transactional motive of holding broad money, as it includes narrow money.

We now consider broad money demand in the context of an open economy. In this respect we incorporate four foreign determinants of broad money demand

in line with the implications of currency substitution theory. The bilateral CZK/DEM and CZK/USD nominal exchange rates[1] (see e.g. Sriram, 1999a) and the returns on foreign assets, as represented by the returns on U.S. Treasury Bills and German Treasury Bills expressed in CZK. The nominal exchange rate describes the effect of indirect currency substitution within the domestic banking system[2] and the returns on T-bills reflect the effect of capital mobility. However, these variables imply that we are analysing short-term, rather than long-term, capital movements, i.e. portfolio investment. Taking these together, we estimate a model of the following form:

$$m2_t = \beta_1 cpi_t + \beta_2 ipp_t + \beta_3 i_t + \beta_4 r_t + \beta_5 \pi_t + \beta_6 e_t + \beta_7 rx_t + \eta_t \qquad (2)$$

where $m2$ is broad money (M2 aggregate), cpi is the consumer price index (CPI), ipp is the scale variable approximation, i is an approximation of the own rate of return on broad money, r is the opportunity cost of holding broad money relative to the alternative of credit repayment, π represents the cost of holding money relative to real assets, e approximates the effect of indirect currency substitution in domestic banking system and rx is a proxy variable denoting capital mobility. Again the variables are in logs except for interest rates and inflation that are in levels (per cent). Where relevant for estimation, we assume that the variables depicting the effect of currency substitution and capital mobility are exogenous from the perspective of the analysed system of variables. All the other variables are deemed to be initially endogenous.

Data Description

We use quarterly time series that span the period from the second quarter of 1993 to the second quarter of 2001. Where the data are not flows, we use

quarterly averages so that all the variables are in the same (continuous) form. We seasonally adjust only the scale variable, since the other variables do not imply any significant seasonality. All the data were obtained from statistics published by Czech National Bank (www.cnb.cz)

The monetary aggregate M1 is used to represent the narrow money here. It traditionally consists of currency in circulation and sight deposits. The applied approximation of a scale variable is the index of industrial production (IPP) with regards to recent research on households' and firms' money demands (see Melecky, 2002a and 2002b). Findings of this work suggest that IPP seems to be the most appropriate scale variable representative. The price level is approximated here by the production price index (PPI). We prefer this variable because it takes into account a relatively stable basket of goods and services and is likely to be more robust to hidden price changes. Since over the period under consideration the majority of narrow money has been held by firms (see Melecky, 2002a and 2002b) PPI should in addition better depict the overall perception of price development.

The interest rate on sight deposits measures the own rate of return on narrow money. This should be an appropriate approximation since currency in circulation has only a minority share in this aggregate according to principles of aggregation. The rate of return on alternative assets or assets not included in the M1 aggregate is represented by the interest rate on short-term deposits. We choose this variable because the portfolio motive of holding such money plays only a minor role relative to the transaction motive. Since we are interested in the substitution (portfolio) effect that stems from changes in relative returns, it is likely that M1 is substituted with short-term deposits. Nevertheless, there are at least two alternatives. One is substitution with real assets, but this is somewhat limited due to allotment restrictions. The other is substitution with foreign

money. The latter is not very important in the context of narrow money, as no foreign currency has substituted for the Czech koruna in its functions of medium of exchange and unit of account, a phenomenon occurring as a result of hyperinflation or massive currency crises[3]. To assess the significance of narrow money substitution with real assets inflation is added into the model to represent the relevant opportunity cost. The coefficient is expected to be negative, although inflation may be perceived as an approximation of uncertainty, as implied by the Sprenkle-Miller model (Sprenkle and Miller, 1980), resulting in a positive coefficient.

As the degree of openness of the Czech economy is fairly high, some external variables are likely to affect the narrow money demand. Thus, the real effective exchange rate (REER) is included in the model to describe the effect of the price elasticity of foreign trade, since the income elasticity is already described by the scale variable. More specifically, REER should capture the consequence of the different financing requirement that imports and exports have on transaction money demand. This is mainly due to the fact that in the case of exports there is no production chain that lowers the needed amount of money for transaction purposes in the economy. Further, foreign direct investment (FDI) is added to capture the effect of increasing capitalisation and the creation of new enterprises. It would be preferable, though the data does not allow this, to divide total FDI into that part which generates new enterprises and the remainder, since the former part has the largest effect on transaction money demand.

Additional Data Used in Broad Money Demand

As the measure of broad money we employ the M2 monetary aggregate, which consists of currency in circulation, sight deposits and time deposits in CZK,

and deposits denominated in foreign currencies. The scale variable is approximated as before using IPP but this time the prices are measured by consumer price index (CPI) as the private agents' holdings dominate within broad money. The own rate of return on M2-type broad money is approximated using the overall interest rate on deposits. However, the term structure of this interest rate does not entirely reflect the composition of the M2 monetary aggregate, since the weights of interest rates on particular deposits are set according to the composition of growth in the M2 aggregate. As a consequence, the gross rate on deposits (which we use) consists of the total rate on new deposits, and not on the existing stock, which would be more relevant for our purposes but is unavailable. The opportunity cost of holding M2 money is approximated by interest rates on credits. In this case we are able to apply the overall interest rate on the stock of credits as published by CNB. This rate is more relevant for our purposes, since agents' decisions are associated with the repayment of the existing stock of debts. As explained earlier, inflation approximates the effect of the alternative costs of holding money compared to real assets. For this purpose we use CPI inflation, measured as the percentage change in the quarterly average CPI index. We annualise this inflation measure so that it can be compared to the other opportunity costs.

