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A TIMING MODEL OF THE RUSSIAN CURRENCY CRISIS: CASES OF NON-LINEAR BEHAVIOR, UNCERTAINTY, AND DEVALUATION EXPECTATIONS

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Исследование посвящено моделированию и эмпирической оценке российского валютного кризиса августа 1998 года. В начале работы дан обзор недавних теоретических и эмпирических разработок в этой области. Основными вопросами, которые были изучены, являются проблемы изучения временных рамок наступления кризиса, разрывных скачков в обменном курсе и различного поведения участников рынка и властей, возможно нелинейного. Проанализировано три модификации стандартной модели, относящейся к так называемому первому поколению моделей валютных кризисов, отражающие соответственно: (1) нелинейное поведение властей; (2) неопределенность относительно параметров внутреннего кредита; (3) девальвацию после спекулятивной атаки. Проведено оценивание этих модификаций на российских данных. В целом был сделан вывод, что эти модификации достаточно хорошо отражают российский случай. Кроме этого, было проведено "внемодельное" эконометрическое исследование показателей финансовых рынков.

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The paper is devoted to the modelling and estimation of the Russian currency crisis that occurred in August 1998. The theoretical and empirical review of the area is provided. Main problems that have been analysed are: timing of the crisis, jump in the exchange rate, and different, possibly non-linear behaviour of monetary authorities and market players. Three modifications of the standard 1st-approach model have been analysed, reflecting: (1) non-linear government behaviour; (2) uncertainty about domestic credit parameters; (3) devaluation after a speculative attack. The estimation of these modifications with the Russian data is provided. In general, it has been found that the modifications fit the Russian case rather well. The "without-model" econometric estimation of financial markets data also has been done.

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Introduction

Current financial crisis in Russia has not only reflected the perturbations in the world economy but also enhanced because of poor condition of public finance sector and delay of actual reforms. The currency crisis born by inability of the Central Bank to support the claimed target zone, has led to the overall financial crisis which is continuing now. One of the main unsolved problems is whether capital flows, deterioration of balance of payments or poor internal economic performance has played a major role in the Russian crisis. The other problem to be discussed is whether the measures taken by authorities were adequate and in due time. The discussion of these problems and interpretation of mechanisms and events which led to the crisis could contribute to the analysis of different policy implications.

The aim of the working on Master Thesis was twofold: first of all, we need to build such a model (or modification of a standard model) that is able to answer at least some particular questions concerning the Russian case as we see it and also explain some features of the Russian case that is not possible or hard to explain using standard models. Second, we would like to investigate the same problems empirically, using data available to market participants at the time and propose some new insights on the cause of this crisis.

The Master Thesis discusses and develops some new results that have been obtained. Among them it is possible to list the following: (1) a definition of currency crisis that was implemented (the 2nd section); (2) separation of short and long run causes (table 1 in the 3rd section); (3) three

modifications of the basic model (their refinement to the Russian case) in the 7th section; (4) the estimation of the Russian case, particularly the timing, devaluation affect and the jump of the exchange rate, using modifications in the 8th section; (5) the econometric analysis of the Russian financial data and sorting all sources of risk in the Russian story.

The Master Thesis consists of nine sections. In the 1st section there is a very brief introduction to the problem in general and to the Russian case, including depiction of some peculiarities that we think make it different from other cases. Such motivation for our research could suggest in the first approach what we want to achieve in the Master Thesis. In the 2nd section we give the definition of currency crisis that we use in this paper. In the 3rd section there will be short discussion of theoretical topics behind currency crises; particularly, the illumination of the main theoretical approaches to the currency crises will be provided. Then, review of recent empirical evidence on such crises with concentration on methodology used in dealing with analyzing data available will be given in the 4th section. The 5th section tries to answer what questions we want to explain in Russian case. Particularly, the general description of Russian economic situation and chronology of the period between October 1997 and August 1998 are given.

Next few sections are the core of the Master Thesis. The 6th section is devoted to the building of the model basing on one of standard approaches that could include and explain features of the Russian case. Then, in the 7th section the main results of the model's modifications and their theoretical description and economic investigation are provided. Finally, in the two consequent sections we deal with empiric questions. The 8th section is

devoted to empiric investigation of some model results. The 9th section studies the Russian case generally without attachment to any model and some interesting results are obtained.

I would like to thank many people for their comments and help on different stages of this project. Irena Denisova, Sergey Guriev and Ksenia Udaeva helped me to find motivation of my research and focus of it. Tatiana Kirsanova pointed me to some features of my devaluation analysis (see the 7th section). All participants in the World Bank sponsored GET project "Financial Crisis in Russia" listened very attentively to all my presentations and asked me a lot of questions as well as critical remarks. We also had interesting meetings with professionals at our GET workshops and among them I would like to mention most of all our discussions with Andrei Klepach and Johan Vermut. These discussions helped me among other things to focus on various causes of the Russian currency crisis and to have a look at the crisis from the point of view of the Central Bank and a foreign investor. Professor Giovanni Urga read a draft version of this paper as well as course paper and made a lot of useful remarks and suggestions at our GET meetings and beyond them. Also I have been intensively using all knowledge that I received during his Econometrics IV and Panel Data classes. Evsey Gurvitch helped me a lot with data as well as with good pieces of advice. Anatoli Peresetski showed me some interesting points concerning log-linearisation of formula (2) in text. My special thanks to my supervisor Arkady Dvorkovitch who collaborated with me closely from the beginning to the end of this project.

Needless to say, all mistakes and misprints are of my own.

Section One. Motivation for Research

This section introduce very briefly what we want to achieve in this research, particularly why we may think that the Russian case is somewhat different from other stories from developed and developing countries that have experienced currency crisis and some of them have been experiencing crises many times. This view does not mean at all that the Russian case is unique and no major similarities can be found between it and, say, Argentina, Brazil or Thailand currency crises. On the contrary, we argue in section five thereafter that the main structure of the crisis of the summer of 1998, i.e. its path, causes, process of evolvement, etc. was rather general and standard. As stated below in the 6th and 7th sections we argue that the Russian case is rather well fitted in the so-called fundamental story (see the 3rd section) with some innovations from the self-fulfilling approach.

But at the same time there are some features that may be unique to the Russian case. For example, Russia had strong net imports over the whole period, although they were declining for some time in the considered period. Then, there was some constant political instability which may have a significant effect on the whole story. It could be also mentioned that market participants understood that with high probability there would be devaluation of the rouble, but not floating it. Important question which we asked in the beginning of research was the question of timing of crisis. Why did the crisis occur in August and not in May or October? Does the fundamental model explain it or should we introduce some modifications to find another solutions to that issue? Another question that has been pushing our interest is the fact of discontinuous jumps of rouble. Is it possible to model this by continuous methods?

Thus, all this suggests that we should try to understand the general issues and the

particular features and try to analyse if it is possible, how to implement this issues into the model.

Section Two. Definition of Currency Crisis

Currency crises can occur under different circumstances, but some features are similar to all of them. First of all, national currency should be fixed to some foreign currency (e. g., to U.S. dollar) or to the basket of currencies, or it should be pegged with some other currencies (e.g., currencies in the European Union). These and some other alternatives such as crawling peg (e.g., in Argentina) and managed floating are very popular, especially among developing countries for various reasons. The geographical distribution of exchange rates (ER) arrangements for such countries in 1982-93 could be found in Agenor and Montiel (1996). Under flexible ER regime there is no possibility for currency speculators to gain infinite profit at any time because of continuous movements in the ER, therefore there is no room to the currency crises as we understand them. So, fixed ER regime (ERR) (or pegged ER regime) that exists at least in the initial situation in the economy is one of the assumptions in our analysis. The second assumption, the importance of which is difficult to overvalue, is the assumption of capital mobility, full or at least partial. It suffices to show that if there is no capital mobility then speculators could not exchange national currency for foreign currency freely without any (in pure capital mobility case) restrictions. Capital mobility can be understood as both the possibility of easy capital inflows or outflows from the country and the possibility of change the national currency to the foreign one in home country.

