The Monetary Models of the Turkish Lira/ Dollar Exchange Rate: Long-run Relationships, Short-run Dynamics and Forecasting

Irfan Civcir

Ankara University, Faculty of Political Sciences,
06590 Cebeci, Ankara, Turkey
E-mail: civcir@politics.ankara.edu.tr

Abstract
This paper examines four versions of the monetary model for Turkish Lira-Dollar exchange rate. Our analysis centered on two issues. First, we test whether the exchange rate is cointegrated with long-run determinants predicted by the economic theory. The sticky price versions of the monetary model results support the hypothesis of cointegration. Then, we construct simultaneous equation systems, which incorporate the long-run equilibrium relationships and complex short-run dynamics. Second issue is the ability of the monetary models to forecast future exchange rate. We show that fully dynamic out-of-sample forecast from the equilibrium correcting monetary models significantly outperforms those of random walk models and differenced vector autoregressive models.

JEL classification: F31; F41; F47
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1. Introduction

The predictability of exchange rates has been an ongoing puzzle in the international economics literature. Meese and Rogoff (1983) compare the predictive abilities of a variety of exchange rate models. They find that no existing structural exchange-rate model could reliably out predict the naive alternative of random walks at short and medium run horizons. Similar findings are also obtained by Backus (1984) and Somanath (1986). Findings from the above-cited papers imply that existing structural models have little in their favor beyond theoretical coherence.

During the past decade, the cointegration approach (and hence the equilibrium correction model) has been widely applied to exchange rate determination. Baillie and McMahon (1989) and Baillie and Pecchenino (1991) fail to detect much evidence for linear long-run relationships between exchange rates and fundamentals. However, recent studies by MacDonald and Taylor (1994), Chinn and Meese (1995), Mark (1995), MacDonald (1999) Groen (2000), Mark and Sul (2001) and Rapach and Wohar (2001) test for a stable long-run relationship between nominal exchange rates and monetary fundamentals using cointegration tests for the post-Bretton Woods float. Interestingly, these studies find strong evidence of cointegration among nominal exchange rates, relative money, and relative real output. Mark and Sul (2001) actually find support for a very simple long-run monetary model. They also find that nominal exchange rate forecasts based on the monetary model are generally superior to forecasts of a naive random walk model. The recent findings of MacDonald (1999) Groen (2000) and Mark and Sul (2001) again renew hope in the ability of monetary fundamentals to track nominal exchange rates.

Previous studies on high inflation countries show that monetary fundamentals are important in determining behavior of the exchange rate (see among others McNown and Wallace (1994), Bahmani-Oskooee and Kara (2000), Moosa (2000) and Civcir (2002). In this paper, the monetary models are examined for Turkish Lira-U.S. Dollar exchange rate during 1986:1-2000:12 period. In particular, we examine the long-run and short-run properties of the models. First, we use multivariate cointegration technique to test for long-run relationship. We find evidence of cointegration on three out of four versions of the monetary models. Our finding of cointegration facilitates an examination of short-run monetary models using dynamic equilibrium correction models. These dynamic equilibrium correction models are used to produce out-of-sample forecasting. Forecasting performance of the monetary models are evaluated with the root mean square error criteria and compared with that of both random walk with drift and random walk without drift models. Further we compared the models forecasting performance with the differenced vector autoregressive models. In all account, the sticky price monetary model augmented with a productivity differential wins the forecasting competition.

Remaining part of the paper organized as follows. Next section presents four versions of the monetary model. Section 3 describes the methodology and the data. Section 4 presents cointegration results. Short-run dynamics are reported in section 5. Section 6 presents out-of-sample forecasting. Paper ends with summary and conclusion.

2. The Monetary Models of Exchange Rate Determination

We consider four versions of the monetary model in this paper: the standard flexible price monetary model (Frenkel (1976), Bilson (1978), the sticky price monetary model (Frenkel (1979)), tradable-non-tradable model (Dornbusch (1976)) and net international reserves model (Hooper and Morton (1982)). These monetary models start from the definition of the exchange rate as the relative price of two monies and attempts to model that relative price in terms of the relative supply of and demand for these monies. The model relies on the assumptions of purchasing power parity, uncovered interest parity, and the existence of stable money demand functions for the domestic and foreign economies. These models can be written as:

Model 1:

$$s_t = b(m_t - m_t^*) - d(y_t - y_t^*) + l(i_t - i_t^*) + c + e_t \tag{1}$$

Model 2:

$$s_t = b(m_t - m_t^*) - d(y_t - y_t^*) - \frac{1}{q}(i_t - i_t^*) + (l + \frac{1}{q})(p_t - p_t^*) + c + e_t \tag{2}$$

Model 3:

$$\begin{aligned} s_t &= b(m_t - m_t^*) - d(y_t - y_t^*) - \frac{1}{q}(i_t - i_t^*) + (l + \frac{1}{q})(p_t - p_t^*) \\ &\quad + g[(P_t^T - P_t^N) - (P_t^{T*} - P_t^{N*})] + c + e_t \end{aligned} \tag{3}$$

Model 4:

$$\begin{aligned} s_t &= b(m_t - m_t^*) - d(y_t - y_t^*) - \frac{1}{q}(i_t - i_t^*) + (l + \frac{1}{q})(p_t - p_t^*) \\ &\quad - w(r_t - r_t^*) + c + e_t \end{aligned} \tag{4}$$

where m_t is the log of the domestic nominal money supply, y_t is the log of real output, i_t is the interest rate, π is the inflation rate, r is the net foreign assets, (P^T- P^N) is the relative price of tradables to non-tradables, corresponding foreign variables are denoted by an asterisk. *c* is an arbitrary constant and e_t is a disturbance term[1].

