Estimation of Russian Money Demand Using A General to Specific Modeling Methodology and Johansen's Cointegration Analysis

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January 1, 2001
Working paper

Abstract: This paper presents a methodological analysis of the macroeconomic data for the Russian transitional economy during the stabilization period of 1995:5 to 1999:6. Using David Hendry's methodology of general to specific modeling, a model is developed that is congruent with the Russian money demand data and also consistent with money demand theory. More specifically, the demand for M2 rubles is found to have a stable long run[1] relationship with the opportunity cost parameter, GKO[2], the rate of return on the government short term securities. The approximate parameters for a long run money demand function[3] are estimated from the cointegrating vector that describes the data; the M2 and GKO variables are cointegrated with a cointegrating vector of (1, .025). Weak exogeneity tests are also conducted and it is determined that the conditional single equation estimation of a money demand function is valid. The relationship between M2 and GKO rates are robust when estimated using both a system and a single equation approach.

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[1] The long run in this paper will not refer to a very long period. The period of interest in this paper covers a span of roughly 4 years using monthly data. As an empirical paper with the modest goal of estimating parameters of a money demand function for the period of interest, the long run will be defined in these terms

[2] Gosudarstvennyie Kratosrochnyie Obligatsie (State Short-term Debt)

[3] Numerical estimation and modeling was conducted on PC-Give and PCFIML Version 9.2.

1. Introduction

This paper presents a methodological analysis of the available macroeconomic data for the Russian transitional economy. Using David Hendry's methodology of general to specific modeling, a model is developed that is congruent with the Russian money demand data and also consistent with money demand theory. Specifically, a money demand relationship is found between the M2 aggregate and the rates of return on the short term government securities, the GKO's. The primary objective of this paper is to estimate the parameters for a money demand function for the period of Russian monetary history from 1995:5 to 1999:6, i.e., from the beginning of the monetary stabilization through the collapse of the ruble. Finally, I conduct weak exogeneity tests on the determinants of Russian money demand to examine the validity of estimating a conditional single equation money demand function.

The paper is organized into 7 sections. Starting in section 2, an introduction to the short history of monetary policy making in Russia's transitional economy summarizes the stages of reform. Beginning with the pre-transition socialist period, the monetary systemof the followed by the initial liberalization period, and then the period of monetary stabilization which collapsed along with the ruble in August of 1998. Section 3 follows with a discussion of the literature that builds the foundation of the theory and modeling that I use in the rest of the paper. In addition, the current literature on empirical studies of the Russian monetary system is presented. Section 4 discusses the economic foundations of money demand and the empirical equations that are found in the literature. Section 5 describes the data that is being modeled along with a discussion of the pitfalls of empirical work using Russian data. Section 6 begins the estimations starting with a vector autoregression representation and ending with a parsimonious conditional single-equation model for Russian money demand. Finally, section 7 contains some concluding remarks.

2. Periods of Russian Monetary Policy

The monetary system in Russia has undergone a number of different phases in its short post socialist history. The Russian monetary system immediately following the loss of power of the Communist party was an artifact of the old Soviet system that consisted of a central bank, Gosbank, that served mainly as an accounting agency for the planned economy. The monetary system had a subordinate role to the coordination and implementation of the socialist economic plan. Monetary and credit policy was primarily a means to facilitate the fulfillment of the plans in the socialist economy.

Soviet monetary system

In actuality, two separate monetary systems, the cash and the non-cash systems, existed prior to the collapse of the Soviet system in 1990. In the cash system, the population's currency on hand and savings accounts supported personal consumption. While a second system, the non-cash system, existed to support the real sectors of the economy.

In the first system, the cash system, wages, pensions and other social transfers were regulated so that the volume of cash was made to correspond to the increase and decrease in the production of consumer goods and services. Therefore, in the initial stages, inflation in the consumer sector was virtually non-existent as long as the central authorities were able to maintain this balance between income and output of consumer goods and services. However, periodic confiscatory monetary reforms were still necessary to suppress open inflation. In the early 1980's , shortages or "deficits" made it necessary for the first time in the post-war period to issue rationing cards and coupons for consumer goods.

In the non-cash system, the State bank was responsible for allocating credits to those enterprises charged with carrying out the state production plans.[4] The volume of non-cash rubles was regulated to correspond to the volume of resources that were centrally determined for each production enterprise. These credits in the non-cash system could not be used for purposes other than those planned by the central authorities. In this way, a barrier was created to prevent the conversion of non-cash rubles into cash rubles. A good description of the Soviet monetary system can be found in Zhukov (1994).[5]

Towards the end of the socialist period, barriers between the cash and non-cash circulations began to break down. The process was accelerated by a number of reforms intended to spark initiative within the enterprises. The intent was to spur production by allowing the individual enterprises to retain partial control over the use of the centrally-allocated credits. The result was that the central planning authorities lost control over wages. Non-cash rubles also became easily convertible into cash rubles through a number of different channels. This led to increasing inflationary pressures in the markets for consumer goods. Unable to put the inflationary genie back into the bottle, Gaidar's government in 1992 tried to monetize the non-cash rubles by giving non-cash rubles the status of full-fledged money. According to Zhukov, this decision contributed to the massive price shock of January 1992.[6]

The Early Transition period (1991- 1995)

This period brought about the greatest change in the Russian monetary system to date. It was during this period that for the first time in 80 years many prices for consumer goods and some intermediate goods were freed from state controls. The collapse of the barrier between the two separate cash and non-cash systems was mentioned above. The world was introduced to a dozen new currencies, e.g., Estonia's Kroon, Kazakhstan's Tenge, Azerbaijian's Manat, etc.) as the ruble zone broke down in 1993. The Russian ruble became convertible with the Western currencies and an independent Russian Central Bank was legally created.

Dramatic changes in Russia's economic institutions were inevitable for a country as large as Russia undergoing its second economic revolution in the same century. In 1990, Russia began the transition to a market economy without a memory of a functioning monetary system in its recent history. The old monetary institutions needed to be dismantled or at least transformed before new institutions could be created that would support the fledgling market economy. All market economies depend upon a monetary and financial system to provide the liquidity and stability for the smooth functioning of its operations. Russia was in effect starting from scratch.

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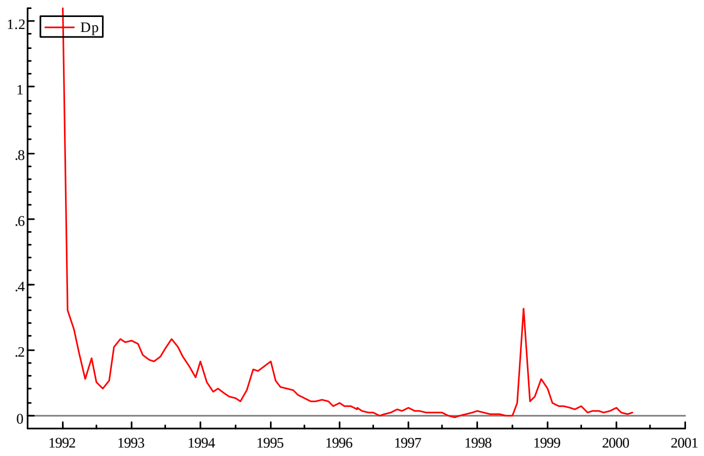
[4] See S. Zhukov (1994).

[5] Ibid.

[6] Ibid.

The abandonment of price controls on consumer goods was one of the first steps undertaken to encourage the formation of markets. The lifting of price controls along with an increase in government credits directed towards favored sectors and regions resulted in the near hyperinflation years of the early 1990's.

Figure 2.1: Monthly Inflation



Early attempts at monetary control were mixed. In 1992, reform minded economists led by Yegor Gaidar carried out conventional anti-inflationary measures; such as, cutting public spending, slowing M2 growth and raising reserve requirements on commercial banks, and managed to bring the inflation rate down to 9% by August 1992. This proved temporary as the political climate dictated renewed growth in M2 and the release of more directed credits. Another attempt at reform in the middle of 1993 brought about a short term respite from double digit monthly inflation. However, this too was short-lived as the release of large directed credits again sidelined attempts to control inflation. There was some success as the Central Bank refinancing rate turned positive during this time for the first time since the reforms began.

It is during this period that the phenomenon of non-payment arrears becomes an important factor in the attempts of the central monetary authorities to control monetary and credit policy. The restrictive credit policies pursued by the reformers during this time led to "creative" financing alternatives for the real sector. In an early commentary on the rampant inflation of the early 1990's, Zhukov (1994) remarks that the response of enterprise managers to a tightening of credit by non-payment should not be surprising given the history of the Soviet split system of cash and non-cash accounting.

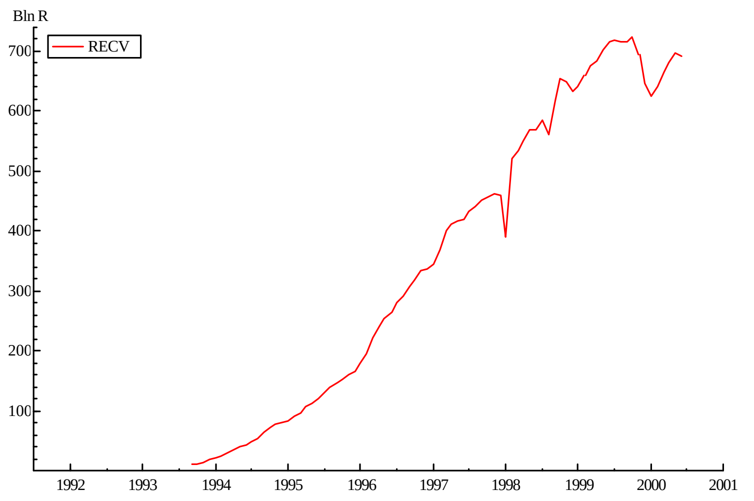
"However, the real sector dispelled these illusions (of reduced inflation) and demonstrated its extraordinary viability by creating a special type of financial imbalance that was highly predictable for a Soviet type economy."[7]

This form of financing by creating liquidity through the use of credits and debits on the individual accounts of enterprises is not much different from the Soviet non-cash

[7] Zhukov, S. (1994) "Monetary Aspects of Russian Reform (Part One)," Problems of Transition, April 1994.

accounting system used during the Soviet planned economy. Managers of enterprises were simply continuing with a financial practice that had been in place for decades. In relation to the central monetary authorities, inter-enterprise arrears threatened the control over monetary policy. Figure 1 below shows the growth of inter-enterprise arrears during the transition.

Figure 2.2:Inter-enterprise Arrears



The growth of arrears has been constant throughout the entire period. Its importance in the present paper lies in the role of arrears as a substitute for money.[8]

Stabilization Period (1995-1998)

The beginning of the stabilization can be traced back to 1995 when both fiscal and monetary discipline brought the rate of inflation down to less than 1% per month (see figure 2.1). A number of different factors can be attributed to the stability that was achieved during this period. First, the central bank significantly increased the reserve requirements for commercial banks to reduce liquidity. Second, the government managed to maintain deficits within levels agreed upon with the IMF and financed the deficits through government securities and foreign borrowing instead of central bank emissions. Deficits of over 20% of GDP in 1992 were brought down to 5.4 % of GDP in 1995.[9] Third, the collapse of the ruble-zone insulated Russia from the inflationary flows from the other republics. Fourth, a law passed in January 1995 formally established, at least in writing, the independence of the Russian central bank.

Stability in the exchange rate for the Russian ruble was also achieved through a ruble corridor, introduced in July 1995. The ruble was maintained within a narrow corridor of R5,000 to R5,600 per dollar allowing for monthly depreciations of up to 1.5%. It is more correct to refer to this type of fixed exchange rate as a “crawling peg” since periodic devaluations still do take place. This crawling peg remained intact for the most part throughout the stabilization period. As figure 2.3 shows below, the devaluations for the ruble during this time period were fairly regular and predictable.

[8] See Slobodkine (1997) “Monetary Policy and Inter-Enterprise Arrears in Russia,” East European Series No.49, Institute for Advanced Studies, Vienna.

[9] See Buch (1998)

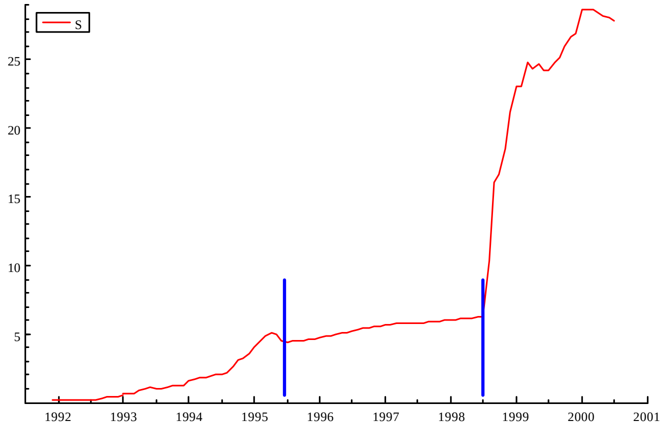


Figure2.3: Ruble/U.S. dollar exchange rate

The crawling peg provided a period of stability and predictability that increased the confidence of domestic and international investors in the Russian reforms. As noted above, government deficits were increasingly financed by sales of government securities to both domestic and international investors during this period.[10] The pegged exchange rate put some constraints upon the ability of the monetary authorities to conduct monetary policy. Sterilized interventions were only possible on a limited basis because of an under-developed market for the Russian government securities.

This less volatile environment also provided the Russian government with its first experience in raising capital on the world capital markets. The first Russian Eurobond debuted in December 1996 raising $1 billion. Numerous other Eurobonds were issued throughout this period raising nearly $9 billion.[11]

The development of financial institutions in Russia during this period continued to be slow and halting. The banking system continued to be dominated by the major commercial banks, many with connections to the financial industrial groups (FIG), and the large state bank, Sberbank. These banks did not perform the financial intermediary role of providing needed capital to the private sector. According to the Russian Economic Trends[12], credits to the private sector by the Russian banking sector amounted to only 7% of GDP, as compared to 15% in Poland, 24% in Hungary, 63% in the Czech Republic, 111% in Germany and 175% in Japan in 1996. A major source of income for the large commercial banks during this time was the large positive returns from the purchase of the government's short term debt, the GKO's. In January 1998, the 30 largest banks held 25% of their assets in government securities.[13] Sberbank alone held more than half of their assets in government securities.

10 Foreign investors were allowed to purchase and repatriate, under limited circumstances, Russian government securities and interest beginning August 1996.

11 Various issues from Economist Intelligence Unit, December 1997, http://~:~@www.securities.com/cgi-bin/news_dp/94dec/RU/News/eiu-ru/971208day.html

12 Russian Economic Trends, Monthly Update, October 1997, website: http://www.hhs.se/site/ret/update/oct97/special.htm

13 Rusline, List of largest 100 Russian banks, January 1998, website: http://banker.rating.ru/ENG/100/98_01_01_100.HTM.

3. Literature Review

The growing field of cointegration analysis in the study of money demand and other long run economic relationships began with the work of Davidson, Hendry, Srba and Yeo (1978) and was formalized by Granger (1983) and Engle and Granger (1987). Their work demonstrated that economic variables that individually contained unit roots with permanent effects could be shown to be cointegrated with their linear combinations being stationary processes. Engle and Granger (1987) were able to show that cointegration of variables in a vector autoregressive representation implied that differencing could not be applied to a VAR process containing integrated variables. In Stock and Watson (1988), they proposed a common trends representation for the cointegrated system. The representation of the cointegrated system that is used in the present paper is the equilibrium correction representation[14]. The main focus of the work on cointegrated systems up to then consisted of estimating and testing the presence of a single cointegration vector linking the integrated variables.

Johansen (1988, 1991) introduced a more general method of estimating the cointegrated system through the use of full-information maximum likelihood to estimate the linear space spanned by the cointegrating vectors. In their work, Johansen and Juselius (1990, 1992) apply Johansen's work to empirical modeling of money demand functions. They address a number of issues that arise in attempting to obtain economically meaningful inference from the maximum likelihood estimates for the cointegrating vectors: these include identification issues, maximum likelihood estimation under restrictions and the asymptotic distributions of the critical values. Johansen's cointegration method and equilibrium correction models have become the standard in doing empirical work on money demand estimation.

The methodology used in this paper follows David Hendry's general to specific modeling of simultaneous equations. The partial listing of the literature on David Hendry's econometric methodology includes his text on Dynamic Econometrics (1995), a paper by Ericsson, Campos and Tran (1991) and the numerous empirical papers listed below.

Empirical work using Johansen's full information maximum likelihood to estimate money demand functions has produced a substantial body of literature. The studies that I name below are only a partial listing of work done in this area. David Hendry and Neil Ericsson have contributed much to this field. Hendry's work with Mizon (1988) and Ericsson (1991) on U.K. money demand laid the groundwork for empirical work on money demand estimation. Ericsson's papers include, a review of the key issues in modeling money demand (1998) and empirical studies on a list of countries: Broad money demand in the United Kingdom (1998); Inflation in Australia (1998), dollarization and money demand in Argentina (1993); and broad money demand in Greece (1998). A recent study on narrow money demand in Malaysia is one of the few that apply cointegration methods to estimating empirical money demand in developing countries (Sriram (1999)).

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[14] Commonly referred to as an Error-correction model. Equilibrium-correction model is more correct. See Hendry (1995) p. 213 for a discussion about the differences between the two.

The short history of modern monetary policy in Russia and the accompanying problem of short data series has held back much of the empirical work on money in Russia. There are also other problems that have also caused problems in empirical modeling of Russian money demand equations; for example, issues concerning dollarization, the under-development of financial institutions and the practice of inter-enterprise arrear. I deal with some of these issues in a later section. In spite of these obstacles, there has been some empirical work done on Russian monetary policy and these include Koen and Marrese (1995), Anderson and Citrin (1995) , De Broeck et al. (1997), Korhonen (1996) and Buch (1998).

A brief look at some of these empirical papers on Russian money demand reveals some of the stylized facts of the Russian macreconomic data. Koen and Marrese (1995) find a relationship between money growth and inflation with a lag of 4 to 5 months using an Almon equation but fail to link output with any of the monetary or price aggregates.

The study by Anderson and Citrin (1995) examines the behavior of inflation and velocity in the Baltics, Russia and the other former Soviet countries during the 1992-1994 period. They find that although the path of inflation closely followed the growth rate of monetary aggregates in these countries, there are divergences between rates of inflation and monetary expansion.

In De Broeck et al. (1997), the study looks at a panel of countries of the former Soviet Union including Russia[15]. They observe the behavior of velocity for the time period of 1993 to 1996 as stabilization programs are implemented across these countries. Some of the stylized facts that they find in these countries are: 1.) Velocity increased in the early stages of stabilization. 2.) Moderate changes in the velocity following stabilization and in the case of Russia, a decline in velocity late into the stabilization

Buch (1998) estimates a single equation equilibrium correction model of money demand by regressing an M2 variable against an equilibrium error term and lags of first differenced M2 and the Russian Central Bank Refinancing rate as the opportunity cost of holding money. She does not employ the two-step Engle and Granger procedure. Unfortunately, there is no systematic discussion of the procedures used to estimate the cointegrating vector.

4. Estimation of Money Demand

Money is demanded in a modern market economy for two reasons: as a means of conducting transactions, the medium of exchange function, and as one of several assets that make up a portfolio, the store of value function. If we represent the demand for real money as a function of these roles for money:

$$\frac{M}{P} = L(Y, R) \qquad 4.1$$

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[15] The countries in the study include the Baltics, Armenia, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Moldova, Russia and the Ukraine. Belarus, Turkmenistan and Uzbekistan were not included because stabilization came later than 1997. Tajikistan was not included because of data problems.

Where,

M - nominal measure of a monetary aggregate
P - the price level
Y - scaling variable that represents economic activity
R - the opportunity cost of holding money

The scaling variable Y represents the transactions demand for real money balances. In empirical work, it is typically proxied by a measure of economic activity such as GDP or industrial output. The opportunity cost of holding money includes rates of return on alternative domestic assets within a closed economy and returns on foreign assets when an open economy is modeled.

Functional Forms of empirical models[16]

PAM (Partial Adjustment Model)

The traditional approach to estimating money demand functions beginning with Chow (1966)[17] has been to use the log-linear equation for a long run money demand function.

$$\ln M^* = \ln A + b_1 \ln Y + b_2 R + u \tag{4.2}$$

$$M^* = AY^{b_1} e^{b_2 R} e^{u} \tag{4.3}$$

Equation 4.2 is the linear form of the multiplicative real money demand function.

M*	is the real Long-Run money demand
Y	is income
R	is the real rate of interest on other assets
b_1	is the elasticity of income
b_2	is the elasticity of the interest rate
u	is the disturbance term

The adjustment equation that is used to model the difference between the Long-Run real money demand and the actual demand is also from Chow (1966).

$$M_t - M_{t-1} = l(M_t^* - M_{t-1}) \tag{4.4}$$

l	is the adjustment of actual money demand compared to equilibrium real demand

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16 Sriram, Subramanian (1999) "Survey of Literature on the demand for money: Theoretical and Empirical work with special reference to Error-Correction models", IMF Working paper no. 64, WP/99/64.

17 Chow, Gregory (1966) "On the Long-Run and Short-Run Demand for Money", The Journal of Political Economy, Vol. 74, Issue 2, pp. 111-131.

M_{t-1} level of previous money stock

By substituting for M* in equation 4.3 with 4.4 we have

$$\ln M_t = \lambda \ln A + \lambda\beta_1 \ln Y + \lambda\beta_2 \ln R + (1-\lambda)\ln M_{t-1} + \varepsilon_t \qquad 4.5$$

The PAM performed well in modeling money demand functions for post-war data up to 1973; but performed badly for data after 1974. Specifically, it was unable to explain the instability of the money demand function in the 1970's during the well known "missing money episode".[18]

Amongst the criticisms of the PAM models is the simplistic modeling of the short term dynamics of the dependent variable. The lagged values of the dependent variable, M_{t-1}, turns out to be highly significant in many estimates and the models implied unrealistic long lag adjustments in money stocks. Another criticism involved the small interest rate elasticity coefficients in the short run and the larger long run interest rate elasticity coefficients, which implied an interest rate overshooting that is not found in the real world.

