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An Error Correction Model for Russian Inflation*

Abstract

This study examines how inflation has responded to changes in the rate of money supply growth in Russia. The study covers the period from January 1992 when price liberalization was introduced to December 1995. The error correction model uses an error correction term (i.e. deviation from long-run equilibrium) extracted from the estimated long-run money demand function.

When the error correction term was included, it was found that much of the effect of monetary expansion was felt within three months. Further, the error correction term is shown to have statistically significant coefficient with a correct sign, implying that deviations from long-term equilibrium contain useful information about future inflation.

The model reinforces the observation that monetary policy inevitably plays the main role in reducing inflation. Thus, if a reduction in inflation is desired, the central bank may find it impossible to reconcile this goal with other obligations, for example, the financing of the central government budget through large deficits.

Keywords: inflation, models, Russia

* I wish to thank Antti Ripatti for very useful comments. All remaining errors and omissions are naturally mine.

1 Introduction

The Russian economy has undergone a massive restructuring during the last six years. Its rigid, centrally planned economy has, to a considerable extent, been transformed into a functional market economy.[1] Quite predictably, the transition to market economy has been accompanied by high inflation and rapid money supply expansion: inflation tax has long been a strategy of governments desperate for revenue, especially when traditional tax collection mechanisms are found to be inadequate. Yet, even though there can be no doubt that this is a major reason behind the rapid inflation in Russia, it is probably not the sole reason. Russian inflation, particularly in the early phase of the economic reforms, was very much driven by the change in relative prices for goods and services as they were corrected from artificially low levels to levels found in most industrialized countries.

The purpose of this study, therefore, is to examine the link between money and prices in Russia. We start with January 1992 when price liberalization was implemented, and end with data from December 1995. In the analysis, inflation is studied with an error correction model where the equilibrium error is derived from the estimated long-term money demand function. The effects of money supply growth on inflation are then examined in this context.

As might be expected, growth in the monetary aggregate is shown to have a significant and fairly rapid influence on inflation. What is interesting, though, is that despite the economic upheavals in Russia during recent years, the estimated money demand function is not obscenely at variance with the predictions of standard money demand models.

[1] For a survey of Russian economic reforms, see eg Sutela (1993) and Koen & Marrese (1995).

2 Rationale for an error correction model of inflation

Many macroeconomic variables of interest, GDP, consumption, prices etc. are not stationary, ie they contain trends. When a time series must be differenced once to be rendered stationary, it is said to be an integrated of order one, or I(1) for short. However, even if some variables are I(1) by themselves, there might exist a linear combination of the variables which is stationary. If such a combination exists, the variables in question are said to be cointegrated. Applying vector notation, if there is a variable vector $x_t = (x_{1t}, x_{2t}, ..., x_{nt})'$ and all x_{it} i=1,..,n are I(1), and a parameter vector $\beta = (\beta_1, \beta_2, ..., \beta_n)$ such that

$$\beta x_t = e_t \tag{1}$$

where e_t is a white noise error term, i.e. deviation from the long-term equilibrium, then variables x_i are said to be cointegrated. If the deviation in one period is non-zero, then it is expected that, *ceteris paribus*, the system will move towards long-term equilibrium in the next period. This, in essence, is the basis of error correction models. Using the notation of equation 1 and setting i=2, an error correction model for x_1 and x_2 would be:

$$\begin{aligned}\Delta x_{1t} &= \alpha_0 + \alpha_1(\beta_1 x_{1t-1} + \beta_2 x_{2t-1}) \\ &+ \sum_{i=1}^{k} \alpha_{1+i} \Delta x_{1t-i} + \sum_{j=1}^{l} \alpha_{1+k+j} \Delta x_{2t-i} \\ \Delta x_{2t} &= \gamma_0 + \gamma_1(\beta_1 x_{1t-1} + \beta_2 x_{2t-1}) \\ &+ \sum_{i=1}^{k} \gamma_{1+i} \Delta x_{1t-i} + \sum_{j=1}^{l} \gamma_{1+k+j} \Delta x_{2t-i}\end{aligned} \tag{2}$$

where α_1 and γ_1 are speed of adjustment parameters, i.e. they show how fast the system converges back to long-term equilibrium after a deviation.