We define hereafter a currency crisis as a situation under which after some period of fixing ER to another currency or basket of currencies monetary authorities find out

that they are unable to sustain this announced fixed ERR any longer due to speculative attack caused by a lack of credibility of a fixed ERR that causes the devastation of monetary authorities' international reserves.

It should be noted that there are possibly other definitions of currency crises, some of them have been already presented in the literature. E.g., Kaminsky, Lizondo and Reinhart (1998) consider the currency crisis to be the situation when the fixed or pegged ERR is under the thread because of the speculative attack. There are two main differences between his understanding and ours. First, they are looking more at the market side of the economy, at the speculators by providing this definition. We are looking more at monetary authorities and at the economy in the whole. Second, we understand by currency crisis only such situation when speculative attack is successful in the sense that fixed ERR is abandoned. They argue that currency crises are all situations when speculative attack occurs even if turns out to be unsuccessful. Another view is proposed by Eichengreen, Rose and Wyplosz (1994) where they define a crisis as large movements in vector of specified arguments. It does not mean that one definition is wrong and another is correct. It means only that because there is no standard meaning of a currency crisis we use this term in the sense we need more.

Section Three. Literature Review: Theory

The causes of currency crises could be seen both in short run (SR) and long run (LR) periods. Roughly speaking, the economy might be in a good or bad condition: this depends on various factors, such as government spending, capital flows, state of banking system, etc. In this paper by SR conditions that highly effect the national financial system we understand (1) current financial situation (the state of business

cycle, banking system, borrowing constraints met by the national government) and (2) government policy behaviour (rule-dependent or state-dependent (see below)). By LR conditions we understand economic fundamentals (e.g., balance of payments, fiscal deficit). Possible interpretation of good or bad condition in LR may lie in the answer to the following question: does government policy in LR consistent or inconsistent with fixed ERR?

Table 1 introduces the general view on causes of currency crises that is accepted in this paper.

	Good Condition in Short Run	**Bad Condition in Short Run**
Good Condition in Long Run	No crisis	?
Bad Condition in Long Run	?	Crisis

Table 1

It is obvious from the table that if the economy in a good condition both in the SR and LR, there is objectively no room for currency crisis. On the contrary, when we have a bad condition both in LR and SR, currency crisis is inevitable. Two other cases are much more delicate to deal with and an answer there is not so direct. It should be pointed out that in the case of imperfect information or some other digressions from the standard assumptions crisis may well occur even under good conditions of economy both in SR and LR.

It is easy to deduce from the table above that there is possible to implement two main approaches to the currency crises: one that deals with LR components and another that accounts for SR reasons. So, there exist two generations of models. Table 2 below introduces some aspects of these approaches and compares them to each other.

The first approach has been chronologically developed much earlier. The first classical work is by Krugman (1979), that is based on earlier papers by Salant and Handerson (1978). Another seminal paper in this direction is by Flood and Garber (1984). The main idea in the first generation approach that currency crisis is born by LR fundamentals, first of all by overly expansive domestic policies. This approach mainly assumes linear government and private behaviour, which means, that e.g. government makes its decision according to the earlier accepted rule up to the time of currency crisis. The example of such a rule is fixing the ER: under this regime the central bank is very restricted in conducting independent monetary policy and has to change national currency for foreign one at any time. As we shall see the main results of this approach is the unique equilibrium in the economy with the currency attack by speculators eventually, that leads to the fatal loss in foreign reserves by central bank, abandonment of the fixed ERR and devaluation of the national currency – all this in case of bad LR conditions.

We shall introduce now the basic first generation model (based on later insignificant modification by Flood and Marion (1998))

$$(1) \qquad m - p = -ai \qquad a > 0$$

Domestic money market equilibrium is given by

In the formula (1) m is the domestic supply of high-powered money (in logs), p is the domestic price level (in logs), i is the domestic-currency interest rate (in

levels), *a* is the parameter of semielasticity of interest rate to money demand.

	First Generation Models	**Second Generation Models**
Basic Literature	Krugman (1979)	Obstfeld (1986)
Some bibliography	Flood and Garber (1984, 1996) Agenor, Bhandari and Flood (1992)	Calvo (1988) Morris and Shin (1995) Obstfeld (1994)
Focus on	Long Run	Short Run
Based on	Linear government and private behaviour	Non-linear government or private behaviour
Results	Unique Equilibrium	Multiple Equilibrium

Table 2

$$(2) \qquad m = d + r$$

Central bank has two assets which back the domestic money supply:

In the formula (2) *d* is domestic credit (in logs), *r* is international reserves (in logs, denominated in domestic currency).[1] Because of international arbitrage conditions the price level and interest rate obey purchasing power parity and interest rate parity (there is no lagging in this model), respectively.

[1] This is a log-linearised identity, which is true only approximately. For our purposes, however, this is enough.

(3) $p = p^* + s$

(4) $i = i^* + \dot{s}$

In the formulas (3) and (4) p^* is the foreign price level (in logs) and i^* is the international interest rate (in levels). We assume through all our analyses that the economy is a small country, so change in i does not affects i^*, and change in p does not affect p^*, opposite is not true.

We assume that government has permanent budget deficit and in order to finance the deficit it has the sole mean of printing money. So, deficit financing requires domestic credit to grow at a constant rate:

$$\dot{d} = \mu,$$

While domestic credit grows at a constant rate, international reserves must fall at the same rate. Suppose also, for simplicity, that

$$\dot{p}^* = \dot{s}^* = 0$$

Under certainty and fixed ERR it follows that

$\dot{s} = 0$ and $i = i^*$

Now, when we substitute all obtained results up to this point into equation (1), we get

(5) $r + d - p^* - \bar{s} = -ai^*$

In the formula (5) *s-bar* stands for fixed ER. Suppose, that if attack occurs, then government sells all its international reserves and allows national currency to float since then. The introduction of the "shadow ER" conception allows to capture the idea behind the process. The shadow ER, first introduced by Flood and Garber (1984), is defined as the floating ER that would prevail if speculators purchase the remaining government reserves committed to the fixed rate and the government

refrains from foreign exchange market intervention thereafter. The shadow ER is therefore is the rate that balances the money market following an attack in which foreign exchange reserves of the central bank are exhausted. For simplicity, let assume that $p^*=0$ and $i^*=0$ in our later analyses. Then the ER that solves the post-attack money-market can be found using the following equation:

$$(6) \qquad d - \tilde{s} = -a\dot{\tilde{s}}$$

In formula (6) *s-tilde* stands for the shadow ER. Now we can arrive at

$$(7) \qquad \tilde{s} = a\mu + d$$

The formula (7) demonstrates that she shadow ER grows with the rate of growth of domestic credit and with the domestic credit itself.[2] It is not difficult to show that the only equilibrium occurs when *s-bar=s-tilde*. Otherwise, speculators find that they are making loss or may earn infinite profit, which is incompatible with our continuous model and rational expectations. Thus, we have the unique equilibrium, the result that was stated in table 2. However, it should be noted here that if we let government or speculators behave non-linearly in our sense of this term, ceteris paribus, then it is possible and it will be shown in the 7th section that not only multiple equilibria exist, but we may observe continuum of equilibria.

We may also easily calculate the timing of attack, which is

$$(8) \qquad T = \frac{r_0 - a\mu}{\mu}$$

In formula (8) *r(0)* is the initial level of international reserves. T grows with *r(0)*, but decreases with μ. This result is rather intuitive.

The basic model is very intuitive and states that permanent deficit financing is incompatible with the fixed ERR. From the empirical point of view it is interesting to see could we apply formula (8) or its modifications to the real data or not.

[2] In the 6th section these results will be obtained more rigorously.

Some further developments to this model have been suggested in recent years. We will mention some interesting modifications. First, new models accounts for effects of sterilisation, which were popular in the early 1990s. As can be shown, sterilisation only worsens situation and T decreases (see, e.g. Flood, Garber, and Cramer, 1996). Second, some authors consider situation where speculators needs risk premium in order to invest in national bonds, therefore equation (4) is no longer valid (this version considered in Willman (1988)). Under these considerations interest rate changes continuously. The result is basically the same. The speculative attack is timed in order that jump in devaluation rate matches the downward jump in the risk premium. Also all these models have been applied to the uncertainty environment, where some new features may evolve, as multiple solutions (for detail analysis see the 7th section). Another directions of research deal with the so-called asset substitutability and sticky prices, borrowing controls, policy switches, etc.