Under the assumption of flexible prices we arrive at Model 1 which only has money, income and nominal interest rates. On the other hand, if we assume slow

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[1] This specification assumes equal and opposite sign on relative money, income and interest rates, that is $b_i = -b_i^*$. The validity of these restrictions should be tested before estimating the model, however, due to the degrees of freedom considerations, it is usually assumed away.

adjustment of goods prices and instantaneous adjustment of asset prices we get Model 2, that also includes expected inflation differential. Model 3 is obtained by assuming PPP holds only for tradable goods and includes relative price of tradable to non-tradable goods. Model 4 is obtained by incorporating financial wealth in the money demand equations thus includes net foreign assets.

During the period 1986-2001 in Turkey, the fiscal policy and the chronic budget deficits dominated the system leading to the crises of 1994 and 2000-2001. Given this fact, one might consider including consolidated budget deficit variable into the models to explain the movements in the Turkish Lira / US Dollar exchange rate. However, effects of the fiscal deficit already reflected in the relatively high domestic interest rates, therefore, we do not include consolidated budget deficit into the models.

3. Methodology and Data

3.1 Methodology

Our modeling strategy follows recent developments in the econometric literature, in particular, the work of Clements and Mizon (1991), Hendry and Mizon (1993), Johansen and Juselius (1994), Johansen (1988, 1995), Mizon and Hendry (2000), and Hendry and Clements (2001). Basically, this process involves starting with a general VAR model specified in levels from which the cointegrating relationships are recovered, and then simplify the full VAR structure to obtain a parsimonious simultaneous equation system. The final set of simultaneous equations have as a feature both long-run relationships and short-run dynamics. The route of moving from the general VAR (a requirement of the Johansen method) to the specific simultaneous system is given below.

It is well known that vector equilibrium correction model (VECM) can be written as

$$\Delta z_t = \sum_{i=1}^{k} \Gamma_i \Delta z_{t-i} + \Phi z_{t-1} + \Psi d + e_t \qquad (5)$$

where z_t is a vector of non-stationary (in levels) variables. The matrix Φ is interpreted as the long-run responses. If the data cointegrate, F must be of reduced rank, $r < N$, where N is the number of variables in z. It can be decomposed as $\Phi = \alpha\beta'$, where α and β are $p \ x \ r$ full rank matrices, and contains adjustment coefficients and the cointegrating vectors respectively. d is the vector of deterministic variables, which may include constant term, the linear trend, seasonal dummies and impulse dummies. Finally, the error term is a normal process.

Having determined the long-run economic relationship, next step is to make the system more parsimonious by exclusion restrictions on Gi. We test for valid reductions in the dimensions of the system. These restrictions are imposed on the basis of the *t*-ratio of an individual coefficient p-values exceed 0.9 and continued down towards 0.05 values. Insignificant variables are deleted and joint significance of these deleted variables is tested by F-statistics. After the imposition of all such restrictions, the parsimonious VECM is obtained.

The final stage in the modeling procedure is to move from this parsimonious VECM to simultaneous econometric models of the individual equations in the system. At this stage we use the weak exogeneity test results and condition the exchange rate on the weakly exogenous variables. In the final simultaneous equation system, each equation is fully specified where it may have contemporaneous as well as lagged dynamic terms, and may contain long-run equilibria. This modeling strategy allows us to work with a full system of equations, rather than a single reduced form.

Finally, we compute fully dynamic predictions from the final simultaneous equation systems. A detail of the forecasting method is given in Section 6.

3.2. Data

Most series are obtained from the Central Bank of Turkey and IMF's *International Financial Statistic*s and spans the 1986:1-2000:12 period. The exchange rate is average-of-month data, expressed in Turkish lira per US dollar unit. For the broad deflator, the wholesale price index (WPI) *IFS* line 63 is used. The measure of money supply is monthly average broad money (M2). Monthly average industrial production index is used as a proxy for real output. Short term interest rates are monthly average interbank rates for Turkey and monthly average federal funds rate for the United States. The producer price index (PPI) and consumer price index (CPI) are used as proxies for the relative price of tradable and non-tradable, respectively. Consumer price index is taken from *IFS* line 64. Net foreign assets differential is obtained by the difference between net foreign assets of Central Bank of Turkey, and net foreign official assets held at Federal Reserve Banks. All variables are in natural logs except the interest rates.

4. **Multivariate cointegration analysis**

4.1 Unit Root Test Results

Before conducting the analysis of long-run relationships between exchange rate and monetary fundamentals, we first investigate the time series properties of the variables by using augmented Dickey-Fuller (1979) unit root tests. Table 1 reports the augmented Dickey-Fuller test results for the data[2]. Columns A and B of Table 1 show unit root tests results which are carried out by including linear trend and constant and only constant respectively. The inclusion of a linear trend is indicated by visual inspection of the series, as well as formal statistical F-tests of Dickey and Fuller (1981). Based on the unit root test results in Table 1, we conclude that all of the variables are I(1).

[Insert Table 1 about here]

The implications of our unit root test results for testing the long-run monetary model is to use cointegration procedures. In the next subsection, we thus test for cointegration between the nominal exchange rate and the fundamentals for Turkey.