The nominal CZK/DEM and CZK/USD bilateral exchange rates are incorporated to estimate the effect of indirect currency substitution within the domestic banking system. Finally, we include returns on U.S. and German Treasury Bills expressed in CZK (return on foreign assets times the relevant exchange rate), since domestic residents are concerned, in their investment decision-making, with proceeds in terms of the domestic currency. We do not

adjust the foreign nominal interest rate, since foreign price developments have no direct consequences for domestic investors.

4 Estimations

As it is common in the time-series analysis we first apply unit root tests (ADF and PP test) to the time series to determine their order of integration and find what methods are appropriate for the estimation. The results are presented in Table A1 in the Appendix. In general most of the series appear to be integrated of order I(1) except for *fdi* which seems to be stationary. Further, we have some indecisive results concerning broad money and prices that may be integrated of order I(2). Application of the additional test (KPSS) with an opposite null hypothesis has not been of any help either. Because of the short time span analysed and low size and power of the tests in small samples we proceed with broad money and prices as I(1) so that the conventional cointegration methods can be used for estimation.

In general, the approach from general to specific is applied here. We begin with an estimation of the broad models and later derive their parsimonious versions. Moreover, we employ several cointegration techniques to increase robustness of acquired estimates. The applied estimation methods are: DOLS, DGLS (see e.g. Stock and Watson, 1993), the Johansen technique (JOH) (see Johansen and Juselius, 1990) and ARDL (see Pesaran and Pesaran, 1997). We emphasise the result obtained from DOLS, as the assumption needed for estimation are not that restrictive as for the other methods and it is still relatively efficient and unbiased in small samples. The lead and lag length considered in all the estimation methods is one due to small number of observations available.

The money demand equations are estimated in nominal terms (forms) as it is now standard in the literature with the possibility of testing the restriction of price homogeneity (unit price elasticity) subsequently. In this respect we follow the work of, for example, Brand and Cassola (2000), Muscatelli and Spinelli (2000), Peytrignet and Stahel (1998), Vega (1998), Hoffman and Rasche (1996), and Hendry S. (1995)[4].

Estimation Results for M1 Money Demand

Estimation results of equation (1) acquired by using the DOLS method are described bellow:

******Table 1 Here******

We can infer from the estimations above that all the domestic variables affect the demand for narrow money in the manner suggested by economic theory. Further, the DOLS estimated coefficient on *ppi* of 1.01 suggests that this variable is a good approximation for prices since according to this measure the agents do not appear to be subjects to money illusion as required by theory. Although the elasticity of money with respect to output is close to one, the point estimate of 0.90 implies risk-averse behaviour concerning M1 money balances. Finally, both interest rates in estimated equation are significant and bear the expected sign. The own rate of return approximated by the interest rate on sight deposits has a significantly higher coefficient (in absolute value). Even though, the opportunity cost of holding M1 money, here interest rate on short-term deposits, is of considerable importance from both a statistical and economic point of view. The lower magnitude of the coefficient of the interest rate on short-term deposits is probably caused by higher volatility of the interest rate on short-term deposits

relative to narrow money[5]. However, the variable is significant and important determinant of narrow money demand in the Czech Republic.

Summarising the other estimates using DGLS, JOH and ARDL, all the considered variables enter the estimated equation with the expected sign and are generally highly significant across estimation methods. Although the measure of the price level appears to be highly significant, the *a priori* assumption of price homogeneity does not have a general support. This may be a result of shocks in prices due to e.g. price liberalisation or introduction of new taxes together with information asymmetry. Both phenomena are present in transition economies. Approximation of the scale variable with the industrial production index appears to be significant with the coefficient generally lower than one. This would imply that agents are risk averse regarding M1 money holdings. The variables that account for the rate of return on narrow money and rate of return on short-term deposits are highly significant as a proxy for the own rate of return and the opportunity cost of holding narrow money respectively

Although the foreign variables do not appear to be significant in general there are some interesting observations apparent from the regression. First, the real effective exchange rate tends to alter the effect of price level movements approximated by the PPI index. This observation is probably due to the close co-movement of the price level and the real exchange rate. More specifically, since the nominal exchange rate was pegged for a significant period, prices have almost exclusively driven the movement of the real exchange rate. The effect of foreign direct investment has its peak at the fourth lag and it is when it becomes significant. Inclusion of the fourth lag, however, substantially reduces the effective length of the already small sample. This problem would not be so important if

longer time-series were available, but this is not currently the case for the Czech Republic and thus the FDI has been excluded from the parsimonious form.

Estimation Results for M2 Money Demand

The table 2 below depicts the estimation results for DOLS and the other estimation methods:

******Table 2 Here******

To summarise the results of the estimation, we can state that agents are concerned with real money holdings, although price homogeneity is not supported by the data. Despite our interest in broad money, the transaction motive forms part of such money demand. More specifically, agents perceive money as a risky asset in view of our estimate of the income elasticity in the Czech Republic. We have not found any effect of the own rate of return on the demand for M2 money. As was pointed out in the data description section, the applied total interest rate on deposits is rather a poor approximation due to changing composition of M2 aggregate. Further, agents adjust their borrowing or repayment in response to interest rate movements. This induces movements in M2 in the expected way so that the coefficient on lending rate is negative, large in absolute value and statistically significant. The opportunity cost of holding money with respect to real assets is not significant and this may be due to recently lower inflation. According to the DOLS estimate of the money demand equation, the current value of the CZK/DEM exchange rate captures the effect of indirect currency substitution in the domestic banking system. Similarly, the effect of capital mobility on money demand is captured by the current return on German Treasury Bills expressed in CZK.