If we look again at Table 2, we could see the differences between the first and the second generation approaches. The second generation approach was the reply to the currency crises in the early 1990s, where apparently they were both caused by bad economic fundamentals, i.e. LR conditions. On the contrary, some other factors such as the state of banking system, borrowing constraints or state-dependent decision making by the government effect the situation on currency markets. This approach concentrates on possible non-linear government behaviour and as a result we get multiple equilibrium as a rule and not as an exclusion. The seminal paper here is by Obstfeld (1986), but this approach is much less consolidated than the first one. We shall concentrate in our discussion on just one basic example which captures the main ideas of this approach.

This example steams from the famous model by Kydland and Prescott (1977) (see also Barro and Gordon (1983)) of time-inconsistent policymaker. Now we are in

fully non-linear model where we study rule vs. discretion in government policy. Suppose (following Obstfeld (1994)) that government conducts the ER policy according to the following loss function:

$$(9) \qquad L = \frac{\theta}{2}\delta^2 + \frac{(\delta - E\delta - u - k)^2}{2}$$

In formula (10) δ is the rate of currency depreciation, Eδ is the expected rate of currency depreciation, *u* is the disturbance variable with standard deviation σ, θ is the parameter, that stands for the relative weight attached to price changes, *k* is the measure of distortion.

Now we can calculate the value of loss functions under different regimes:

$$(10) \qquad EL^r = \frac{\sigma^2 + k^2}{2}$$

$$(11) \qquad EL^d = \frac{1+\theta}{2\theta}\left(k + \frac{\theta}{1+\theta}\sigma\right)^2$$

Formula (11) stands for the rule regime, under which the rate of currency depreciation equals to zero and the announced policy is fully credible. Formula (12) is the loss function if the government follows discretion. If we take that θ=1

$$(12) \qquad EL^d = \frac{\sigma^2 + 4k^2}{4}, \qquad \theta = 1$$

for simplicity, then formula (12) looks

These equations postulate the well-known result: if there are no shocks, society is worse off with discretion rather than with a rule, but when shocks start playing some role, discretion becomes better and better, and for sufficiently high σ

(relative to *k*) distortion is preferable.

So, this direction of 2nd-generation approach deals with time inconsistency of government policy, credibility issues, reputations and various possible signals which are received by market participants. The main result of the second generation approach is in multiple equilibrium and in the fact that non-linear behaviour could lead to such multiplicity.

Some attempts have been made to reconcile these two approaches (see Flood and Marion (1998) for some further notes), but they have to be yet approved to consider them independently. Apparently, works in this direction can bring about fruitful results. For some ideas of implementing it to the Russian case see also the 7th section.

Section Four: Literature Review: Empirical Studies

Empirical studies of the currency crises should answer many questions, among them, whether crises can be predicted on the basis of fundamentals' behaviour or the behaviour of current financial indicators, or it is mainly unpredicted events like apparently stock crashes. Empirical evidence of the currency crises is generally twofold and no general conclusion about causes of currency crises has been drawn yet.

The summarising of all empirical evidence that will be discussed in this section is shown in table 1 in the Appendix A.

First empirical studies on the currency crises pursued the aim of fitting the theoretical models with available data sets. At this stage only one-country samples were considered. Let consider some interesting examples. The seminal paper by Blanko and Garber (1986) tried to investigate the application of the Flood and

Garber (1984) modification of initial Krugman (1979) model to predict the timing and magnitude of devaluations forced by speculative attacks on the Mexican peso in 1973-82. They used a standard money demand function and modelled the rate of domestic growth using first-order autoregressive process. The forward ER was taken as the shadow ER. International reserves declined as the difference between domestic money supply and money demand. When some critical level is reached, speculative attack occurs.

Another study by Cumby and van Wijnbergen (1989) took a similar approach to analyse attacks on Argentina currency in the early 1980s. They estimated different time series processes for the money demand disturbance, the foreign interest rate and domestic credit growth. Also they treated level of international reserves at which central bank allows floating ERR and implements devaluation as a stochastic variable. The main finding in their study was that a sharp increase in the growth of domestic credit was the main factor triggering the attack on the currency.

Other portion of studies do not build directly on the theoretical literature like Krugman model. E.g. Klein and Marion (1994) use panel data for 16 Latin American countries for the period 1957-91 to study the determinants of the duration of ER pegs. The timing of the collapse of ER in their study is defined by the decisions of optimising government. Their main results in the conclusion that the probability of a fixed rate being abandoned increases with the extent of real overvaluation and that it declines with the level of foreign assets.

Another study by Edwards (1993) examined currency attacks in developing countries in the period 1948-82. Using panel data Edwards finds that in the period preceding a devaluation the foreign assets of the central bank typically decline, the real ER becomes overvalued, and fiscal policy becomes excessively expansionary.

Limitation of this analysis is that it compares devaluation episodes not the attacks episodes.

Study by Eichengreen, Rose, and Wyplosz (1994) illuminates the problem of currency attacks on the pegged European currencies in the 1980s and early 1990s. Generally their study can be put into the second generation theoretical approach, because they arrive at multiple-equilibrium solutions which generate self-fulfilling attacks. They define attacks as large movements in ERs, interest rates or international reserves (which presumably broads the empirical evidence). Subject of study is a panel of 20 industrial countries over the 1959-1993 period (so in this study it is more adequate to use "pegged" rather than "fixed" terminology). The main construction that is widely used in this study is an index of speculative pressure which picks up both successful and unsuccessful attacks. Special index that was implemented from previous study by Girton and Roper (1977) takes the form:

$$(13) \qquad K_t = \omega_1 \Delta s_t + \omega_2 (-\Delta r_t) + \omega_3 \Delta i_t > T$$

In formula (13) K is the index of speculative pressure, ωs are the weights and T is the two-standard-deviation threshold. If $K>T$ at time t, then crisis occurs. The authors find that for European currencies it is not possible to reject the null hypothesis of no significant differences in the behaviour of key macroeconomic variables between crisis and non-crisis periods. This null hypothesis, on the contrary, can be significantly rejected for developing countries. Actually, as Flood and Marion (1998) point out, these empirical novice does not help to predict crisis more adequate, especially because two of the three indicators in formula (13) point in the wrong direction at the devaluation time. The conclusion of these researchers is that data-defined crises are hard to predict using standard fundamentals or panel

methods.

Recent study by Frankel and Rose (1996) use a panel of annual data for over one hundred developing countries from 1971 through 1992 to characterise currency crashes. They define a currency crash as a large change of the nominal ER that is also a substantial increase in the rate of change of the nominal depreciation (compare it to the definition in the previous study). They study various macroeconomic variables, and also some other external factors. In order to concentrate on some particular variables all variables are classified into 4 categories: (1) foreign variables (like international interest rates and output), (2) domestic macroeconomic indicators, (3) external variables (such as the current account and the level of indebtedness), (4) the composition of the debt. The currency crash is defined as a depreciation of the nominal ER of at least 25% that is also at least a 10% increase in the rate of nominal depreciation. This definition of crashes yields 117 different crashes in the period studied. As a whole, they consider six variables relevant to the speculative attack literature: the rate of growth of domestic credit, the government budget as a fraction of GDP, the ratio of reserves to imports, the current account as a percentage of GDP, the growth rate of real output, and the degree of over-valuation. It is especially interesting for the purposes of further possible application to recent Russian crisis to concentrate on the composition of the debt, that is implemented in this paper. The authors examine seven different characteristics of the composition of capital inflows or the debt. Each is expressed as a percentage of the total stock of external debt. The variables are: (1) the amount of debt lent by commercial banks, (2) the amount which is concessional, (3) the amount which is variable-rate, (4) the amount which is public sector, (5) the amount which is short-term, (6) the amount lent by multilateral development banks, (7) the flow of foreign direct investment (see the

paper, p.10). The main findings is that output growth, the rate of change of domestic credit, and foreign interest rate are significantly related to currency crashes. Another conclusion is that a low ratio of foreign direct investment to debt is consistently associated with a high likelihood of a crash. Curiously, neither current account nor government budget deficits appear to play an important role in a typical crash.