4.2 Cointegration Test Results

Johansen procedure is used to determine the rank *r* and to identify a long-run monetary model of exchange rate amongst the cointegrating vectors. The first stage of estimating the VECM is to determine the proper lag length. Lag length decision is based on the evidence provided by both the likelihood ratio test and AIC, however, in the case of serial correlation sufficient number of lags is introduced to eliminate the serial correlation of the residuals. To capture the effects of seasonality on the variables, we introduced a set of monthly centered seasonal dummy variables, a constant term, and also five impulse dummy variables: D91 is included to capture the effects of Gulf War, which is 1 in 1991:03; D94:3-4 for the currency crises in 1994, D98:8 for the Russian Crises, D99:8 for earthquake and D00:1-12 to capture the 2000 stabilization program.

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[2] Phillips-Perron (1988) test results are almost the same. Therefore, we do not present those results here, but available from the author upon request.

Following Hendry and Doornik (1994) and Doornik et al (1998) impulse indicator variables are entered unrestrictedly to the cointegration space.

The diagnostics in the form of vector statistics are presented in Table 2. Statistics indicate that our VAR model is satisfactorily a close approximation to actual data generating process, apart from some non-normality of residuals, particularly in the interest rate series[3]. However, Gonzalo (1994) has shown that the performance of the maximum likelihood estimator of the cointegrating vectors is little affected by non-normal errors.

[Insert Table 2 about here]

Table 3 reports the estimated trace and maximum eigenvalue statistics for four versions of the monetary model. In determining the number of cointegrating vectors we used degrees of freedom adjusted version of the maximum eigenvalue and trace statistics, since, for small samples with too many variables or lags Johansen procedure tends to overestimate the number of cointegrating vectors (see Cheung and Lai (1993) and Gonzalo and Pitarakis (2000)). For the flexible price monetary model (Model 1) the computed test statistics can not reject the null hypothesis of no cointegration. Therefore, no further analysis is conducted on this model. For the rest of the specifications we strongly reject the null hypothesis of no cointegration in favor of one cointegration relationship[4].

[Insert Table 3 about here]

Table 4 reports standardized eigenvectors, b'. All of the coefficients in the cointegrating vector have anticipated signs and magnitudes. Magnitudes of money and income (proxied by industrial production) differential variables are consistent with predictions of the monetary model. The interest rate differential enters with negative sign, which indicates that, an increase in the Turkish interest rate relative to U.S. interest rate leads to an appreciation of the Turkish Lira. These findings are consistent with the sticky price monetary model of the exchange rate. Inflation differentials enter

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[3] To save space, these results are not given here but available upon request from the author.

[4] . However, without the degrees of freedom adjustment result did not alter much.

with a positive sign indicating that an increase in the inflation relative to US leads to a depreciation of the domestic currency. The relative price variable has an anticipated positive signs. In the Model 4, net foreign asset differential has a negative sign and is not consistent with the theoretical expectation. However, we will keep this model for the further analysis.

The estimated response of each of the variables to the equilibrium correction terms, α, is presented in Table 5. The first term in α represents the speed at which the dependent variable in the first equation of the VECM moves towards restoring the long-run equilibrium, and second term shows how fast differential money responds to the short-run disequilibrium in the cointegration vector, so forth. In all sticky price versions of the monetary model the exchange rate responds to the equilibrium correction term by moving to reduce the disequilibrium. However, the rate of response is very slow.

Various hypotheses on the parameters of α matrix can be tested. A first interesting aspect is represented by the possibility of identifying long-run weak exogeneity of the variable(s) with respect to the parameters of equilibrium relationships. If the cointegration vector does not have any influence on a particular variable, a case in which, all the weights are zero, then that variable is said to be long-run weakly exogenous with respect to long-run parameters. These weak exogeneity test results guide us to model short-run relationships in the system framework.

In model 2, we can not reject the weak exogeneity of the interest rate differential at 5 percent significance level, as the computed likelihood ratio statistic $\chi^2(1)=2.3486$ and associated p-value 0.1254 indicate. In model 3, interest rate differential and the relative prices are jointly weakly exogenous, given the likelihood ratio statistics and the p-values, which are $\chi^2(2)=1.9653$, 0.3743, respectively. In the final model, joint test of weak exogeneity shows that interest rate differential and the net foreign asset differential variables are weakly exogenous at 5 percent significance level, the computed statistic and the associated p-value are $\chi^2(2)=0.082350$, 0.9597, respectively. For the rest of the variables we reject the null hypothesis of weak exogeneity. The evidence found here consistent with the fact that interest rates are mainly determined outside this system by the dynamics of the public sector deficit in Turkey.

5. Short-run dynamics

In this section we use the long-run multivariate relationships derived in the previous section (model 2-4) to model the short-run exchange rate dynamics for the lira-dollar exchange rate. Ideally, the equations in the simultaneous econometric models should be economically meaningful and interpretable. Unfortunately, theoretical exchange rate models are not particularly explicit about the short-run dynamics, with the exception of the overshooting model. Therefore, we will use the statistical identification procedure suggested by Johansen and Juseliues (1994).

Having determined the long-run equilibrium relationships, the next step is to establish a parsimonious representation of the system. First of all, we map the VECM into I(0) space with an identity, which corresponds to the cointegrating vector together with dummy variables and constants. In the light of the weak exogeneity test results we condition exchange rate on the relevant variable(s). For example, in the second model, we condition exchange rate on interest rate differential. In model 2, VECM contains five endogenous variables (changes in the exchange rate, output differential, inflation differential, and one equilibrium correction term) and interest rate differential enters as a non-modeled variable to the system. The endogenous variables are determined by four stochastic equations, one identity and one exogenous variable.