With "normal" money demand functions, one would expect to find a cointegrating relationship among money, prices, output and interest rates. Yet, given the severe economic upheavals in Russia during the last years, even a somewhat stable money demand relationship cannot be assumed. In order to build an error correction model for Russian inflation, the possible cointegration between the variables mentioned must first be examined. If a cointegrating vector can be identified, then the resulting deviations from long-term equilibrium can be used in the ECM model. Further, lags of the relevant differentiated variables can also be used. Of special interest here are the lags in money supply change.

The long-term money demand function to be estimated has the familiar form:

$$m_t = \varphi_0 + \varphi_1 p_t + \varphi_2 y_t + \varphi_3 i_t \tag{3}$$

The demand for nominal money balances (in this application monetary aggregate M2) depends positively on the price level and the level of economic activity, and negatively on interest rate which represents the opportunity cost of holding money. All variables except the interest rate are in natural logarithms. If a long- term relationship is found, then this relationship can be used to derive a series of equilibrium errors. These equilibrium errors will in turn be used in the error correction model. Thus, the part of the resulting error correction model pertaining to Russian inflation is:

$$\begin{aligned}\Delta p_t &= \beta_0 + \beta_1(\gamma_0 + \gamma_1 m_{t-1} + \gamma_2 p_{t-1} + \gamma_2 y_{t-1} + \gamma_3 i_{t-1}) \\ &+ \sum_{i=1}^{4} \beta_{1+i} \Delta m_{t-i} + \sum_{j=1}^{4} \beta_{5+j} \Delta p_{t-j} \\ &+ \sum_{n=1}^{4} \beta_{9+n} \Delta y_{t-n} + \sum_{q=1}^{4} \beta_{13+i} \Delta i_{t-q}\end{aligned} \tag{4}$$

Similar equations are estimated for money, output and interest rate as well, but we are mainly interested in inflation. The ECM is first estimated with four lags on all variables and later the number of lags is shortened according to various information criteria. The first term in the brackets is the lagged value of the deviation from equilibrium cointegration relationship. β_1 is the speed with which the adjustment to the equilibrium occurs. Lagged terms of money growth are added to study the speed of the transmission from money growth to inflation, and lagged terms of inflation itself are added to examine whether Russian inflation contains elements of inertia.[2] Also the lagged values of differenced interest rates and industrial production are used.

3 Description of data

The data used are the consumer price index of Russia, the M2 monetary aggregate (currency in circulation plus various deposits held by the public), the volume index of industrial production[3], and the refinancing rate of the Central Bank of Russia from February 1992 to December 1995. The raw time series for the CPI is calculated as a monthly average, while M2 is reported as the value at the end of the month. To ensure that the time frame for both time series is similar, a monthly average for the money aggregate was calculated by simple linear interpolation. The resulting variables are designated as p_t, m_t, y_t, and i_t.

When testing a time series for cointegration, it is necessary to first test the order of integration, i.e. how many times the time series must be differenced to be stationary. Just from visual inspection of the relevant variables (Charts 1 and 2) it is immediately clear that p_t, m_t, and y_t are at least I(1) variables. Differences Δp_t and Δm_t (Chart 2) might be stationary, but this remains to be tested.

Next, a Dickey-Fuller (DF) test and an augmented Dickey-Fuller (ADF) test are used to determine the order of integration. The DF test statistic is calculated by first estimating the following equation from the data:

$$\Delta x_t = \alpha + \beta x_t + \varepsilon_t \qquad (5)$$

The test statistic is the t value for hypothesis $\beta=0$. If $\beta=0$, x_t contains a unit root and Δx_t is stationary. If the residuals of the estimated equation exhibit autocorrelation, it is possible to use the ADF test. As the name implies, the Dickey-Fuller test is augmented by adding further terms, namely lags of Δx_t. The equation to be estimated is:

$$\Delta x_t = \alpha + \beta x_t + \sum_{i=1}^{s} \gamma_i \Delta x_{t-i} + \varepsilon_t \qquad (6)$$

Here the number of lags s is chosen so that the residuals of the regression are white noise.