BSM (Buffer Stock Models)

In the 1980's, the Buffer Stock Model paradigm became the common alternative procedure used to estimate money demand functions. Derived from the theoretical foundations of the "precautionary motive" of money demand, the BSM overcame two shortcomings of the PAM procedure, namely, the interest rate overshooting and the long lag in money stock adjustments. This line of modeling improved upon the PAM in certain ways, but also fell short in a number of ways. In particular, the BSM's introduced a more complex dynamic structure to the estimation of money demand functions and explicitly included money shocks in the model to address the criticisms levied against the PAM models. However, the BSM faired poorly when actually used in estimation.

The Buffer Stock Models differs from the PAM in that changes to the money stock are considered to be exogenous and primarily determined by supply factors. Individual agents hold stocks of real balances as "buffer stocks" to smooth over unexpected mismatches of expenditures and real balances. Economic agents thus allow temporary deviations of their holdings of money stocks from their desired levels when an unexpected monetary shock produces an inflow into current holdings. Adjustments are made according to an average target level of desired holdings. A survey of the BSM literature can be found in Laidler (1984, 1988), Cuthbertson and Taylor (1987), Milbourne (1988) and Cuthbertson and Barlow (1991).

Equilibrium Correction Models

The most recent empirical studies on money demand estimation have used equilibrium correction model (ECM) analysis to capture both the short run dynamics in the movements in money and the long run relationship between money demand and its principle components. The ECM structure retains the information that the variables in levels provides about the long run relationship between the variables. Whereas the VAR analysis

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[18] Sriram, Subramanian (1999), page 31.

in first differences solved the problem of spurious and nonsensical regressions, it lost important information found in the levels of the variables. The application of equilibrium correction models, along with the general to specific research program in the modeling of money demand equations has provided a great impetus to investigating parameter constancy in the long run money demand relationship.

Methodology

The general to specific methodology is an attempt to discover a parsimonious model that is congruent with the data through a methodical testing and evaluation of reductions of the most general model formulation that describes the data. The approach brings together both the theory-driven approach and the data-driven approach that characterizes much of the empirical work done in macroeconomics today. The following describes a typical theory-driven approach. Model building starts with a postulated theoretical model. Data evidence is then used to calibrate the theoretical model's parameters. If the data is consistent with the theoretical model, it may or may not confirm the validity of the theory. The problem arises when the empirical evidence cannot be made consistent with the theoretical model. In practice, this can often lead to revisions in the empirical model, the measurements instruments and/ or the theory until consistency is finally achieved.

On the other hand, the data-driven approach starts with the data. It imposes no structure upon the data and develops a model just to describe the data. The problem here lies in data dependence where accidental and transient data features are embodied as tightly into the model as the permanent aspects. These models are bound to fail predictive and forecasting tests as the sample is expanded outside the original data set. Restrictions to offset this dependence can only bring structure if the resulting parameters are really invariant aspects of the underlying relations.[19]

The general to specific methodology is an attempt to test and evaluate simplifications of the most general description of the data generating process in order to arrive at "simple parametric relationships which remain reasonably constant over time, account for the findings of pre-existing models, and are interpretable in the light of the subject matter"[20]. The simplifications of the general model are conducted through a series of transformations and reductions. Typical transformations include aggregation and standard mathematical operations of division, logarithms, etc. Reductions include reductions of lag lengths and other unwanted variables, but also conditioning on exogenous variables. The outline of the modeling procedure that is followed below is consistent with Hendry (1995). It can be summarized as follows:

- Data description and analysis including; graphical, order of integration of variables, seasonal adjustments, financial innovation, dummy variables, trends, constants, visible correlations. Check the residual correlations for the system to get a preliminary sense of the direction to be modeled
- "System congruency" against historical data.

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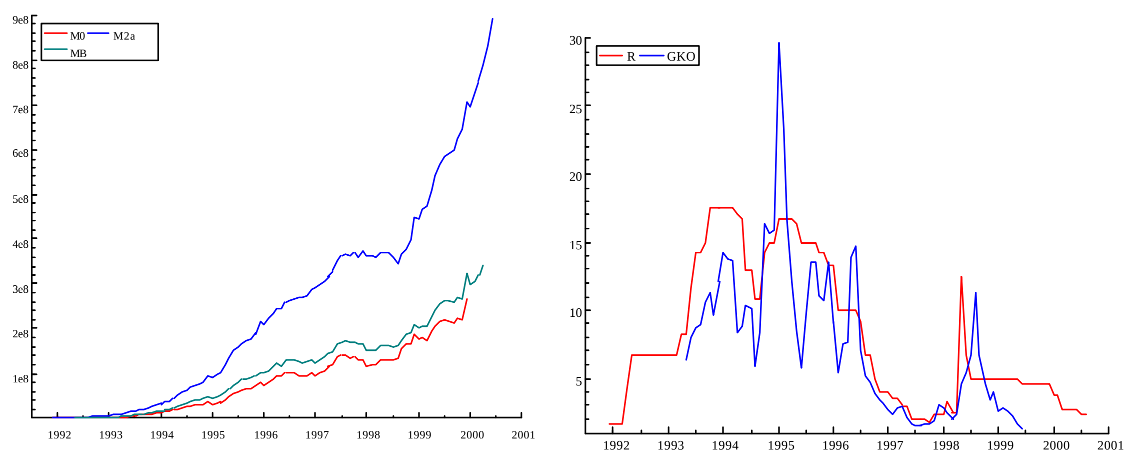
19 Hendry (1995) Ch. 15.

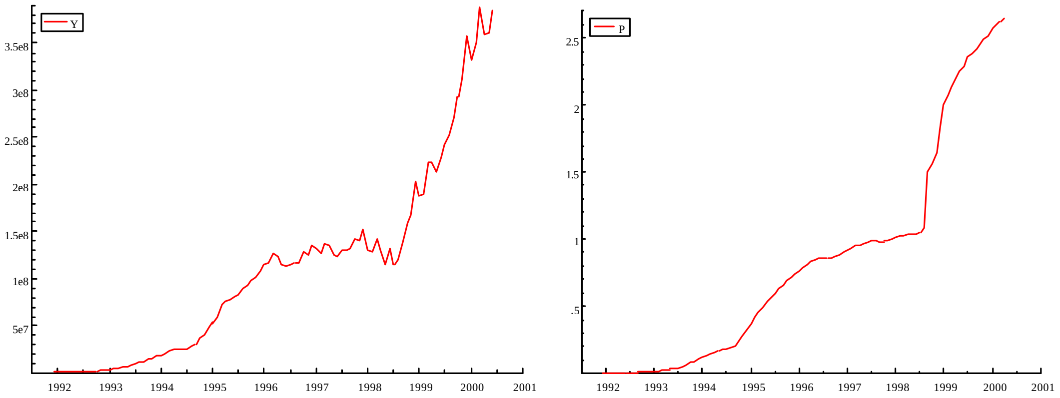
20 Ericsson, Campos and Tran (1991)

    1. Check the unrestricted VAR estimates and look for significance in the coefficients. If many are not significant, considerable simplification should be possible after suitable transforms designed to facilitate the interpretation of this multi-dimensional evidence.
    2. Check reports on statistics for lag lengths. (see page 593, table 16.3 in Hendry (1995))
    3. Check the graphics of the system, the actual and fitted, cross-plots, and scaled residuals. Especially the residuals to see if they look like white noise.
    4. Check the statistics of the goodness to fit evaluation. Ex. Equation residual standard deviations, single equation evaluation statistics for no serial correlation; no ARCH, no heteroscedasticity; normality; and analogous system (vector) tests.
    5. Checking parameter constancy using recursive estimation. Since the data are non-stationary, constancy statistics are descriptive rather than inferential. Looking at the 1 step residuals for each equation, then the corresponding sequences of breakpoint Chow tests and finally the system breakpoint test sequence.
- After a satisfactory outcome, investigate cointegration.
- Test for weak exogeneity of inflation, income and interest rates for the parameters of the money demand function. (This determines the mapping to I(0) space and the extent of feasible conditioning reductions, i.e. the size of the system to be jointly modeled.)
- If a single equation is practical, model by reduction of lag length and transformations to a more interpretable parameterization.
- Check for parameter constancy, especially across interventions.

Figure 5.1: Data


a) Monetary aggregates

b) GKO and Central bank refinancing rate


c) Indutrial output

d) Consumer Price Index

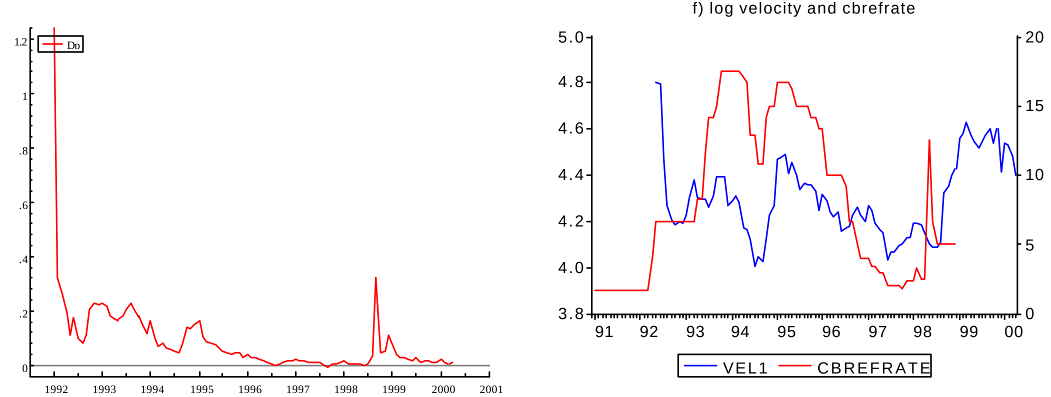
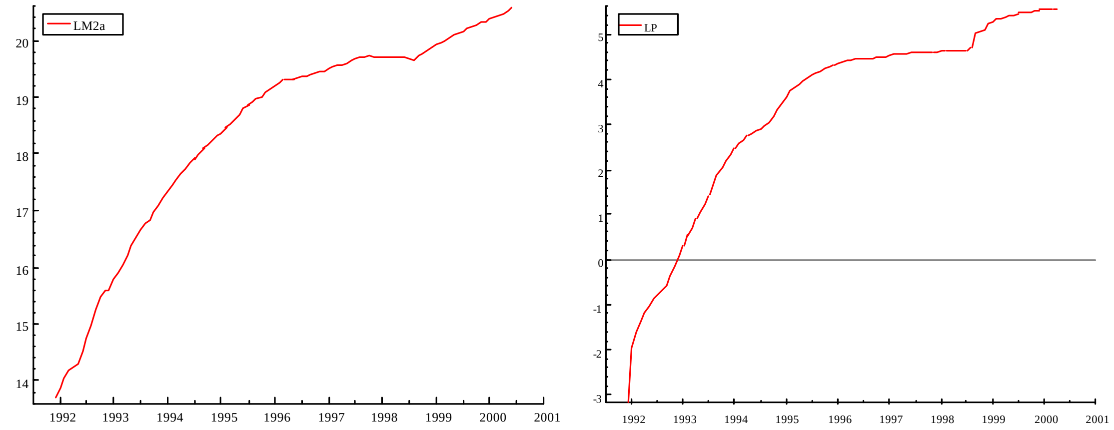
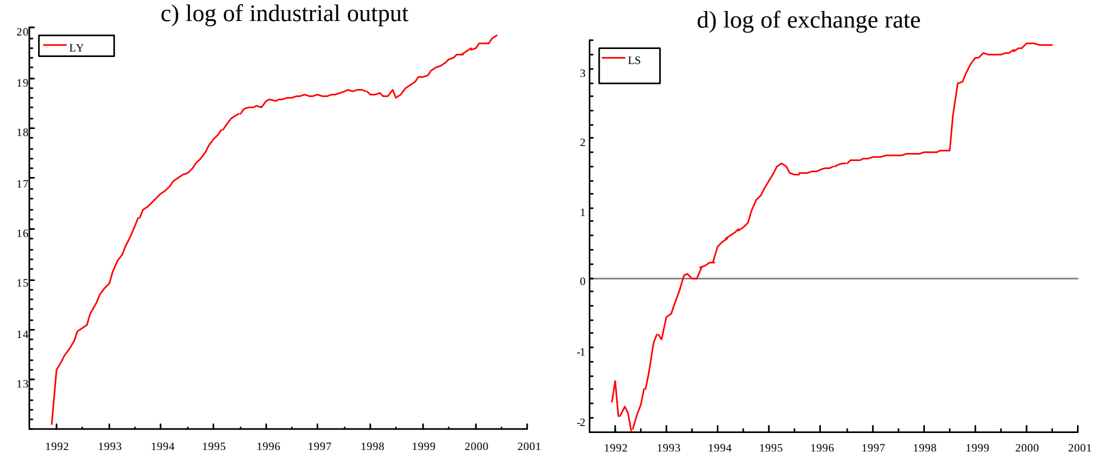

e) Monthly inflation rate

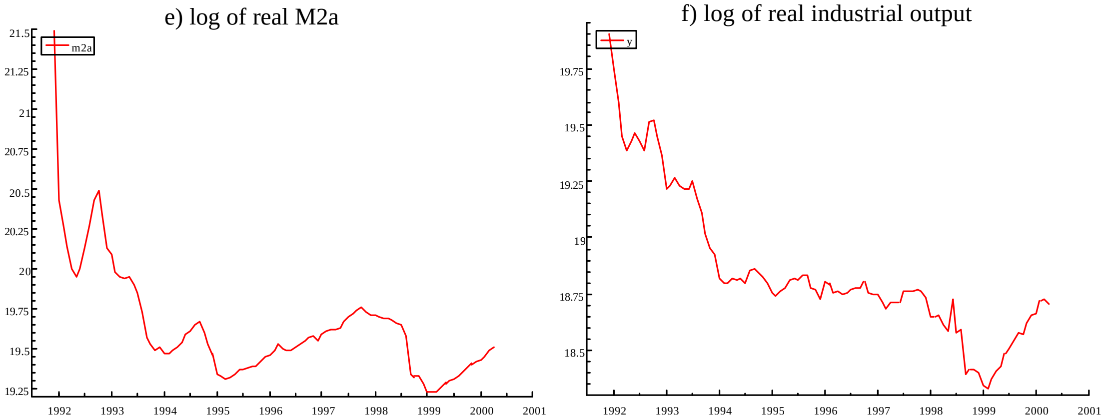
Figure 5.2: The log of the variables


a) log of M2a

b) log of CPI

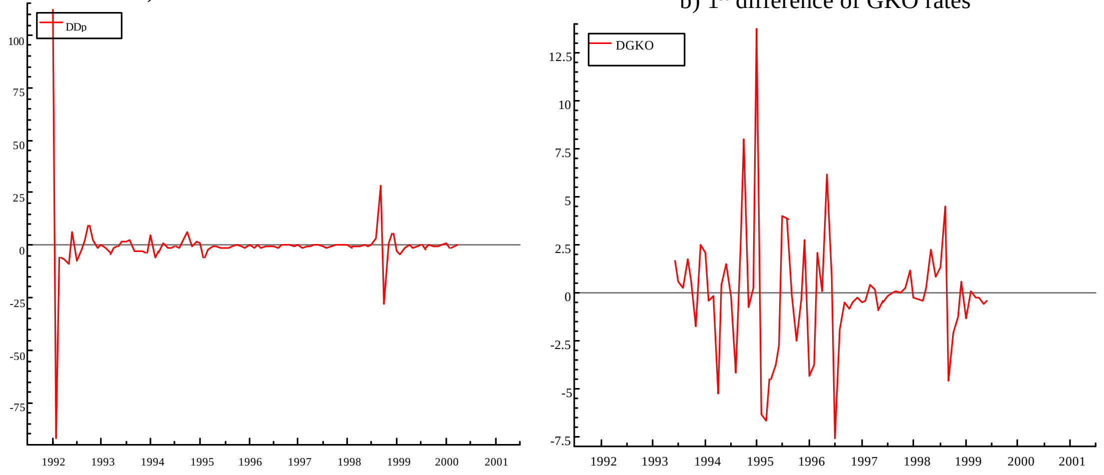

c) log of industrial output

d) log of exchange rate


e) log of real M2a

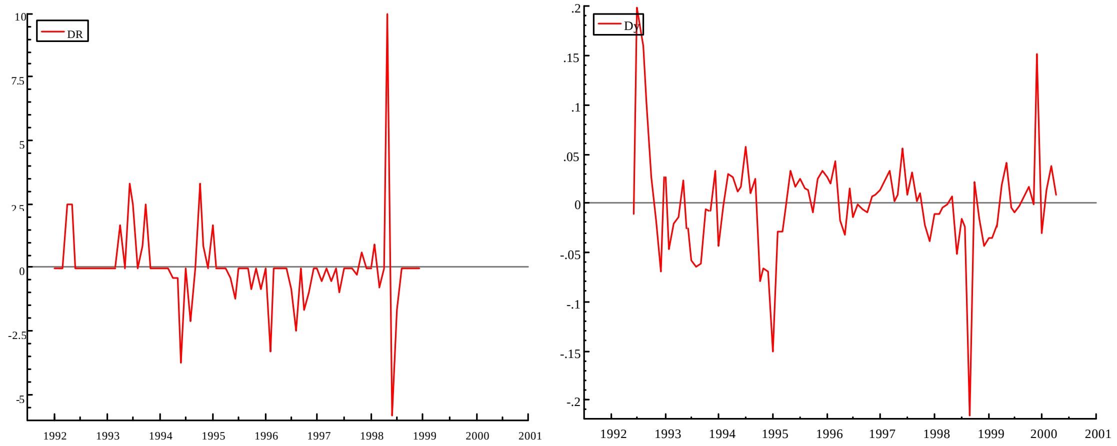
f) log of real industrial output

Figure 5.3: 1st Differences of variables



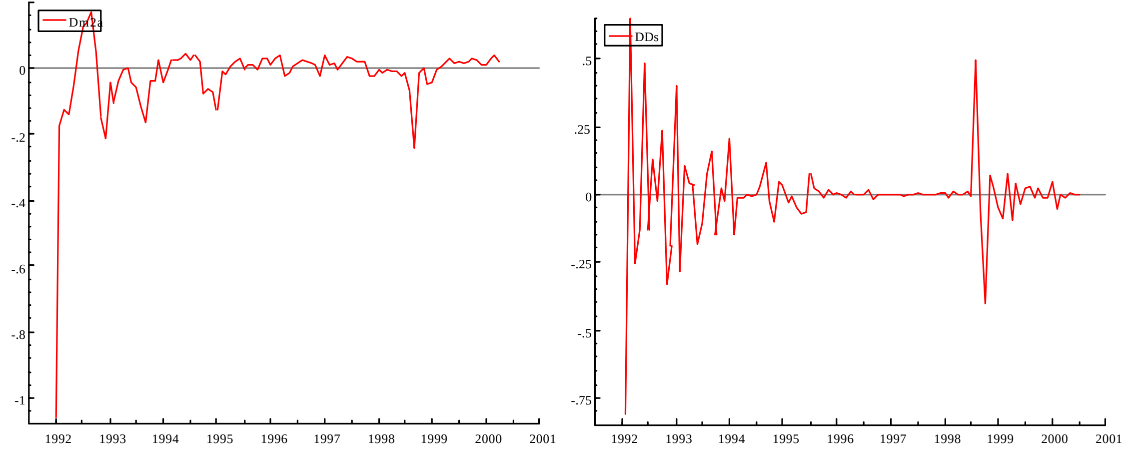
a) 1st difference of inflation

b) 1st difference of GKO rates



c) 1st difference in CB refinancin rate

d) rate of change in industrial output



e) rate of change in real M2a

f) rate of change in devaluation

5. Data Description

Monetary Aggregates

Figure 5.1a) shows the measures for monetary aggregates that are available for the present analysis. The convention I use in designating variables is as follows. Nominal variables are denoted by capital letters and real variables are in small letters. The three available monthly series includes M0, M2 and a monetary base series[21]. M0 is the stock of ruble currency and coins in circulation outside the banking system. The source of this series is the Bulletin of the Central Bank of Russia. M2 is from the IMF and defined as M0 + the value of current bank accounts + deposit or interest bearing accounts. The last series, the monetary base is high-powered money and also from the IMF. The monetary base is the sum of reserve accounts of financial institutions at the Central Bank and currency in circulation.

As figure 5.1a) show, there are two different series for M2, the old series from 1990:12 to 1997:12 and the new series from 1998:01 to the present. These two series were combined to construct an adjusted M2a series[22]. The analysis below will use both the adjusted M2a series and the monetary base series, MB, seasonally adjusted[23].

Opportunity Cost

Figure 5.1b) graphs monthly rates of returns on three different instruments in Russia and the rate of return on real goods can be proxied by the inflation rate in 5.1e). CBREFRATE is the Central Bank refinancing rate. The refinancing rate is the rate that the Russian Central Bank uses to indicate the direction of monetary policy. It isn’t the rate at which commercial banks borrow from the Central bank as in other economies; instead, it serves as a cap for yields on the government’s debt. Therefore, it serves as a proxy for the return on the short term government debt, the GKO[24].

GKO rates are the average yield on the secondary markets for the Russian government’s debt instruments. This series was also collected from two sources, the Russian Economic Trends database and the Datastream data service[25]. The interbank rate is the 1-30 day interbank rate for borrowing between the commercial banks.

The movements for all three rates of return do seem to move together, rather loosely, in the long run. The series for the GKO rates and the interbank rates are not available for the period from about mid-1997 onwards. Data for the GKO rates were no longer available after the collapse of the ruble fixed rate regime and the default on the government debt in 1998:8.

Scale variable

The series that are available to capture the transaction demand for the ruble are industrial output and GDP. Figure 5.1c) shows IND, RDGPSA and RGDPSUN. IND industrial output at current prices dates back to 1990:12. However, the series for GDP,

---

[21] Time series are from Russian Economic Trends, database August 2000.

