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Abstract

This study examines how inflation and money supply growth have interacted in Russia. It covers the period from January 1992, when price liberalization was introduced, to December 1997. An error correction model includes an error correction term (ie 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 on inflation was felt within three months. Further, the error correction term is shown to have a statistically significant coefficient with the correct sign in the money demand equation, implying that deviations from long-run equilibrium contain useful information on future monetary growth.

The model reinforces the observation that monetary policy inevitably plays the key 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, with financing of the central government budget via large deficits.

Keywords: inflation, models, Russia, JEL classification: E4, E5

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1 Introduction

The Russian economy has undergone a massive restructuring during the last six years. This formerly rigid, centrally planned economy has, to a considerable extent, been transformed into a functional market economy.* Quite predictably, the transition to a market economy has been accompanied by high inflation and rapid expansion of the money supply. The 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 underlying factor in the rapid inflation in Russia, it is probably not the sole cause. Russian inflation, particularly in the early phase of economic reform, was very much driven by changes in relative prices of goods and services as they were corrected from artificially low levels to levels found in most industrial countries.

The purpose of this study is therefore to examine the link between money and prices in Russia. We look at the period starting in January 1992, when price liberalization was implemented, and ending with data for December 1997. Inflation is analysed using a vector error correction model in which 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 quick impact on inflation. It is interesting, that despite the economic upheavals in Russia in recent years, the estimated long-run 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

Many macroeconomic variables of interest, such as GDP, consumption and prices, 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, denoted I(1). However, even when certain variables are I(1) by themselves, there may exist a linear combination of them 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 $x_t = (x_{1t}\ x_{2t} \dots x_{nt})$= and all $x_{it,}$ i=1,..,n are I(1), and there exists a parameter vector $\beta = (\beta_1\ \beta_2 \dots \beta_n)$ such that

$$\beta x_t = e_t$$

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

$$\Delta x_{1t} = \alpha_0 + \alpha_1(\beta_1 x_{1t-1} + \beta_2 x_{2t-1}) + \sum_{i=1}^{k} \alpha_{1+i} \Delta x_{1t-i} + \sum_{j=1}^{l} \alpha_{1+k+j} \Delta x_{2t-1}$$

$$\Delta x_{2t} = \gamma_0 + \gamma_1(\beta_1 x_{1t-1} + \beta_2 x_{2t-1}) + \sum_{i=1}^{k} \gamma_{1+i} \Delta x_{1t-i} + \sum_{j=1}^{l} \gamma_{1+k+j} \Delta x_{2t-i}$$

where α_1 and γ_1 are speed-of-adjustment parameters, ie parameters that indicate how fast the system converges back to long-run equilibrium following a deviation. With 'normal' money demand functions, one would expect to find a cointegrating relationship between money, prices, output and interest rates. Yet, given the severe economic upheavals in Russia in recent years, one cannot assume the existence of even a fairly stable money demand relationship. In order to build an error correction model (ECM) for Russian inflation, one must first test for the abovementioned possible cointegration between the variables. If a cointegrating vector can be identified, then the resulting deviations from long-run equilibrium can be used in the ECM. Lags of the relevant differenced variables can also be used. Of special interest here are the lags in money supply change.

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

$$m_t = \varphi_0 + \varphi_1 p_t + \varphi_2 y_t + \varphi_3 i_t$$

The demand for nominal money balances (in this application, the monetary aggregate M2) depends positively on the price level and the level of economic activity, and negatively on the interest rate, which represents the opportunity cost of holding money. All variables except the interest rate are in natural logarithm form. If a long-run 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 ECM. Thus, the part of the resulting ECM pertaining to Russian inflation is:

$$\Delta p_t = \beta_0 + \beta_1(\gamma_0 + \gamma_1 m_{t-1} + \gamma_2 p_{t-1} + \gamma_2 y_{t-1} + \gamma_3 i_{t-1}) + \sum_{i=1}^{k} \beta_{1+i} \Delta m_{t-i} + \sum_{j=1}^{l} \beta_{k+1+j} \Delta p_{t-j} + \sum_{n=1}^{p} \beta_{k+l+n} \Delta y_{t-n} + \sum_{q=1}^{m} \beta_{k+l+p+i} \Delta i_{t-q}$$

Similar equations are estimated for money, output and the interest rate. The ECM is first estimated with four lags on each variable and later the number of lags is reduced. The first term in brackets is the lagged value of the deviation from the equilibrium cointegration relationship. β_1 is the speed of the adjustment to equilibrium. Lagged terms for 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] Lagged values of differenced interest rates and industrial production are also used.