The results of the DF and ADF tests on the variables are reported in Table 1. In the DF and ADF test for Δp_t, a constant and trend were added to the regressions as the inflation rate clearly has a downwards trend. If no trend is added, the null hypothesis that p_t is I(2) is not rejected in either the DF or the ADF tests. In the ADF tests, the null of p_t being I(2) cannot be rejected beyond the lag length 5, but as the standard error of the equation is smallest at lag 4, we conclude that p_t is a I(1) variable. The DF test for Δm_t clearly indicates that m_t is I(1). Here the inclusion of a constant and/or trend makes no difference. In the ADF test, the possibility of the null of m_t being I(2) can be rejected at all lags from 1 to 5. If the constant and trend are excluded, the result remains the same. Including only the constant means that the null is rejected up to lag 3. The null hypothesis that y_t and i_t are I(2) is very clearly rejected.

[2] Latin America, where high inflation has long persisted has provided rich opportunites for researchers to study inertial inflation. Indeed, the wide-spread use of indexation schemes bespeaks the degree of acceptance of high inflation. Bruno et al (1988) provide excellent discussion on both the theoretical and empirical aspects of this phenomenon. In Russia's case, however, such relatively complex arrangements have yet to emerge because high inflation is historically a very recent occurrence and the country's judicical structure is still quite weak.

[3] The reason the index of industrial production is used is that it is the only monthly series long enough. Quite understandably, it would be preferable to use an indicator of total production, especially since the relative importance of services has grown in the Russian economy during the transition years.

Chart 1 **Levels of the prices, money supply, industrial output and interest rate**