The VECMs are simplified by sequentially removing insignificant variables based on t-values and F-test results. The regressors which remain in the parsimonious VECMs are all significant at least the 5 % level. In order to reduce the sample dependence of the system and increase its invariance to change (see Hendry and Doornik (1994), we determined the individual simultaneous equations of the system. In the final simultaneous equation system equations exclusion restrictions are imposed on differenced variables and, in light of these experiments, the whole system is estimated by FIML. The final exchange rate equations of the models are reported in Table 6[5].

[Insert Table 6 about here]

Without going into the details of each model, we can make the following points about the short-run dynamics of the exchange rate equations, estimated short-run parameters are, generally, consistent with theory and expectations, and short-run elasticities are much smaller than long-run elasticities. In all of the models equilibrium correction terms are significant and have expected negative signs and higher than the long-run adjustment coefficients.

6. Out-of-sample forecasting performance

Main purpose of any exchange rate modeling is to determine how well forecasts from estimated models perform relative to a random walk, based on the root mean squared errors (RMSEs) criteria. In order to see whether the equilibrium correction terms are affecting the forecasting performance of the models, we further investigate the forecasting performance of the models in the parsimonious differenced VAR model form as well.

We compute fully dynamic predictions from the simultaneous equation systems. Predictions are computed in the following way. The models were estimated up to the end of 2000. This estimated equation was then used to forecast the exchange rate for five forecasting horizons, namely, three, six, nine, twelve and fifteen months ahead over the period 2001:l to 2002:3. It is important to note that the exchange rate itself appears among the right hand side variable, both in the cointegrating vector and in first differences. As we are testing the monetary model, we use actual realized values of the fundamentals when forecasting. However, for the exchange rate variable on the right hand side the predicted values are used when standing in period t and using the values of the exchange rate in period $t+i$. Furthermore, we only estimate each model once. The estimated coefficients remain fixed throughout the forecasting period (see MacDonald and Marsh (1997) for the same procedure).

Since all of the stochastic equations in the system are in equilibrium correction form, a simple dVAR version of the model can be obtained by omitting the equilibrium correcting terms from the equations and re-estimating the coefficients of the differenced variables. However, simply omitting the level terms while retaining the intercept may seriously damage the dVAR forecast (see Mizon and Hendry (2000)). Therefore, we decided to re-model all the equations in the system, in terms of differences alone, in order to make the residuals of the dVAR equations white noise.

For the evaluation of the out-of-sample forecasts of the models we utilize the ratio of the root mean square error (RMSE) of the regression forecasts relative to the RMSE of random walk based forecasts. A ratio equal to 1 indicates that the predictive

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[5] . The whole system estimates are available from the author.

performance of the model is equal to that of random walk, a ratio smaller (greater) than 1 indicates that the regression has a superior (inferior) forecasting performance. Table 7a,b gives the ratio of the RMSE of exchange rate forecasts from the estimated equilibrium correction models and differenced VAR models to that of two alternative benchmark forecasts over a range of horizons.

Before presenting the forecasting results the fit of the models are given in Figure 1-3. The actual and fitted values of the change in the exchange rates over the period 1986:l to 2000:12, and out-of-sample forecasting periods are reported. Further evidence of the goodness of fit of our estimated equations is revealed by these figures. Thus, in Figure 1-3 the predicted exchange rate change from the model tracks the actual exchange change well and manages to get a considerable number of turning points correct. More significantly, the model is also able to get most of the out-of-sample turning points correct.

[Insert Figure 1-3 here]

The results from the forecasting exercises are reported are of considerable interest. In Table 7a a driftless random walk model is taken as a benchmark. In all instances VECM and the dVAR models out-perform the random walk model. However, forecasting performance of the VECM is better than the dVAR models. If we look at the table more carefully, forecasting performance of the Model 3 in VECM form outperforms all other models. In Table 7b the benchmark model is a random walk with a drift, again we can easily see that Model 3 in VECM form produces best forecasting outcome, beats both random walk and dVAR models. If we look at the forecasting performance of the Model 2, we can see that dVAR model outperforms both the VECM and the random walk models in the first three periods, however, in the last two periods lose the competition to the random walk model. Model 4 in VECM form beats both the random walk and dVAR models in the forecasting competition, but, inferior to the Model 3 in VECM form[6].

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[6] This result is not surprising. The monetary model of exchange rate assumes that purchasing power parity (PPP) is maintained between countries for broad price indices. However Civcir (2002a) provides an evidence for the weak form of PPP for Turkey. Given these findings on PPP, the model should allows for movements in relative prices of tradable to nontradables

[Insert Table 7 about here]