3 Data

The data used are the Russian consumer price index, 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 1997. The raw time series for the CPI is calculates a monthly average and 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 denoted p_t, m_t, y_t, and i_t.

The Dickey-Fuller (DF) test and an augmented Dickey-Fuller (ADF) test were used to determine the order of integration of the variables.[4] The DF test statistic is calculated by first estimating the following equation from the data:

$$\Delta x_t = \alpha + \beta x_t + \varepsilon_t$$

[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.

[4] All tests and estimations are done using PcFiml 9.00, see Doornik & Hendry (1997).

The test statistic is the t-value for the hypothesis β=0. If β=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 ADF test is the Dickey-Fuller test augmented by adding certain terms, in this case lags of Δx_t. The most basic form for the test is the following:

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

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 a trend factor were added to the regressions since the inflation rate clearly follows a downtrend. When no trend is added, the null hypothesis that p_t is I(2) is not rejected by either DF or ADF tests. Based on the tests with trend, we conclude that p_t is an 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. The null hypothesis that y_t and i_t are I(2) is very clearly rejected.

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

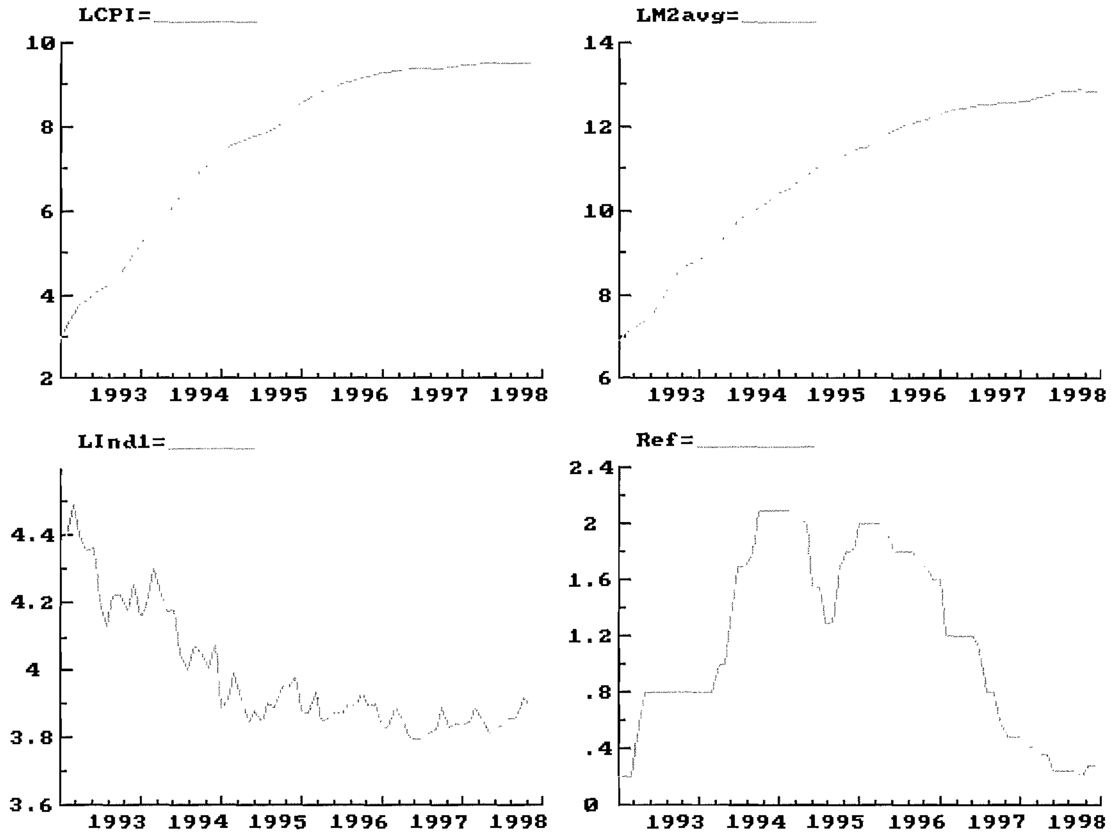


Table 1a **Test for unit roots in m_t, p_t, y_t, and i_t**

Null and alternative –hypothesis	m_t	p_t	i_t	y_t
H_0: I(1); H_1: I(0)	DF -3.013 ADF -2.5687	DF -3.7915* ADF -2.796	DF -0.3612 ADF -1.3519	DF -1.9872 ADF -1.8364

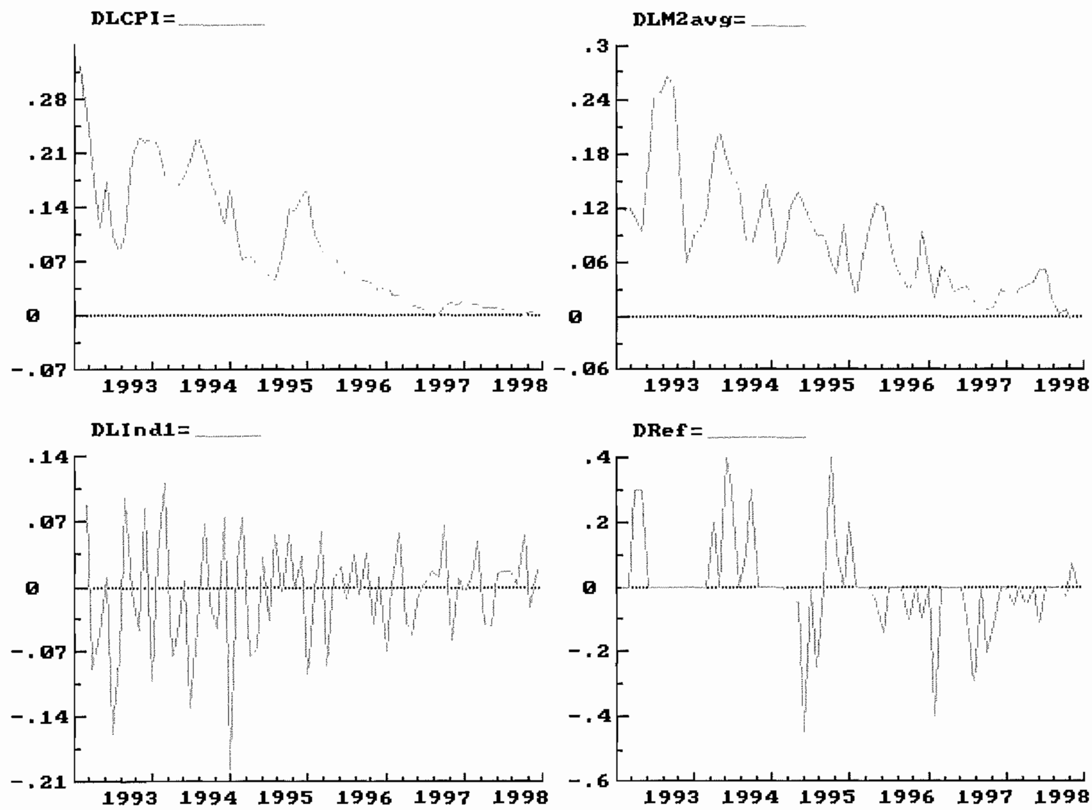
* indicates rejection of the null hypothesis at the 5% critical level and ** at the 1% level. The number of lags in ADF test for i_t and y_t is 6 and for p_t and m_t 4. A constant and a linear trend were added to the test regressions of p_t and m_t and a constant to i_t and y_t.