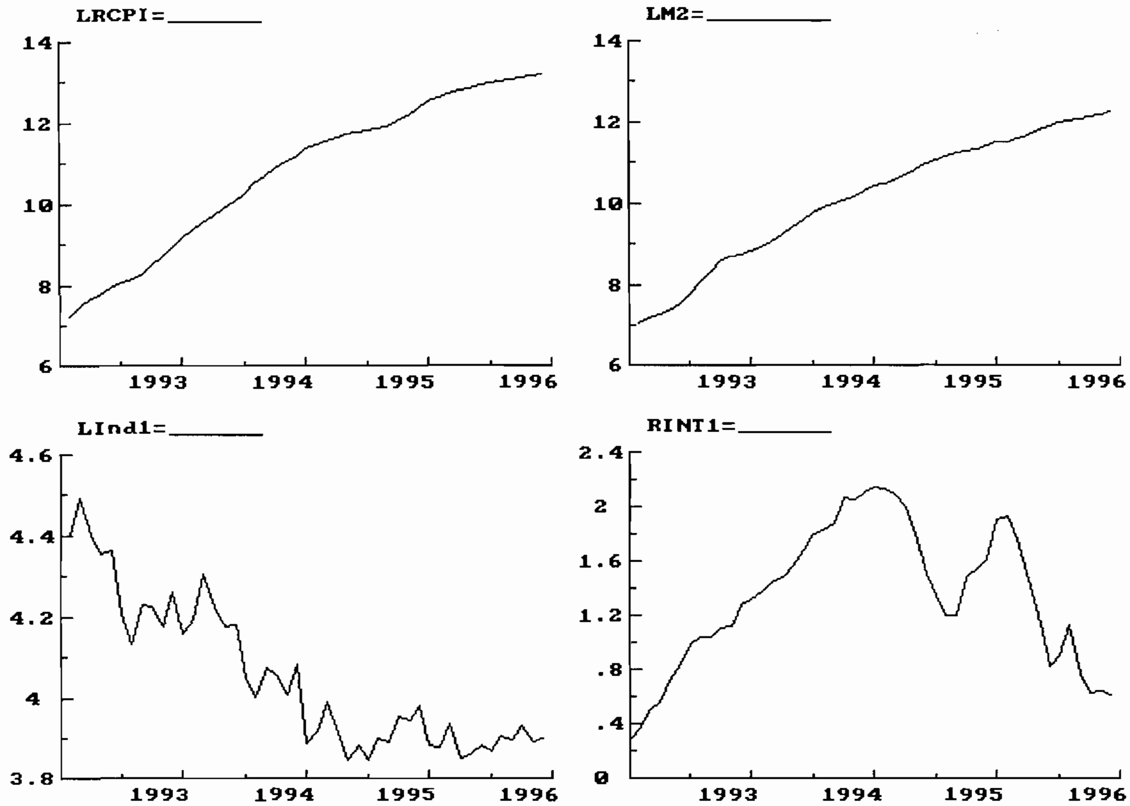
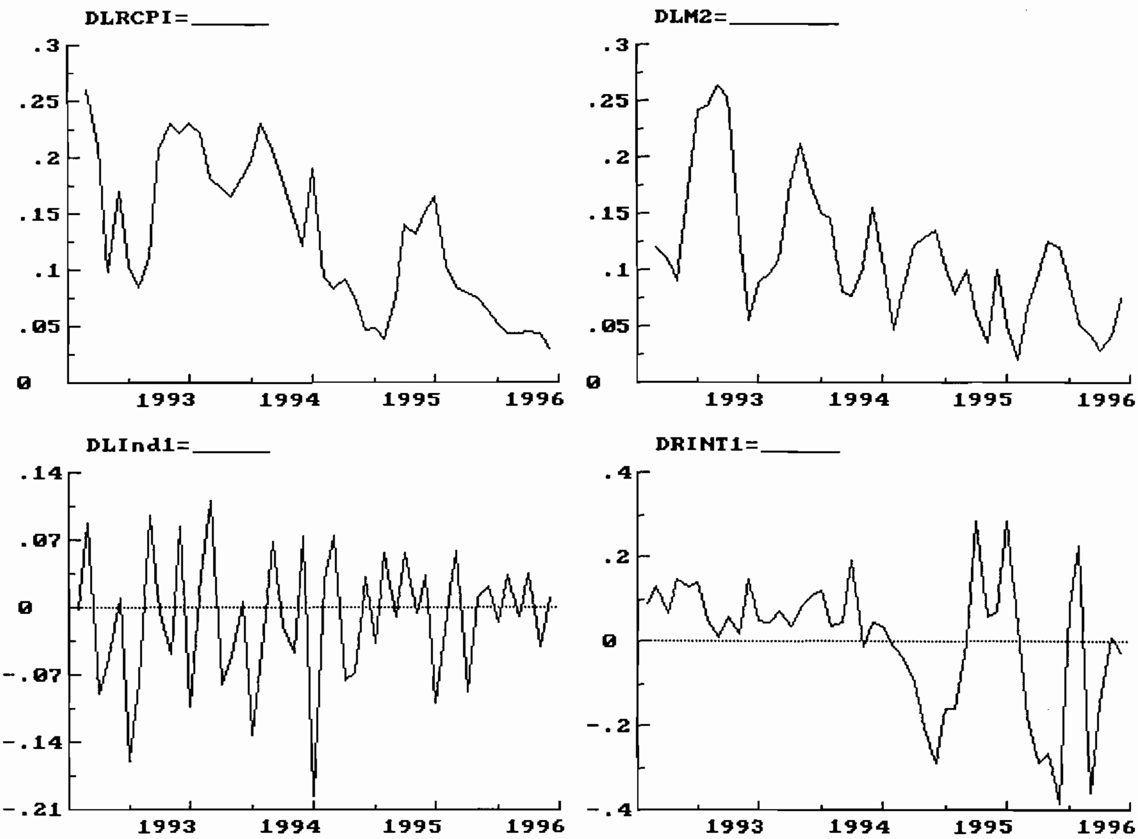


Table 1 **Test for unit roots in differences of m_t, p_t, y_t, and i_t**

Null and alternative hypothesis	m_t	p_t	i_t	y_t
H_0: I(2); H_1: I(1)	DF -3.802** ADF -4.523***	DF -3.564** ADF -3.971**	DF -3.931*** ADF -2.620**	DF -9.258*** ADF -4.343***

* indicates rejection of the null hypothesis at 10% critical level, ** at 5%, and *** at 1% level. The number of lags in ADF test is 4. A constant and linear trend were added to the test regressions of p_t and m_t.