[22] The older series is adjusted by taking the mean of an adjustment term (ratio of the value in the new series to the value in the old series) for the overlapping values and using it to adjust the older series.

[23] Seasonally adjusted using X12arima.

[24] Gosudarstvennyie Kratosrochnyie Obligatsie (State Short-term Debt)

[25] RET, various issues of the Bulletin from 1997 to 2000. Datastream service.

both nominal and real, are discontinued after 1998:8 for the monthly format and released quarterly thereafter. RGDPSA is the seasonally adjusted measure of RGDP and RGDPSUN is the seasonally unadjusted series. The analysis will include estimations using both the long industrial output series, seasonally adjusted and the shorter RGDP measures.

It is generally accepted that much of the economic output in Russia is under reported in the official government figures so that these measures are downward biased.

Price index

The price index is from the consumer price index that is seasonally adjusted and normalized at 1997:12. A comparison of the producer price index and the consumer price index show that the two indices are identical up to 1998:8 when the two series begin to diverge.

Inflation

Figure 1 also shows the growth rate of P. It is evident from figure 1 that the inflation rate has decreased in variance from the early 1990's to the present, excluding the period following the ruble collapse and government default. There is also a slightly noticeable reduction in the variance of output growth rates.

Innovations, Breaks in Trends and other Issues

There have been a number of changes in the conduct of monetary policy that need to be assessed to provide congruency with the data. Beginning in 1995, the monetary authorities fixed the ruble to a narrow band relative to the U.S. dollar. The fixed exchange crashed in August 1998. The dummy variables D1 and D2 are included in the VAR estimation to adjust for the largest outliers during the collapse of the ruble in August 1998. D1 is an impulse dummy variable representing the shocks of to the inflation rate from the 1998 devaluation. A value of 1 at 1998:8 and 1998:9. These were the two turbulent months for inflation and real balances. D2 is a step function to account for the collapse of the GKO market in the default after 1998:8.

A trend term enters the cointegration space so that a quadratic trend is avoided in the levels. The use of dummy variables and trends follows their treatment in Hendry (1995).

Integration of variables

The problem of stationarity requires testing the variables of interest to determine: 1) whether a variable is integrated and 2) the order of integration of a variable. Attempts to make inference in regressions with non-stationary residuals leads to nonsensical and spurious results[26]. Therefore, the standard unit root tests using the Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) critical values are conducted for the variables of interest, their first difference and the second difference before moving onto the analysis of the system. The sample size for the unit root tests includes all available observations. The actual test results are provided in appendix 1 and summarized in table 5.1 below. In addition, a graphical analysis is included to help clarify and confirm the results of the tests.

[26] See Granger and Newbold (1974) and Phillips (1986)

Table 5.1: Summary of ADF(13) statistics for testing for a unit root[b]

Variables

Null Hypothesis	mb	m2a	p	R	GKO	y	s
I(1)	-1.6664 (0.93754)	-2.8424 (0.9300)	-3.6628* (0.96473)	-2.9229 (0.86857)	-3.1877 (0.70295)	-1.4906 (0.93687)	-2.1326 (0.94527)
I(2)	-6.9266** (0.24530)	-5.5284** (0.48063)	-2.9990* (0.78827)	-9.5005** (-0.14797)	-7.0850** (0.054656)	-6.9266** (0.24530)	-5.6056** (0.46480)

Notes:

a For a given variable and null order, two values are reported: the significant order ADF statistic estimated with a constant and a trend; and (in parentheses) the estimated b coefficient on the lagged variable, *where that coefficient should be 1 under the null hypothesis.* For variables with no visible trends, tests were conducted without the trend.

b Lags for the ADF tests reflect the first significant lag.

* rejects at the 5% level

** rejects at the 1% level

The results from the unit root tests show that we cannot reject the null hypothesis that the variables are integrated of degree one for: (mb, m2a, R, GKO, y and s). The results also indicate that we reject the null for p that it is integrated at the 5% significance level. We also reject the null of p being integrated of degree two, i.e., the null that Δp is integrated of degree one. Since there is no convincing way to distinguish between stationary and non-stationary processes in finite samples, there is still some uncertainty in coming to a final conclusion on the stationarity of these variables. There is some indications from the figures above that p is integrated of order two, such that Δp is integrated of degree one. In figure 5.1 Δp does not appear to be stationary whereas $\Delta^2 p$ in figure 5.3 does appear stationary. We will therefore assume that Δp is integrated of degree one.

6. General to Specific Modeling

Specifying a VAR

In following David Hendry's econometric methodology[27], we start with the most general model formulation to fit the available data and check for congruency. The most general model for the data available is a vector autoregressive system of the four variables (GKO, m2a , y, Δp) including the dummy variables D1 and D2 discussed above. The lag length is determined by starting from a lag length of 12 and examining the reduction of each

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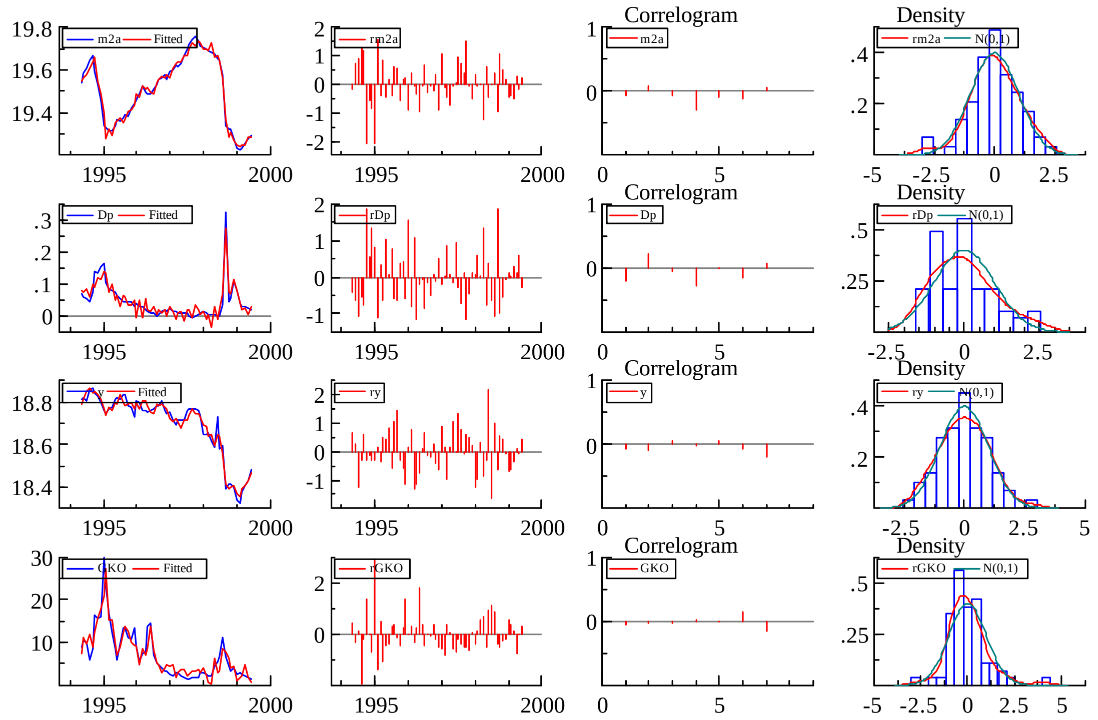
[27] A summary of David Hendry's "general-to-specific" methodology is found in Ericsson, Campos and Tran (1991), International Finance Discussion Papers, No. 406, August 1991, Board of Governors of the Federal Reserve System.

lag length through an overall F-test and a model-selection criterion. The residuals are also checked to make sure that they are normally distributed white noise. A lag length of 6 is determined to satisfy the conditions of whitening the residuals. See Appendix 2 for the PCFIML output. Figure 6.1 below shows the residuals from a VAR(6).

Figure 6.1: residuals for the VAR(6)



The first column shows the graphs of the fitted and actual values of the VAR(6) system for (m2a, Δp, y, GKO). The close fit is a result of the non-stationary nature of the variables and should not be taken as evidence for the goodness of the system representations. The second column graphs the scaled residuals from the estimation and reveals fairly random (white noise) errors. The third column plots the correlograms of the residuals without any evidence of autocorrelation in the residuals. The final column graphs the residual histograms. A cursory look at the graphs shows that the fit seems satisfactory.[28] Additional tests also confirm the residuals are normal.

Table 6.1: Vector normality and vector error autocorrelation tests

`Vector AR 1-4   F(64, 60) =    1.4165 [0.0876]`

`Vector normality` c^2`( 8)=    14.504 [0.0695]`

Overview of Johansen Method

Based on the VAR(6) system that was estimated above, we test for cointegration among the I(1) variables (m2a, Δp, y, GKO). We start by considering a different representation for the VAR(6), the equilibrium-correction representation, equation 6.2. Let X_t denote an (nx1) vector containing ($m2a_t, \Delta p_t, y_t, GKO_t$). D_t includes the dummy variables (D1 and D2) and $\boldsymbol{e}_t$ are identical and independently distributed N(0, Ω). The VAR representation with 6 lags can be written as:

$$X_t = \sum_{i=1}^{6} \Phi_i X_{t-i} + \Phi_D D_t + \boldsymbol{e}_t \qquad 6.1$$

In appendix 3, I show that we can rewrite 6.1 in the following equilibrium correction form:

$$\Delta X_t = \sum_{i=1}^{5} \Gamma_i \Delta X_{t-i} - \Pi X_{t-1} \Phi_D D_t + \boldsymbol{e}_t \qquad 6.2$$

This representation allows us to model both the short run and long run dynamics of the system. The first equation in the equilibrium correction model is the equation of the growth rate of money represented by:

$$\Delta m2a_t = \sum_{i=1}^{5} \left(g_{1i} \Delta m2a_{t-i} + g_{2i} \Delta^2 p_{t-i} + g_{3i} \Delta y_{t-i} + g_{4i} \Delta GKO_{t-i} \right) + \Pi X_{t-1} + \Phi_D D_t + \boldsymbol{e}_t \qquad 6.3$$

The growth rate of money is not only a function of the 6 lagged growth rates of money, inflation, income and interest rates, it is also determined by the levels of the variables of the previous month. Notice that all the variables on the left side of equation 6.2 are first differenced so that they are I(0). On the right side of the equation, all the terms are also I(0) since they are first differenced except the term in levels, ΠX_{t-1}. Π is the long run impact matrix of the equation that describes how the growth rate of money is impacted by the levels from the previous period. In order for ΠX_{t-1} to be I(0), there must be linear combinations of the variables in levels that are stationary. Johansen uses the multivariate technique of partial canonical correlations to formulate the hypothesis of cointegration as the hypothesis of reduced rank of the long run impact matrix, $\Pi = \boldsymbol{ab}$[29]. There are three different cases that might apply:

---

[28] Refer to Hendry (1995) and Hendry and Doornik (2000) for help with the analysis.

[29] Johansen, S. (1988) "Statistical Analysis of Cointegration Vectors", Journal of Economic Dynamics and Control, Vol. 12, pp. 231-54.

1) Rank(Π) = p, i.e., Π has full rank or in the present case p=4. This implies that X_t is stationary so that each variable is a single cointegrating vector.[30]
2) Rank(Π) = 0, i.e., Π is the null matrix and equation (6) above is just the traditional 1st differenced vector model.
3) Rank(Π) = r<p which implies that there are pxr matrices a and b such that $\Pi = ab$.

b are the cointegrating vectors that have the property that bX_t is stationary even though X_t is not stationary. a are the long run adjustment coefficients that "corrects" for the disequilibrium in the long run relationship, bX_t .

These parameters for the long run impact matrix are, unfortunately, not uniquely identified, i.e., given any choice for a and b and any non-singular matrix, x (rxr), the choice of ax and ax will give the same matrix Π and the same probability distribution for the variables. It is more correct to refer to the cointegration space spanned by the columns of the b vectors and the adjustment space spanned by the a vectors. The identification of these parameters will be discussed in subsequent sections.

Among the three categories for the rank of the long run impact matrix, case 3) is the relevant case for this study. This implies that there are r<p cointegrating vectors corresponding to the largest statistically significant eigenvalues which are the squared partial correlations of the reduced rank regression of ΔX_t on X_t .[31] First solving for the eigenvalues and then calculating the corresponding eigenvectors determine the cointegrating vectors b . The eigenvectors are normalized by $\hat{V}S_{11}\hat{V}$ =I.[32]

Table 6.2 below shows the results of the maximum likelihood estimation for the reduced rank regression on the Russian data. The hypothesis $H_1(r)$ is the hypothesis of reduced rank of Π that the process ΔX_t is stationary, but X_t is not stationary and bX_t is stationary. In other words, bX_t are the cointegrating relations with r cointegrating vectors. $H_0(p)$ is the null hypothesis of the full rank VAR model, equation 6.3.

The likelihood ratio test is given by the trace eigenvalues and maximal eigenvalues statistics.[33]

Table 6.2: Cointegration results for Russian money demand data

```
eigenvalue     loglik for rank
                   591.398   0
    0.80258        631.959   1
   0.469305        647.798   2
```

---

[30] See below, Unit root tests using cointegration system's analysis.

[31] See Appendix 5 for a treatment of the reduced rank regression. See also Johansen (1995) and Johansen and Juselius (1990).

[32] See Appendix 4.

[33] Ibid.

```
      0.139858       651.564   3
     0.0408921       652.608   4

Ho:rank=p  -Tlog(1-\mu)   using T-nm   95%  -T\Sum log(.)  using T-nm   95%
 p ==  0        81.12**      42.18**  27.1      122.4**      63.66**  47.2
 p <=  1        31.68**      16.47    21.0       41.3**      21.48    29.7
 p <=  2        7.533        3.917    14.1       9.62        5.003    15.4
 p <=  3        2.088        1.086     3.8      2.088        1.086     3.8

standardized \beta' eigenvectors
          m2a         GKO          Dp           y
       1.0000   0.0012838     -5.3400      5.3891
       29.520      1.0000      22.899     -37.332
      0.30341   -0.020300      1.0000    0.042569
       1.6307   -0.037479      18.652      1.0000

standardized \alpha coefficients
 m2a           -0.071780  -0.0057481   -0.034979  -0.0050796
 GKO             -4.5731    -0.31173      5.1575     0.39899
 Dp             0.099033  -0.0011091    0.015952  -0.0059377
 y              -0.11790    0.010713   -0.058523   -0.022757

long-run matrix Po=\alpha*\beta', rank 4
                     m2a         GKO          Dp           y
 m2a            -0.26036  -0.0049398     0.12195    -0.17881
 GKO             -11.560    -0.43725      29.881     -12.389
 Dp             0.061449  -0.0010832    -0.64903     0.56984
 y               0.14348    0.012602     0.39192     -1.0606
```

Notes:

1. The statistics $l_{\max}$ and l_{trace} are Johansen's maximal eigenvalue and trace eigenvalue statistics for testing for cointegration. $l^{a}_{\max}$ and are the statistics adjusted for degrees of freedom. (See Reimers (1992)) The 5% critical values are taken from Osterwald-Lenum (1992) Throughout this paper, the superscripts * and ** denote that the 5% and 1% critical values are exceeded.

Both the maximal eigenvalue and the trace eigenvalue statistics ($l_{\max}$ and l_{trace}) reject the null of no cointegration at the 5% level and 1% level respectively. They both reject the null of one cointegrating vector at the 1% level. Johansen's critical values therefore suggest that there are two cointegrating vectors. The statistics are also adjusted for the small sample by using a degrees of freedom correction[34]. These statistics reject the null of no cointegration in the variables when they are adjusted for the degrees of freedom, but cannot reject the null of 1 cointegrating vector. Even though Osterwald-Lenum's critical values corrected for the small sample suggests that the rank is one, I continue the analysis under the assumption that there are two cointegrating vector. The justification for this is that the largest two eigenvalues appear to be significantly larger than the other two and more stable (refer to the third column in figure 6.2).

---

[34] See Osterwald-Lenum (1992)

Table 6.2 also lists the associated b eigenvectors associated with the eigenvalues and the a adjustment coefficients. A closer look at the two cointegrating vectors reveals that the signs of the coefficients for the second cointegrating vector correspond to the expected signs for our money demand equation. Therefore, I hypothesize that the first cointegrating vector represents an excess demand relation, whereas the second cointegrating vector describes the money demand relation.

Figure 6.2 plots the results of the cointegration estimates. The first column in figure 6.2 plots the estimated disequilibria $\hat{b}x_t$ for the first two cointegration vectors and the remaining two non-stationary components, together with their fitted and actual values in column 2. The final column graphs the eigenvalues estimated recursively. $\hat{b}x_t$ was estimated by partialling out the full-sample short-run dynamics and unrestricted variables[35]. The disequilibrium for the first cointegrating vector is substantial, whereas the second cointegrating vector does not show a great divergence from the fitted equilibrium. The last two graphs show that the fit does not match the data. There isn't much evidence from the graphs that the first two eigenvalues are more constant than the other two. This is to be expected with the short sample of observations. However, there is evidence that the first two cointegration vectors are stationary compared to the later two.

Figure 6.2: Cointegration vectors and recursive eigenvalues

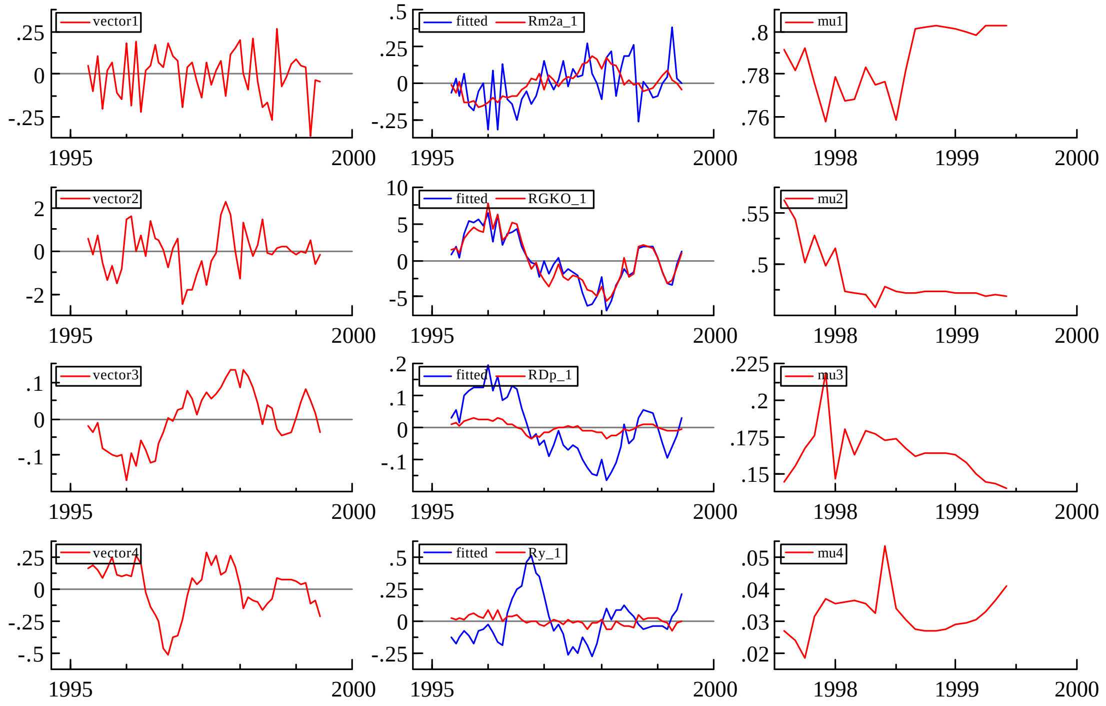


Table 6.3: Restricted cointegrating vectors and adjustment coefficients, rank=2

```
\beta'
           m2a          GKO          Dp           y
```

---

[35] See Hendry and Doornik (2000) PC-Give, Volume II, Timberlake Consultants, Ltd., London.

```
      0.11532  -0.0017061    -0.96373      1.0000
       1.0000    0.033869     0.77460     -1.2635

\alpha
 m2a           -0.41662    -0.19343
 GKO            -26.545     -10.713
 Dp             0.57507     0.00000
 y             -0.68490     0.27736

Standard errors of alpha
 m2a            0.10073    0.068476
 GKO             10.491      7.2934
 Dp            0.080861     0.00000
 y              0.24286     0.16876

Restricted long-run matrix Po=\alpha*\beta', rank 2
                    m2a         GKO          Dp           y
 m2a           -0.24147  -0.0058404     0.25168    -0.17223
 GKO            -13.774    -0.31754      17.284     -13.010
 Dp            0.066317 -0.00098111    -0.55421     0.57507
 y              0.19838    0.010562     0.87490     -1.0353
```

Testing for stationarity in the variables

In testing restrictions on the long run b parameters, a multivariate version test of a unit root is available. When a stationary variable is added to the system of variables, this is equivalent to adding a cointegrating vector to the cointegrating space. In the present exercise, the stationarity of m2a could be tested to see if the cointegration space could be restricted to include the cointegrating vector (1, 0, 0, 0). Table 6.4 below shows the results of the multivariate tests for stationarity of the variables.

Table 6.4: Multivariate Stationarity Tests

```
m2a    LR-test, rank=2: Chi^2( 3) = 31.147 [0.0000] **
GKO    LR-test, rank=2: Chi^2( 3) = 27.037 [0.0000] **
Dp     LR-test, rank=2: Chi^2( 3) = 28.279 [0.0000] **
Y      LR-test, rank=2: Chi^2( 3) = 28.68 [0.0000] **
```

These tests confirm the univariate unit root tests conducted in the previous section that the variables are non-stationary.

Unique Identification

The cointegration vectors associated with the first two eigenvalues are not identified since they are stationary relations and any linear combination of the two vectors would also be stationary. Therefore, identifying restrictions must be placed on the eigenvectors in order for unique identification to be possible.