Table 1b **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 -4.8272* ADF -7.673**	DF -3.475 ADF -4.168**	DF -6.325** ADF -3.00*	DF -11.108** ADF -4.936**

* indicates rejection of the null hypothesis at the 5% level and ** at the 1% level. The number of lags in ADF test is 3. A constant and a linear trend were added to the test regressions of p_t and m_t and a constant to i_t and y_t.

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



4 Cointegrating relationship between the variables and the resulting error correction model

Because p_t, m_t, y_t, and i_t are all considered to be I(1) variables, there is the possibility that stationary linear combinations may exist. The possible presence of a cointegrating vector is tested via the method of Johansen (1988). In this context the hypothesis of a linear combination of p_t, m_t, i_t, and y_t entails a traditional money demand function. Moreover a trend is restricted to the cointegration space. Here the trend can be interpreted as a change in the velocity.

Even though cointegration should be considered a long-run relationship, data limitations here restrict the time period studied to six years. Although the number of monthly observations can be considered reasonable, six years does not constitute a true long-run time frame. According to Hakkio & Rush (1991), increasing the number of observations by taking shorter time intervals can give misleading results in cointegration tests due to the low power of the tests. However, this six years of data essentially represents the entire history of relatively free price determination in Russia and can thus be considered the longest run possible. Moreover, cointegration has frequently been used to analyse episodes shorter than six years. In particular, classic hyperinflation episodes have been analysed in this way by eg Taylor (1990) and Engsted (1994). And, the testing of the forward rate unbiasedness hypothesis has been done with less than six years of data by eg Sosvilla-Rivero & Park (1992).

Our analysis indicates that there is one cointegrating vector in the system. The cointegration relationship was first estimated with six lags. Eigenvalues and trace test statistics for cointegration are reported in table 2 along with the 95 per cent critical values. While the null hypothesis of no cointegration is clearly rejected, there also appears to be no evidence of more than one cointegrating vector.

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

Eigenvalues	**λ_{trace} test**	**95% critical values**
λ_1=0.44196	37.92	31.5
λ_2=0.23398	17.33	25.5
λ_3=0.19142	13.81	19.0
λ_3=0.07140	4.815	12.3