Chart 2 **Differences in prices, money supply, industrial output, and interest rates**



4 Cointegrating relationship between variables and the resulting error correction model

Because p_t, m_t, y_t, and i_t are all deemed to be I(1) variables, there is the possibility that stationary linear combinations may exist. The presence of a cointegrating vector is tested for using the method suggested by Johansen (1988). In this context the hypothesis of a linear combination between p_t, m_t, i_t, and y_t entails a traditional money demand function.

Even though cointegration must be interpreted as a long-term relationship, the availability of data in this study limits the time period examined to four years. Even though the number of monthly observations may be deemed reasonable, four years is probably not "long-run". According to Hakkio & Rush (1991) adding to the number of observations by moving to shorter time intervals can give misleading results in cointegration tests due to the low power of the tests. However, this four years of data essentially represents the entire history of relatively free price-setting in Russia and could thus be interpreted as the longest run possible. Moreover, cointegration has frequently been used to analyse episodes shorter than four years. In particular, classic hyperinflation episodes have been analysed in this way by e.g. Taylor (1990) and Engsted (1994). Also testing of a forward rate unbiasedness hypothesis has been done with less than four years of data by e.g. Sosvilla-Rivero & Park (1992).

Our analysis indicates that there is one cointegrating vector in the system. The cointegration relationship was estimated with five lags, and with

Table 2 **Eigenvalues and test statistics for cointegration**

Eigenvalues	λ_{trace} test	95% critical values
λ_1=0.76002	51.57	47.2
λ_2=0.43260	20.17	29.2
λ_3=0.28179	7.702	15.4
λ_3=0.01891	0.420	3.8

Table 3 **The normalized cointegrating vector**

m_t	p_t	y_t	i_t
1.00	-0.803	-0.476	0.094

a constant. Residuals of the equation for output exhibit slight autocorrelation, but the null of no autocorrelation could not be rejected in the vector autoregression F test. Eigenvalues and degrees of freedom adjusted trace test statistics of cointegration as well as 95% critical values are reported in Table 2.[4] While the null hypothesis of no cointegration is clearly rejected, there also appears to be no evidence of more than one cointegrating vector.

The normalized cointegrating vector is reported in Table 3. The resulting equilibrium relationship between the four variables is then used in the error correction model for inflation. Inspection of the cointegrating vector reveals that the parameter values are at least of the right sign, i.e. of the sign suggested by the standard money demand equation.