Finally, very recent paper by Kaminsky, Lizondo and Reinhart (1998) explores leading indicators of currency crises. The paper examines the empirical evidence on currency crises and proposes a specific early warning system. This system involves monitoring the evolution of several indicators that tend to exhibit an unusual behaviour in the periods preceding a crisis. When an indicator exceeds a certain threshold value, this is interpreted as a "warning signal" that a currency crisis may take place within the following 24 months. The variables that have the best track record within the approach suggested in the paper include exports, deviations of the real ER from trend, the ratio of broad money to gross international reserves, output, and equity prices. This paper is also interesting for it survey of more than 40 previous studies of the currency crashes with respect to leading indicators which were used in these studies.

Section Five: The Russian Case

Russian currency crisis in the summer of 1998 was preceded by government and central bank attempts to curb the panic and cope with high distrust from investors both foreign and home. But actually, the crisis was prepared by all reforms that had been taken since 1992. Therefore, the first part of this section is devoted to the brief description of general economy conditions before the crisis (since 1992) and

reforms that were taken. Then we will proceed to the description of crisis itself starting from October 1997 to August 1998. The first part of this section is based upon the paper by Illarionov (1998a) and also upon unpublished manuscripts by Aleksashenko (1998) and Illarionov (1998b).

The reforms and general condition of Russian economy can be explored by analysing both fiscal policy and monetary policy. According to Illarionov (1998a), important features of Russian budgetary policy are: (1) the value of real distributed financial resources through budgetary system; (2) the level of officially planned tax burden; (3) the level of realism in the budget laws; (4) the level of disbalance of government budget, its scale and instruments of its financing; (5) the quality of government debt management; (6) the capability if authorities to make well-time corrections in budget policy.

As is shown by official statistics (see table 2 in Appendix A), both federal and consolidated budgets (in % to officially calculated GDP) were disbalanced all years under consideration. Under different calculations of GDP that counts for real payments in the economy (Illarionov, 1998a, p. 27) this negative balance is even more higher.

Another feature of the Russian case is that there has been significant debt of economic agents to the federal and regional budgets. Then, authorities used to be overoptimistic in their forecasting of budget incomes, therefore increasing planning expenditures which they could not later pay.

The budget deficit can be financed through different instruments. Russia used mainly three of them: (1) money emission, (2) domestic credits, (3) foreign credits. As is evident, with permanent budget deficit it is irrelevant in the LR which particular instrument for financing government deficit is used because of the so called Ricardian equivalence. However, in the SR, these three forms of financing

are quite different. Nevertheless, all these led to the fast accumulation of government debt. Table 3 in Appendix A shows the rates of growth of dollar-denominated government debt. Such fast accumulation should have led to financial crisis later or sooner.

It is obvious that such accumulation led to the growth of expenditures on the debt service payments which rose from 5.4% in 1992 to 60.9% in 1998 (first six months) in terms of tax payments to federal budget or from 1.8% in 1992 to 34.9% in 1998 (first six months) in terms of federal budget expenditures. Debt crisis had become inevitable partly because of the fact that authorities had not decreased non-debt payments.

Another source for analysis of Russian reforms and economy is the monetary policy of authorities, government and central bank. Russian monetary policy can be characterised as a rule policy after July 1995 when currency band was introduced. At the same time GKO had become popular financial instrument both for government and for investors. Table 4 in Appendix A introduces the main parameters of Russian financial system. In the last column the average rate of growth of all parameters is given (data is from Illarionov, 1998b).

It is possible to see from the table 6 that hard currency reserves has never grown as much as M1 or M2. However, before 1997, June at least the movement of growth was in same direction. After the October situation has changed and hard currency reserves fall at least twice.

Non-residents were able to participate in GKO market since beginning of 1996 and all barriers had been decreasing step by step, partly because of 1997 agreement with IMF. According to this agreement, all barriers had to be pushed away since 1998 on. The enter of non-residents to GKO market had both positive and negative sides, The positive one consisted in the rise of liquidity, curbing interest rates and

possibility to issue LR(for 3-5 years) obligations. The negative one consisted in the significant part of non-resident on the market (30% since 1997, and 50% in some issues of GKO). Massive foreign investments into Russian financial sector was one of the main reasons for the unique growth of Russian stock market. A small table below gives data for foreign investments into Russia.

In bln dollars	1993	1994	1995	1996	1997	1998 (Jan-Jul)
Foreign investments	2.8	3.2	13.3	19.0	34.1	3.6

Table

We shall treat the October 1997 as a first step in the Russian currency crisis. Aleksashenko (1998)[3] told us that although not many people could suspect at those late October days[4] that crisis would become a global and a long one, non-residents became to make forward contracts on large sums (value increased from $1.5 bln from $3 bln in a week). It was a first sign of non-resident distrust to Russian rouble. Central Bank had to curb interest rate on GKO and sold about 5 bln dollars. After the loss of this sum it was decided that Central bank should abandon the policy of supporting interest rates and concentrate only on backing rouble. The realisation of such policy had begun on December 1, 1997. In January there was another unsuccessful attack on the GKO market, that has shown that Russian market is not stable in sense that it is enough 1 bln dollars for great panic to evolve.

In March it became evident that positive current account had fallen and current

[3] The first vice-chairman of the Central Bank of Russia at the time until September, 1998.
[4] The Asian crisis began on October 27, 1997; for chronology, see below in the text.

account deficit in 1998 became reality. As Aleksashenko (1998) notes it was the time when the change of policy from the fixed (or currency band) to the flexible had become seriously discussed in the Central Bank. But the retirement of Chernomyrdin government made it impossible.[5] In May situation went out of the control completely for the first time: Central bank had to increase its interest rate (rate of refinance) to 150% - therefore actually Central Bank continued to support rouble.

In June Russia issued foreign obligations with 12% interest rate payments (earlier obligations had less than 10%) showed that government did not have any other sources of financing its deficit. Even more, the situation with the current account had been worsening and it became evident to investors. Interest rates on GKO start growing. On June, 17 Ministry of Finance refused to issue new GKO series and borrowed money from the Central Bank to cancel old series. This situation had been continuing until the crisis. Aleksashenko (1998) admits that after weeks of debates it was decided to turn to the flexible rouble policy in August partly because August was considered to be the plain month. At the same time it was evident that there was a crisis of liquidity in the banking system. Then there was a short break after the money transhs from IMF. On August 14 it was finally decided after the massive campaign in the media to abandon the fixed policy. All preceding week investors actively sell GKO and invest money in dollars.

Crisis explicitly started on August 17 when there were announced by Government and the Central Bank (1) restructurisation of GKO (default de-facto), (2) change to

[5] Unfortunately, it is impossible to infer any truthful ideas about facts from Aleksashenko (1998), because he is not precise in facts and even ambiguous, when contradicts himself: on page 4 he says that Central Bank discussed the change to the flexible rouble and then the Central Bank decided to write a letter to the President about these suggestions. On the contrary, on the page 5 he admits, that at the same time Central bank did send the letter where it argued for the necessity of continuing fixed policy.

wide currency band (from 6 to 9 roubles per dollar), (3) 90-day moratorium on all bank payments abroad. In the following two weeks rouble fell from 6.2 to more than 15 roubles per dollar.

In order to sum up the facts that were discussed in this chapter table 5 is given in Appendix A, which summarises events that preceded the currency crisis, is given below.

Some stylised facts about Russian currency crisis last summer are given below:

1. Permanent government budget deficit (for at least 6 years) became one of the reasons for the crisis.
2. Inability of the government to manage its debt (both domestic and foreign) was another source of the crisis).
3. Turning of the balance of payments into deficit in October 1997 was one more possible reason.
4. Central bank tried (before December 1997) to pursue twofold monetary policy, supporting both currency market and domestic bonds (GKO) market. After December 1997 it supported mainly currency market.
5. The special mechanism of forward contracts for foreign investors might played its role in the crisis, too.
6. World financial crisis (started October 1997) possibly was another reason for escalating Russian financial crisis.