Table 3 **The normalized cointegrating vector**

m_t	p_t	y_t	i_t	**trend**
1.00	-1.00	-0.638	0.345	0.015

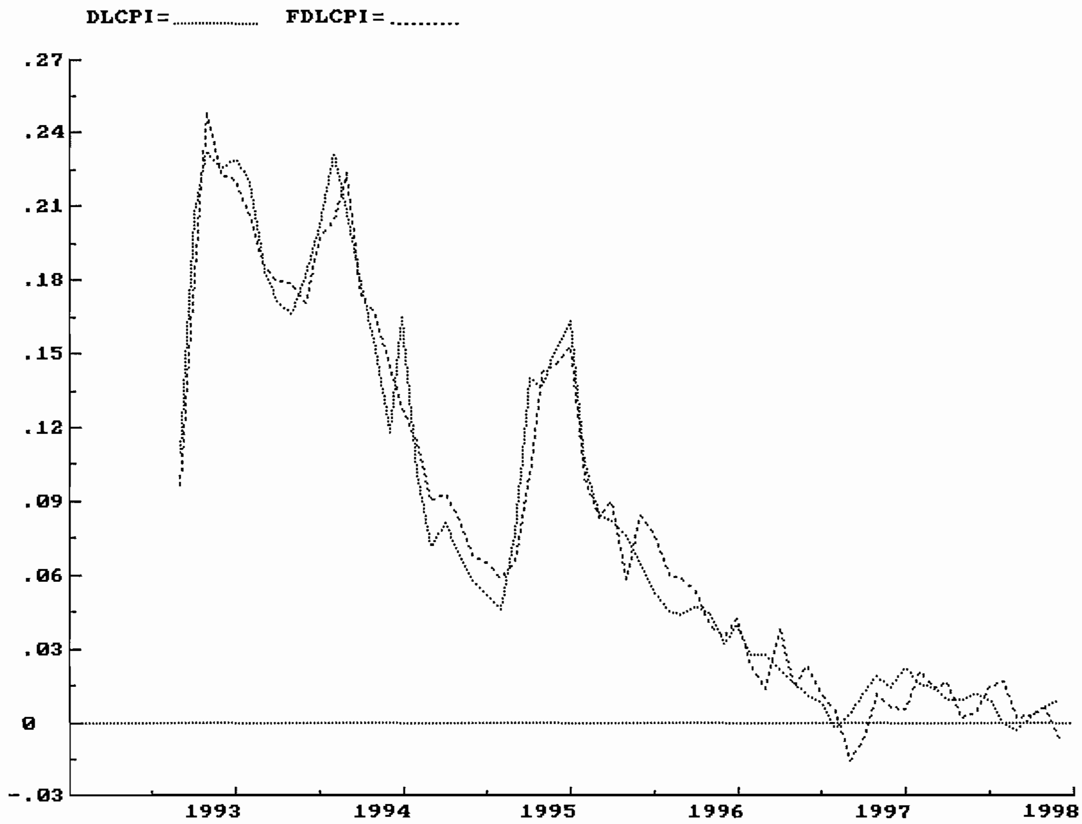
After checking the number of cointegrating vectors the coefficient on p_t is restricted to -1. This naturally means that in the long run changes in money supply are reflected fully in price changes. This restriction is not rejected in an LR test (p-value 0.55). The resulting normalized cointegrating vector, including the restriction, is reported in table 3. This equilibrium relationship between the four variables (and trend) is then used in the ECM. Inspection of the cointegrating vector reveals that the parameter values at least take the right sign, ie of the sign suggested by the standard money demand equation. The long-run income elasticity is somewhat lower than that usually found in such exercises, but here one can probably look again to the high degree of dollarization of the Russian economy, which is bound to affect such estimates.

The estimated ECM for inflation is used to assess the short-run dynamics of inflation. The ECM was first estimated with a constant and four lags of each differenced variable.[5] 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 exceeding 10 per cent in F-tests, unless a longer lag of the same variable had a p-value of less than 10 per cent). The validity of reduction was not rejected by a likelihood ratio test. The resulting VECM is reported in the appendix.

One can readily see that lagged changes in the money supply are clearly relevant for inflation, even when the error correction term is added. In the inflation equation the error correction term has the correct sign but is not significant. This can make the interpretation of the model somewhat problematic. The deviations from equilibrium affect money growth, and it is through this channel that inflation then changes, but there appears to be no direct link from equilibrium error to inflation. One lag of inflation is included, and this is very 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 the reducing of inflation more difficult and may also raise the costs involved.

[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**



Three lags of money growth were considered significant under the criteria described above. Here one should keep in mind that during the transition process the monetary policy lag has in all probability lengthened, and thus it might now be longer than three months. The parameter values of the multipliers for the first three lags of money supply growth would suggest that the short-run effect on the monthly inflation rate of a positive 1 per cent shock to Δm_t is 0.4 per cent. In addition, there is naturally the long-run effect deriving from the error correction term. The model also included two lags on changes in industrial production and four lags on changes in the interest rate.

The error correction term enters the money demand equation and is highly significant. This implies that if in a given period the level of money is higher than equilibrium, then in the next period M2 growth would be expected to decelerate. There seems to be considerable inertia also in the growth of M2 as evidenced by the large coefficient values for the lags of Δm_t.

The diagnostics reported in the appendix reveal the possibility of autocorrelation in the error terms of the output equation, but the other equations seem to be free from this problem. The residuals of all equations appear to be normally distributed, and there is no evidence of heteroscedastic errors. (These tests are not reported.) Thus the diagnostics 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 values produced by the models are plotted from November 1992 to December 1997. The fit seems reasonably good, and the model appears to have done a fair job of predicting major turning points in the inflation rate. (Admittedly, the ability of the model to explain developments in-sample is not an ideal way of assessing a model.) It could be that the fit worsens somewhat after the latter half of 1996.