Regarding the other estimates in Table 2, the estimation of money demand in nominal form appears to be desirable, since coefficient on *cpi* variable is generally somewhat higher than one (with JOH being the only exemption). This means that the nominal money demand function does not seem to be linearly homogenous in prices. However, the price movements appear to be important. The transaction motive approximated by IPP is noticeably present even in demand for broader money, although its estimated coefficient differs using JOH compared to the other methods. JOH favours the effect of accumulation of wealth that is usually related to this variable, whereas all the other methods favour the risk-averse attitude of agents to money holdings. Neither the other methods find a support for inclusion of the own rate of return on broad money using the total interest rate on new deposits. The opportunity costs of holding money related to credit repayments are in almost all cases highly significant. As a representative of opportunity costs in relation to real assets, inflation is not statistically significant in most cases. Only in the case of JOH does this variable appear to be highly significant.

The estimation of the CZK/USD coefficient varies according to its lag and applied estimation method. The coefficient for current CZK/USD is significant and has an economically important magnitude when using JOH and ARDL. The lagged value is significant only at the 10 % level and has the opposite sign to that expected from the theory. In the case of our estimates the coefficient for current CZK/DEM is significant only in the case of DOLS and DGLS estimates and has the expected sign and reasonable magnitude. The estimates give only limited support for the inclusion of lagged CZK/DEM.

The capital mobility factor is represented by the returns on U.S. and German Treasury Bills expressed in CZK. Again the results are mixed according

to applied estimation methods and correspond to the exchange rate estimates. The coefficient on the return on U.S. assets is highly significant in the case of the JOH and ARLD. The coefficient on the return on German assets is significant only when DOLS and DGLS are used. The lagged values of the returns on both U.S. and German assets bear no support from our estimates.

5 Stability Tests

In the next step the parsimonious model and coefficient estimates are tested for stability. This should further scrutinize robustness of the obtained estimates and reveal whether the estimated equations are potentially useful for forecasting of equilibrium money growth. First, the coefficient stability is inspected using the coefficients' recursive estimates. Second, tests on the overall stability of the estimated models are performed. These are the one-step-forecast test and Chow's one- and N-step-forecast and breakpoint tests.

Stability of M1 Money Demand Estimates

The results of the stability tests when applied to equation (1) estimated by DOLS are presented in Figure 1:

******Figure 1 Here******

The recursive estimates of the *ppi* and *ipp* coefficients reveal some changes in elasticity associated with those variables. Since 1999 the elasticity of the narrow money with respect to *ppi* has been declining whereas the one with respect to *ipp* rising steadily. The recursive estimates of the coefficients on the interest rates appear to be fairly stable since 1999. The four model-stability tests do not reveal any significant shifts that would affect the predictive power of the DOLS

estimated equation. Regarding the other estimates only the JOH estimates show some instability during the fourth quarter of 1998 in the case of the Chow's one-step forecast test.

Stability of M2 Money Demand Estimates

The stability of the parsimonious model and the coefficient estimates for broad money demand are examined in the same way as above. The results for the DOLS estimation are described in Figure 2:

******Figure 2******

The recursive coefficient estimates of the domestic variables seem to be fairly stable since 1999. The recursive estimates of the *czk/dem* coefficient are slightly declining in their magnitude from 1999 onwards. On the other hand, the recursive estimates of the German Treasury Bill return in CZK have been increasing over last couple of years. These opposite movements in the two coefficient estimates over time may indicate increasing interest of agents in investment abroad. The domestic agents are encouraged to diversify abroad owing to completed financial account liberalization. The model tests do not show any significant instability episodes over the period analysed. The tests of the other estimates do not indicate any instability either.

6 The Short-Run Dynamics and Policy Implications

When we found stable money demand functions that fit the M1 and M2 monetary aggregate data well we have made some recommendations for the equilibrium money growth. Nevertheless, there is still an interesting question of what if the central bank fails to keep money growth close to the equilibrium path

for both aggregates. Although the system should converge towards equilibrium, i.e. the loading (speed of adjustment) on money should be negative, it is not likely that the error-correction term (the residual from the cointegration equation) is entirely eliminated during one period.

The existence of an error-correction term and its consequent effect on the dynamics of certain variables also has a theoretical underpinning (see e.g. Hendry S., 1995). For instance, a positive error-correction term would represent excessive money supply, hence, there should be a negative loading (speed of adjustment) on the variable representing money. Likewise, there should be a positive speed of adjustment on the money-gap variable in the short-run output and price equations and in the equation of own rate of return. Furthermore, there should be a negative loading on variables representing the opportunity cost of money that can be, according to the theory, considered primarily endogenous, so that money demand can rise to offset any excess money supply.