After discussing the main facts that preceded Russian currency crisis and its history in the previous chapter we shall concentrate on how an economist should deal with this crisis from both the point of view of theory and empirical. First, it is important to decide what data is significant in analysing Russian case. The decision upon what data we should use in theoretic model or empirical analysis should be made taking into the account what data is available on a regular basis and what data other

researchers used in similar works. Table 6 in Appendix A gives the description of the main data that we suggest might be relevant for studying Russian currency crisis.[6]

From the theoretical point of view it is important to point the main similarities and departures from the theoretical models. On the basis of intuition it is possible to produce an initial hypothesis that Russian currency crisis can be fit better in the model of the so called first generation models (see the 3rd section). Therefore it is argued here, that it might be the fact that fundamental reasons are much more serious and that they are the main reasons for explosion of crisis. Let discuss some peculiarities of this hypothesis, pointing some initial problems that will be discussed later in much more detail. For this purpose we shall use table 2 from the 3rd section. It says that 1st generation models concentrate on linear government behaviour, while the 2nd generation models concentrate on non-linear government behaviour (we may suppose that in our economy private agents in both cases behave optimally). As we may see from the discussion in this chapter the behaviour of Russian government, including the Central Bank, was rather linear: (1) Russian government had had since 1992 permanent deficit of budget (as in the classical models discussed in chapter 1), (2) Central bank had pursued since July 1995 till the crisis in August the fixed ER policy[7]. This supports the idea of the applicability of the 1st generation model. However, as we should also mention, there was some ambiguity among the market participants about the principal decision of the Central bank to hold its fixed policy, as can be shown by some earlier (though unsuccessful) attacks in December, January and March. Aleksashenko (1998) admits that the leaders of the Central bank had been discussing these ideas. It is not difficult to imagine that some

[6] Although we do not use all the data listed in the paper, it might be relevant for further studies.

[7] Actually it was a policy of a moving currency band, but in our case it coincides with the fixed ER policy. The main idea is that Central Bank did not refuse from its policies until the crisis time.

participants were informed about such discussions. So, we do not have pure 1st generation model. Even more, the classical model by Krugman (1979) suggests that there is permanent current account deficit along with the permanent budget deficit. In Russia it was not the case: current account had started turning into deficit only since October, 1997. There are two possible answers to this fact: or the Russian case does not fit into the framework of the Krugman (1979) model or the Krugman model can be modified to account for the fact that current account deficit evolved much later than budget deficit. All this suggests that in constructing the model of Russian currency crisis we should also use some features of the 2nd generation models. If we look further at the table 2 in the 1st chapter we may see that it is impossible to say, at least now, was the crisis because of the LR or SR reasons (also we argue in our hypothesis that it is primarily of the LR nature). Further it is impossible to see at a glance did we have unique or multiple equilibrium system? The last question is more of theoretical nature but nevertheless is very interesting.

So, we need to construct a model of Russian currency crisis, based primarily upon the 1st generation approach, but also using 2nd generation approach. We also have come to conclusion that no model we know (or no model that was discussed in the 1st chapter) fits Russian case well enough so we need some new modification model of previous known models.

The main question we ask in out theoretical and empirical work was about the possibility of estimating the timing of the crisis, because the need for a crisis is out of question due to all description in this chapter. Also interesting question that have been asking ourselves is: could Russian government postpone or even fully abandon the crisis. The next two sections discusses our modification of the basic model, while the 8th section points out to the empirical estimation of our model, including further examples.

Section Six: Building the Model

As was pointed out at the end of the previous chapter we are interested very much in the estimating of time occurrence of the crisis. Particularly: will our model predict August 1998 as a crisis month or will it be later or sooner. What modifications if needed may show that the crisis could have place in August in the model. We determine here the basic framework, in the next section we show our results of some modifications that could change the timing of the model and give all of them economic interpretation. Then, in the 8th section we show that using data we need to modify our model and that at least some of our modifications could fit well into the scheme, although it is obviously not possible to give any final answer here.

We follow here the standard Flood and Garber model as the basic framework (see Flood and Garber (1984), Agenor, Bhandari and Flood (1992) and Agenor and Montiel (1996) for the sources of our combined basic model). It was described in some detail in the 3rd section. Here we give some further assumptions on which we use this model and then go to our modifications.

The model describes in continuos time a small open economy (i.e. capital is perfectly mobile), which produces a single tradable and perishable good. Domestic supply is fixed at some level and purchase power parity holds. There are three assets in this economy: (1) domestic money, (2) domestic bonds, (3) foreign bonds. Domestic money is held only by domestic residents and domestic and foreign bonds are perfect substitutes. Also in our model there is no private banks, therefore money supply is equal to domestic credit plus domestic currency value of foreign reserves held by the Central Bank. Domestic credit is issued by the Central Bank. International reserves earn no interest. We assume also in our model perfect

foresight.

The source of all troubles is the growth of domestic credit in order to finance budget deficit. We assume that this growth is constant and linear.

After all these assumptions a log-linearised model (1) – (5) in the 3rd section applies. The introduction of shadow ER helps to solve the model explicitly. We skipped the solution of this model in the 3rd section and gave there only an answer. But now the solution becomes of inherent importance for us.

It turns out that the general form of the shadow ER could be found from the following equation:

$$(14) \quad \tilde{s}_t = \frac{\gamma}{\alpha} \int_t^{\infty} e^{\frac{t-k}{\alpha}} (D_t + (k-t)\mu) dk + Ae^{\frac{t-T}{\alpha}}$$

where T is the expected date of crisis.

This equation is obtained by the forward expansion of equation (6) in the 3rd section. The second member in this equation is a so-called bubble part. We may let A=0 to ensure there is no bubble (it could be obtained formally by introducing transversality condition). By integration by parts equation (14) solution (assuming no bubbles) arrives:

$$(15) \quad \tilde{s}_t = \gamma(D_0 + \alpha\mu) + \gamma\mu t$$

which is a modified version of equation (7) in the 3rd section. We will use this result intensively in the next section.

If there is a bubble because of come economic factors, then we could not let A=0 and the expression (15) is no longer valid – it would be a bit more complex. It suffices to show that it will take the form:

$$(15') \quad \tilde{s}_t = \gamma(D_0 + \alpha\mu) + \gamma\mu t + Ae^{\frac{t-T}{\alpha}}$$

In the next section we will show how to use this expression in the Russian case.

The graphical solution to this problem is shown on graph 1 in Appendix B. In equilibrium agents can never expect a discrete jump in the level of the ER, since a jump would provide them with infinite profitable arbitrage opportunities. Thus, our model in both cases (without and with a bubble) predicts a continuous movement of the ER.

Section Seven. Main Results of the Model

Now we turn to our modifications of this model. As was stated in the previous sections, the main question for our theoretical investigation has been the question of estimating the timing of crisis. Also the problem of a jump in the ER will be underlined. Using the shadow ER formula (15) it is possible to time the Russian case (it has been done and described in the 8th section) Is it possible for a crisis to occur earlier or later than anticipated by the model? Here we give three different but positive and in some way coherent answers to this question. Also, we give partially positive answer to the question of modelling of discontinuous jump.[8] First of all, we will introduce the non-linear government behaviour in a special way. Then , we will focus on the uncertainty that might have played a crucial role in the SR events. Finally we will turn to another post-collapse regime – devaluation that actually took place instead of simple floating.

The first modification (the idea has been suggested by Flood and Marion (1998)) studies shifts in the government policy, therefore introducing for the first time in this model non-linear government behaviour. Actually it is the introducing into the 1st approach model elements of the 2nd approach. Let us return to the framework of the previous model and let all equations (1) – (6) hold. The only difference is that

now government follows the strategy of changing of the growth rate of domestic credit in response to the successful attack. The government strategy takes the form of the kind:

$$(16) \qquad \dot{d} = \mu_0 \quad \text{if there is no crisis}$$
$$\dot{d} = \mu_1 \quad \text{after the crisis}$$

Where $\mu(0)<\mu(1)$.