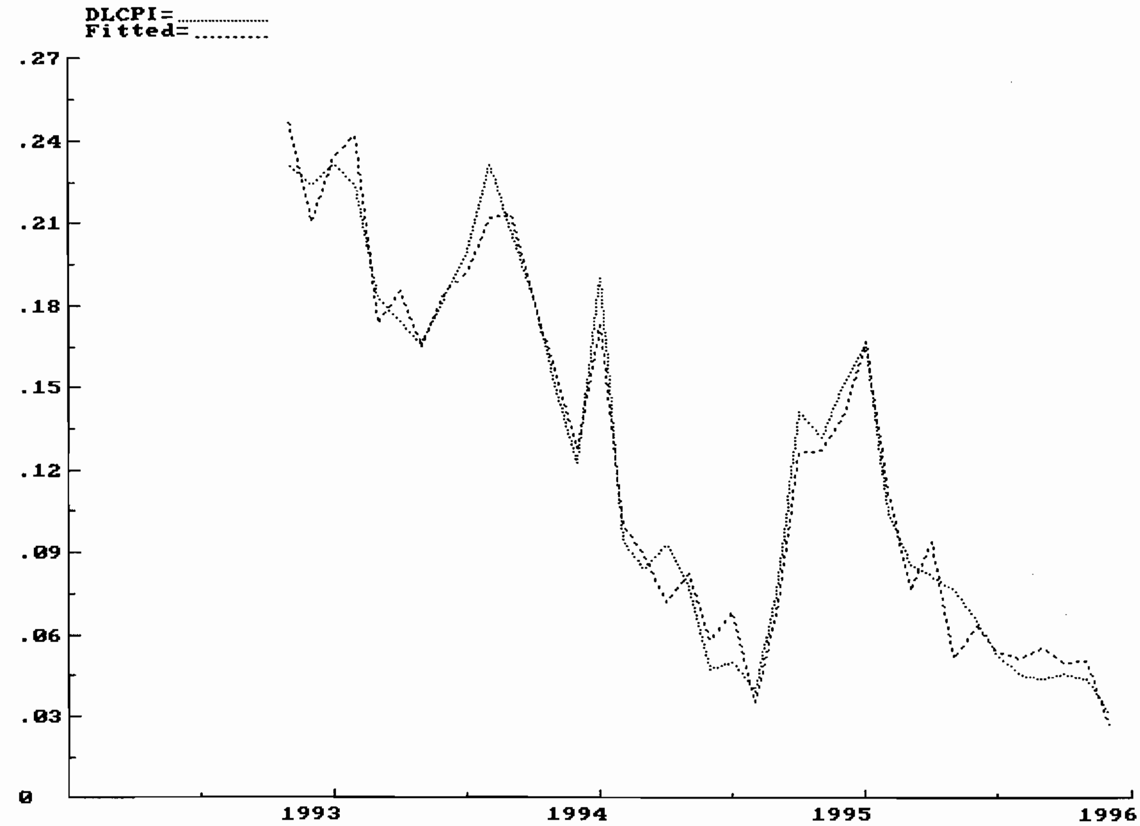
The estimated error correction model of inflation is used to assess the speed with which the actions of the monetary authorities affect inflation. The ECM was first estimated with a constant and four lags of each differenced variable.[5] Since the constant was not statistically significant in any of the equations, it was dropped. Next, the number of lags of different variables was decreased by simply removing all clearly insignificant lags (in practice, this was done by eliminating all variables with p values of more than 20% in F tests, unless a longer lag of the same variable had a p value of less than 20%). The validity of reduction was not rejected by a likelihood ratio test. The resulting error correction model for inflation is reported in Appendix 1.

One can readily see that changes in the money supply are clearly relevant, even when the error correction term is added. The error correction term has the correct sign and is clearly significant, meaning that an expanding money supply now will mean adjustment via higher inflation sometime in the future. Four lags of inflation are included, and all are clearly significant. This significance points to some inertia in Russian inflation, even after changes in the money supply are taken into account. This inertia will naturally make lowering

[4] Degree-of-freedom-adjusted test statistics were calculated with PcFiml econometric software.

[5] Of course, the maximum number of lags is determined more by the availibility of data than theoretical considerations. This Russian case presented here is consistent with findings of eg Koen & Marrese (1995).

Chart 3 **Actual and fitted values for Russian inflation**



inflation harder, and may also raise the costs of inflation reduction. Three lags of money growth were deemed significant by the criteria described above. Here one must remember that during the transition process the lag of monetary policy has in all probability increased, and thus it currently might be longer than three months. The parameter values of the multipliers of the first three lags of money supply growth would suggest that the short-run effect of a positive shock with a magnitude of 1% in Δm_t on monthly inflation rate is 0.4%. In addition, there is naturally the long-term effect arising from the error correction term. Four lags of changes in industrial production and changes in interest rates were also included in the model. Diagnostics revealed no autocorrelation in the error terms of any of the equations, nor could the normality of any of the error terms be rejected. The diagnostics thus seem to indicate that the model does provide a reasonable approximation of the actual money demand process.

In Chart 3 the actual inflation and the models fitted values are plotted from November 1992 to December 1995. The goodness of fit seems to be reasonable, and the model seems to have predicted to turning points in the inflation rate reasonably well. (Admittedly, the ability of the model to explain developments in-sample is a poor way to assess a model.)