In the next step we are interested just in the dynamic (short-run) equation for variables such as *m1, ppi, ipp* and *i* in the case of M1 money demand and *m2, cpi, ipp* and *i* in the case of M2 money demand. For each aforementioned variable of interest we estimate equations of the following form:

$$\Delta y_t = \delta \Delta y_{t-1} + \alpha EC_{t-1} + \sum_{i=0}^{1} \phi_i d_t + \nu_t \qquad (3)$$

where y_t is *(m1, ppi, ipp,i)* and (*m2, cpi, ipp,i*) for M1 and M2 respectively. δ and ϕ are vectors of estimated parameters, α is a vector of loadings, d is a vector of exogenous variables and ν is the error term. Further, $EC1_t = \hat{\varepsilon}_t$ and similarly, $EC2_t = \hat{\eta}_t$.

We first present and comment on the former case and then address the latter case in the same manner. The results of the M1 money demand case are presented in Table 3[6]:

******Table 3 Here******

The results in Table 1 indicate that the dynamics of narrow money allow the money market to adjust to its long-run equilibrium with considerable speed. In particular, the estimates imply *ceteris paribus* elimination of money gap in about three periods. Price level dynamics also contribute to elimination of the liquidity gap, however, the coefficient on the price level is rather small and significant only at the 10 % level. The *ipp* dynamics and the dynamics of the interest rate on sight deposits appear to be insignificant in eliminating money market disequilibrium, although the former variable has the expected sign as suggested by theory. To summarise our findings, the narrow money appears endogenous.

Summarizing for all the methods applied, the dynamics (speed of adjustment) of the $m1$ variable pulls the system quite strongly back to equilibrium as defined by the cointegration equation. The loading on *ppi* is also positive, consistent with theory, though the coefficient is small. This result is further supported by the estimates of the loading on the first difference of *cpi* (i.e. inflation), which is of primary concern from the central bank viewpoint. This coefficient is somewhat larger. On the other hand, the loadings on *ipp* give ambiguous results, and the speed of adjustment on the own rate of return on M1 money is not consistent with the theory.

The loadings estimates of selected variables in the M2 case are presented in Table 4:

Table 4 Here

The short-run dynamics of the endogenous variables under M2 money market conditions closely follows those reported for M1. Again, the M2 monetary aggregate dynamics drives the system back to its equilibrium. The magnitude of its loading is lower than in the M1 case so that the system needs almost four periods to reach the given steady state. The *cpi* dynamics contributes significantly to the elimination of the M2 money market gap from both a statistical and economic point of view. The loading on *ipp* and *i* are, as in the previous case, insignificant and only output seems to be affected by money market disequilibrium in accord with theory.

Summarizing over the estimation methods, based on the loadings of the *m2* variable the system significantly adjust to its long-run equilibrium. This process is further intensified by the dynamics of the *cpi* variable, where the particular loadings are generally positive[7] and have a larger coefficient than in the M1 case. The same conclusion might be made for the dynamics of the first difference of *cpi*. Moreover, the *ipp* loadings is positive, so excessive money supply affects economic performance as well as price adjustment. Finally, there is only ambiguous evidence for the own rate of return playing a role in the short-run adjustment of the money demand system.

In conclusion the money demand relation still plays an important role in the transmission mechanism of monetary policy. The deviation from the equilibrium path of money growth has, based on our estimates, at least two consequences. A positive deviation, i.e. excessive money supply, leads to rising prices in the case of both M1 and M2 money and to increasing output in the case of M2 money. The central bank should be aware of these potential consequences

and use its operational tool(s) in such a way as to keep money growth close to its equilibrium path. This supervision of money growth should help the central bank fulfil its primary objective of maintaining price stability.

7 Conclusions

In this paper we have attempted to analyse money demand in a framework of an open economy as applied to the Czech Republic, taking into account the influence of selected foreign variables. The first part deals with modelling of narrow money demand. We use the M1 monetary aggregate as the dependent variable. The set of explanatory variables includes the price level, the scale variable, the own rate of return and the opportunity cost of holding narrow money. Moreover, we include the real effective exchange rate and gross domestic foreign direct investment as foreign variables likely to affect narrow money demand in the Czech Republic. We find all the traditional explanatory variables to be important for movements in the M1 aggregate. The inclusion of the real effective exchange rate does not seem to bring any additional information above that already contained in the price level. On the other hand, the inclusion of FDI does seem to be important for narrow money demand, although its peak effect comes only with the fourth lag. We prefer not to include this variable in the final equation for narrow money demand, since four observations are lost in the already small sample.

The M2 aggregate is used for modelling of demand for broad money in the Czech Republic. M2 comprises M1 plus time deposits and deposits in foreign currency. In addition to the price level, the scale variable and the own rate of return, the right-hand-side variables include the interest rate on credits and

inflation which represent the opportunity costs of holding M2 money. The added foreign variables are the nominal CZK/USD and CZK/DEM exchange rates (to represent the return on foreign money holdings) and the return on U.S. and German assets expressed in Czech korunas (to represent the effect of capital mobility). We find all the domestic explanatory variables, except for inflation, to be important determinants of M2 money demand. In addition, after taking account of the domestic variables we find currency substitution and capital mobility significantly influencing the movements of the M2 aggregate.

In the last section of the empirical part we have presented and discussed the estimates of the possible effect of disequilibrium money growth on the dynamics of important macroeconomic variables such as the inflation rate and output. We find that deviations of narrow and broad money from their long-run equilibrium values significantly affect the short-run dynamics of prices and output - variables of central importance to policy makers. We conclude that in the case of the Czech Republic the central bank should be aware of such possible effects.