These results shows that the equilibrium correction terms are important both in sample (since they are significant in the simultaneous equations) and out of sample (where they improve forecast performance). So where does this forecasting accuracy come from? In this paper, models are estimated by using data up to 2000:12 and forecasting period covers 2001:1-2002:3 monthly data. At the beginning of 2001, Turkey faced with a severe economic crisis and the exchange rate started to float freely in February 2001. This policy shift will have an effect on the forecasting performance of the models. Clements and Hendry (1995a,b, 1996, 1998) have examined several issues in macro econometric forecasting, including relative performance of dVAR and VECMs. Assuming constant parameters in the forecast period, dVAR is misspecified relative to correctly specified VECMs, and therefore, dVAR forecast will be suboptimal. However, if the parameters change after the forecast made then the VECM is also mispecified in the forecast period. Clements and Hendry shown that forecasts from a dVAR are robust with respect to certain classes of parameters change. Hence in practice, VECM forecasts may turn out to be less accurate than forecasts derived from a dVAR. However, dVAR can be seen as a special case of a VECM where the long-run relationship is excluded from the system in the forecast period, this in turn makes the VECM model misspecified. Therefore, the outcome of a horse-race is no longer can be taken granted, since both models are misspecified relative to the mechanism that prevails in the period of forecasting. Further, Eitrheim, Husebo and Nymoen (1999) shown that the dVAR models offer protection against pre-forecast shifts in the long-run mean shift. The dVAR automatically intercept correct to the pre-forecast break, the VECM will delivers inferior forecast unless model users are able to detect the break and correct the forecast by intercept correction. They also showed that neither the VECM nor the dVAR protect against post-forecast breaks which is the case in this paper. For multi-step forecast, the dVAR model excludes growth when it is present in the data generating process and may compete favorably with the VECM over moderate

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within and across countries (see Cheung and Chinn (1998), Husted and MacDonald (1999) and Civcir (2002b).

forecast horizons. However, if the data generating process contains deterministic growth the VECM will win the forecasting competition, which is the case here.

7. Conclusions

In this paper, we have examined the four versions of the monetary model using data for the Turkish Lira - Dollar exchange rate. A number of novel findings were reported. In particular, we demonstrated that the flexible price monetary model (Model 1) has no cointegration relationship, and the sticky price versions of the models (Model 2-4) there were statistically significant cointegrating vectors between the exchange rate and the monetary fundamentals.

By using the estimated cointegrating vector and weak exogeneity test results we conditioned the exchange rate on the relevant variables and the dynamic equilibrium correction models are estimated. Further, we compute fully dynamic predictions from simultaneous equation systems where predicted values of the exchange rate are used on the right hand side of the models (both in levels and differences).

Sticky price equilibrium correction monetary model augmented with productivity differential outperforms both random walk and parsimonious differenced VAR models in 3, 6, , 9, 12 and 15 months forecast horizons.

Overall, results provided in this paper suggest that the monetary classes of exchange rate models are useful in explaining exchange rate behavior and exchange rates are predictable at short horizons.

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Table 1: ADF(k) Unit Root Test Results

(LEVELS)							(FIRST DIFFERENCES)			
Variables	**k**	**A**	**B**	**F3**	**F1**		**Variables**	**k**	**A**	**B**
S	12	-2.108	1.107	4.181	2.422		Δs	7	-4.374**	-4.142**
m^d (M2)	12	-1.838	-0.130	3.634	5.885*		Δm^d (M2)	7	-4.6472**	-4.6564**
y^d	12	-1.397	-1.397	4.613	0.367		Δy^d	7	-6.7452**	-6.7337**
i^d	12	-3.241	-2.887	2.334	7.667**		Δi^d	7	-6.5833**	-6.6172**
π^d (CPI)	12	-0.867	-1.579	5.577	4.176		$\Delta\pi^d$ (CPI)	7	-4.7144**	-3.7911**
π^d (WPI)	12	-0.990	-1.473	1.026	2.840		$\Delta\pi^d$ (WPI)	7	-4.5790**	-3.6609**
P^{dTN}	12	-1.772	0.694	4.119	3.071		ΔP^{dTN}	7	-6.4151**	-6.2880**
F^d	12	-2.837	-0.705	5.840	0.749		ΔF^d	7	-6.693**	-6.701**
1% Crt.Val*		-4.026	-3.478	8.730	6.700		1% Crt.Val*		-4.026	-3.478
5% Crt. Val		-3.443	-2.882	6.490	4.710		5% Crt. Val		-3.443	-2.882

Notes:

1) k is the number of lagged dependent variables in the ADF regression

2) Column A and B give the t-statistics from ADF regression including constant and trend, and constant respectively. Column F3 and F1 are Dickey-Fuller F statistics, the critical values are from D-F (1981)

3) The critical values are from MacKinnon (1991). The superscripts * and ** denotes rejection at 5% and 1% critical values.

Table 2 : Vector Test Statistics

	Model 1	Model 2	Model 3	Model 4
Vector AR 1-12 test:	1.0336 [0.4075]	1.1859 [0.1237]	0.93927 [0.6607]	1.1187 [0.2038]
Vector Normality test:	225.53 [0.0000]**	106.92 [0.0000]**	88.894 [0.0000]**	123.07 [0.0000]**
Vector hetero test:	0.31113 [1.0000]	1754.4 [0.7748]	3034.5 [0.4429]	2431.0 [0.8961]

Notes :

1) VAR in Model 1 contains 9 lags; Model 2 and 3, 12 lags; and Model 4, 10 lags

2) p-values of each test statistics are reported in square brackets.

3) ** and * indicates 1 percent and 5 percent significance levels respectively.