This behaviour is very well intuitively clear: after a successful attack government faces a completely different financial and economic situation caused by the currency crisis. Devastation of its reserves may cause debt repayment problems, financial and political instability, running away of serious LR investors. Thus, authorities loose their reputation, can not borrow from abroad or in home country and do not have other means to finance its deficit but only print more money. Another intuitive explanation is that after a currency crisis there will be a political crisis and collapse of the government (as it was in August 1998). New government does not have the obligations given by the former government and has the right to change the parameter μ. In this case μ(1) could be as well less than μ(0), if government would like to rebuild its reputation, for instance. The result for this case are symmetric to what we are considering next.

Let us start with a bit simpler situation when speculators consider the decision at the moment they are aware of the decision (16). The situation is depicted therefore on graph 2 in Appendix B. We face the multiple equilibria which have enormously interesting interpretation for the Russian case. At T(0) crisis is inevitable as well as impossible before T(1). This is true, because at T(0) all agents are solely interested

[8] The case is to implement a model without jump in a structure, so we do not use Wiener

in the attack, while at any *t* before T(1) no agent could b interested in it. Consider the arbitrary point T(1)<T<T(0). At this point speculative attack may occur but it generally depends on the market structure. Because today's shadow ER is below the fixed ER, in case of competitive market each very small speculator will not attack the ER: because of his size the attack will be unsuccessful if too few speculators join him in the ride. Then he will loose his money. But on the other hand, if we have *n* speculators (*n* is any natural number) and all other *n-1* speculators decided to attack, then our speculator should attack also. So, to attack is a Nash equilibrium. although not very attainable because of need of cooperation between players. As shares become to decrease sharply no co-ordination outcome is much more plausible (remind that status quo is no attack). Thus, if a player has enough power he will attack and other would join him. If the market structure is oligopolistic, then cooperation is much easier and some players have more chances to succeed when they attack. The result is: the more oligopolistic the market the sooner will be the attack. In case of monopoly, e.g., the attack would be at T(1). In Russia it was obviously oligopolistic structure (see unpublished essay by Krugman (1998)) with notoriously known "seven bankers" and also some prominent foreign participants. So, in this case the crisis was generally sooner than could be predicted by a standard model. In the 8th section we show the estimation of this hypothesis.

Also it should be pointed out that at any point T(1)<T≤T(0) we have a jump both in the ER and shadow ER that was impossible in the basic model, and the more oligopolistic market the larger will be a jump in the shadow ER.

Another case is when speculators could decide at any time. In formula (16) D(0) will be different depending on the time of attack. The situation is depicted on graph 3 in appendix B (note that the illustration for one moment. With increasing of *t* the

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processes.

shadow ER line moving parallel down). The results are generally the same, but interval [T(1), T(0)] could have shorter length.

Let summarise the results of this subsection. The policy non-linearity is in shift in the rate of growth of domestic credit. If there is no attack, growth rate is less than it could be after the attack. This rule is known to all speculators and credible. Now we have to introduce two shadow rates for two possible regimes. This introduction gives life to the multiple equilibrium. If domestic credit is very low, than there is for sure no speculative attack. If it is too high, speculative attack is inevitable and immediate. But if domestic credit lies somewhere between two values, which can be determined, multiple equilibrium occur. For speculators generally it is profitable to attempt an attack, but if they are uncoordinated attack may be unsuccessful and then those speculators who take part in an attack, lose and national currency "survives". But if speculators are somehow co-ordinated or if there is a large speculator who leads the market, then an attack might be successful.

The second modification lies in the sphere of introducing some uncertainty to

$$(17) \qquad \mu \sim F(\mu)$$

government behaviour, so now we have

where F(μ) is a distribution function.

This equation tells us that government increase domestic credit at some constant rate, but this rate is not known perfectly to speculators. They are aware only of a distribution function. Risk-neutral speculators form an expectation of μ:

$$(18) \qquad E\mu = \int \mu dF(\mu)$$

$E\mu$ could be very well not equal to actual μ. In the case when $E\mu > \mu$ the situation could be again depicted using graph 2 in Appendix B (now $E\mu$ is $\mu(1)$ and μ is $\mu(0)$) with difference that at T(1) we have crisis for sure. Government in case of a

successful speculative attack may also jump to new μ, because it is more optimising, e.g., from the point of view of deficit financing.[9] thus, expectations formation affect the model enormously. The uncertainty story is at least partially true for Russia, where monetary authorities always have something to hide from investors and therefore do not have reputation for being truthful, therefore investors always have all foundations not to believe in official figures, statistics and information. The drawback of this modification is that in this form although it allows for a discrete jump of the shadow ER, but does not permit this jump in the ER itself.

At last, we introduce another modification: let after the speculative attack government decides not float its currency, but devalue it.[10] Then we can not ignore a bubble term in the equation (14) because transversality condition no longer holds. Assume the situation, when government decides to float the currency freely for some period of time as it was actually in Russia for at least two weeks, and then stick it again at some announced value.[11] Then, as suffices to show, this will cause the first crisis happen earlier.

Suppose, that if at T a successful attack occurs, then at the moment T+T(1) devaluation takes place (T(1)>0) and new devalued ER is known to be *s(1)-tilde* (contrasted to previous ER *s(0)-tilde*).

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[9] Although it should be noted that this point is not perfectly clear to us: actually refer to the government optimising needs to introduce as well contract mechanism under which government decides to choose actual μ when it knows the distribution function in order to choose the optimal attack time if such exists.

[10] In this subsection we mainly follow Agenor, Bhandari and Flood (1998), but with reconsidering their method to the Russian case.

[11] The government may need some time to find optimal in some way new fixed rate or it would be a floating because of change in the government. We need to implement this in our model, because, as it would be shown in the text, if devaluation would be immediately after the crisis, then it is profitable to attack at the very beginning of the system functioning. Another case of implementing

The shadow ER in this case will look like (15`) if T≤t≤T+T(1), where the last member is the result of a bubble. Then we may impose restrictions on (15`) on order to find T and A.

These restrictions are given by:

$$(19) \qquad \tilde{s}_0 = \gamma(D_0 + \alpha\mu) + \gamma\mu T + Ae^{\frac{T}{\alpha}}$$

$$(20) \qquad \tilde{s}_1 = \gamma(D_0 + \alpha\mu) + \gamma\mu(T + T_1) + Ae^{\frac{T+T_1}{\alpha}}$$

and now we may get finally:

$$(21) \qquad A = Ce^{-\frac{T}{\alpha}}$$

$$(22) \qquad T = \frac{\tilde{s}_0 - \alpha\gamma\mu - \gamma D_o - C}{\alpha\gamma\mu}$$

where

$$(23) \qquad C = \frac{(\tilde{s}_1 - \tilde{s}_0 - \gamma\mu T_1)}{e^{\frac{T_1}{\alpha}} - 1}$$

Graph 4 in Appendix B shows the situation. Comparing (15'), where we use (21) and (23) to (8) in the 3rd section we see that the crisis occur earlier. Easier to compare it with the graph 1 in the same Appendix.

Some very interesting notes about that solution could be underlined. The crisis will be sooner if s(1)-tilde is large in comparison with s(0)-tilde and if T(1) is small. Therefore, if agents fear devaluation, crisis will occur before the standard deadline. At the GET project we had some meetings with prominent investors. All they told

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the devaluation mechanism is to introduce uncertainty when devaluation could be immediately or

us they had been waiting for devaluation since March-April 1998. There also a few subtle notes here. First of all, neither of them could imagine that devaluation would be actually in four times (50-75% was there "reasonable" judgement). Then although they expected devaluation, they did not suggest the default on domestic bonds (if they had done the crisis would have been even earlier).

The difficulties with implementing this approach arise when trying to estimate all parameters. However, some preliminary judgements about the Russian case are suggested in the 8th section.

It is possible also to combine two or all three modifications, because both uncertainty and fears of devaluation with change of government behaviour took actually place. In the next section example of one such modification is shown.

Section Eight. Empirical Investigation of the Model

In this section we will implement our analysis to the Russian data. The questions which we ask ourselves are: (1) Does the model or any modification could predict that the crisis happened in August? (2) Could the authorities prevent the crisis by changing their behaviour and what had they to sacrifice at what time? (3) If we prolong the model to the current date what will be our prediction?