First, the rank restriction of two cointegrating vectors is imposed upon the model and the subsequent analysis will continue with this restriction. Table 6.3 above presents the estimates of the a and b coefficients under the condition of rank=2. Next, I test restrictions on the b coefficients in order to identify the cointegrating vectors. These tests turn out to have conventional asymptotic c^2 distributions[36] because all the tests on a and b are conditional on the hypothesis of rank=2, i.e., they are in I(0) space. PCFIML allows for restrictions on individual coefficients. Under the hypothesis that one of the cointegrating vectors is a money demand relation, the other cointegrating vector is assumed to be an excess demand relation[37] with output having a positive relation to inflation and a negative one to interest rates. The following restrictions were imposed on the b coefficients: for the money demand relation, the coefficient on the income variable is constrained to be 0. This restriction turns the relation into a Cagan hyperinflation money demand relation where the effect of real output is overshadowed by inflation; and for output, the restrictions include no effect from money. Table 6.5 below shows the results of these restrictions.

Table 6.5: Identifying restrictions on the b coefficients.

```
\beta'
          m2a         GKO          Dp           y
      0.00000  -0.0048982    -0.91914      1.0000
       1.0000    0.027681    -0.38664     0.00000

Standard errors of beta'
          m2a         GKO          Dp           y
      0.00000   0.0012198     0.23689     0.00000
      0.00000   0.0033777     0.65599     0.00000

\alpha
 m2a            -0.17224    -0.24147
 GKO             -13.008     -13.776
 Dp              0.57510    0.066291
 y               -1.0353     0.19835

Standard errors of alpha
 m2a             0.12860    0.071937
 GKO              13.392      7.4912
 Dp              0.10356    0.057929
 y               0.30999     0.17341

Restricted long-run matrix Po=\alpha*\beta', rank 2
                     m2a         GKO          Dp           y
 m2a            -0.24147  -0.0058403     0.25168    -0.17224
 GKO             -13.776    -0.31760      17.282     -13.008
 Dp             0.066291 -0.00098197    -0.55423     0.57510
 y               0.19835    0.010561     0.87490     -1.0353

Standard errors of long-run matrix
 m2a            0.071937   0.0023650     0.10732     0.12860
 GKO              7.4912     0.24628      11.176      13.392
 Dp             0.057929   0.0019045    0.086420     0.10356
 y               0.17341   0.0057010     0.25870     0.30999
```

---

[36] See Appendix 4.

[37] See a similar analysis in Hendry (1995), pp.597-600.

These restrictions are non-binding and do not change the long run impact matrix from the previous rank restriction of two cointegrating vectors. However, the b coefficient on inflation does not appear significant; therefore I also set it to 0.

These restrictions were then tested for lying in the cointegration space, jointly with testing for y_t, Δp_t and GKO_t being long-run weakly exogenous for the money demand parameters when the excess demand relation is excluded from the first equation. This is equivalent to checking to see if the first column of a is (0, *, *, *)' when b was identified as described, and the second was (*, 0, 0, 0)'. Testing for weak exogeneity of the variables ($y_t , \Delta p_t , GKO_t$) for the parameters in the long run money demand parameters is a critical step that will allow me to investigate the conditional model for money demand. A more detailed discussion of exogeneity in systems analysis can be found in Ericsson and Irons (1994)[38]. Under the restrictions imposed above, the money demand cointegrating vector only enters the first equation and the excess demand relation doesn't enter the first equation. This test is a conventional c^2 and the test results are reported below in Table 6.6. These restrictions cannot be rejected at the 5% significance level.

Table 6.6: Joint Restrictions on the the b and a (weak exogeneity tests).

```
\beta'
          m2a         GKO          Dp           y
      0.00000  -0.0043919     -1.0026      1.0000
       1.0000    0.025292     0.00000     0.00000
Standard errors of beta'
          m2a         GKO          Dp           y
      0.00000   0.0011516     0.22128     0.00000
      0.00000   0.0019316     0.00000     0.00000
\alpha
 m2a             0.00000    -0.31942
 GKO             -31.091     0.00000
 Dp              0.60988     0.00000
 y              -0.69457     0.00000
Standard errors of alpha
 m2a             0.00000    0.055309
 GKO              10.855     0.00000
 Dp             0.086635     0.00000
 y               0.23876     0.00000
Restricted long-run matrix Po=\alpha*\beta', rank 2
                     m2a         GKO          Dp           y
 m2a            -0.31942  -0.0080786     0.00000     0.00000
 GKO             0.00000     0.13655      31.173     -31.091
 Dp              0.00000  -0.0026785    -0.61149     0.60988
 y               0.00000   0.0030505     0.69640    -0.69457

Linear Switching (scaled analytical); result: Strong convergence
(eps1=0.0001, eps2=0.005)

loglik = 642.37104  -log|\Omega| = 25.694842  unrestr. loglik = 647.79794
LR-test, rank=2: Chi^2(5) = 10.854 [0.0544]
```

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[38] Ericsson, Neil and John S. Irons (1994) Testing Exogeneity, Oxford University Press, Oxford.

The likelihood ratio statistic for the joint restrictions is $c^2(5) = 10.854$[39] [0.0544] with the asymptotic p-value in brackets. The restrictions cannot be rejected at the 5% significance level. The restrictions on the a coefficients alone result in the likelihood ratio statistic of $c^2(2) = 5.0377$ [0.0806], whereas the restrictions on the b coefficients has the $c^2(3) =$ 5.8163 [0.1209][40]. This test reveals that the hypothesis of a cointegrating vector represented in equation 6.5 as the only cointegrating vector in the money equation, along with its exclusion from the other equations cannot be rejected.

The only coefficient in the second column of a in Table 6.6 shows that the long run money demand relation enters only the money equation with the adjustment value of -0.32. The coefficient measures the feedback effect of the disequilibrium onto the money variable in the VAR. This corresponds to a negative relationship between the growth of money and the disequilibrium in the long run money demand. Lagged excess money induces smaller current holdings.

The two cointegrating vectors are now I(0) linear combinations, they are given by the two equations below. The equations have been adjusted to have mean zero by subtracting their sample means[41]:

$$CI1_t = y_t - .004GKO_t - 1.00\Delta p_t - 18.66 \tag{6.4}$$

$$CI2_t = m2a_t + .025GKO_t - 19.72 \tag{6.5}$$

These equations can also be rewritten as identities with the first differences of the variables and the equilibrium-correction models. These representations will be useful in modelling the parsimonious vector-autoregression below.

$$CI1_t \equiv CI1_{t-1} + \Delta y_t - .004GKO_t - 1.00\Delta^2 p_t \tag{6.6}$$

$$CI2_t \equiv CI2_{t-1} + m2a_t + .025\Delta GKO_t \tag{6.7}$$

Equation 6.5 shows the hypothesized long run equilibrium relationship between money and the GKO rate of return. As estimated, money and the GKO rate of return are cointegrated with cointegrating vector (1, .025, 0, 0). The long run money demand relation then depends negatively and solely upon the rate of return on the GKO. A few words need to be said about these results before the analysis continues. One interpretation of these results could mean that the rate of return on the GKO became a dominant determinant of money demand during the time period of this analysis, 1995:7 to 1999:6.
As the market for Russian government securities grew in this period, it became one of the only alternatives to holding real balances. Real goods, proxied by the inflation rate are another alternative to real balances; however, inflation during this time period was relatively stable for Russia, staying within a few percents on a monthly basis.

In addition, the under-developed financial system and the high degree of dollarization has constrained the demand for real balances to a group of influential banks.

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[39] Restriction tests are conducted in PcFiml, see Hendry and Doornik (2000) p. 284 and Johansen (1995) pp. 108-112.

[40] See Hendry and Doornik (2000), p. 75.

[41] Subtracting the mean does not impose any restrictions upon the system. See Hendry (1995) p.599.

The stabilization of the ruble with the establishment of the crawling peg removed an important source of revenue (currency speculation) for the banking sector. Income from the high rates of government securities replaced currency speculation as a main source of profit. It is possible that the cointegration between real balances and the GKO rates reflects the importance of GKOs in the demand for real balances during this period.

Another interpretation of these results might be that there is some misspecification in the estimated system. As stated in the introduction, money demand in Russia is complicated by a number of factors that have not yet been discussed in this analysis. The growing use of inter-enterprise arrears as a substitute for monetary liquidity might be a relevant parameter in Russian money demand. Another issue is the role of dollarization and the use of foreign currencies as a substitute for real balances. Incorporating these variables into a more general money demand relation may address some of the misspecifications in the present analysis. I return to these issues after finishing the discussion of the system above.

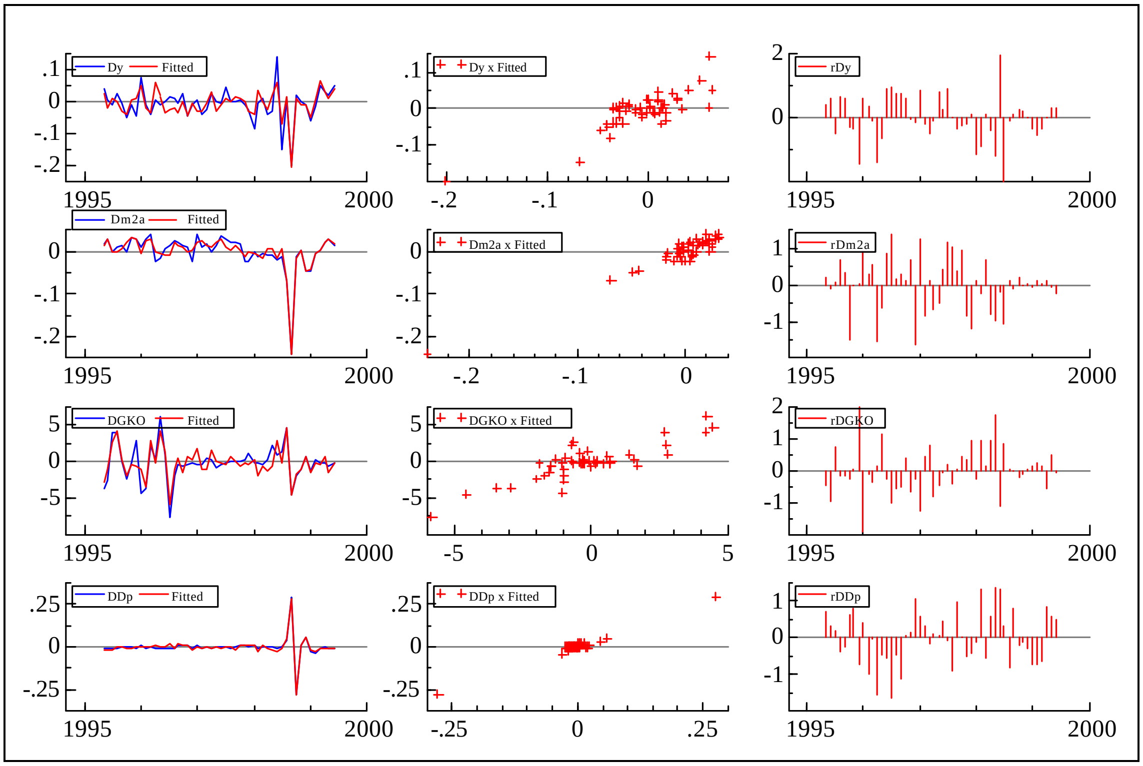
Reduction of the system to an I(0) PVAR

Having found the two unique cointegrating combinations, the data can now be mapped to I(0) series without any I(1) variables. The system is formulated in differences and combinations of cointegrating vectors. Recall equation 6.2 with X_t denoting an (nx1) vector containing $(m2a_t, \Delta p_t, y_t, GKO_t)'$, D_t - the dummy variables (D1 and D2) and $\boldsymbol{e}_t$ - identical and independently distributed N(0, Ω). Replacing ΠX_{t-1} with the cointegrating vectors $CI1_{t-1}$ and $CI2_{t-1}$, we get the following:

$$\Delta X_t = \sum_{i=1}^{5} \Gamma_i \Delta X_{t-i} + A_1 CI1_{t-1} + A_2 CI2_{t-2} + \Phi_D D_t + \boldsymbol{e}_t \qquad 6.8$$

Equation 6.8 is estimated using OLS and the results are listed in appendix 6. Since all the tests are conducted in I(0) form, they have conventional critical values. The I(0) system is tested to check for serial correlation, normality and heteroscedasticity. The single equation tests in the system (see appendix 6) reveal that none of the tests are significant at the 1% level. There is some evidence of serial correlation in the error terms of the money equation. A closer look is needed as the modeling continues at the single equation level. On the system level none of the three tests are significant at the 1% level. Figure 6.3 summarizes the estimation in graphical form.

Figure 6.3: Fitted and actual values and scaled residuals from I(0) VAR



The first column plots the actual with the fitted values from the OLS estimation. The fit does not appear to show too much divergence from the actual values of the growth rates. The second column cross plots the correlation between the fitted and actual values. It can be seen that the change in inflation during this period was minimal except during the few months following the collapse of the ruble. The scaled residuals in the third column also do not show any noticeable outliers or discernible patterns.

Figure 6.4 next graphs the recursive statistics (using 20 initial values) which include the recursive 1-step residuals between their recursive 95% confidence bands and the recursive break-point Chow test[42]. The first four plots are the 1-step residuals and their 95% confidence bands ($\pm 2\hat{s}$). As the graphs show, the residuals are all within the their confidence bands. However, the standard errors are not constant as can be seen most clearly in the bands of the differenced inflation residuals. The breakpoint Chow test also reveals that the parameters for the differenced inflation equation are not constant. The system Chow test rejects at the 1% level.

Figure 6.4: Recursive constancy statistics

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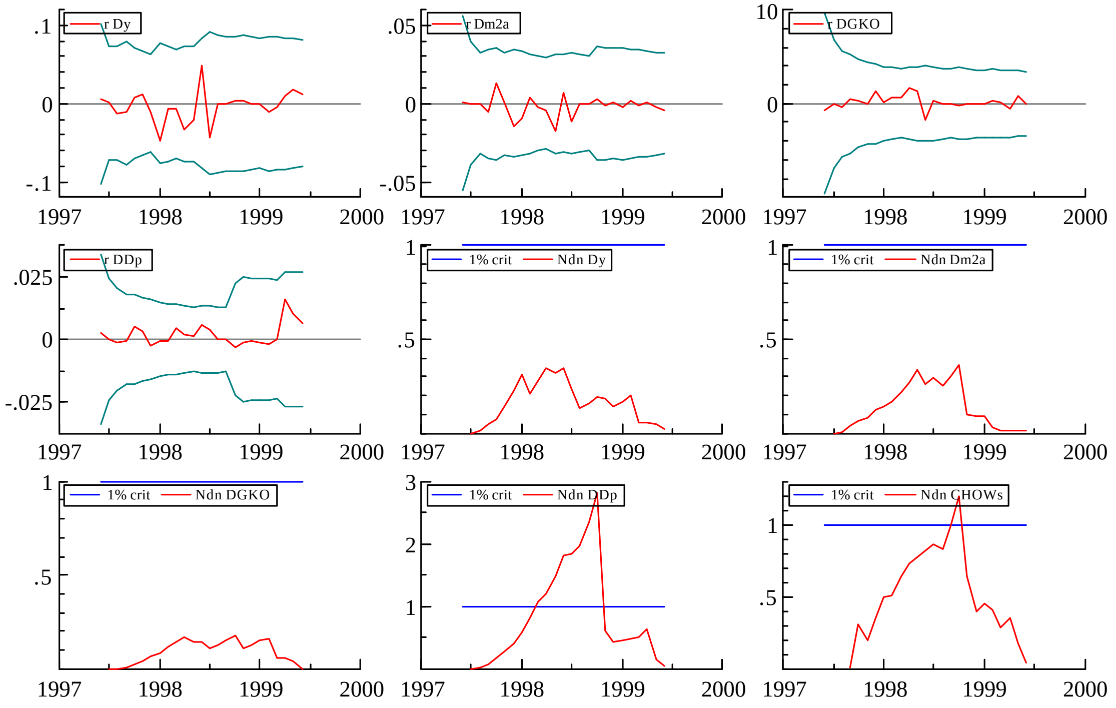
[42] Recursive estimation starts with an initial value of T for estimation and proceeds to re-estimate sequentially with T+1, T=2, etc.



A further reduction of the VAR at the level of the system is motivated by the F-tests for the various variables in the system. A look at the F-tests in appendix 6 shows that many of the variables are not significant in the system. The following variables are removed and the system is re-estimated by OLS:

Table 6.7: System reduced by the following variables

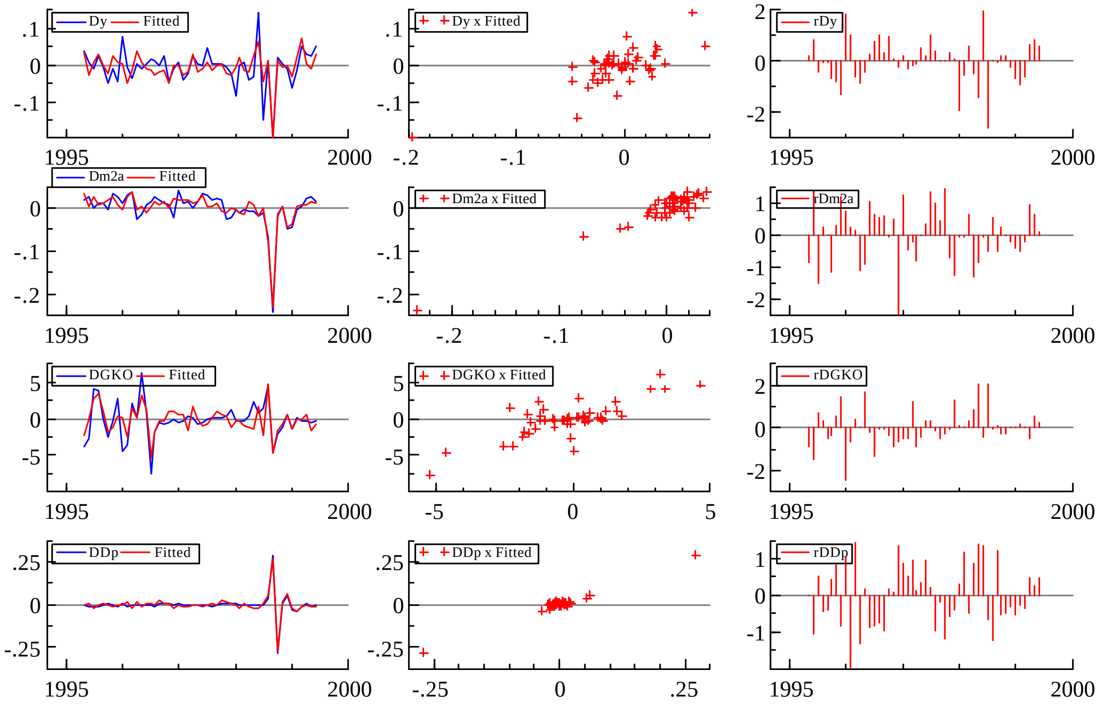
$\Delta m2a_{t-1}$, $\Delta m2a_{t-2}$, $\Delta m2a_{t-4}$, $\Delta m2a_{t-5}$

Δy_{t-1}, Δy_{t-5}

ΔGKO_{t-1}, ΔGKO_{t-3}, ΔGKO_{t-5}

The full results are found in appendix 7, but a summary of the results are highlighted in figure 6.5. It appears that the fit of the system changed little with the reduction of the system by the variables above. A comparison of the correlation matrix of the fitted and actual values in appendices 6 and 7 confirm this observation.

Figure 6.5: Fitted and actual values and scaled residuals from I(0) VAR



The Conditional Single Equation Money demand model[43]

Before turning to the conditional money demand model, I again test the weak exogeneity of the explanatory variables, $(\Delta p_t, y_t, GKO_t)$. This time, I test the weak exogeneity restrictions by using FIML, i.e., imposing specific restrictions on each equation of the system and using an LR test against the unrestricted system. More specifically, the restrictions imposed on the system are that $CI1_{t-1}$ enters the Δy_t, ΔGKO_t and $\Delta^2 p_t$ equations only and that $CI2_{t-1}$ enters the $\Delta m2a_t$ equation only. Again the full results are available in the appendices with only the LR test statistics highlighted in table 6.7 below. In appendix 8, the unrestricted FIML estimation is reported. Appendix 9 contains the results of the restricted FIML estimation.

Table 6.8: Test of weak exogeneity using FIML

```
loglik = 695.05128   log|\Omega| = -22.421   |\Omega| = 1.83096e-010   T = 62
LR test of over-identifying restrictions: Chi^2(4) = 8.84411 [0.0651]
```

---

[43] David Hendry also refers to the conditional model as a contingent plan model, see Hendry and Ericsson (1991) and Hendry (1995).

The LR test cannot reject these over-identifying restrictions and confirms the weak exogenity test that was conducted above (refer to table 6.6). This again shows that the variables, ($\Delta p_t, y_t, GKO_t$), are weakly exogenous and that the conditional single money demand equation can be used to conduct valid inference.

The reductions in the system by the variables listed table 6.7 were not formally tested and are tested below. Using the unrestricted FIML estimate in appendix 8, the LR test is conducted for the restrictions and is soundly rejected in table 6.9. The reductions of the system in table 6.7 will need to be reconsidered in light of this test.

Table 6.9: Test restrictions from table 6.7 using FIML

```
loglik = 668.20168  log|\Omega| = -21.5549  |\Omega| = 4.3534e-010  T = 62
LR test of over-identifying restrictions: Chi^2(36) = 62.5433 [0.0040] **
```

The weak exogeneity tests above using an LR test on the restrictions on the system re-confirm the validity of considering the conditional, single equation money demand equation. Therefore, I next turn to the single equation conditional model by starting with a general sixth order autoregressive distributed lag (ADL) in the variables, $(m2a_t, \Delta p_t, y_t, GKO_{t)}$. The ADL is a simple but general form of describing the data with the feature that virtually "every type of single-equation model in empirical time-series econometrics is a special case of it."[44] Through a series of simplifications, this general representation of the data is pared down to a more interpretable and parsimonious model of money demand. The steps to simplifying the general unrestricted ADL are motivated by the following considerations[45]:

1) A parsimonious model is more easily interpretable than the unrestricted ADL.
2) Shorter lag lengths are preferable to longer lag lengths.
3) Transformations are made to re-parameterize the variables into orthogonal regressors.
4) Based on significance tests, variables are eliminated that have small t-values.
5) Specific criteria are used to determine the validity of the reductions.[46]

The ADL includes the same dummies that were included in the vector autoregression above. Specifically, D1 for 1998:8 and 1998:9 account for the fluctuations in money demand during the devaluation and default of August 1998 and D2 is a step function with a value of 1 after 1998:8 to account for the collapse of the GKO market. The analysis in this section closely follows the discussions on conditional single equation money demand equations in Hendry (1995), de Brouwer and Ericsson (1995) and Ericsson and Sharma (1996).