Table 3 : Cointegration Analysis of Monetary Models

Hypotheses	r = 0	r <= 1	r <= 2	r <= 3	r <= 4	r <= 5
Model 1						
λ-Trace (A)	52.96 [0.061]	25.66 [0.366]	9.57 [0.685]	4.18 [0.398]		
λ-Max (A)	27.30 [0.071]	16.08 [0.304]	5.40 [0.844]	4.18 [0.397]		
λ-Trace (B)	40.97 [0.428]	19.85 [0.735]	7.41 [0.865]	3.23 [0.548]		
λ-Max (B)	21.12 [0.345]	12.44 [0.620]	4.17 [0.936]	3.23 [0.547]		
Model 2						
λ-Trace (A)	132.80 [0.000]**	51.60 [0.081]	27.38 [0.274]	9.25 [0.716]	2.98 [0.593]	
λ-Max (A)	81.20 [0.000]**	24.22 [0.169]	18.13 [0.178]	6.27 [0.757]	2.98 [0.592]	
λ-Trace (B)	81.72 [0.019]*	31.75 [0.855]	16.85 [0.887]	5.69 [0.955]	1.83 [0.805]	
λ-Max (B)	49.97 [0.000]**	14.91 [0.819]	11.16 [0.736]	3.86 [0.953]	1.83 [0.804]	
Model 3						
λ-Trace (A)	181.79 [0.000]**	77.53 [0.044]*	45.61 [0.231]	27.23 [0.281]	10.21 [0.625]	3.92 [0.436]
λ-Max (A)	104.26 [0.000]**	31.92 [0.106]	18.38 [0.556]	17.02 [0.241]	6.29 [0.754]	3.92 [0.435]
λ-Trace (B)	112.76 [0.010]*	48.09 [0.899]	28.29 [0.944]	16.89 [0.885]	6.33 [0.928]	2.43 [0.694]
λ-Max (B)	64.67 [0.000]**	19.80 [0.822]	11.40 [0.966]	10.56 [0.786]	3.90 [0.951]	2.43 [0.693]
Model 4						
λ-Trace (A)	162.84 [0.000]**	91.01 [0.002]**	47.25 [0.178]	27.71 [0.258]	13.09 [0.364]	1.98 [0.778]
λ-Max (A)	71.83 [0.000]**	43.75 [0.002]**	19.55 [0.462]	14.61 [0.421]	11.11 [0.252]	1.98 [0.777]
λ-Trace (B)	103.72 [0.052]*	56.45 [0.628]	29.31 [0.923]	17.19 [0.873]	8.12 [0.812]	1.23 [0.905]
λ-Max (B)	44.55 [0.015]*	27.14 [0.319]	12.12 [0.948]	9.06 [0.890]	6.89 [0.686]	1.23 [0.904]

Notes:

1) The estimation period is 1987:1-2000:12

2)VAR includes 9 lags on each variable in Model 1, 12 lags in Model 2 and 3, and 10 lags in Model 4 , constant term is restricted into the cointegration space. Centered seasonal dummy, D91 dummy and D94 dummy and D00 variables are unrestricted to the cointegration space.

3) The λ-Max and λ-Trace are maximum eigenvalue and trace test statistics, (A) and (B) indicates without and with adjusted for degrees of freedom respectively. The critical values are taken from Osterwald-Lenum (1992).

4) [.] gives probability; ** and * indicate 1% and 5% significance levels, respectively

Table 4 : Standardized Eigenvectors Beta (scaled on diagonal)

	Vector 1	Vector 2	Vector 3	Vector 4	Vector 5	Vector 6
Model 1						
S	**1.0000**	-1.0714	0.2829	-703.2000		
m^d	**-0.9356**	1.0000	-0.2664	634.9300		
y^d	**1.6357**	0.6404	1.0000	527.9700		
i^d	**-0.0048**	-0.0034	0.0008	1.0000		
Constant	**-4.6536**	5.1436	-1.4529	4061.5000		
Model 2						
S	**1.0000**	-1.0847	2.3155	309.2200	1.0009	
m^d	**-0.9367**	1.0000	-1.9826	-298.2600	12.5990	
y^d	**0.9144**	-1.3967	1.0000	-150.8400	-772.0000	
i^d	**0.0010**	0.0007	0.0113	1.0000	-1.0907	
π^d	**-0.0292**	0.0075	-0.0205	-3.0937	1.0000	
Constant	**-4.9857**	5.1218	-11.5070	-1444.1000	-104.5900	
Model 3						
S	**1.0000**	-2.0738	0.8041	-771.3600	172.7000	-3.3252
m^d	**-0.8479**	1.0000	-0.7062	718.0800	-178.5500	3.3164
y^d	**1.1927**	-0.4158	1.0000	-908.0500	-243.2400	-7.7639
i^d	**0.0007**	-0.0084	0.0009	1.0000	0.0866	-0.0262
π^d	**-0.0253**	0.0609	-0.0053	5.5516	1.0000	0.0518
P^{dTN}	**-2.8686**	27.6990	-0.5457	50.6400	329.9900	1.0000
Constant	**-5.4303**	11.2620	-4.0536	3558.6000	-955.8700	14.4280
Model 4						
S	**1.0000**	-1.4946	-0.3700	640.2100	-160.4700	-76.2510
m^d	**-0.9110**	1.0000	-0.1306	-636.5900	141.7000	69.8780
y^d	**0.9672**	-2.3565	1.0000	421.9500	-238.9000	58.4860
i^d	**0.0020**	0.0025	-0.0049	1.0000	-0.2463	0.1207
π^d	**-0.0254**	0.0074	-0.0012	-3.6727	1.0000	0.2291
F^d	**-0.1798**	1.7154	2.0559	146.0000	11.8910	1.0000
Constant	**-5.2184**	11.8890	7.7722	-2583.9000	836.8700	408.6500

Notes:

1) The estimation period is 1986:1-2000:12

2)VAR includes 9 lags on each variable in Model 1, 12 lags in Model 2 and 3, and 10 lags in Model 4 , constant term is restricted into the cointegration space. Centered seasonal dummy, D91 dummy and D94 dummy and D00 variables are unrestricted to the cointegration space.