We will use first the shadow ER formula (15). With this form we have to estimate all these parameters, using Russian data. We do it in the following way.[12] The initial date is assumed to be July 1997. Money demand is equal to M2 (363 bln roubles in July 1997). Reserves at that time were $20.4 bln and ER 5.782.[13],[14] With this data it

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it will not be at all. See below in the text.

[12] All data used in this section has been obtained at the Central Bank of Russia web site: www.cbr.ru

[13] We use only currency reserves, because gold reserves are not highly liquid and can not be used in currency market operations.

was possible to obtain the value of domestic credit D(0) and therefore parameter γ. It was found to be 0.72. This parameter is very stable over the whole period and changes in range (0.72, 0.75).

Parameter μ is estimated by simplified assumption that reserves were declining linearly (actually it was not true). Because in July 1998 reserves were at the level of \$8.2 bln μ=0.21. Finally, parameter α is considered to be consistent with the Baumol-Tobin model (see Blanchard and Fischer, 1992), α=0.5.

With this data it is possible to reproduce the graph 5 in Appendix B. On this graph two shadow ER are reproduced for two values of γ=0.72 and γ=0.75. As we see, model predicts the crisis to be between the middle of September and beginning of December. The sensitivity analysis shows that these results are highly robust to α, but more sensitive to γ and μ. About γ it is less trouble, because γ is very stable over the whole period, but with μ it is more difficult, because we had to linearise μ in order to have estimation for future values. But we may also use monthly data for μ. With this data it is impossible although to build a forecast. The result of this estimation is that crisis could not be before September. With linear μ if μ=0.27 then we have crisis in August.

If we have a devaluation fears then we should use equation (15`) with a bubble. Graph 6 in Appendix B shows this case. We estimated parameter A to be 0.03. With this value crisis is in September. Again, the analysis is sensitive to this parameter, especially because we have exponential function.

Using the data we may try answering some further questions. First of all, how it is possible to implement here a jump in the ER. Let combine in our analysis fears of devaluation and uncertainty. Let investors are not sure about the new devalued ER

[14] We use denominated rouble value elsewhere. In July 1997 5.782 new roubles = 5782 old

and have wrong expectations about it, particularly their expectations are lower then actual value. This assumption is backed by what investors told us. This means that crisis should be earlier then August, for instance, in April or even in March it would be more optimal, but because investors believed it would be later (in August or September, the last month was believed to be the date of rouble devaluation), then the Central Bank had the opportunity to maintain the ER longer but with trade-off: at the moment of crisis the real devaluated value would become known and there would be a jump. The situation is depicted on the graph 7 in Appendix A. Crisis should be in January, but it happens in August and therefore the ER goes to more than 9 roubles immediately. Although precise figures may provoke doubt, the whole picture is very likely to be this way.

Second, with this model, is it possible to show what is happening now? Actually, it is possible. The only difficulty that we have too many results in a sense depending upon our initial assumptions. The story is even more difficult because the government introduced serious restrictions on capital mobility. Nevertheless it is possible to predict that today's level of 24-25 roubles per 1$ is also at some period of the time will be attacked because of the rules of development of shadow ER. Because monetary authorities obviously restrict the growth of dollar we have the situation of some fixing which should be attacked earlier or later.

Finally, we would like to ask what authorities had to do before August crisis to prevent the attack. The very simple answer is to decrease the value of μ by decreasing the deficit. If the value of μ decreased by 0.05 to 0.16, then the crisis in the basic model occurs from December to February, and if μ is 0.1, then crisis occurs only in April-May, so at the time this MT has been finishing. But let suppose it is out of their jurisdiction. Then we see that authorities nevertheless have some

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roubles.

possibilities to prevent the crisis in sense to postpone it. Here are some of them: (1) to claim that they are not considering devaluation (it has been done actually and worked for some period of time), (2) to increase the currency reserves by converting gold and precious metals into hard currency, (3) to escape uncertainty or to found such an uncertainty that investors have wrong expectations in the needed direction. Needless to say, all these tricks are only for the SR. And in the LR the crisis is inevitable and in case of a jump it could even worse, so, may be, it is more optimal for the government (if it can not decrease μ substantially) to devalue its currency in the moving band according to the behaviour of μ

Section Nine. Empirical Investigation of the Russian Case

This section is devoted to the general empirical investigation of the Russian case based upon financial data that is available to us. It should be viewed as a supplement to the previous sections in the sense it fills the gap of econometric estimating the scales and timing of the Russian currency crisis. We came to the conclusion that in general, "without-model" research it is not possible to extract currency crisis from other crises that had place at the same time, therefore we study the whole range of parameters and give general conclusions.

The econometric research will be provided, including economic interpretation of the main results. Some interesting results will be obtained. In the first place we start with the very general stuff that includes description of the financial variables we have been using in our analysis, graph representation, unit root tests, Granger causality tests and preliminary look at cointegration properties of our series. Then we turn to the main bulk of an analysis that in our case will be VAR modelling;

thus, we will explain initially why we should use the VAR analysis and why it is preferred to other possibilities. After this we study the problems of structural breaks and introduce some of them, showing that they are significant and important. Finally, we give some economic interpretation of our data as a whole when we introduce different risks, particularly default, devaluation, and convertation risks then will be formally defined.

We use data on GKO average yield (variable GKO), U.S. dollar forward today rate (variable DOLLAR), U.S. dollar futures 6-month rate (variable FUTURES), Russian Eurobonds yield (variable EUROBOND), U.S. Bond yield (variable USBOND).[15] Some explanation of peculiarities of this data and description of their weak and strong points follows.

GKO issues by Russian Ministry of Finance were with different maturities from 30 days to 1 year. GKO variable is the weighted average (where weights reflect the share of the issue of a given maturity in the market trade value). We know that other researchers use some indexes of GKO, such as the Rinako index. Unfortunately, these indices are not perfect to our investigation, because we shall compare GKO with another variables, such as EUROBOND or FUTURES that are given in levels and in yield as EUROBOND. Therefore we use this averaged data. Also trade days on GKO were Monday, Tuesday, Thursday and Friday, so data on Wednesday is obtained as an arithmetic mean of Tuesday and Thursday yields.

DOLLAR is the today average rate of U.S. dollar to rouble (number of Russian roubles for one dollar) at the MMVB.[16] Trade days are from Monday to Friday.

FUTURES is the average today futures ER for variable DOLLAR with maturity of 6 months. Trade were from Monday to Friday at Moscow FOREX. We use 6

[15] All data has been provided by the Economic Expert Group of Ministry of Finance of Russian Federation. All figures in the foregoing section are round to 5 significant numbers.

[16] MMVB stands for Moscow Interbank Currency Exchange.

months futures, although trade was on various maturities from 1 month to 1 year. The reason is quite simple: The largest weight in GKO is 6-month maturity obligations.

EUROBOND is the average day yield on the issue of Russian federation with 9.25% coupon denominated in U.S. dollars and with maturity on 27th of November, 2001. This bonds are traded under code number ZR6U five days a week from Monday to Friday. We chose this issue because of its short (in comparison with other Russian eurobonds) maturity.

USBONDS is the average day yield on U.S. Treasury bonds with 7.5% coupon and maturity on 15th of November, 2001. This bonds are traded under code number US912827D25 five days a week from Monday to Friday. The reason why we use this particular issue is that we need risk-free comparable alternative to EUROBOND, therefore we use the same currency denominated bonds with approximately the same maturity.

All series are from October 24th 1997 to August 14th 1998 (211 observations) except FUTURES: from October 24th 1997 to July 10th 1998 (186 observations).

It is possible to obtain some information from graphical representation of the data. DOLLAR and FUTURES are represented on graph 8 in Appendix B. EUROBOND and GKO are depicted on graph 9 there and EUROBOND and USBONDS are depicted on graph 10. First of all, behaviour of all variables (except DOLLAR) are obviously non-linear when we take all the sample, but possibly linear and stationary when we take some shorter period in the beginning of our range. Variable DOLLAR grows linearly: it has an economic explanation, because (as was discussed in the 5th section) ER was allowed to change only in some confined interval – the so-called corridor. Therefore, this linear increase of the ER or permanent depreciation of rouble was rather well predicted and expected by the market participants. However,

as FUTURES variable shows, the expectation of the market ER in 6 months was very unstable through the period and generally higher than the real value of 6-month ahead dollar ER.