Appendix

******Table A1 Here******

References

Aarle, Van B. and Budina, N. (1995). Currency Substitution in Eastern Europe. Discussion Paper Series 2, Center for Economic Research Tilburg University

Arlt, J.; Guba, M.; Radkovsky, Š.; Sojka M., and Stiller, V. 2001. Vliv vybraných faktorů na vývoj poptávky po penězích v letech 1994-2000. Czech National Bank Working Paper 34.

Brand, C., and Cassola, N. 2000. A Money Demand System for Euro Area M3. European Central Bank Working Paper Series 39

Coenen, G., and Vega, J.-L. 1999. The Demand for M3 in Euro area. ECB Working Paper 6

De Brouwer, G.; Ng, I., and Subbaraman, R. 1993. The Demand for Money in Australia: New Tests on Old Topic. Reserve Bank of Australia. Research Discussion Papers 9314

Doornik, J. A., and Hendry D. F. 2000. *Modelling Dynamic systems using PcGive volume II.* Timberlake Consultants Ltd.

Doyle, B. M. 2000. "Here, Dollars, Dollars..." – Estimating Currency Demand and Worldwide Currency Substitution. International Finance Discussion Papers 657, Board of Governors of the Federal Reserve System

Ericsson, N. R. 1998. Empirical Modeling of Money Demand. *Empirical Economics* 23, 295-315.

Feige, E. L.; Faulend, M.; Šonje, V., and Šosic, V. 2000. Currency Substitution, Unofficial Dollarization and Estimates of Foreign Currency Held Abroad: The Case of Croatia in Blejer M and Skreb M, eds. *Financial Vulnerability and the Exchange Rate Regime,* MIT Press

Giovannini, A., and Turtelboom, B. 1992. Currency Substitution National Bureau of Economic Research Working Paper Series 4232, Cambridge

Gomis-Porqueras, P.; Serrano, C., and Alejandro, S. 2001. Currency Substitution in Latin America: Lessons from the 1990s *mimeo*

Hanousek, J.; Kubin, J., and Tůma, Z. 1995. Poptávka po penězích a ražebné v období transformace. *The Czech Economic Journal* 7.

Hanousek, J., and Tůma, Z. 1995. Poptávka po penězích v české ekonomice. *The Czech Economic Journal* 5

Hayo, B. 1999. The Demand for Money in Austria Economic. Working Paper Archive at WUSTL, Macroeconomics wuwpma 9902

Hendry, D. F.; Ericsson, N. R., and Prestwich, K. M. 1997. The Demand for Broad Money in the United Kingdom 1878-1993. Board of Governors of the Federal Reserve System, Discussion Papers 596

Hendry, D. F., and Ericsson, N. R. 1991. Modeling the Demand for Narrow Money in the United Kingdom and the United States. *European Economic Review* 35, 833-81

Hendry, S. 1995. Long-Run Demand for M1 Bank of Canada. Working Paper 95-11

Hoffman, D. L., and Rasche, R. H. 1996. *Aggregate Money Demand Functions: Empirical Applications in Cointegrated Systems*. Kluwer Academic Publishers Group

Johansen, S. and Juselius, K. 1990. Maximum Likelihood Estimation and Inference on Cointegration - With Applications to Demand for Money. *Oxford Bulletin of Economics and Statistics*, 52(2), 169-210

Klacek, J., and Šmídková, K. 1995. The Demand-for-Money Function: the Case of the Czech Economy. Czech National Bank Working Paper 41.

Kozel, D. 2000. Poptávka po oběživu. *The Czech Economic Journal* 12, 673-684

McNown, R., and Wallace, M. 1992. Cointegration Test of Long-run Relation Between Money Demand and the Effective Exchange Rate. *Journal of International Money and Finance* 11, 107-114.

Melecky, M. 2001. Stabilita dlouhodobé poptávky po široce definovaných penězích v otevřené ekonomice: případ ČR 1994-2000. Czech National Bank Working Paper 38

Melecky, M. 2002. Poptávka po penězích v ČR (M1). *The Czech Economic Journal* 2.

Melecky, M. 2002a. Analyza diskrepanci v poptavce po penezich domacnosti a firem: cast I, domacnosti. *The Czech Economic Journal* 7-8.

Melecky, M. 2001b. Analyza diskrepanci v poptavce po penezich domacnosti a firem: cast II, firmy. *The Czech Economic Journal* 9.

Mishkin, F. S. 2001. Financial Policy and the Prevention of Financial Crises in Emerging Market Countries. NBER Working Paper Series 8087

Muscateli, V. A., and Spinelli, F. 2000. The Long-Run Stability of the Demand for Money: Italy 1861-1996. *Journal of Monetary Economics* 45, 717-739.

Peytrignet, M. and Stahel, C. H. 1998. Stability of Money Demand in Switzerland: A Comparison of the M2 and M3 Cases. *Empirical Economics* 23, 437-454.

Pesaran, M. H., and Pesaran, B. 1997. *Working with Microfit 4.0.* Oxford University Press

Pesaran, M. H.; Shin, Y., and Smith, R. .J 1996. Testing for the Existence of a Lon-Run Relationship. DAE Working Paper 9622, University of Cambridge

Sahay, R., and Vegh, C. A. 1995. Dollarization in Transition Economies: Evidence and Policy Implications. International Monetary Fund Working Paper 103/95/96, Washington DC

Sarajevs, V. 2000. Econometric Analysis of Currency Substitution: A Case of Latvia. Bank of Finland Discussion Papers 4, Institute for Economies in Transition

Sommer, M. 1997. Vazba mezi peněžní zásobou, agregátní nabídkou a nominálním domácím produktem ČR v letech 1992-1996. *Bankovnictví* 16.