Table 5 : Standardized Loadings, a

Model 1

S	0.02165	-0.00327	0.02790	0.00001		
m^d	0.00206	-0.03775	-0.00899	-0.00001		
y^d	0.02577	-0.02113	-0.08587	0.00004		
i^d	76.51800	13.53300	10.39100	-0.01331		

Model 2

S	**-0.00873**	-0.06422	0.00124	0.00002	-0.00002	
m^d	-0.04413	0.01313	-0.00196	0.00006	0.00002	
y^d	-0.05881	0.04113	-0.03200	-0.00001	-0.00003	
i^d	21.91100	-179.20000	-6.54780	0.00049	0.02059	
π^d	7.11410	1.86490	-0.90306	0.00790	-0.00100	

Model 3

S	**-0.00128**	0.00659	0.04185	-0.00005	0.00000	-0.00144
m^d	-0.05619	-0.01070	0.01066	0.00001	0.00009	-0.00066
y^d	-0.12310	0.00575	-0.18541	-0.00005	-0.00002	-0.00236
i^d	26.89400	3.03040	45.84300	-0.19099	0.03162	0.97597
π^d	10.54900	-1.26330	-6.56050	-0.00292	0.00001	-0.28173
P^{dTN}	-0.01716	-0.00291	0.02129	-0.00001	-0.00004	0.00001

Model 4

S	**-0.00436**	-0.01649	0.00651	0.00006	-0.00007	0.00007
m^d	-0.02184	-0.04755	-0.01676	0.00005	0.00016	-0.00007
y^d	-0.03024	0.05517	0.00530	0.00000	0.00060	0.00026
i^d	-3.96500	-73.98200	42.97300	0.05252	-0.01855	-0.07565
π^d	10.39900	-4.04900	0.27244	0.00498	0.01729	0.00540
F^d	-0.01117	-0.23151	-0.03073	-0.00011	0.00012	0.00018

Notes:

1) The estimation period is 1986:1-2000:12

2)VAR includes 9 lags on each variable in Model 1, 12 lags in Model 2 and 3, and 10 lags in Model 4 , constant term is restricted into the cointegration space. Centered seasonal dummy, D91 dummy and D94 dummy and D00 variables are unrestricted to the cointegration space.

Table 6 : FIML Estimates of Exchange Rate Equations

Model 2	**Coefficient**	**t-value**	***Model 3***	**Coefficient**	**t-value**	***Model 4***	**Coefficient**	**t-value**
Δi^d	0.00006	2.540	Δi^d	0.00019	11.200	Δs_1	0.65943	13.300
Δs_1	0.48961	12.500	Δs_1	0.42807	11.200	Δi^d_1	0.00024	17.400
Δi^d_1	0.00019	12.200	Δm^d_1	0.09019	2.640	ΔF^d_1	0.07459	4.260
$\Delta \pi^d$_1	0.00081	3.630	Δi^d_1	0.00018	10.600	Δi^d_2	0.00004	2.780
Δs_3	0.18637	5.000	$\Delta \pi^d$_1	0.00065	2.930	Δm^d_3	-0.04039	-1.350
Δi^d_3	-0.00006	-5.950	Δi^d_4	0.00007	7.030	Δi^d_3	-0.00005	-4.290
$\Delta \pi^d$_4	-0.00036	-2.050	Δy^d_5	-0.02854	-1.970	Δi^d_4	0.00007	7.130
Δm^d_5	-0.07691	-2.650	Δi^d_5	0.00003	3.540	$\Delta \pi^d$_4	-0.00045	-2.170
Δy^d_5	-0.02624	-1.900	$\Delta \pi^d$_5	0.00058	2.830	Δy^d_5	-0.04904	-3.460
Δm^d_6	0.03364	1.240	Δm^d_6	0.08136	2.520	Δi^d_5	0.00010	8.520
$\Delta \pi^d$_8	-0.00071	-3.940	Δi^d_6	0.00002	2.500	$\Delta \pi^d$_5	0.00063	3.020
Δm^d_9	-0.09362	-3.200	$\Delta \pi^d$_7	-0.00058	-2.860	Δi^d_6	0.00002	2.560
$\Delta \pi^d$_9	0.00055	2.950	Δs_8	0.14195	3.120	Δs_7	0.18364	3.980
Δy^d_11	-0.03530	-2.690	Δi^d_8	0.00003	3.650	$\Delta \pi^d$_7	-0.00074	-3.740
Δi^d_11	-0.00003	-3.680	Δm^d_9	-0.07511	-2.250	Δs_8	0.12129	3.030
$\Delta \pi^d$_11	-0.00073	-3.990	Δi^d_9	-0.00003	-2.610	Δi^d_8	0.00003	3.240
D9103	0.06604	5.080	ΔP^{dTN}_10	-0.23704	-3.440	Δm^d_9	-0.05449	-2.120
D9111	-0.03178	-2.380	$\Delta \pi^d$_11	-0.00086	-4.770	Δy^d_9	0.04285	3.050
D9402	0.06274	4.100	D9103	0.07089	5.300	$\Delta \pi^d$_9	0.00063	3.720
D9403	-0.09840	-2.790	D9111	-0.03138	-2.250	D9103	0.07519	5.740
D9404	0.13992	3.260	D9402	0.03494	2.300	D9111	-0.04258	-3.230
D9809	-0.02586	-2.010	D9403	-0.30426	-8.810	D9402	0.08881	6.740
D0001	-0.03260	-2.470	D9404	0.32111	10.200	D9403	-0.04026	-2.770
D0006	-0.04049	-3.160	D0006	-0.03537	-2.620	D9909	0.02679	2.100
D0012	-0.06601	-5.120	D0012	-0.10926	-7.200	D0001	-0.05028	-3.810
Seasonal_2	0.00862	2.250	Seasonal_5	0.01285	2.840	D0006	-0.04919	-3.830
Seasonal_4	0.01476	3.830	EC_1	-0.01018	-3.650	Seasonal_1	0.0104	2.620
Seasonal_5	0.01353	3.240				Seasonal_4	0.0223	5.320
EC_1	-0.01152	-5.000				Seasonal_5	0.0151	3.630
						Seasonal_6	0.0130	3.030
						EC_1	-0.0033	-1.970
$\hat{s}$ = 0.0124977			$\hat{s}$ = 0.0132649			$\hat{s}$ = 0.0124855		