5 Conclusions

It has been seen that for Russia 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 here, changes in monetary policy clearly affect subsequent inflation. The equilibrium error term extracted from the long-term money demand function had a multiplier of correct sign in the estimates equation for inflation, although it was not statistically significant. Multiplier in the equation for money was correctly signed and significant. 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 monetary policy. Indeed, in the present study, much of the effect can be observed within three months.

The present study can only be considered preliminary, as the time span is insufficient to permit a more detailed inquiry. Further, the structural changes that have taken place in Russia in recent years have probably modified the data generating processes to some extent as well. This means that when additional data do become available, it is important that the researcher assess the possibility of structural changes in that data. As well, he should attempt to 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 **The error correction model**

	Δp_t	Δm_t	Δy_t	Δi_t	F-test and p-value
Constant	-0.048686 (-1.065)	0.46565 (8.336)	-0.11605 (-0.829)	0.43406 (1.133)	
EC term	0.006906 (0.835)	-0.082784 (-8.184)	0.019705 (0.777)	-0.089415 (-1.289)	24.9129 (0.0000)
Δp_{t-1}	0.80924 (9.981)	-0.57984 (-5.851)	0.26334 (1.060)	0.078161 (0.115)	46.6909 (0.0000)
Δm_{t-1}	0.35929 (4.438)	0.79914 (8.075)	-0.36456 (-1.469)	-0.56162 (-0.828)	22.1057 (0.0000)
Δm_{t-2}	-0.19919 (1.756)	-0.27825 (-2.006)	0.16464 (0.473)	1.1531 (1.212)	2.09038 (0.0963)
Δm_{t-3}	0.21590 (2.828)	0.35805 (3.837)	0.0022968 (0.010)	-0.54507 (-0.852)	5.27283 (0.0013)
Δy_{t-1}	0.13897 (3.390)	-0.075805 (-1.513)	-0.52852 (-4.207)	0.70553 (2.053)	6.41792 (0.0003)
Δy_{t-2}	0.042047 (1.043)	-0.0092491 (-0.188)	-0.43271 (-3.502)	0.28610 (0.847)	3.38341 (0.0160)
Δi_{t-1}	0.024293 (1.440)	0.060987 (2.958)	-0.057773 (-1.118)	0.12050 (0.852)	3.96762 (0.0072)
Δi_{t-2}	0.025483 (1.468)	0.077173 (3.636)	-0.066920 (-1.257)	0.17393 (1.195)	5.96798 (0.0005)
Δi_{t-3}	-0.006226 (-0.359)	0.009929 (0.469)	-0.069827 (-1.314)	0.16442 (1.132)	1.40989 (0.2446)
Δi_{t-4}	-0.046596 (-3.037)	0.014873 (0.793)	-0.073427 (-1.562)	-0.15438 (-1.200)	3.86678 (0.0083)
Standard deviation of residuals	0.015571	0.019034	0.047726	0.130527	

t-values in parentheses.

Diagnostic tests:

Error autocorrelation in individual equations from lags 1 to 12:

	p-value
Δp_t	
$Chi^2(12) = 4.4242$	(0.9745)
F-form(12,40) = 0.24754	(0.9939)
Δm_t	
$Chi^2(12) = 14.225$	(0.2866)
F-form(12,40) = 0.95259	(0.5074)
Δy_t	
$Chi^2(12) = 22.926$	(0.0284)*
F-form(12,40) = 1.8605	(0.0706)
Δi_t	
$Chi^2(12) = 12.955$	(0.3723)
F-form(12,40) = 0.84597	(0.6048)

Vector tests:

Vector normality $Chi^2(8) = 21.956$ (0.0050)**
Vector Xi^2 F(220,206) = 0.75687 (0.9789)

* indicates rejection of the null hypothesis at the 5% level and ** at the 1% level.

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