[44] See Hendry (1995) p. 212.

[45] Similar motivations serve as guidelines for simplification in Hendry (1995), de Brouwer and Ericsson (1995) and Ericsson and Sharma (1996).

[46] Refer to appendix 11 for details of the reductions.

The results of the OLS estimation of the ADL(6) are found in appendix 10 where it can be noted that most of the individual coefficients are not significant. The residual statistics show that the errors are well-behaved without any of them being significant. The large number of variables and parameters make the OLS estimation of the unrestricted ADL difficult to interpret. Also, recall that it was established that the variables in the ADL are integrated of order 1 leaving the possibility of spurious and non-sensical regression results. A transformation of the equation into an I(0) Equilibrium correction representation (ECM) will provide a form that is more economically interpretable and has stationary regressors on the right hand side.

Before leaving the ADL estimation, the static long run solution of the general ADL(6) estimate is considered. This solution is a hypothetical deterministic situation in which all change has ceased.[47] The static long run solution is given in equation 6.9. with standard errors in parentheses[48]. The only significant coefficient in the static long run solution is the GKO with a value very close to that obtained in the Johansen analysis above for the VAR (see equation 6.5) and again indirectly confirming the validity of weak exogeneity of the explanatory variables.

$$\begin{array}{llllllll} m2a = & +11.7 & -0.261\ Dp & +0.4307\ y & -0.02759\ GKO & -\ 0.1065\ D1 & -\ 0.2432\ D2 & \quad 6.9 \\ & (14.65) & (1.057) & (0.7834) & (0.006025) & (0.1449) & (0.2219) & \end{array}$$

The ADL can also be transformed into the following equilibrium correction representation[49].

$$\Delta m2a_t = \sum_{i=1}^{5} (g_{1i}\Delta m2a_{t-i} + g_{2i}\Delta^2 p_{t-i} + g_{3i}\Delta y_{t-i} + g_{4i}\Delta GKO_{t-i}) + g_5 (m - m^*) + g_6 D_t + \boldsymbol{e}_t \qquad 6.10$$

This general equation for the growth rate of money in differences and levels not only provides a more interpretable representation of the conditional money equation, it also transforms the variables into I(0) variables. The short run adjustments to the determinants of money demand are captured by the lagged differences, whereas adjustments to the long run equilibrium relationship is relegated to the ECM term, $m - m^*$, with m* as the desired real money stock. The ECM representation is also a more general form of the traditional partial adjustment model discussed in section 4 above. It builds on the partial adjustment model by including the short run dynamics in the lagged differences. Another theoretical interpretation of the ECM representation is the "inventory adjustment" theory in which short run factors determine fluctuations in money holdings within given bands, whereas the long run factors influence the levels of the bands[50].

Table 6.10 lists the results of the unrestricted equilibrium correction representation (ECM) for real money conditional on inflation, real output and GKO rates. A number of observations on the unrestricted ECM before turning to the reduced parsimonious model.

---

[47] For a derivation of the long run static solution, see Hendry (1995) section 6.5.

[48] Ibid.

[49] For a discussion on the relationship between ADL, ECMs and long run solutions, see de Brouwer and Ericsson (1995).

[50] See Miller and Orr (1966), Akerlof (1979), Akerlof and Milbourne (1980), Milbourne (1983) and Smith (1986) from Ericsson and Sharma (1996).

First, a look at the coefficients of the lagged variables in levels shows a consistency with previous findings in the systems analysis. Namely, the coefficients on Δp_{t-1} and y_{t-1} are insignificant, whereas the coefficients on $m2a_{t-1}$ and GKO_{t-1} are significant. This is consistent with the findings above that $m2a_{t-1}$ and GKO_{t-1} are cointegrated in a long run relationship. Notice also that many of the coefficients are insignificant.

Table 6.10: The Unrestricted Equilibrium Correction Representation for real money conditional on inflation, real output and GKO rates.

Lag	0	1	2	3	4	5	Sum
Dm2a	-1	-0.0887	-0.0975	0.139	0.206	-0.00258	-0.844
StdErr	0	0.188	0.172	0.206	0.171	0.187	0.35
Constant	3.3	0	0	0	0	0	3.3
StdErr	4.29	0	0	0	0	0	4.29
Dy	0.152	0.119	0.0582	-0.0785	-0.124	-0.00418	0.123
StdErr	0.102	0.116	0.166	0.196	0.187	0.149	0.624
DGKO	-0.00141	0.00321	0.00271	0.00376	0.00288	0.00243	0.0136
StdErr	0.00245	0.00313	0.00218	0.00158	0.00116	0.00107	0.00699
DDp	-0.274	-0.119	-0.107	-0.0184	0.0141	0.0339	-0.47
StdErr	0.235	0.266	0.235	0.269	0.233	0.113	0.99
D1	-0.03	0	0	0	0	0	-0.03
StdErr	0.0397	0	0	0	0	0	0.0397
D2	-0.0685	0	0	0	0	0	-0.0685
StdErr	0.0663	0	0	0	0	0	0.0663
GKO	0	-0.00777	0	0	0	0	-0.00777
StdErr	0	0.00251	0	0	0	0	0.00251
y	0	0.121	0	0	0	0	0.121
StdErr	0	0.22	0	0	0	0	0.22
Dp	0	-0.0735	0	0	0	0	-0.0735
StdErr	0	0.299	0	0	0	0	0.299
m2a	0	-0.282	0	0	0	0	-0.282
StdErr	0	0.0734	0	0	0	0	0.0734

Reducing the unrestricted ECM by following the guidelines outlined above, the following parsimonious and statistically acceptable ECM results[51]:

$$\begin{aligned}
\Delta m2a_t = & \underset{(0.62)}{3.25} + \underset{(0.057)}{0.166}\Delta y_t + \underset{(0.059)}{0.269}\Delta y_{t-1} - \underset{(0.063)}{0.197}\Delta y_{t-4} + \underset{(0.073)}{0.27}\Delta m2a_{t-4} \\
& - \underset{(0.057)}{0.39}\Delta^2 p_t - \underset{(0.031)}{0.16}(m2a_{t-1} + 0.0242 GKO_{t-1}) - \underset{(0.011)}{0.071} D2_t \qquad 6.11
\end{aligned}$$

R^2 =0.85849 F(7,42) = 36.4 [0.0000] $\hat{s}$ = 0.0169021 DW = 1.55

---

[51] Results of the estimation of the parsimonious conditional model is in appendix 12.

RSS = 0.01199854688 for 8 variables and 50 observations

```
AR 1- 4 F( 4, 38) =     1.1385 [0.3531]
ARCH 4  F( 4, 34) =     1.4343 [0.2439]
Normality Chi^2(2)=     1.7741 [0.4119]
Xi^2    F(13, 28) =     0.7493 [0.7022]
Xi*Xj   F(34,  7) =    0.33424 [0.9853]
RESET   F( 1, 41) =     5.2322 [0.0274] *
```

In equation 6.11, the standard errors are in parentheses below the coefficients. The coefficients on all the variables are significant at the 1% level. The misspecification tests all fail to reject except Ramsey's RESET misspecification test at the 5% significance level. This test indicates that there is some evidence that the functional form of the regression is misspecified. In particular, the addition of powers of the fitted values might lead towards an improvement in the fit. However, the last simplification of dropping the differenced lags of the seems to have caused the RESET test to reject the null of functional form misspecification. Adding the lags back corrects this misspecification.

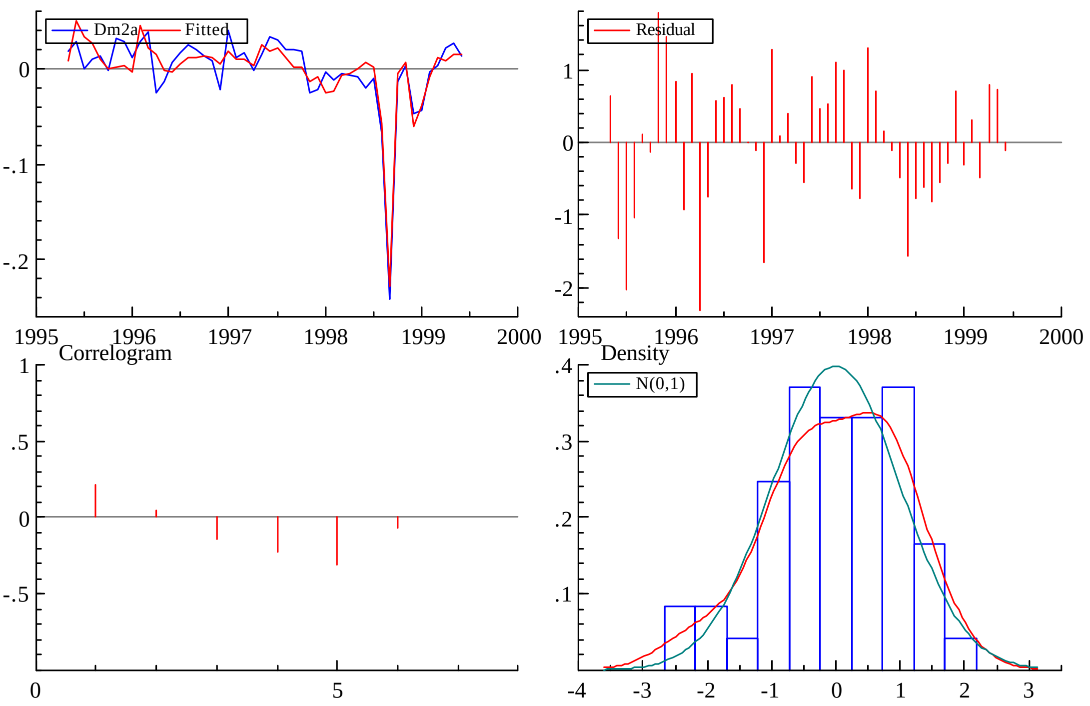
The coefficients in the long run ECM term are very close to parameters that were estimated using Johansen's cointegration analysis. Specifically, the coefficient on GKO_{t-1} is nearly the same as from the cointegration analysis. The long run adjustment coefficient is also very close. The a from the cointegration estimate was -0.32 compared to -0.16 in the parsimonious ECM estimate above. This is further evidence for the weak exogeneity of the explanatory variables and the validity of the conditional money equation.

Statistical Properties of the Parsimonious ECM

The results of the graphic analysis of equation 6.11 are found below in figure 6.6. The test statistics of the residuals (under equation 6.11) for the conditional model confirm that there are no missspecifications except for the functional form RESET test (see discussion above). A visual inspection shows that residuals are not completely well-behaved in terms of being serially independent white noise innovations. Even though the LM test does not reject in terms of autocorrelation, there does appear to to some pattern in the residual correlogram. A possible explanation of the pattern is that some seasonality may still be present in the data.

Another important issue concerns the parameter constancy of the coefficients of the money demand equation. One of the main motivations behind the literature related to equilibrium correction models (ECM) of money demand was the search for a constant underlying money demand relationship in view of episodes similar to the "missing money" puzzle. The constancy of the ECM during these periods proved to be one of its most important contributions made to empirical money demand modeling.

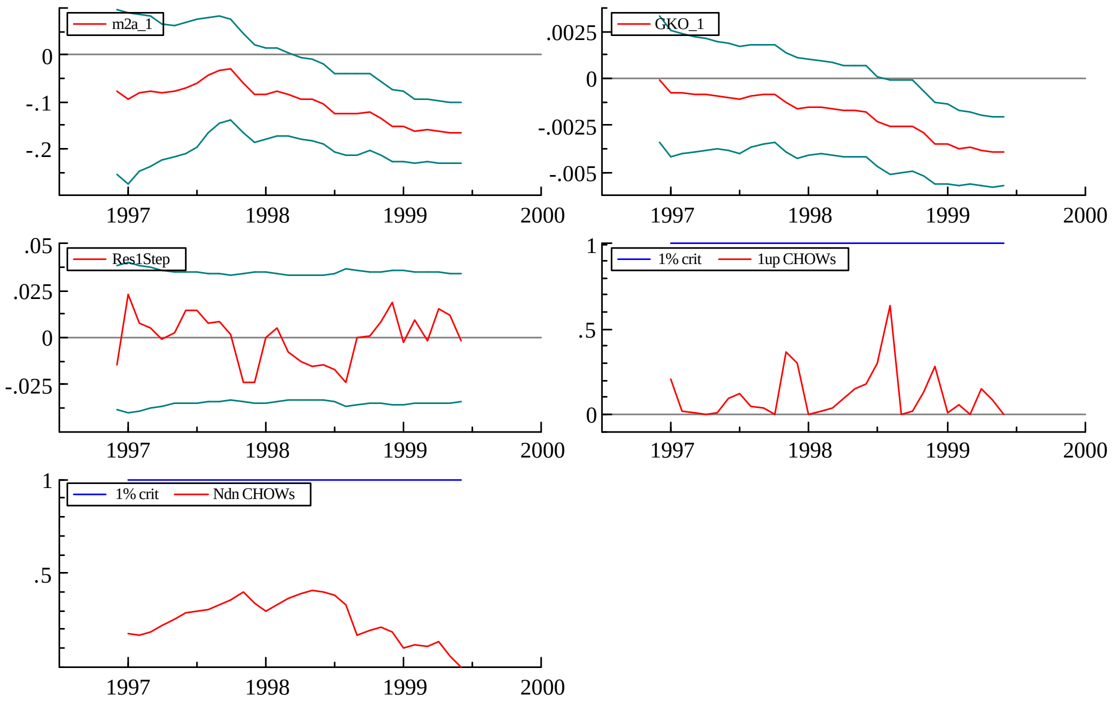
Figure 6.6: Fitted and actual values and scaled residuals of the conditional money equation



In testing for parameter constancy, recursive least squares estimation is used and the following is shown in figure 6.6 below. The first two graphs show the recursive parameter estimates for the disequilibrium adjustment coefficient and the coefficient on GKO_{t-1} along with their approxiamte 95% confidence intervals ($\pm 2s$) respectively. The lack of constancy is not surprising given the short length of the data series. The next graph plots the 1-step ahead residuals (these can also be thought of as forecast errors) and their 95% confidence intervals. The confidence bands for the residuals appear to fairly constant over this period. The last two graphs, the 1-step Chow and the break-point Chow tests, do not reject that the parameters are constant.

The results of parameter constancy are therefore somewhat mixed. Although the recursive Chow tests do show that the parameters are constant, the recursive estimates of the parameters do not appear constant.

Figure 6.7: Recursive constancy statistics for the conditional money equation



Omitted Variables in the Russian Money Demand equation

The analysis is repeated under the alternative hypothesis that the demand for money in Russia does not only include variables of opportunity cost and transaction scales. The other variables of interest relevant for Russian money demand are inter-enterprise arrears and measurements of dollarization.

7. Concluding remarks

The general to specific modeling of the Russian macroeconomic money demand data demonstrates that this approach to modeling money demand can be applied to data from a transitional economy to reveal some interesting robust results. Johansen's cointegration analysis of Russian money demand data shows that a cointegrating vector for real ruble balances and the rate of return on the Russian government securities exists. This cointegrating vector is re-estimated and found to be nearly identical from estimations in a conditional money demand model.

Following Hendry's general to specific methodology, a systematic approach is used to discover a congruent money demand model. Starting with a general unrestricted VAR(6) model, a system of I(1) variables (m2a, Δp, y, GKO) is tested using Johansen's reduced rank regression analysis to find long run cointegrating relationships in the variables. A series of identifying restrictions and weak exogeneity tests are conducted and it is determined that there is a cointegrating vector (1, .025) between the variables, m2a and GKO. It is also determined that the variables, (Δp, y, GKO), are weakly exogenous for the parameters of the cointegrating vector in the money equation.

Further tests are conducted using full information maximum likelihood (FIML) to again test the weak exogeneity of the variables, (Δp, y, GKO), for the money demand coefficients. The variables are again found to be weakly exogenous.

The conditional equilibrium correction model (ECM) of money demand is finally considered and estimated using OLS. The results of the OLS estimation reveal that the coefficients for long run relationship in the levels are nearly identical to those found in the cointegration analysis of the system of variables with comparable values for the disequilibria adjustment coefficient. It is significant that the numerical estimates of a long run relationship between the variables m2a and GKO from both methods are close. During the time period of the analysis, there was a strong demand for government short term debt from the large commercial banks. It seems plausible that the main opportunity cost of holding real ruble balances during the stabilization period was the rate of return on the GKOs.

Appendix 1: Unit Root Tests

mb

```
Unit-root tests 1993 (7) to 2000 (4)
Critical values: 5%=-3.465 1%=-4.073; Constant and Trend included

                 t-adf      beta Y_1    \sigma lag  t-DY_lag  t-prob  F-prob
m              -1.9153       0.89070  0.041933  13  0.041411  0.9671
m              -1.9880       0.89132  0.041620  12  -0.94033  0.3504  0.9671
m              -2.3360       0.87726  0.041584  11  -0.12786  0.8986  0.6482
m              -2.4980       0.87531  0.041287  10  -0.56902  0.5712  0.8279
m              -2.8277       0.86649  0.041087   9    1.0361  0.3037  0.8765
m              -2.6528       0.87855  0.041108   8  -0.63133  0.5298  0.8142
m              -2.9435       0.87077  0.040936   7    1.1724  0.2449  0.8522
m              -2.7345       0.88320  0.041041   6   0.20458  0.8385  0.7848
m              -2.8063       0.88563  0.040774   5   0.38224  0.7034  0.8550
m              -2.8196       0.88969  0.040542   4  -0.47300  0.6376  0.8985
m              -3.1611       0.88366  0.040334   3    2.2236  0.0291  0.9260
m              -2.6030       0.90526  0.041354   2    2.3330  0.0223  0.6318
m              -2.1006       0.92317  0.042516   1    2.6217  0.0105  0.3145
m              -1.6664       0.93754  0.044068   0                    0.0979
```

We cannot reject the null of a unit root for the log of the real balances with a trend and a constant at the 1% level.

m2a

```
Unit-root tests 1993 (2) to 2000 (4)
Critical values: 5%=-3.461 1%=-4.066; Constant and Trend included

                 t-adf      beta Y_1    \sigma lag  t-DY_lag  t-prob  F-prob
m2a            -2.3383       0.92846  0.038086  13   0.85163  0.3973
m2a            -2.5879       0.92284  0.038013  12  -0.97986  0.3304  0.3973
m2a            -2.7129       0.91962  0.038003  11   -1.1413  0.2575  0.4356
m2a            -3.0245       0.91232  0.038080  10   -1.2342  0.2210  0.4012
m2a            -3.4741*      0.90268  0.038213   9    1.7525  0.0838  0.3515
m2a            -3.0916       0.91506  0.038730   8    1.0330  0.3049  0.1949
m2a            -2.9276       0.92191  0.038747   7   0.87815  0.3826  0.2082
m2a            -2.8051       0.92727  0.038690   6    1.3623  0.1770  0.2373
m2a            -2.5811       0.93392  0.038899   5  -0.26799  0.7894  0.2007
m2a            -2.6980       0.93260  0.038673   4  -0.91013  0.3655  0.2651
m2a            -2.8530       0.92948  0.038632   3   0.67772  0.4999  0.2850
m2a            -2.8496       0.92981  0.038504   2   0.97586  0.3320  0.3270
m2a            -2.8424       0.93001  0.038493   1    5.3123  0.0000  0.3366
m2a            -2.4887       0.92949  0.044293   0                    0.0006
```

We cannot reject the null of a unit root for the log of the adjusted m2a with a trend and a constant at the 1% level.

p

```
Unit-root tests 1993 (2) to 2000 (4)
Critical values: 5%=-3.461 1%=-4.066; Constant and Trend included

                 t-adf      beta Y_1    \sigma lag  t-DY_lag  t-prob  F-prob
p              -2.8112       0.96775  0.041482  13  -0.44598  0.6570
p              -2.8352       0.96941  0.041251  12  -0.43996  0.6613  0.6570
p              -2.8167       0.97009  0.041022  11  -0.78621  0.4343  0.8231
p              -2.7786       0.97064  0.040916  10  -0.20371  0.8391  0.8025
p              -2.7931       0.97068  0.040654   9   0.17479  0.8617  0.9034
```

```
p              -2.8090       0.97070  0.040394   8   0.49578  0.6215  0.9560
p              -2.8433       0.97051  0.040195   7   0.37279  0.7103  0.9704
p              -2.8587       0.97051  0.039973   6  -0.19878  0.8430  0.9836
p              -2.8752       0.97052  0.039729   5  -0.73145  0.4667  0.9925
p              -2.8561       0.97083  0.039614   4  -0.29813  0.7664  0.9911
p              -2.8569       0.97119  0.039390   3    1.5453  0.1262  0.9953
p              -3.2173       0.96799  0.039722   2    1.2407  0.2182  0.9595
p              -3.6628*      0.96473  0.039851   1    4.6018  0.0000  0.9276
p              -6.3270**     0.94187  0.044380   0                      0.0402
```

We can reject the null of a unit root for the log of the CPI with a trend and a constant at the 5% level.