5 Conclusions

It has been seen that in Russia's case an ordinary money demand function might provide a reasonably good explanation of the interaction between money, price level, output and interest rates. In the dynamic model constructed, changes in monetary policy clearly affect subsequent inflation. The equilibrium error term extracted from the long-term money demand function had a multiplier of the correct sign in the estimated error correction model, implying that a greater supply of money in a previous period will accelerate inflation. In addition to equilibrium error, changes in the money supply up to three lags were found to be statistically significant in explaining inflation. Thus, this study reinforces the message of Hoggart (1996) and Koen & Marrese (1995): inflation in Russia responds fairly quickly to changes in the monetary policy. Indeed, in the present study, much of the effect can be observed within three months. Thus, the desired reduction in the inflation rate (Russia and IMF agreed on a target of 1% monthly inflation for this year when negotiating the extended fund facility) necessarily implies tighter monetary policy. This, in turn, means greater fiscal discipline as monetary expansion has been associated with large budget deficits in the past.

The present study can only be considered preliminary, as the length of relevant data is insufficient to permit a more detailed inquiry. Further, the structural changes which have taken place in Russia in recent years have probably changed the data generating processes to some degree as well. This means that when additional data does become available, it is important for the researcher to assess the possibility of structural changes in that data as well as determine whether the transmission mechanism from money supply to inflation has changed significantly. This presents a potentially rich area of analysis for further research.

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Appendix 1 **The error correction model**

	Δp_t	Δm_t	Δy_t	Δi_t	F test and p value
EC term	0.193844 (3.257)	-0.161230 (-1.523)	0.0322919 (0.160)	0.769329 (1.290)	3.63313 (0.0232)
Δp_{t-1}	0.713570 (5.968)	-0.454347 (-2.136)	0.387948 (0.955)	-0.262920 (-0.220)	12.6088 (0.0000)
Δp_{t-2}	0.532226 (3.124)	0.519849 (1.715)	0.335416 (0.579)	3.6309 (2.127)	2.92984 (0.0482)
Δp_{t-3}	-0.844070 (-4.403)	-0.369396 (-1.083)	0.468031 (0.718)	-0.619286 (-0.322)	4.32362 (0.0118)
Δp_{t-4}	0.669465 (4.287)	0.180240 (0.649)	-0.653380 (-1.231)	-0.682117 (-0.436)	4.63614 (0.0088)
Δm_{t-1}	0.682477 (6.598)	0.881716 (4.792)	-0.542976 (-1.545)	0.990819 (0.956)	12.1593 (0.0000)
Δm_{t-2}	-0.901152 (-6.083)	-0.473607 (-1.797)	0.485605 (0.965)	-0.156034 (-0.105)	8.38743 (0.0004)
Δm_{t-3}	0.630201 (5.762)	0.276632 (1.422)	-0.677167 (-1.822)	-1.2371 (-1.129)	8.80940 (0.0003)
Δy_{t-1}	0.187575 (3.263)	0.0708917 (0.693)	-0.440776 (-2.256)	-0.216494 (-0.376)	3.42688 (0.0286)
Δy_{t-2}	0.148085 (2.585)	0.141647 (1.390)	-0.381376 (-1.959)	0.585312 (1.020)	2.55767 (0.0722)
Δy_{t-3}	0.0173466 (0.300)	0.0628842 (0.611)	0.00594199 (0.030)	-0.468094 (-0.808)	0.2313212 (0.9173)
Δy_{t-4}	0.212231 (4.254)	0.0513752 (0.579)	-0.373057 (-2.200)	0.213545 (0.427)	4.85552 (0.0072)
Δi_{t-1}	0.0506089 (2.357)	-0.0119786 (-0.314)	-0.157342 (-2.156)	0.453680 (2.109)	2.99799 (0.0448)
Δi_{t-2}	-0.0424886 (-1.943)	0.0342490 (0.880)	0.0476496 (0.641)	-0.489854 (-2.236)	1.95817 (0.1421)
Δi_{t-3}	0.0628942 (2.974)	-0.0483798 (-1.286)	-0.178629 (-2.485)	0.349019 (1.647)	4.18437 (0.0135)
Δi_{t-4}	-0.0183955 (-0.825)	0.0532826 (1.343)	-0.120789 (-1.594)	-0.507677 (-2.273)	1.95854 (0.1420)
Standard deviation of residuals	0.01417939	0.02522405	0.04818785	0.1420464	

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