Sprenkle, C. M. and Miller, M. H. 1980. The Precautionary Demand for Narrow and Broad Money. *Economica* 47, 407-421.

Sriram, S. S. 1999. Survey of Literature on Demand for Money: Theoretical and Empirical Work with Special Reference to Error-Correction Models. IMF Working Paper 64.

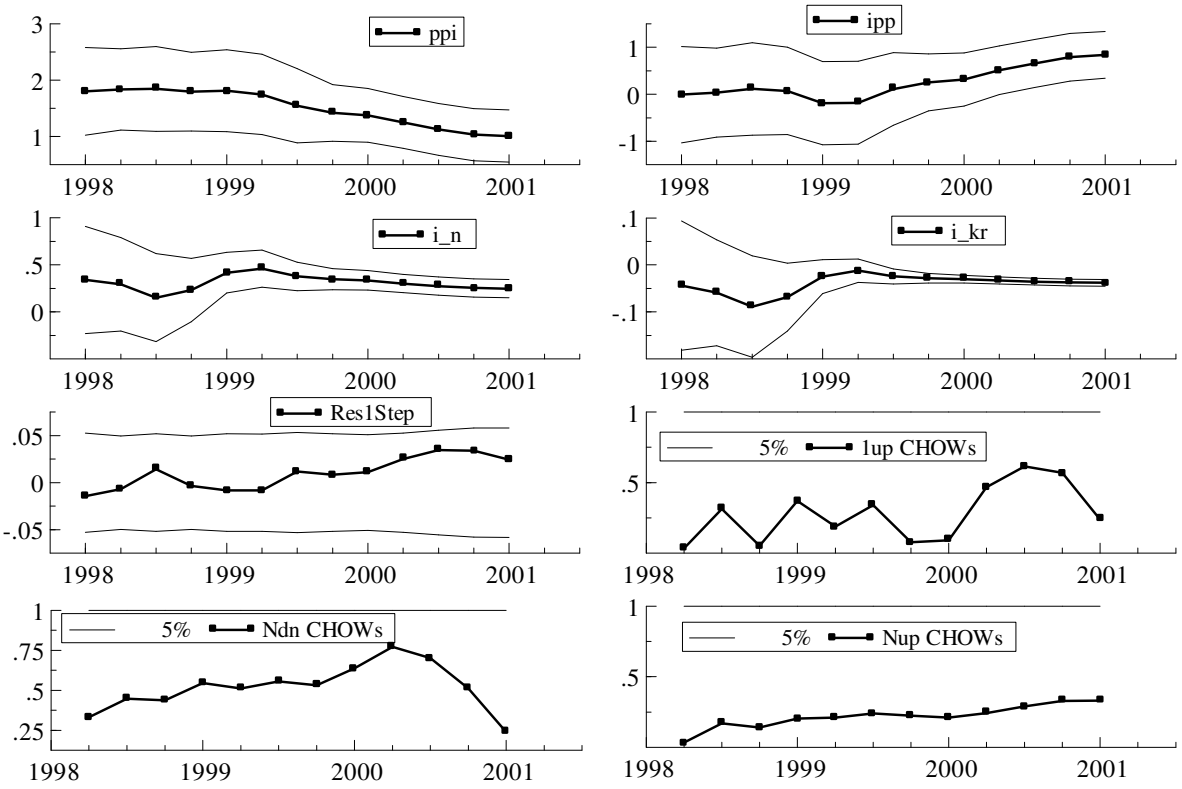
Sriram, S. S. 1999. Demand for M2 in an Emerging-Market Economy: An Error-Correction Model for Malaysia. IMF Working Paper 173

Stock, J. H. and Watson, M. W. 1993. A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems. *Econometrica* 61, 1035-1056.