R

```
Unit-root tests 1993 (2) to 2000 (8)
Critical values: 5%=-3.459 1%=-4.061; Constant and Trend included

                 t-adf      beta Y_1    \sigma lag  t-DY_lag  t-prob  F-prob
R              -2.8113       0.85309    1.6037  13 0.0027883  0.9978
R              -2.8377       0.85311    1.5931  12   0.30829  0.7587  0.9978
R              -2.8419       0.85397    1.5837  11  -0.55776  0.5786  0.9542
R              -2.8968       0.85212    1.5767  10   0.20523  0.8379  0.9405
R              -2.9073       0.85277    1.5671   9   0.11789  0.9065  0.9789
R              -2.9322       0.85348    1.5574   8   0.36209  0.7182  0.9936
R              -2.9280       0.85645    1.5490   7 0.0057893  0.9954  0.9966
R              -2.9903       0.85650    1.5396   6   0.82288  0.4130  0.9990
R              -2.9029       0.86268    1.5366   5   0.12110  0.9039  0.9963
R              -2.9387       0.86360    1.5275   4   0.63396  0.5278  0.9986
R              -2.8864       0.86799    1.5221   3    1.7276  0.0877  0.9984
R              -2.6930       0.87608    1.5396   2  -0.18087  0.8569  0.9570
R              -2.7457       0.87515    1.5310   1  -0.97990  0.3299  0.9739
R              -2.9229       0.86857    1.5307   0                    0.9664
```

We cannot reject the null of a unit root for R using the ADF test with a constant and a trend.

GKO

```
Unit-root tests 1994 (7) to 1999 (6)
Critical values: 5%=-3.485 1%=-4.116; Constant and Trend included

                 t-adf      beta Y_1    \sigma lag  t-DY_lag  t-prob  F-prob
GKO            -2.0529       0.60195    3.1603  13  -0.28392  0.7778
GKO            -2.1798       0.59063    3.1279  12   0.17831  0.8593  0.7778
GKO            -2.2325       0.59929    3.0948  11   0.27226  0.7866  0.9457
GKO            -2.2637       0.61236    3.0642  10    1.4651  0.1496  0.9801
GKO            -1.9242       0.67833    3.1005   9  -0.38680  0.7006  0.6999
GKO            -2.1205       0.66118    3.0735   8   0.22340  0.8242  0.7973
GKO            -2.1599       0.67079    3.0442   7 -0.081114  0.9357  0.8759
GKO            -2.2866       0.66748    3.0144   6  -0.20099  0.8415  0.9297
GKO            -2.4883       0.65857    2.9864   5  -0.94291  0.3501  0.9604
GKO            -3.0882       0.60900    2.9833   4  -0.38442  0.7022  0.9484
GKO            -3.6424*      0.58786    2.9597   3    2.1203  0.0386  0.9663
GKO            -2.9874       0.67547    3.0523   2  -0.80575  0.4239  0.7638
GKO            -3.6705*      0.63890    3.0427   1    1.7705  0.0821  0.7798
GKO            -3.1877       0.70295    3.0992   0                    0.6254
```

We cannot reject the null of a unit root for GKO using the ADF test with a constant and a trend.

y

```
Unit-root tests 1993 (2) to 2000 (4)
Critical values: 5%=-3.461 1%=-4.066; Constant and Trend included

                t-adf      beta Y_1    \sigma lag  t-DY_lag  t-prob  F-prob
y             -1.9226       0.89867  0.045390  13  -0.53079  0.5972
y             -1.9358       0.89848  0.045163  12 -0.022825  0.9819  0.5972
y             -1.9615       0.89836  0.044852  11  -0.28089  0.7796  0.8686
y             -2.0470       0.89600  0.044572  10   0.43172  0.6672  0.9482
y             -2.0119       0.90070  0.044330   9    2.1718  0.0330  0.9690
y             -1.5662       0.92249  0.045401   8   0.89693  0.3726  0.4197
y             -1.4212       0.93108  0.045343   7   -1.2745  0.2063  0.4494
y             -1.7160       0.91827  0.045524   6  -0.26761  0.7897  0.3941
y             -1.8328       0.91542  0.045256   5   0.84401  0.4012  0.4880
y             -1.6823       0.92477  0.045175   4   0.94150  0.3493  0.5165
y             -1.5525       0.93152  0.045143   3  -0.14180  0.8876  0.5270
y             -1.5976       0.93065  0.044872   2    1.6673  0.0993  0.6098
y             -1.3444       0.94171  0.045351   1  -0.56998  0.5702  0.4687
y             -1.4906       0.93687  0.045168   0                    0.5203
```

We cannot reject the null of a unit root for y using the ADF test with a constant and a trend.

s

```
Unit-root tests 1993 (2) to 2000 (7)
Critical values: 5%=-3.46 1%=-4.062; Constant and Trend included

                t-adf      beta Y_1    \sigma lag  t-DY_lag  t-prob  F-prob
s             -2.0743       0.94068  0.076884  13   -1.5873  0.1167
s             -2.3614       0.93282  0.077659  12    1.8977  0.0616  0.1167
s             -2.0239       0.94236  0.078977  11  -0.37941  0.7054  0.0511
s             -2.0967       0.94106  0.078536  10  -0.15637  0.8762  0.1055
s             -2.1531       0.94044  0.078044   9  0.097657  0.9225  0.1852
s             -2.1729       0.94080  0.077553   8  -0.12619  0.8999  0.2833
s             -2.1974       0.94060  0.077074   7   0.84870  0.3986  0.3906
s             -2.1572       0.94188  0.076941   6  -0.10359  0.9177  0.4263
s             -2.1746       0.94179  0.076476   5  -0.57174  0.5691  0.5281
s             -2.2465       0.94037  0.076165   4   0.54129  0.5898  0.5922
s             -2.2171       0.94162  0.075844   3    1.2270  0.2232  0.6529
s             -2.0657       0.94593  0.076069   2  -0.15243  0.8792  0.6040
s             -2.1326       0.94527  0.075636   1    4.5837  0.0000  0.6795
s             -1.8654       0.94691  0.083884   0                    0.0139
```

Δmb

```
Unit-root tests 1993 (8) to 2000 (4)
Critical values: 5%=-3.465 1%=-4.074; Constant and Trend included

                t-adf      beta Y_1    \sigma lag  t-DY_lag  t-prob  F-prob
Dm            -2.5496       0.12436  0.042778  13   -1.3662  0.1766
Dm            -3.3188     -0.057540  0.043058  12   0.52572  0.6008  0.1766
Dm            -3.3688     0.0019761  0.042825  11    1.4069  0.1641  0.3479
Dm            -3.0488       0.14780  0.043132  10   0.63635  0.5267  0.2577
Dm            -3.0347       0.21157  0.042946   9    1.0409  0.3016  0.3477
Dm            -2.8489       0.30287  0.042971   8  -0.43539  0.6646  0.3551
Dm            -3.2612       0.26330  0.042725   7    1.3177  0.1918  0.4521
Dm            -2.9770       0.36363  0.042943   6  -0.24909  0.8040  0.3866
Dm            -3.3561       0.34298  0.042667   5   0.37060  0.7120  0.4806
Dm            -3.5115*      0.37147  0.042417   4   0.50338  0.6162  0.5633
Dm            -3.6634*      0.40991  0.042206   3    1.4527  0.1505  0.6286
Dm            -3.3422       0.49357  0.042513   2   -1.3395  0.1844  0.5319
Dm            -4.3985**     0.40206  0.042731   1   -1.8763  0.0644  0.4717
Dm            -6.9266**     0.24530  0.043416   0                    0.3136
```

Δm2a

```
Unit-root tests 1993 (3) to 2000 (4)
Critical values: 5%=-3.462 1%=-4.067; Constant and Trend included

                 t-adf      beta Y_1    \sigma lag  t-DY_lag  t-prob  F-prob
Dm2a           -3.1250       0.30283  0.039733  13  0.033947  0.9730
Dm2a           -3.1678       0.30378  0.039453  12  -0.20683  0.8367  0.9730
Dm2a           -3.5551*      0.28596  0.039190  11    1.4585  0.1490  0.9786
Dm2a           -3.2225       0.39212  0.039491  10    1.6100  0.1117  0.5527
Dm2a           -2.8283       0.48887  0.039914   9    2.1503  0.0348  0.3322
Dm2a           -2.2926       0.59058  0.040867   8  -0.81673  0.4167  0.1110
Dm2a           -2.6571       0.54758  0.040777   7  -0.27626  0.7831  0.1402
Dm2a           -2.9117       0.53266  0.040532   6  -0.27039  0.7876  0.2010
Dm2a           -3.2228       0.51762  0.040290   5  -0.90821  0.3666  0.2705
Dm2a           -3.9365*      0.46234  0.040245   4   0.33511  0.7384  0.2925
Dm2a           -4.1598**     0.48030  0.040022   3   0.79108  0.4312  0.3625
Dm2a           -4.1266**     0.51087  0.039929   2  -0.50603  0.6142  0.3955
Dm2a           -4.6614**     0.48875  0.039747   1  -0.14594  0.8843  0.4540
Dm2a           -5.5284**     0.48063  0.039512   0                    0.5282
```

Δp

```
Unit-root tests 1993 (3) to 2000 (4)
Critical values: 5%=-2.895 1%=-3.507; Constant included

                 t-adf      beta Y_1    \sigma lag  t-DY_lag  t-prob  F-prob
Dp             -1.9793       0.83723  0.044014  13  -0.37926  0.7056
Dp             -1.9548       0.84388  0.043752  12  -0.34981  0.7275  0.7056
Dp             -1.9752       0.84324  0.043488  11  -0.11876  0.9058  0.8762
Dp             -2.0030       0.84254  0.043197  10   0.41147  0.6819  0.9638
Dp             -1.9835       0.84567  0.042957   9-0.0060381  0.9952  0.9785
Dp             -2.0136       0.84561  0.042674   8  -0.37035  0.7122  0.9939
Dp             -2.0858       0.84215  0.042434   7  -0.72862  0.4684  0.9967
Dp             -2.2589       0.83231  0.042306   6  -0.62548  0.5335  0.9932
Dp             -2.4352       0.82332  0.042143   5  -0.19132  0.8488  0.9932
Dp             -2.5161       0.82103  0.041888   4   0.16348  0.8706  0.9970
Dp             -2.5272       0.82214  0.041636   3  -0.35875  0.7207  0.9988
Dp             -2.5840       0.81985  0.041414   2   -2.4660  0.0157  0.9993
Dp             -2.9990*      0.78827  0.042663   1   -2.7043  0.0083  0.8497
Dp             -3.8626**     0.73050  0.044237   0                    0.4022
```

ΔR

```
Unit-root tests 1993 (3) to 1998 (12)
Critical values: 5%=-3.474 1%=-4.093; Constant and Trend included

                 t-adf      beta Y_1    \sigma lag  t-DY_lag  t-prob  F-prob
DR             -1.8943      -0.20432    1.9475  13  -0.54552  0.5876
DR             -2.2407      -0.32576    1.9350  12   0.17691  0.8602  0.5876
DR             -2.3688      -0.28617    1.9182  11  -0.23384  0.8160  0.8490
DR             -2.6740      -0.33395    1.9022  10    1.1555  0.2527  0.9436
DR             -2.4225      -0.14494    1.9077   9 -0.045226  0.9641  0.7979
DR             -2.6388      -0.15268    1.8915   8   0.33255  0.7407  0.8918
DR             -2.7373     -0.097347    1.8774   7   0.15831  0.8747  0.9374
DR             -2.9534     -0.071342    1.8624   6   0.41907  0.6766  0.9684
DR             -3.0409     -0.013590    1.8500   5  -0.32699  0.7448  0.9805
DR             -3.4830*    -0.057055    1.8368   4   0.29185  0.7714  0.9892
DR             -3.7359*    -0.019501    1.8236   3  -0.15525  0.8771  0.9943
DR             -4.3676**   -0.039706    1.8099   2   -1.1504  0.2542  0.9973
DR             -6.5007**    -0.21088    1.8143   1   0.44574  0.6572  0.9912
DR             -9.5005**    -0.14797    1.8034   0                    0.9941
```

ΔGKO

```
Unit-root tests 1994 (8) to 1999 (6)
Critical values: 5%=-3.486 1%=-4.119; Constant and Trend included

                 t-adf      beta Y_1    \sigma lag  t-DY_lag  t-prob  F-prob
DGKO           -2.5232      -1.6525    3.3438  13   0.12813  0.8986
DGKO           -2.6874      -1.6038    3.3062  12   0.71266  0.4798  0.8986
DGKO           -2.6208      -1.3534    3.2881  11   0.38540  0.7018  0.7749
DGKO           -2.6987      -1.2225    3.2575  10   0.32920  0.7435  0.8828
DGKO           -2.8181      -1.1168    3.2265   9  -0.84748  0.4010  0.9424
DGKO           -3.7655*     -1.4370    3.2170   8   0.90337  0.3708  0.9184
DGKO           -3.8078*     -1.1552    3.2110   7   0.33282  0.7407  0.8977
DGKO           -4.2915**    -1.0574    3.1823   6   0.66247  0.5107  0.9377
DGKO           -4.7365**   -0.88186    3.1647   5   0.90537  0.3695  0.9474
DGKO           -5.1814**   -0.67295    3.1592   4    1.9360  0.0583  0.9385
DGKO           -4.8052**   -0.32952    3.2401   3    1.7658  0.0832  0.7399
DGKO           -4.4583**  -0.077931    3.3030   2  -0.76455  0.4479  0.5651
DGKO           -6.7424**   -0.20221    3.2905   1    2.0968  0.0406  0.5961
DGKO           -7.0850**   0.054656    3.3889   0                    0.3718
```

Δy

```
Unit-root tests 1993 (8) to 2000 (4)
Critical values: 5%=-3.465 1%=-4.074; Constant and Trend included

                 t-adf      beta Y_1    \sigma lag  t-DY_lag  t-prob  F-prob
Dy             -2.5496      0.12436  0.042778  13   -1.3662  0.1766
Dy             -3.3188    -0.057540  0.043058  12   0.52572  0.6008  0.1766
Dy             -3.3688    0.0019761  0.042825  11    1.4069  0.1641  0.3479
Dy             -3.0488      0.14780  0.043132  10   0.63635  0.5267  0.2577
Dy             -3.0347      0.21157  0.042946   9    1.0409  0.3016  0.3477
Dy             -2.8489      0.30287  0.042971   8  -0.43539  0.6646  0.3551
Dy             -3.2612      0.26330  0.042725   7    1.3177  0.1918  0.4521
Dy             -2.9770      0.36363  0.042943   6  -0.24909  0.8040  0.3866
Dy             -3.3561      0.34298  0.042667   5   0.37060  0.7120  0.4806
Dy             -3.5115*     0.37147  0.042417   4   0.50338  0.6162  0.5633
Dy             -3.6634*     0.40991  0.042206   3    1.4527  0.1505  0.6286
Dy             -3.3422      0.49357  0.042513   2   -1.3395  0.1844  0.5319
Dy             -4.3985**    0.40206  0.042731   1   -1.8763  0.0644  0.4717
Dy             -6.9266**    0.24530  0.043416   0                    0.3136
```

Δs

```
Unit-root tests 1993 (3) to 2000 (7)
Critical values: 5%=-3.46 1%=-4.064; Constant and Trend included

                 t-adf      beta Y_1    \sigma lag  t-DY_lag  t-prob  F-prob
Ds             -2.5514      0.42111  0.077813  13  -0.58302  0.5617
Ds             -2.9111      0.37813  0.077465  12    1.4214  0.1594  0.5617
Ds             -2.6012      0.46267  0.077990  11  -0.50396  0.6158  0.3158
Ds             -2.9281      0.42949  0.077607  10   0.53382  0.5950  0.4628
Ds             -2.9225      0.46245  0.077245   9   0.60767  0.5452  0.5809
Ds             -2.8870      0.49697  0.076933   8    1.1359  0.2595  0.6632
Ds             -2.6868      0.54507  0.077074   7  0.085550  0.9320  0.6106
Ds             -2.7760      0.54882  0.076594   6  -0.44409  0.6582  0.7175
Ds             -3.0173      0.52962  0.076214   5  -0.29119  0.7716  0.7846
Ds             -3.3027      0.51506  0.075787   4   0.74633  0.4576  0.8469
Ds             -3.2386      0.54884  0.075585   3   -1.1854  0.2393  0.8625
Ds             -4.0660**    0.48153  0.075767   2   -1.2309  0.2218  0.8199
Ds             -5.4301**    0.40179  0.075996   1    1.1404  0.2573  0.7715
Ds             -5.6056**    0.46480  0.076129   0                    0.7412
```

Appendix 3: Equivalence of VAR and Equilibrium Correction Representation

Starting from a VAR(p) representation, let X_t be an (nx1) vector:

$$\left(I_n - \Phi_1 L - \Phi_2 L^2 - \cdots - \Phi_p L^p\right) X_t = \boldsymbol{e}_t \tag{A3.1}$$

Φ_s denotes an (nxn) matrix for s = 1, 2, 3, ..., p and $\boldsymbol{a}$ and $\boldsymbol{e}_t$ are (nx1) vectors.

The following are equivalent:

$$\left(I_n - \Phi_1 L - \Phi_2 L^2 - \cdots - \Phi_p L^p\right) = \left(I_n - \boldsymbol{r}L\right) - \left(\Gamma_1 L + \Gamma_2 L^2 + \cdots + \Gamma_{p-1} L^{p-1}\right)(1 - L) \tag{A3.2}$$

where

$$\boldsymbol{r} \equiv \Phi_1 + \Phi_2 + \cdots + \Phi_p \tag{A3.3}$$

$$\Gamma_s \equiv -\lfloor \Phi_{s+1} + \Phi_{s+2} + \cdots + \Phi_p \rfloor \quad \text{for s = 1, 2, ..., p-1} \tag{A3.4}$$

It follows that any VAR(p) can be rewritten from (1) above in the form

$$\left(I_n - \boldsymbol{r}L\right) X_t - \left(\Gamma_1 L + \Gamma_2 L^2 + \cdots + \Gamma_{p-1} L^{p-1}\right)(1 - L) X_t = \boldsymbol{e}_t$$

or

$$X_t = \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + \cdots + \Gamma_{p-1} \Delta X_{t-p+1} + \boldsymbol{r} X_{t-1} + \boldsymbol{e}_t \tag{A3.5}$$

now, subtracting X_{t-1} from both sides produces

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + \cdots + \Gamma_{p-1} \Delta X_{t-p+1} + \Gamma_0 X_{t-1} + \boldsymbol{e}_t \tag{A3.6}$$

where $\Gamma_0 = \boldsymbol{r} - I_n = -\left(I_n - \Phi_1 - \Phi_2 - \cdots - \Phi_p\right) = -\Phi(1)$ A3.7
therefore, replacing (7) into (6), we get

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + \cdots + \Gamma_{p-1} \Delta X_{t-p+1} - \Phi(1) X_{t-1} + \boldsymbol{e}_t \tag{A3.8}$$

now $\Phi(1) = BA'$ (This follows from the implications of cointegration for the Vector Moving Average representation and Vector Autoregressive representation, see Hamilton (1994), p. 574 and 579) So we have,

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + \cdots + \Gamma_{p-1} \Delta X_{t-p+1} - BA' X_{t-1} + \boldsymbol{e}_t \tag{A3.9}$$

Appendix 5: Discussion on weak exogeneity

Exogeneity plays an important role in empirical modeling that has implications for statistical inference, forecasting and policy analysis. A general definition of exogeneity states that a variable is exogenous when that variable can be taken as "given" without losing information for the purpose at hand.[52] The three levels of exogeneity include weak exogeneity, strong exogeneity and super exogeneity. For the purposes of this paper, the condition of weak exogeneity suffices to do inference on a single equation conditional model of money demand. A few words will be said about the other two levels of exogeneity in closing.

Weak exogeneity for the parameters of interest is a necessary condition in order to carry out efficient inference (i.e. estimation and hypothesis testing) in a conditional model. Specifically, weak exogeneity implies that inference on the parameters of interest can be conducted on the conditional density alone (rather that from the joint density) without loss of information. The following example, adapted from Ericsson and Irons (1994), serves to illustrate the main concepts of weak exogeneity. Consider a simple bivariate normal process. This process is factored into its conditional and marginal densities. The analysis of the conditional density will lead to the concepts of parameters of interest and variation free. If the parameters of interest are only functions of the parameters of the conditional distribution, and if the parameters of the conditional and marginal distributions are variation free, then the variables are weakly exogenous for the parameters of interest.

Example: Let the two variables y_t and z_t be jointly normally distributed and serially independent:

$$\begin{bmatrix} y_t \\ z_t \end{bmatrix} \sim IN(m, \Omega) \qquad t = 1, ..., T. \qquad \text{A5.1}$$

Where $\sim IN(m, \Omega)$ denotes that the variables are distributed independently and normally with mean m and covariance matrix Ω. Define m and Ω as:

$$m = \begin{bmatrix} m_1 \\ m_2 \end{bmatrix} \qquad \Omega = \begin{bmatrix} w_{11} & w_{12} \\ w_{21} & w_{22} \end{bmatrix} \qquad \text{A5.2}$$

Let x_t be $(y_t, z_t)'$ and define e_t as an error term that is distributed $IN(0, \Omega)$. A5.1 can then be rewritten in a model form as:

$$x_t = m + e_t \qquad e_t \sim IN(0, \Omega) \qquad \text{A5.3}$$

---

[52] See Ericsson and Irons (1994) Testing Exogeneity

We can factor A5.1 into the conditional density of y_t given z_t and the marginal density of z_t, as follows:

$$y_t | z_t \sim IN(a + bz_t, s^2) \qquad \text{A5.4a}$$

$$z_t \sim IN(m_{2t}, w_{22}), \qquad \text{A5.4b}$$

where $b = \frac{w_{12}}{w_{22}}$, $a = m_1 - bm_2$ and $s^2 = w_{11} - \frac{w_{12}^2}{w_{22}}$. In model form, A5.4 can be rewritten as:

$$y_t = a + bz_t + v_{1t} \qquad v_{1t} \sim IN(0, s^2) \qquad \text{A5.5a}$$

$$X \qquad {}_t \qquad e_{2t} \sim IN(0, w_{22}) \qquad \text{A5.5b}$$

In terms of densities, the relationship can be given by:

$$F_x(x_t; q) = F_{y|z}(y_t \mid z_t; l_1)\ F_z(z_t; l_2) \qquad \text{A5.6}$$

$F_x(x_t; q)$ is the joint density of x_t, $F_{y|z}(y_t \mid z_t; l_1)$ is the conditional density of y_t given z_t and $F_z(z_t; l_2)$ is the marginal density of z_t. The parameter vector q is the full set of parameters in the joint process; l_1 and l_2 are the parameters of the conditional and marginal models; and the respective parameter spaces are Θ, Λ_1 and Λ_2. Let l be $(l_1', l_2')'$ and its parameter space, Λ. Then, there is a one to one function g(.) such that l =g(q). From the equations above, $q = [m', vec(\Omega)']'$, $l_1 = (a, b, s^2)'$ and $l_2 = (m_2, w_{22})$.