Notes:
1) _i shows the number of lags
2) EC is the equilibrium correction term.
3) s is the standard error of the regression
4) In Model 2 interest rate differential is exogenous; in Model 3 interest rate differential and relative price differential are exogenous; in Model 4 interest rate differential and net foreign asset differentials are exogenous

Table 7a: Out of sample forecasts: driftless random walk versus monetary models

Forecast Horizon (months):	3	6	9	12	15
Equilibrium Correction Models					
Model 2	0.886	0.911	0.909	0.923	0.938
Model 3	0.764	0.801	0.776	0.812	0.861
Model 4	0.822	0.832	0.827	0.834	
Differenced VAR Models (dVAR)					
Model 2	0.841	0.852	0.827	0.867	0.911
Model 3	0.929	0.936	0.903	0.932	0.993
Model 4	0.901	0.908	0.891	0.921	

Notes:
1) Table indicates ratio of model RMSE to driftless random walk RMSE
2) Estimation period is 1986:1-2000:12 and forecast periods is 2001:1-2002:3.

Table 7b: Out of sample forecasts: random walk versus monetary models

Forecast Horizon (months):	3	6	9	12	15
Equilibrium Correction Models					
Model 2	1.051	1.062	1.095	1.068	1.040
Model 3	0.907	0.933	0.933	0.939	0.955
Model 4	0.975	0.970	0.995	0.965	
Differenced VAR Models (dVAR)					
Model 2	0.997	0.993	0.995	1.003	1.010
Model 3	1.102	1.091	1.086	1.078	1.101
Model 4	1.069	1.058	1.072	1.065	

Notes:
1) Table indicates ratio of model RMSE to random walk with drift RMSE
2) Estimation period is 1986:1-2000:12 and forecast periods is 2001:1-2002:3.

Figure 1: Actual and fitted values from conditional dynamic model (Model 2)

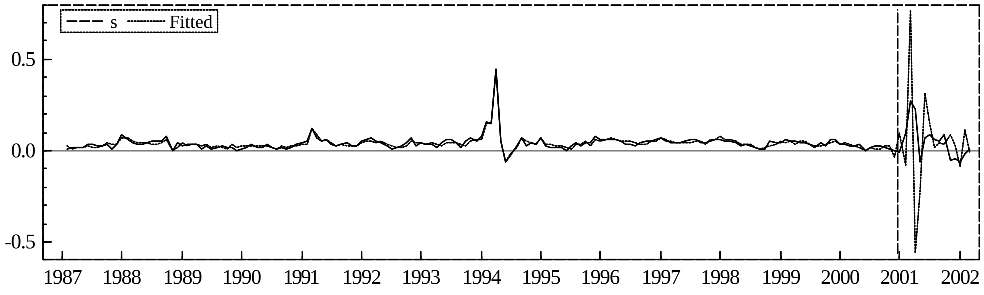

Figure 2: Actual and fitted values from conditional dynamic model (Model 3)

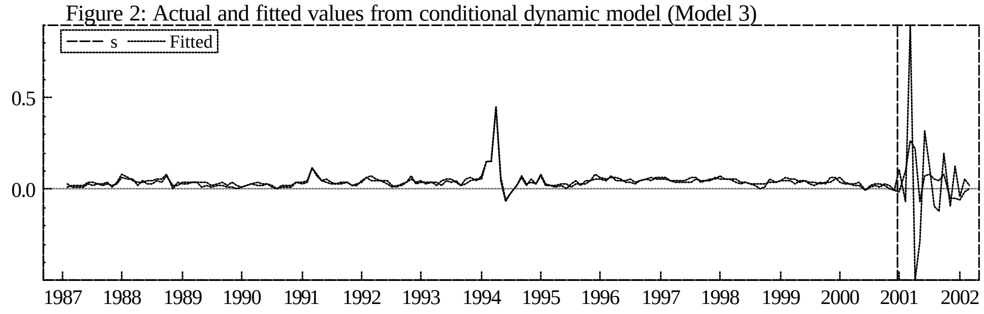

Figure 3: Actual and fitted values form conditional dynamic model (Model 4)