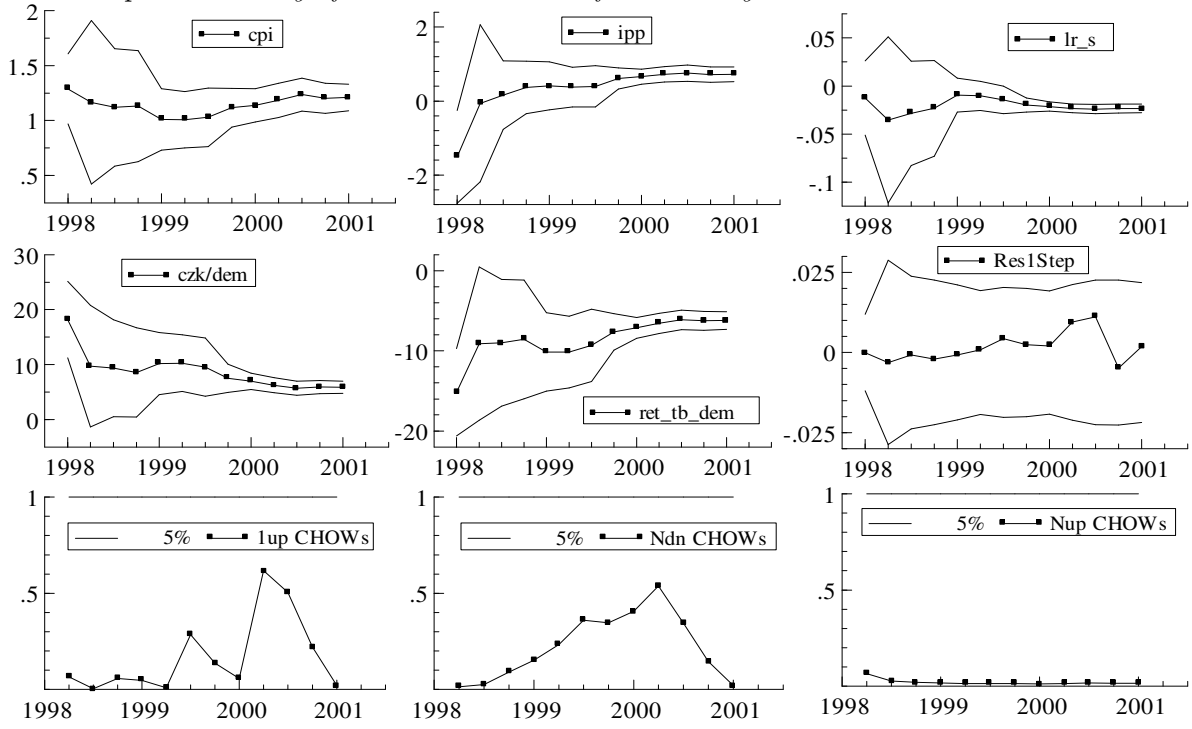
Vega, J. L. 1998. Money Demand Stability: Evidence from Spain. *Empirical Economics* 23, 387-400.

Figures

Figure 1: Stability of DOLS Estimates of M1 Money Demand



Graph 2: Stability of DOLS Estimates of M2 Money Demand



Tables

Table 1: Estimates of Equation (1) Using Various Cointegration Techniques

Variable	DOLS	DGLS	JOH	ARDL
ppi	1.01 (0.27)***	0.95 (0.24)***	0.64 (0.25)**	0.72 (0.11)**
ipp	0.90 (0.30)***	0.80 (0.25)***	0.66 (0.23)**	0.66 (0.08)*
i	0.25 (0.07)***	0.23 (0.05)***	0.17 (0.07)***	0.28 (0.03)**
r	-0.04 (0.004)***	-0.04 (0.004)***	-0.05 (0.005)***	-0.09 (0.003)***
constant	-4.22 (1.68)**	-3.29 (1.03)***	unrestrict.	0

*, ** and *** indicate significance at 10%, 5% and 1% probability levels respectively (S.E.s in brackets). 0 denotes an acceptance of zero-restriction on the particular coefficient. In the case JOH and ARDL the variables m_{cz}, *ppi, ipp, i* and *r* are assumed to be endogenous. The variables *ppi, i* and *r* seem to be weakly exogenous when using JOH and *ppi* and *r* likewise when using ARDL. The lag and lead length considered in all estimation methods is one.

Table 2: Estimates of Equation (2) Using Various Cointegration Techniques

Variable	DOLS	DGLS	JOH(1)	ARDL(1)
cpi	1.21 (0.06)***	1.23 (0.07)***	0.58 (0.17)***	1.69 (0.12)***
ipp	0.72 (0.09)***	0.63 (0.10)***	2.00 (0.23)***	0.71 (0.14)***
i	0	0	0	0
r	-0.02 (0.002)***	-0.02 (0.003)***	0	-0.03 (0.004)***
inf(-1)	0	0	-0.01 (0.004)***	0
czk/usd	0	0	6.11 (1.73)***	3.32 (1.25)***
czk/usd(-1)	-----	-----	-0.58 (0.23)*	-0.42 (0.13)***
czk/dem	5.86 (0.54)***	6.21 (0.60)***	0	0
czk/dem(-1)	-----	-----	0	0
rx_usd	0	0	-5.60 (1.73)***	-3.35 (1.27)***
rx_usd(-1)	-----	-----	0	0
rx_dem	-6.21 (0.55)***	-6.58 (0.61)***	0	0
rx_dem(-1)	-----	-----	0	0
constant	-1.60 (0.50)***	-1.15 (0.55)***	unrestrict.	-3.42 (0.73)***

*, ** and *** indicate significance at 10%, 5% and 1% probability levels respectively (S.E.s in brackets). 0 denotes an acceptance of zero-restriction on the particular coefficient and ----- indicates that the given variable was not included in the estimated equation. When applying JOH and ARDL the variables m_{cz}, *cpi, ipp, i, r* and *inf* are assumed to be endogenous. The lag and lead length considered in all estimation methods is one.

Table 3: Loadings of Selected Variables (VECM) – M1 Case

Loadings on	DOLS	DGLS	JOH	ARDL
m1	-0.37 (0.12)***	-0.41 (0.12)***	-0.38 (0.05)***	-0.35 (0.08)***
ppi	0.07 (0.03)*	0.07 (0.03)*	0.04 (0.002)*	0.04 (0.02)*
ipp	0.28 (0.22)	0.18 (0.23)	-0.19 (0.18)	-0.28 (0.16)*
dcpi	0.09 (0.05)*	0.10 (0.05)*	0.06 (0.04)	0.06 (0.03)*
i	-0.18 (0.41)	-0.34 (0.42)	-0.55 (0.31)*	-0.51 (0.30)*

*, ** and *** indicate significance at 10%, 5% and 1% probability levels respectively (S.E. in brackets). The estimation method is OLS.