In A5.6, the joint density of x_t if factorized into the conditional density of y_t given z_t and the marginal density of z_t. There is no loss of generality in this factorization. However, analyzing the conditional density $F_{y|z}(y_t \mid z_t; l_1)$ without considering the marginal density $F_z(z_t; l_2)$ is with loss of generality, and in general does imply a loss of information about the conditional process being modeled. Analyzing the conditional model alone is the statistical formalization of taking z_t as given.

The concept that the parameters, l_1 and l_2, are variation free needs to be defined. The lack of dependence between the two parameters is an overly strong condition. l_1 and l_2 are considered variation free when the parameter space Λ_1 is not a function of the parameter l_2 and the parameter space Λ_2 is not a function of the parameter l_1. This condition and the factorization above in A5.6 is said to operate a sequential cut of the density function, $F_x(x_t; q)$.

Definition of Weak Exogeneity: The variable z_t is weakly exogenous over the sample period for the parameters of interest, ψ if and only if there exists a reparametrization of θ as λ such that:

1) ψ is a function of λ_1 alone and
2) the factorization, $F_x(x_t;\theta) = F_{y|z}(y_t \mid z_t; \lambda_1)\ F_z(z_t; \lambda_2)$ operates a sequential cut, where $\lambda \in \Lambda_1 \times \Lambda_2$.

[Engle, Hendry, and Richard (1983, p. 282)]

The condition of strong exogeneity is the conjunction of weak exogeneity and Granger non-causality. This allows valid conditional forecasting . An even stronger condition is super exogeneity which is a conjunction of weak exogeneity and “invariance”. This condition permits valid policy simulations.

Appendix 6: Results from an OLS estimation of the VAR in I(0)

```
SYS(13) Estimating the unrestricted reduced form by OLS  (using Data1.in7)
The present sample is:  1995 (5) to 1999 (6)

URF Equation 1 for Dy
Variable     Coefficient    Std.Error  t-value  t-prob
Dy_1            0.015853      0.26270    0.060  0.9524
Dy_2             0.32397      0.24422    1.327  0.1966
Dy_3             0.61459      0.38184    1.610  0.1201
Dy_4             0.50067      0.31530    1.588  0.1249
Dy_5             0.30536      0.32433    0.942  0.3554
Dm2a_1           0.58332      0.44163    1.321  0.1985
Dm2a_2           0.47696      0.40810    1.169  0.2535
Dm2a_3           0.52238      0.44113    1.184  0.2475
Dm2a_4          0.040407      0.44584    0.091  0.9285
Dm2a_5           0.18287      0.41961    0.436  0.6667
DGKO_1        -0.0083354    0.0068804   -1.211  0.2370
DGKO_2        -0.0013744    0.0046634   -0.295  0.7706
DGKO_3        -0.0044438    0.0037232   -1.194  0.2439
DGKO_4       -0.00012445    0.0027159   -0.046  0.9638
DGKO_5       3.4979e-005    0.0026600    0.013  0.9896
DDp_1           -0.65023      0.38848   -1.674  0.1066
DDp_2           -0.14329      0.47704   -0.300  0.7664
DDp_3            0.41001      0.46892    0.874  0.3902
DDp_4            0.30361      0.43951    0.691  0.4961
DDp_5            0.18232      0.23946    0.761  0.4535
CI1_1           -0.94673      0.30387   -3.116  0.0046
CI2_1            0.16307      0.17990    0.906  0.3733
Constant        0.024976     0.016307    1.532  0.1382
D1             -0.090414     0.046981   -1.924  0.0657
D2              -0.18793     0.083597   -2.248  0.0336

\sigma = 0.0406204   RSS = 0.041250489

URF Equation 2 for Dm2a
Variable     Coefficient    Std.Error  t-value  t-prob
Dy_1             0.15842      0.10473    1.513  0.1429
Dy_2             0.20370     0.097362    2.092  0.0467
Dy_3             0.10608      0.15223    0.697  0.4923
Dy_4            0.027987      0.12570    0.223  0.8256
Dy_5             0.16325      0.12930    1.263  0.2184
Dm2a_1          0.094354      0.17607    0.536  0.5968
Dm2a_2         -0.064140      0.16270   -0.394  0.6968
Dm2a_3           0.26617      0.17587    1.513  0.1427
Dm2a_4           0.21279      0.17774    1.197  0.2425
Dm2a_5         -0.078852      0.16729   -0.471  0.6415
DGKO_1      -2.0971e-005    0.0027430   -0.008  0.9940
DGKO_2         0.0036851    0.0018592    1.982  0.0586
DGKO_3         0.0026908    0.0014843    1.813  0.0819
DGKO_4         0.0030288    0.0010828    2.797  0.0098
DGKO_5         0.0023313    0.0010605    2.198  0.0374
DDp_1          -0.035611      0.15487   -0.230  0.8200
DDp_2          0.0085496      0.19018    0.045  0.9645
DDp_3            0.19944      0.18694    1.067  0.2962
DDp_4            0.17537      0.17522    1.001  0.3265
DDp_5            0.10509     0.095465    1.101  0.2814
CI1_1           -0.15806      0.12114   -1.305  0.2039
CI2_1           -0.26154     0.071719   -3.647  0.0012
Constant        0.017604    0.0065013    2.708  0.0120
D1             -0.087747     0.018730   -4.685  0.0001
D2              -0.13699     0.033328   -4.110  0.0004
```

```
\sigma = 0.0161943   RSS = 0.006556359493

URF Equation 3 for DGKO
Variable     Coefficient    Std.Error  t-value  t-prob
Dy_1              13.244       11.155    1.187  0.2463
Dy_2              24.016       10.370    2.316  0.0290
Dy_3              14.870       16.213    0.917  0.3678
Dy_4              27.523       13.388    2.056  0.0504
Dy_5             -19.718       13.771   -1.432  0.1646
Dm2a_1           -40.821       18.752   -2.177  0.0391
Dm2a_2            12.871       17.329    0.743  0.4645
Dm2a_3            22.265       18.731    1.189  0.2457
Dm2a_4           -5.8084       18.931   -0.307  0.7615
Dm2a_5            21.912       17.817    1.230  0.2302
DGKO_1           0.40954      0.29215    1.402  0.1733
DGKO_2          -0.42785      0.19801   -2.161  0.0405
DGKO_3           0.24061      0.15809    1.522  0.1406
DGKO_4          -0.17017      0.11532   -1.476  0.1525
DGKO_5          0.066877      0.11295    0.592  0.5591
DDp_1            -39.727       16.495   -2.408  0.0237
DDp_2             2.3334       20.256    0.115  0.9092
DDp_3             22.223       19.911    1.116  0.2750
DDp_4             24.350       18.662    1.305  0.2039
DDp_5             11.496       10.168    1.131  0.2690
CI1_1            -17.168       12.903   -1.331  0.1953
CI2_1            -11.610       7.6386   -1.520  0.1411
Constant         0.78643      0.69243    1.136  0.2668
D1                2.6939       1.9949    1.350  0.1890
D2               -9.3580       3.5496   -2.636  0.0142

\sigma = 1.7248   RSS = 74.37317929

URF Equation 4 for DDp
Variable     Coefficient    Std.Error  t-value  t-prob
Dy_1            -0.20301     0.086808   -2.339  0.0276
Dy_2            -0.46652     0.080701   -5.781  0.0000
Dy_3            -0.38258      0.12618   -3.032  0.0056
Dy_4            -0.39546      0.10419   -3.796  0.0008
Dy_5            -0.32522      0.10717   -3.035  0.0056
Dm2a_1          -0.13084      0.14594   -0.897  0.3785
Dm2a_2          0.065837      0.13486    0.488  0.6297
Dm2a_3          -0.28536      0.14577   -1.958  0.0615
Dm2a_4         0.0088585      0.14733    0.060  0.9525
Dm2a_5           0.22192      0.13866    1.600  0.1221
DGKO_1         0.0043198    0.0022736    1.900  0.0690
DGKO_2        -0.0024126    0.0015410   -1.566  0.1300
DGKO_3       -0.00017032    0.0012303   -0.138  0.8910
DGKO_4      -5.6416e-006   0.00089748   -0.006  0.9950
DGKO_5       -0.00020765   0.00087900   -0.236  0.8152
DDp_1           -0.34021      0.12837   -2.650  0.0138
DDp_2           -0.42235      0.15764   -2.679  0.0129
DDp_3           -0.59426      0.15495   -3.835  0.0008
DDp_4           -0.48015      0.14523   -3.306  0.0029
DDp_5           -0.19954     0.079128   -2.522  0.0184
CI1_1            0.56096      0.10041    5.587  0.0000
CI2_1           0.069512     0.059446    1.169  0.2533
Constant       -0.036595    0.0053888   -6.791  0.0000
D1               0.14142     0.015525    9.110  0.0000
D2               0.19141     0.027624    6.929  0.0000

\sigma = 0.0134229   RSS = 0.004504374277
```

```
correlation of URF residuals
                      Dy        Dm2a        DGKO         DDp
 Dy               1.0000
 Dm2a            0.46884      1.0000
 DGKO           -0.66452    -0.39633      1.0000
 DDp           0.0062790    -0.22640   0.0063265      1.0000

standard deviations of URF residuals
           Dy        Dm2a        DGKO         DDp
     0.040620    0.016194      1.7248    0.013423

loglik = 646.87205  log|\Omega| = -25.8749  |\Omega| = 5.79004e-012  T = 50
log|Y'Y/T| = -17.1458
R^2(LR) = 0.999838  R^2(LM) = 0.7971

F-test on all regressors except unrestricted, F(100,89) = 7.2179 [0.0000] **
No variables entered unrestricted.

F-tests on retained regressors, F(4, 22)
       Dy_1     2.21658 [0.1003]          Dy_2     12.0638 [0.0000] **
       Dy_3     4.27632 [0.0104] *        Dy_4     7.91889 [0.0004] **
       Dy_5     2.46510 [0.0749]        Dm2a_1     1.29052 [0.3041]
     Dm2a_2     1.36895 [0.2769]        Dm2a_3     2.92613 [0.0442] *
     Dm2a_4    0.420641 [0.7920]        Dm2a_5     1.49553 [0.2378]
     DGKO_1     1.61518 [0.2059]        DGKO_2     3.33205 [0.0281] *
     DGKO_3     2.37318 [0.0834]        DGKO_4     2.96522 [0.0423] *
     DGKO_5     1.68079 [0.1903]         DDp_1     7.05560 [0.0008] **
      DDp_2     1.65687 [0.1958]         DDp_3     4.60328 [0.0075] **
      DDp_4     3.80094 [0.0170] *       DDp_5     2.67343 [0.0589]
      CI1_1     14.0340 [0.0000] **      CI2_1     5.59770 [0.0029] **
   Constant     12.8186 [0.0000] **         D1     20.0034 [0.0000] **
         D2     20.0150 [0.0000] **

correlation of actual and fitted
           Dy        Dm2a        DGKO         DDp
      0.81714     0.96056     0.84655     0.98669

Dy      :Portmanteau  6 lags=  0.43356
Dm2a    :Portmanteau  6 lags=   5.5097
DGKO    :Portmanteau  6 lags=   12.841
DDp     :Portmanteau  6 lags=   11.984
Dy      :AR 1- 4 F( 4, 21) =    0.20031 [0.9354]
Dm2a    :AR 1- 4 F( 4, 21) =     3.3132 [0.0297] *
DGKO    :AR 1- 4 F( 4, 21) =     1.0639 [0.3990]
DDp     :AR 1- 4 F( 4, 21) =     0.8976 [0.4830]
Dy      :Normality Chi^2(2)=     4.0065 [0.1349]
Dm2a    :Normality Chi^2(2)=     1.4936 [0.4739]
DGKO    :Normality Chi^2(2)=     4.6748 [0.0966]
DDp     :Normality Chi^2(2)=    0.12531 [0.9393]
Dy      :ARCH 4  F( 4, 17) =     1.2396 [0.3315]
Dm2a    :ARCH 4  F( 4, 17) =     0.2403 [0.9116]
DGKO    :ARCH 4  F( 4, 17) =    0.66321 [0.6261]
DDp     :ARCH 4  F( 4, 17) =    0.52043 [0.7220]
Vector portmanteau  6 lags=   76.358
Vector AR 1-4  F(64, 25) =     1.2503 [0.2724]
Vector normality Chi^2( 8)=    13.623 [0.0921]
```

Appendix 7: Results from the reduced VAR in I(0)

```
SYS(18) Estimating the unrestricted reduced form by OLS  (using Data1.in7)
The present sample is:  1995 (5) to 1999 (6)

URF Equation 1 for Dy
Variable     Coefficient    Std.Error  t-value  t-prob
Dy_2             0.40992      0.19548    2.097  0.0435
Dy_3             0.61278      0.24863    2.465  0.0189
Dy_4             0.34801      0.24751    1.406  0.1688
Dm2a_3           0.44177      0.35989    1.227  0.2281
DGKO_2        0.00047466    0.0033333    0.142  0.8876
DGKO_4         0.0020393    0.0021302    0.957  0.3452
DDp_1           -0.55829      0.22288   -2.505  0.0172
DDp_2           -0.18474      0.19745   -0.936  0.3561
DDp_3            0.38508      0.28374    1.357  0.1837
DDp_4            0.34282      0.24267    1.413  0.1668
DDp_5           0.025759      0.15108    0.170  0.8656
CI1_1           -0.61366      0.13500   -4.546  0.0001
CI2_1          -0.056776      0.11466   -0.495  0.6237
D2              -0.19885     0.056842   -3.498  0.0013
D1             -0.097241     0.044156   -2.202  0.0345
Constant        0.024037    0.0099066    2.426  0.0207

\sigma = 0.0403132   RSS = 0.05525529869

URF Equation 2 for Dm2a
Variable     Coefficient    Std.Error  t-value  t-prob
Dy_2             0.16116     0.085820    1.878  0.0690
Dy_3            -0.14207      0.10915   -1.302  0.2018
Dy_4            -0.12070      0.10866   -1.111  0.2745
Dm2a_3           0.21861      0.15800    1.384  0.1755
DGKO_2         0.0042230    0.0014634    2.886  0.0067
DGKO_4         0.0025946   0.00093518    2.774  0.0089
DDp_1          -0.051783     0.097849   -0.529  0.6001
DDp_2            0.15637     0.086682    1.804  0.0801
DDp_3            0.10019      0.12456    0.804  0.4268
DDp_4          -0.017469      0.10654   -0.164  0.8707
DDp_5          -0.061975     0.066327   -0.934  0.3567
CI1_1           0.017542     0.059266    0.296  0.7690
CI2_1           -0.21457     0.050339   -4.263  0.0002
D2             -0.075487     0.024955   -3.025  0.0047
D1             -0.095370     0.019385   -4.920  0.0000
Constant       0.0060786    0.0043491    1.398  0.1713

\sigma = 0.0176981   RSS = 0.01064952115

URF Equation 3 for DGKO
Variable     Coefficient    Std.Error  t-value  t-prob
Dy_2              14.384       8.5595    1.680  0.1020
Dy_3              17.244       10.887    1.584  0.1225
Dy_4              36.881       10.838    3.403  0.0017
Dm2a_3            37.864       15.758    2.403  0.0219
DGKO_2          -0.30486      0.14595   -2.089  0.0443
DGKO_4          -0.22372     0.093272   -2.399  0.0221
DDp_1            -33.403       9.7592   -3.423  0.0016
DDp_2            -9.0811       8.6454   -1.050  0.3009
DDp_3             27.472       12.424    2.211  0.0338
DDp_4             37.385       10.626    3.518  0.0013
DDp_5             16.901       6.6153    2.555  0.0153
CI1_1            -21.308       5.9111   -3.605  0.0010
CI2_1            -3.1341       5.0207   -0.624  0.5366
```

```
D2               -6.9475       2.4889   -2.791  0.0085
D1                2.6473       1.9334    1.369  0.1799
Constant         0.63795      0.43377    1.471  0.1506

\sigma = 1.76516   RSS = 105.9373623

URF Equation 4 for DDp
Variable     Coefficient    Std.Error  t-value  t-prob
Dy_2            -0.36161     0.073299   -4.933  0.0000
Dy_3           -0.010478     0.093227   -0.112  0.9112
Dy_4            -0.16800     0.092808   -1.810  0.0791
Dm2a_3         -0.056524      0.13495   -0.419  0.6780
DGKO_2        -0.0022055    0.0012499   -1.765  0.0866
DGKO_4       -0.00053971   0.00079874   -0.676  0.5038
DDp_1           -0.38840     0.083574   -4.647  0.0000
DDp_2           -0.60038     0.074036   -8.109  0.0000
DDp_3           -0.28919      0.10639   -2.718  0.0103
DDp_4           -0.22317     0.090994   -2.453  0.0195
DDp_5          -0.028686     0.056650   -0.506  0.6159
CI1_1            0.30850     0.050620    6.095  0.0000
CI2_1            0.13763     0.042995    3.201  0.0030
D2               0.13871     0.021314    6.508  0.0000
D1               0.13886     0.016557    8.387  0.0000
Constant       -0.021251    0.0037146   -5.721  0.0000

\sigma = 0.0151161   RSS = 0.007768854816

correlation of URF residuals
                      Dy        Dm2a        DGKO         DDp
 Dy               1.0000
 Dm2a            0.38571      1.0000
 DGKO           -0.59915    -0.26643      1.0000
 DDp           -0.040972    -0.32432     0.10357      1.0000

standard deviations of URF residuals
           Dy        Dm2a        DGKO         DDp
     0.040313    0.017698      1.7652    0.015116

loglik = 600.4298  log|\Omega| = -24.0172  |\Omega| = 3.71079e-011  T = 50
log|Y'Y/T| = -17.1458
R^2(LR) = 0.998963  R^2(LM) = 0.710562

F-test on all regressors except unrestricted, F(64,123) = 9.2433 [0.0000] **
No variables entered unrestricted.

F-tests on retained regressors, F(4, 31)
       Dy_2     10.3682 [0.0000] **       Dy_3     6.21442 [0.0009] **
       Dy_4     9.40903 [0.0000] **     Dm2a_3     4.19535 [0.0079] **
     DGKO_2     3.49308 [0.0182] *      DGKO_4     2.86309 [0.0396] *
      DDp_1     14.3789 [0.0000] **      DDp_2     15.7333 [0.0000] **
      DDp_3     5.86811 [0.0012] **      DDp_4     9.77895 [0.0000] **
      DDp_5     3.04487 [0.0316] *       CI1_1     33.5253 [0.0000] **
      CI2_1     5.77474 [0.0014] **         D2     22.4873 [0.0000] **
         D1     17.6472 [0.0000] **   Constant     13.0811 [0.0000] **

correlation of actual and fitted
           Dy        Dm2a        DGKO         DDp
      0.74492     0.93509     0.77226     0.97692
```