Table 4: Loadings on Selected Variables (VECM) – M2 Case

Loading on	DOLS	DGLS	JOH	ARDL
m2	-0.27 (0.18)*	-0.27 (0.18)*	-0.11 (0.03)***	-0.34 (0.08)***
cpi	0.20 (0.10)**	0.20 (0.10)**	-0.07 (0.01)***	0.13 (0.09)
ipp	0.34 (0.46)	0.34 (0.46)	0.13 (0.07)**	0.35 (0.37)
dcpi	0.23 (0.11)**	0.23 (0.11)**	-0.07 (0.03)**	0.11 (0.09)
i	-1.19 (2.45)	-1.19 (2.45)	0.60 (0.46)	1.09 (1.96)

*, ** and *** indicate significance at 10%, 5% and 1% probability levels respectively (S.E. in brackets). The estimation method is OLS.

Table A1: Unit Root Tests of Time Series Applied

Variable	ADF Test	PP Test
cpi	-2.105 (3,c)	-3.646(1, c)***
d(cpi)	-3.105(2,c,t)	-3.884(0,c)***
d^2(cpi)	-10.846(0)***	-14.579(9)***
czk/dem	-3.279(1, c)**	-1.804(5,c)
d(czk/dem)	-4.300(1, 0)***	-3.809(16)***
czk/usd	-2.687(1,c,t)	-1.928(5,c,t)
d(czk/dem)	-4.136(0)***	-4.036(5)***
fdi	-4.826(0,c,t)***	-4.936(9,c,t)***
d(fdi)	-5.872(2,c)***	-8.882(16)***
r_m1	-1.674(1,c,t)	-1.299(3,c,t)
d(r_m1)	-3.376(0)***	-3.358(2)***
r_m2	-1.644(1,c,t)	-1.704(4)*
d(r_m2)	-2.991(0)***	-2.983(3)***
i_m1	-2.211(3,c,t)	-3.507(0,c,t)*
d(i_m1)	-3.701(0)***	-3.686(3)***
i_m2	-1.825(1,c,t)	-1.331(2,c,t)
d(i_m2)	-3.240(0)***	-3.225(2)***
inf_cpi	-2.900(2,c,t)	-5.594(1,c,t)
d(inf_cpi)	-13.014(0)***	-16.829(7)***
inf_ppi	-3.133(0,c,t)	-3.017(4,c,t)
d(inf_ppi)	-5.844(0)***	-6.800(7)***
ipp	-3.519(3,c)**	-2.132(2,c)
d(ipp)	-4.430(3)***	-5.463(2)***
m1	-2.233(5,c,t)	-1.873(4,c)
d(m1)	-1.883(2)**	-2.875(2)***
m2	-2.577(1,c,t)	-3.075(1,c,t)
d(m2)	-2.580(0,c)*	-2.467(2,c)
d^2(m2)	-6.303(0)***	-7.162(8)***
ppi	-1.854(1,c)	-2.538(0,c)
d(ppi)	-2.662(0,c)*	-2.703(2,c)*
d^2(ppi)	-5.822(0)***	-6.751(7)***
reer	-3.977(1,c,t)**	-2.094(6,c,t)
d(reer)	-3.695(0)***	-3.469(9)***
rx_dem	-2.525(1,c)	-2.322(2,c)
d(rx_dem)	-2.669(0)***	-2.669(0)***
rx_usd	-3.171(1,c,t)	-2.295(0,c)
d(rx_usd)	-2.234(0)**	-2.234(0)**

*, ** and *** indicate rejection of the null hypothesis of a unit root. Numbers in brackets indicate the number of lags (ADF test) or the bandwidth (PP test). The letters c and t indicate that constant and trend are included in the particular test. The lag length for ADF test was chosen according to Schwartz Information Criterion and the bandwidth used in PP test was Newey-West.

Footnotes

[1] Exchange rates CZK/USD (Czech koruna per U.S. dollar) and CZK/DEM (Czech koruna per Deutsche Mark) are dominating components of the nominal effective exchange rate. Since they have experienced a somewhat different historical development it is desirable to include them separately into the estimated equation.

[2] The M2 monetary aggregate includes foreign money holdings in the domestic banking system in the Czech Republic (see data description section below).

[3] Further in this paper we distinguish between the direct currency substitution, where domestic money is substituted with foreign money for its unit-of-account or medium-of-exchange function; or indirect substitution, where domestic money is substituted with foreign money for store-of-value purposes (see, for example, Feige, Faulend, Šonje and Šošić, 2000; Gomis-Porqueras, Serrano and Somuano, 2000). We will consider the effect of indirect currency substitution later when modelling the M2 aggregate.

[4] Hendry S. (1995, pp. 34) further points out that the assumption of real money as a dependent variable imposes neutrality of money in both the short run and the long run.

[5] For such a purpose some authors prefer to employ long-term interest rates, since these are less volatile. This would result in a somewhat higher coefficient for this variable. The large volatility of short interest rates seems due to the defence of the pegged exchange rate in the Czech Republic during 1996-1998.

[6] We present here only estimates of coefficients on the error-correction term, since these are of main interest. We do so in the M2 case as well.

[7] The negative coefficient of the *cpi* loading in the case of the JOH estimates is probably due to the fact that inflation is perceived to be an alternative cost of holding M2 money in this case.