Appendix 8: FIML estimation of the reduced system

```
Equation 1 for Dy
Variable     Coefficient    Std.Error  t-value  t-prob        HCSE
Dy_1           -0.081819      0.18921   -0.432  0.6679     0.28244
Dy_2             0.15866      0.16184    0.980  0.3333     0.13862
Dy_3             0.34510      0.20468    1.686  0.1002     0.22328
Dy_4             0.35626      0.19046    1.871  0.0693     0.18128
Dy_5             0.20083      0.19024    1.056  0.2980     0.20858
Dm2a_1           0.42837      0.32840    1.304  0.2001     0.34053
Dm2a_2           0.54109      0.32567    1.661  0.1051     0.30975
Dm2a_3           0.35767      0.32332    1.106  0.2758     0.34440
Dm2a_4          0.029839      0.33409    0.089  0.9293     0.31180
Dm2a_5           0.35345      0.29331    1.205  0.2358     0.24787
DGKO_1        -0.0065356    0.0030654   -2.132  0.0397   0.0024958
DGKO_2        -0.0032029    0.0026840   -1.193  0.2403   0.0028586
DGKO_3        -0.0027936    0.0024471   -1.142  0.2610   0.0022355
DGKO_4       -0.00036203    0.0019989   -0.181  0.8573   0.0019658
DGKO_5        0.00054041    0.0019025    0.284  0.7780   0.0019876
DDp_1           -0.66023      0.31292   -2.110  0.0417     0.27146
DDp_2           -0.22509      0.36201   -0.622  0.5379     0.35915
DDp_3           0.086385      0.33679    0.256  0.7990     0.26611
DDp_4           0.024113      0.28011    0.086  0.9319     0.23404
DDp_5            0.11241      0.15495    0.725  0.4727     0.14074
CI1_1           -0.80296      0.18993   -4.228  0.0001     0.23358
CI2_1           0.090889     0.087174    1.043  0.3039    0.077869
D2              -0.17116     0.055447   -3.087  0.0038    0.072999
Constant        0.013942    0.0083338    1.673  0.1028    0.010281
D1             -0.072618     0.034832   -2.085  0.0440    0.026538

\sigma = 0.0360762

Equation 2 for Dm2a
Variable     Coefficient    Std.Error  t-value  t-prob        HCSE
Dy_1            -0.10156      0.15099   -0.673  0.5054     0.13738
Dy_2            0.010272      0.12915    0.080  0.9370     0.11633
Dy_3            -0.34924      0.16334   -2.138  0.0392     0.21290
Dy_4           -0.091524      0.15199   -0.602  0.5507     0.13640
Dy_5           0.0036917      0.15182    0.024  0.9807     0.14875
Dm2a_1          0.076841      0.26207    0.293  0.7710     0.25609
Dm2a_2           0.18096      0.25990    0.696  0.4906     0.19879
Dm2a_3           0.19349      0.25802    0.750  0.4580     0.24517
Dm2a_4          -0.16594      0.26661   -0.622  0.5375     0.27047
Dm2a_5           0.11414      0.23407    0.488  0.6287     0.15469
DGKO_1         0.0016544    0.0024462    0.676  0.5031   0.0031963
DGKO_2         0.0027005    0.0021419    1.261  0.2153   0.0024214
DGKO_3         0.0016880    0.0019529    0.864  0.3929   0.0015733
DGKO_4         0.0019231    0.0015952    1.206  0.2356   0.0012434
DGKO_5         0.0023531    0.0015183    1.550  0.1297   0.0013112
DDp_1           -0.20780      0.24972   -0.832  0.4107     0.26834
DDp_2           0.013443      0.28889    0.047  0.9631     0.24161
DDp_3           -0.18490      0.26877   -0.688  0.4958     0.21294
DDp_4           -0.33133      0.22353   -1.482  0.1467     0.19157
DDp_5           -0.14790      0.12365   -1.196  0.2393     0.14383
CI1_1           0.021908      0.15157    0.145  0.8859     0.16186
CI2_1           -0.17076     0.069567   -2.455  0.0189     0.10170
D2             -0.055626     0.044248   -1.257  0.2166    0.050269
Constant       0.0023556    0.0066506    0.354  0.7252   0.0079328
D1             -0.099224     0.027797   -3.570  0.0010    0.021657

\sigma = 0.0287898
```

```
Equation 3 for DGKO
Variable     Coefficient    Std.Error  t-value  t-prob        HCSE
Dy_1              25.722       16.423    1.566  0.1258      19.025
Dy_2              23.360       14.048    1.663  0.1048      12.832
Dy_3              20.728       17.767    1.167  0.2508      26.243
Dy_4              18.951       16.532    1.146  0.2590      20.477
Dy_5             -6.0212       16.513   -0.365  0.7175      17.515
Dm2a_1           -15.014       28.505   -0.527  0.6015      30.227
Dm2a_2           -17.030       28.269   -0.602  0.5506      26.897
Dm2a_3            34.343       28.064    1.224  0.2288      26.979
Dm2a_4            49.492       28.999    1.707  0.0963      35.321
Dm2a_5            23.850       25.460    0.937  0.3550      21.716
DGKO_1          -0.32128      0.26608   -1.207  0.2349     0.31623
DGKO_2          -0.70325      0.23297   -3.019  0.0046     0.29243
DGKO_3          -0.12028      0.21241   -0.566  0.5747     0.19039
DGKO_4          -0.22777      0.17350   -1.313  0.1974     0.15056
DGKO_5          -0.16833      0.16514   -1.019  0.3147     0.15042
DDp_1            -26.957       27.161   -0.992  0.3274      32.716
DDp_2            -24.998       31.423   -0.796  0.4314      26.605
DDp_3             9.7010       29.234    0.332  0.7419      27.162
DDp_4             38.522       24.314    1.584  0.1216      24.153
DDp_5             26.017       13.450    1.934  0.0607      17.395
CI1_1            -33.069       16.486   -2.006  0.0522      20.573
CI2_1            0.12492       7.5668    0.017  0.9869      9.3038
D2               -8.5263       4.8129   -1.772  0.0847      6.1274
Constant         0.82900      0.72338    1.146  0.2591      1.0806
D1                3.2380       3.0234    1.071  0.2911      1.9084

\sigma = 3.13144

Equation 4 for DDp
Variable     Coefficient    Std.Error  t-value  t-prob        HCSE
Dy_1            0.062146      0.12082    0.514  0.6101     0.10548
Dy_2            -0.19930      0.10335   -1.928  0.0615     0.11487
Dy_3             0.18656      0.13071    1.427  0.1619     0.17316
Dy_4           -0.084907      0.12162   -0.698  0.4895     0.11902
Dy_5           -0.094039      0.12149   -0.774  0.4438     0.11820
Dm2a_1         -0.035195      0.20971   -0.168  0.8676     0.16042
Dm2a_2         -0.051823      0.20797   -0.249  0.8046     0.18915
Dm2a_3         -0.018736      0.20647   -0.091  0.9282     0.20664
Dm2a_4           0.25403      0.21335    1.191  0.2414     0.18946
Dm2a_5         -0.093838      0.18731   -0.501  0.6193     0.14580
DGKO_1        0.00030871    0.0019575    0.158  0.8755   0.0020102
DGKO_2        -0.0012819    0.0017140   -0.748  0.4593   0.0017125
DGKO_3        0.00030480    0.0015627    0.195  0.8464   0.0013576
DGKO_4        0.00015557    0.0012765    0.122  0.9037   0.0010885
DGKO_5       -0.00056774    0.0012149   -0.467  0.6430  0.00094865
DDp_1           -0.35764      0.19983   -1.790  0.0817     0.15497
DDp_2           -0.43408      0.23117   -1.878  0.0683     0.19866
DDp_3          -0.047320      0.21507   -0.220  0.8271     0.19233
DDp_4            0.15964      0.17887    0.892  0.3779     0.16684
DDp_5           0.081364     0.098949    0.822  0.4162    0.097039
CI1_1            0.26431      0.12129    2.179  0.0358     0.11824
CI2_1            0.10768     0.055668    1.934  0.0608    0.063474
D2               0.12126     0.035408    3.425  0.0015    0.039612
Constant       -0.015106    0.0053219   -2.838  0.0073   0.0058850
D1               0.13169     0.022243    5.920  0.0000    0.026045

\sigma = 0.0230379

Optimization result: Strong convergence
(eps1=0.0001, eps2=0.005)
```

```
loglik = 699.47334  log|\Omega| = -22.5637  |\Omega| = 1.58755e-010  T = 62

correlation of residuals
                      Dy        Dm2a        DGKO         DDp
 Dy               1.0000
 Dm2a            0.34062      1.0000
 DGKO           -0.42400    -0.62638      1.0000
 DDp            -0.16210    -0.72280     0.33498      1.0000
```

Appendix 9: Test of weak exogeneity using FIML

```
MOD(28) Estimating the model by FIML  (using Data1.in7)
The present sample is:  1994 (5) to 1999 (6)

Equation 1 for Dy
Variable     Coefficient    Std.Error  t-value  t-prob        HCSE
Dy_1           -0.087916      0.18587   -0.473  0.6389     0.28835
Dy_2             0.13886      0.16093    0.863  0.3936     0.13792
Dy_3             0.33918      0.20238    1.676  0.1020     0.20848
Dy_4             0.31553      0.18650    1.692  0.0989     0.18841
Dy_5             0.15593      0.18537    0.841  0.4055     0.20865
Dm2a_1           0.40784      0.32814    1.243  0.2215     0.34488
Dm2a_2           0.51867      0.32522    1.595  0.1190     0.33269
Dm2a_3           0.32847      0.32183    1.021  0.3139     0.34629
Dm2a_4         0.0074708      0.33219    0.022  0.9822     0.28969
Dm2a_5           0.33309      0.29266    1.138  0.2622     0.23195
DGKO_1        -0.0045731    0.0024329   -1.880  0.0678   0.0018069
DGKO_2        -0.0017353    0.0022937   -0.757  0.4540   0.0024458
DGKO_3        -0.0016335    0.0021873   -0.747  0.4598   0.0019792
DGKO_4        0.00038039    0.0018716    0.203  0.8400   0.0016909
DGKO_5         0.0011489    0.0018136    0.634  0.5302   0.0018282
DDp_1           -0.57613      0.30274   -1.903  0.0646     0.26279
DDp_2           -0.15353      0.35569   -0.432  0.6684     0.35575
DDp_3            0.13639      0.33338    0.409  0.6847     0.25572
DDp_4           0.037692      0.27901    0.135  0.8933     0.21780
DDp_5           0.095465      0.15236    0.627  0.5347     0.13065
CI1_1           -0.73991      0.17430   -4.245  0.0001     0.22363
D2              -0.18711     0.050603   -3.698  0.0007    0.070686
Constant        0.015336    0.0080411    1.907  0.0641   0.0096208
D1             -0.062886     0.033262   -1.891  0.0663    0.025169

\sigma = 0.0361184

Equation 2 for Dm2a
Variable     Coefficient    Std.Error  t-value  t-prob        HCSE
Dy_1            -0.11526      0.11658   -0.989  0.3291    0.097548
Dy_2            0.024583      0.12843    0.191  0.8492     0.11669
Dy_3            -0.36086      0.13984   -2.580  0.0139     0.15635
Dy_4           -0.066764      0.14468   -0.461  0.6471     0.11594
Dy_5            0.031491      0.14327    0.220  0.8272     0.12225
Dm2a_1          0.087072      0.26056    0.334  0.7401     0.26648
Dm2a_2           0.19256      0.25769    0.747  0.4595     0.19551
Dm2a_3           0.20417      0.24915    0.819  0.4176     0.22793
Dm2a_4          -0.16606      0.24943   -0.666  0.5096     0.23208
Dm2a_5           0.12188      0.22951    0.531  0.5985     0.15490
DGKO_1        0.00030052    0.0018034    0.167  0.8685   0.0023062
DGKO_2         0.0016999    0.0017239    0.986  0.3303   0.0014337
DGKO_3        0.00085637    0.0017444    0.491  0.6263   0.0014610
DGKO_4         0.0013588    0.0015181    0.895  0.3764   0.0010968
DGKO_5         0.0018812    0.0014677    1.282  0.2077   0.0012840
DDp_1           -0.26538      0.23858   -1.112  0.2730     0.25896
DDp_2          -0.032088      0.27867   -0.115  0.9089     0.22367
DDp_3           -0.22950      0.26607   -0.863  0.3938     0.20185
```

```
DDp_4           -0.35394      0.21546   -1.643  0.1087     0.16544
DDp_5           -0.14790      0.10156   -1.456  0.1535    0.090934
CI2_1          -0.099390     0.037533   -2.648  0.0117    0.051915
D2             -0.035642     0.020184   -1.766  0.0855    0.023430
Constant      0.00045738    0.0051701    0.088  0.9300   0.0058744
D1              -0.10867     0.025592   -4.246  0.0001    0.021136

\sigma = 0.0288177

Equation 3 for DGKO
Variable     Coefficient    Std.Error  t-value  t-prob        HCSE
Dy_1              26.667       14.902    1.790  0.0815      16.214
Dy_2              23.393       13.764    1.700  0.0974      11.884
Dy_3              21.559       16.611    1.298  0.2022      22.567
Dy_4              19.268       15.809    1.219  0.2304      18.835
Dy_5             -5.7092       15.693   -0.364  0.7180      15.482
Dm2a_1           -14.697       28.033   -0.524  0.6031      29.937
Dm2a_2           -16.756       27.766   -0.603  0.5498      26.553
Dm2a_3            34.928       27.284    1.280  0.2083      26.939
Dm2a_4            50.362       27.909    1.805  0.0791      32.253
Dm2a_5            24.231       24.907    0.973  0.3368      21.592
DGKO_1          -0.32806      0.20014   -1.639  0.1094     0.23973
DGKO_2          -0.70900      0.19079   -3.716  0.0006     0.21705
DGKO_3          -0.12268      0.18556   -0.661  0.5125     0.19831
DGKO_4          -0.22771      0.16004   -1.423  0.1629     0.11918
DGKO_5          -0.16787      0.15516   -1.082  0.2861     0.14253
DDp_1            -27.240       25.756   -1.058  0.2969      31.415
DDp_2            -25.413       30.242   -0.840  0.4060      24.804
DDp_3             10.069       28.487    0.353  0.7257      26.254
DDp_4             39.175       23.615    1.659  0.1054      22.152
DDp_5             26.678       12.404    2.151  0.0379      14.449
CI1_1            -34.402       12.377   -2.779  0.0084      14.636
D2               -8.9326       3.7023   -2.413  0.0208      4.3135
Constant         0.87246      0.64449    1.354  0.1838     0.93604
D1                3.3445       2.7939    1.197  0.2387      1.4018

\sigma = 3.09031

Equation 4 for DDp
Variable     Coefficient    Std.Error  t-value  t-prob        HCSE
Dy_1            0.069934      0.11083    0.631  0.5318     0.10962
Dy_2            -0.22176      0.10624   -2.087  0.0436     0.12556
Dy_3             0.19275      0.12533    1.538  0.1324     0.16131
Dy_4            -0.12729      0.12146   -1.048  0.3012     0.11359
Dy_5            -0.14118      0.12048   -1.172  0.2485     0.11512
Dm2a_1         -0.054702      0.21625   -0.253  0.8017     0.17369
Dm2a_2         -0.073518      0.21412   -0.343  0.7332     0.18867
Dm2a_3         -0.043388      0.20963   -0.207  0.8371     0.20621
Dm2a_4           0.24188      0.21338    1.134  0.2641     0.19403
Dm2a_5          -0.11128      0.19176   -0.580  0.5651     0.14460
DGKO_1         0.0024819    0.0015121    1.641  0.1090   0.0019069
DGKO_2        0.00033357    0.0014506    0.230  0.8194   0.0013473
DGKO_3         0.0016149    0.0014262    1.132  0.2646   0.0013032
DGKO_4         0.0010200    0.0012351    0.826  0.4141   0.0011888
DGKO_5        0.00014829    0.0011979    0.124  0.9021   0.0010245
DDp_1           -0.26484      0.19826   -1.336  0.1895     0.16586
DDp_2           -0.35792      0.23271   -1.538  0.1323     0.20047
DDp_3           0.016274      0.21977    0.074  0.9414     0.18805
DDp_4            0.18545      0.18128    1.023  0.3128     0.15897
DDp_5           0.072090     0.093134    0.774  0.4437    0.080703
CI1_1            0.31661     0.083639    3.785  0.0005     0.10495
D2              0.096309     0.025720    3.745  0.0006    0.030261
Constant       -0.012802    0.0047925   -2.671  0.0111   0.0056343
```

```
D1               0.14469     0.021358    6.774  0.0000    0.028027

\sigma = 0.023858

loglik = 695.05128  log|\Omega| = -22.421  |\Omega| = 1.83096e-010  T = 62
LR test of over-identifying restrictions: Chi^2(4) = 8.84411 [0.0651]

correlation of residuals
                      Dy        Dm2a        DGKO         DDp
 Dy               1.0000
 Dm2a            0.30303      1.0000
 DGKO           -0.41749    -0.61821      1.0000

 DDp            -0.10117    -0.72971     0.32022      1.0000
```

Appendix 10: Results of the ADL(6) estimation by OLS

```
EQ( 2) Modeling m2a by OLS  (using Data1.in7)
The present sample is:  1995 (5) to 1999 (6)

Variable     Coefficient    Std.Error  t-value  t-prob PartR^2
Constant          3.2957       4.2894    0.768  0.4513  0.0287
Dp_1            0.082151      0.16462    0.499  0.6232  0.0123
Dp_2            0.012143      0.20724    0.059  0.9539  0.0002
Dp_3            0.088282      0.21399    0.413  0.6843  0.0084
Dp_4            0.032551      0.15476    0.210  0.8355  0.0022
Dp_5            0.019754      0.16556    0.119  0.9062  0.0007
Dp_6           -0.033888      0.11284   -0.300  0.7670  0.0045
y                0.15202      0.10237    1.485  0.1531  0.0993
y_1             0.088714      0.12598    0.704  0.4894  0.0242
y_2            -0.061216      0.13250   -0.462  0.6491  0.0106
y_3             -0.13673      0.13951   -0.980  0.3388  0.0458
y_4            -0.045479      0.12263   -0.371  0.7146  0.0068
y_5              0.11981      0.17623    0.680  0.5044  0.0226
y_6            0.0041802      0.14928    0.028  0.9779  0.0000
Dp              -0.27449      0.23533   -1.166  0.2572  0.0637
m2a_1            0.62966      0.22072    2.853  0.0098  0.2892
m2a_2         -0.0088154      0.26792   -0.033  0.9741  0.0001
m2a_3            0.23654      0.25360    0.933  0.3621  0.0417
m2a_4           0.066727      0.26248    0.254  0.8019  0.0032
m2a_5           -0.20835      0.26574   -0.784  0.4422  0.0298
m2a_6          0.0025767      0.18750    0.014  0.9892  0.0000
GKO           -0.0014149    0.0024534   -0.577  0.5706  0.0164
GKO_1         -0.0031424    0.0033579   -0.936  0.3605  0.0420
GKO_2        -0.00050206    0.0035480   -0.142  0.8889  0.0010
GKO_3          0.0010436    0.0025843    0.404  0.6906  0.0081
GKO_4        -0.00087385    0.0017415   -0.502  0.6213  0.0124
GKO_5        -0.00045448    0.0013454   -0.338  0.7390  0.0057
GKO_6         -0.0024275    0.0010651   -2.279  0.0338  0.2062
D1             -0.030009     0.039704   -0.756  0.4586  0.0278
D2             -0.068499     0.066321   -1.033  0.3140  0.0506

R^2 = 0.996323  F(29,20) = 186.85 [0.0000]  \sigma = 0.0152979  DW = 2.11
RSS = 0.004680487867 for 30 variables and 50 observations

AR 1- 4 F( 4, 20) =     2.1149 [0.1167]
ARCH 4  F( 4, 16) =     0.3185 [0.8614]
Normality Chi^2(2)=     3.6264 [0.1631]
RESET   F( 1, 23) =    0.23781 [0.6304]
```

Appendix 11: Reduction strategy for the parsimonious ECM

The following variables do not appear either numerically or statistically significant and were eliminated in the given sequence.

1) The lags Δp_{t-1} , $\Delta^2 p_{t-1}$, $\Delta^2 p_{t-2}$, $\Delta^2 p_{t-3}$, $\Delta^2 p_{t-4}$, $\Delta^2 p_{t-5}$; Δy_{t-2}, Δy_{t-3}, Δy_{t-5}; and $m2a_{t-5}$.
2) The lags of $\Delta m2a_{t-1}$ $\Delta m2a_{t-2}$ $\Delta m2a_{t-3}$, and ΔGKO_t;
3) y_{t-1} and D_t.
4) The coefficients on all the lagged differences of short run GKO_t terms are close to zero and are dropped.

The following models correspond to the above restrictions.

Table A11.1: Reduction tests of the unrestricted ECM

```
Model statistics
     dep.var            T   k   df         RSS       \sigma      Schwarz
  5: Dm2a          OLS   50   9   41    0.0119885    0.0170998     -7.63166
  4: Dm2a          OLS   50  14   36   0.00742143     0.014358     -7.72004
  3: Dm2a          OLS   50  16   34   0.00611554    0.0134115      -7.7571
  2: Dm2a          OLS   50  20   30   0.00593038    0.0140599     -7.47488
  1: Dm2a          OLS   50  30   20   0.00468049    0.0152979     -6.92916

 Progress to date for modeling Dm2a:
 Model   1 -->  2: F(10,  20) =   0.53409 [0.8460]

 Model   1 -->  3: F(14,  20) =     0.438 [0.9409]
 Model   2 -->  3: F( 4,  30) =   0.23416 [0.9169]

 Model   1 -->  4: F(16,  20) =   0.73201 [0.7343]
 Model   2 -->  4: F( 6,  30) =    1.2571 [0.3064]
 Model   3 -->  4: F( 2,  34) =    3.6301 [0.0372] *

 Model   1 -->  5: F(21,  20) =     1.487 [0.1896]
 Model   2 -->  5: F(11,  30) =     2.786 [0.0127] *
 Model   3 -->  5: F( 7,  34) =    4.6645 [0.0010] **
 Model   4 -->  5: F( 5,  36) =    4.4308 [0.0030] **
```

The first half of table A11.1 show the parameter restrictions of the model according to the list above. Model 1 represents the unrestricted ECM. Model 2 represents the unrestricted ECM plus the restrictions listed in 1 above. Model 3 represents model 2 plus the restrictions listed under 2 above. Model 5 represents the estimation of the ECM with all the restrictions listed above. The Schwarz information criteria is also given for the reduced models.

$$\mathrm{SC} = \log \tilde{s} + k\frac{(\log T)}{T} \qquad \text{A11.1}$$

As a penalty for a large number of parameters, the smaller SC indicates the preferred model.

The second half of the table lists the F-tests for the restrictions in both sequential order of reductions and tests comparing models out of sequence. As can be seen, the final representation of the conditional money equation is model 5. All the restrictions taken together cannot be rejected using the F-test from the unrestricted model; however, a sequential reduction of the general unrestricted ECM would not reject model 3 and reject model 4.

Appendix 12: Parsimonious conditional money demand equation estimated by OLS

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EQ( 5) Modeling Dm2a by OLS  (using Data1.in7)
The present sample is:  1995 (5) to 1999 (6)

Variable     Coefficient    Std.Error  t-value  t-prob PartR^2
Constant          3.2518      0.61572    5.281  0.0000  0.3991
Dy_1             0.26916     0.058740    4.582  0.0000  0.3333
Dy_4            -0.19710     0.063126   -3.122  0.0032  0.1884
Dy               0.16603     0.057419    2.891  0.0060  0.1660
Dm2a_4           0.27125     0.072542    3.739  0.0006  0.2498
DDp             -0.39212     0.056769   -6.907  0.0000  0.5318
D2             -0.070935     0.011356   -6.247  0.0000  0.4816
CI2_1           -0.16474     0.031259   -5.270  0.0000  0.3981

R^2 = 0.85849  F(7,42) = 36.4 [0.0000]  \sigma = 0.0169021  DW = 1.55
RSS = 0.01199854688 for 8 variables and 50 observations


AR 1- 4 F( 4, 38) =     1.1385 [0.3531]
ARCH 4  F( 4, 34) =     1.4343 [0.2439]
Normality Chi^2(2)=     1.7741 [0.4119]
Xi^2    F(13, 28) =     0.7493 [0.7022]
Xi*Xj   F(34,  7) =    0.33424 [0.9853]
RESET   F( 1, 41) =     5.2322 [0.0274] *
```

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