A quick look at graph 11 may suggest as the first approach the idea that EUROBOND and GKO are interrelated, because they have the same dynamical patterns through the whole period, including the last two months, although GKO has much more instability then EUROBOND and in some periods (e.g., in the middle of February 1998) there are some abnormal behaviour of GKO in comparison to EUROBOND. We need to explain if it is possible this interrelation and these digressions.

The overall view of all graphs suggest that all variables except USBONDS are much more volatile at the end of investigated range than at the beginning. Because USBONDS is considered to be the only asset in our series that is not affected by Russian circumstances (or their effects are quite negligible) it means that towards the crisis in August financial markets had been coming in turmoil earlier than in August and that this turmoil was due to Russian internal events.

Let us now turn to the unit root tests of all variables that we have. Unit root tests are important in examining the stationarity of a time series. For our purposes it is important because we use the results later on in cointegration analysis and are able to find out whether the disturbance term in the cointegrating vector has a unit root. Also it would be very useful if we could establish that all our variables have he same number of unit roots.

We conducted the augmented Dickey-Fuller test on all variables and have chosen 4 lags because we have the weekly data. The overall results of our unit root test are shown in Table 7 (see Appendix A). Thus, we obtained that with minor exclusions (such as DOLLAR in levels without both intercept and time rend) we can not

exclude unit root when data is represented in levels, but we are able always without any exception to exclude unit root when data is represented in 1st differences. So, we may generally speak that we have integrated data of the 1st order. This fact enables us to go further into VAR and cointegration analysis.

Before going to the VAR analysis let us look a bit at cointegration test results. The combined cointegration statistics on DOLLAR and FUTURES is represented in Table 8 in Appendix A. We see that there is a cointegration vector if we do not include data trend. The same result could be obtained for another pairs (e.g., EUROBOND and GKO). Going a bit further, we could find, interestingly enough, that Granger test fails to establish any Granger causation between out time series.

This was an introduction to Vector Autoregression (VAR) model that we will implement now. We use VAR modelling because of its successful usage for simulating and forecasting systems of interrelated time series variables – the time series we have in this section. It is preferable to other types of modelling in that all variables in our model could be endogenous and we would like to have an opportunity to count them as endogenous. Standard methodology, for instance, does not allow that. It is possible to conduct two types of VAR analysis: unrestricted vector autoregression and a vector correction model. The last case is implemented if there is a cointegration on the VAR level.

Cointegration analysis studies long-run equilibrium relationships among variables. We conducted cointegration analysis on our VAR model and found out that, depending on assumptions, there at least two cointegrating vectors, and possibly, if assumption about no deterministic trend and intercept in cointegration vectors and no data trend is correct that we have 3 cointegrating vectors. Table 9 in Appendix B gives the overview of all results, while table 10 points out to the one particular case. In any case we should use vector error correction and not unrestricted VAR. We

made a restricted VAR analysis and found the following cointegrating equations (see table 11 in Appendix B).

It is difficult to interpret the VAR coefficients themselves, therefore let us turn to the impulse response functions and variance decompositions of the system in order to try to draw some conclusions about our system. Some results are intuitively understandable (graph 11 in Appendix A). For example, GKO increases in response to the growth of DOLLAR innovation and this growth has linear specification. We may also see some very interesting pictures there. For instance, GKO responses positively to EUROBOND and this response increases with time.

If we look at variance decomposition (graph 12 in Appendix A), we may found that variance in GKO depends on EUROBOND and on GKO, and FUTURES interestingly depends on EUROBOND and GKO. All this may suggest some economic relationship between all these variables. We turn to it later on.

Structural breaks also brought very interesting results, e.g. if we divide our range in two subperiods with breakpoint is of 15th of May, in the1st subperiod some variables are not cointegrated and in the 2nd period some variables are cointegrated, although earlier they were not. The problem with using structural break here is with evident observance of two subperiods because of several before crisis months in summer. Therefore it is very difficult to find the dividing point. We will not proceed in this direction.

Now let us turn to the economic interpretation of all our scheme. We use actually two Russian yield functions: EUROBOND and GKO. The reasonable question is why yield on these two Russian assets so different (graph 2 shows it) and not only yield, but also volatility changes in very different way, and in the same time there is obviously some similar pattern, some interrelation, that has been caught by cointegration analysis. Another question is why these yields are different from

USBONDS.

We consider USBONDS as risk-free alternatives to all assets, therefore all risky alternatives and Russian assets are buy no means such alternatives, should have higher returns. EUROBOND stands for Russian eurobond, denominated in U.S. dollar. This issue is a part of Russian external debt on the world financial markets. GKO stands for Russian obligations denominated in rouble and this is considered to be the internal financial debt.

It is argued here that the main difference in external and internal debt lies in the difference between system of risks that investor pondering buying an asset should include into his consideration. Higher risks should mean higher returns and this is what we have here. Let us look first at eurobond issue: it differs from the treasury bonds in two major affairs. First of all, Russia belong to the developing financial markets and investor should cover the risk of overall financial default on developing financial markets. Now, we may introduce new variable to our system, DEVELOP, that stands for G. P. Morgan index of developing countries bonds. This variable differs from U. S. bonds and the difference counts the risk that has just been mentioned. Another risk that is inherent in the Russian eurobond issues is the default of Russian government on its external issues. This default risk should explain the difference between the yield on EUROBOND and USBONDS extracting before developing countries default.

GKO has different set of risks. The risk of the world developing economies collapse and default is the same, because it touches both internal and external debt. Then, there is a risk of Russian internal default. Obviously, two risks (Russian internal default and Russian external default) have much in common, although there should be some difference and investors may think that country will be rather defaulting on its external debt than on its internal and vice versa. In the Russian case

risk of external debt was obviously lower than the risk of internal debt. Therefore, even if GKO had had only these two risks, their yield would have been higher than on Eurobond yield.

But GKO had another very important risks. One of them was risk of devaluation. However, it is not correct to consider the risk of devaluation to be the undivided risk. Actually, devaluation could have two faces: planned devaluation and unplanned or unexpected devaluation. Due to reason that Russian Central Bank used currency corridor to manage rouble floating we had stable and planned devaluation over the investigated period of time. DOLLAR traces this risk. Another risk is in unexpected devaluation. We do not consider the variable FUTURES to be an ideal representative of this risk but unfortunately there are no other alternatives.[17] Finally, we have one more risk – risk of convertation. It means that investor could be afraid of the situation when he receives his returns on GKO, but he is forbidden from transferring these returns in dollars or another hard currency. It happened before in developing countries for many times.

[17] It is highly possible that futures ER on rouble traded in Chicago is better for our purposes, but we could not find information about it. We think that forward ER is even better, but it is impossible to get truthful information about it.

Conclusion

The Master Thesis is devoted to the modelling of some peculiarities of the Russian currency crisis that occurred in August 1998. Particularly, we have been dealing with the analysis of timing of the crisis, and also with some minor points such as jumps in the exchange rates. It has been found that it is possible to explain the timing of the currency crisis with at least three modifications of the standard fundamental approach model. All these modifications are important because one could see all of them in the actual Russian crisis last summer.

The first modification focuses on possibly non-linear government behaviour, when authorities conduct conditional policies of domestic credit growth rate, i.e., they change the rate of growth depending on the dummy variable, that states for crisis or no crisis (in sense attack or no attack). In case of speculative attack the rate of growth changes and this is the cause of multiple equilibria and bias of timing (to an earlier crisis if the rate of domestic credit growth would be higher after the crisis). The interesting economic interpretation of this for Russia states that in case of oligopolistic market structure crisis will be significantly sooner than in the basic model. In this modification we also have a solid jump in the exchange rate.

The second modification focuses on the case of uncertainty that is believed to play a significant role in the evolvement of the Russian overall financial crisis. If participants at the currency market do not know the value of the domestic credit growth rate or do not trust authorities, then we again could have multiple equilibria. Timing could be earlier or later depending on the bias of expectations of risk-neutral players. If the

bias is towards the bigger value of the rate than actual one, then a crisis will be sooner. This model, however, does not allow for jumps in the exchange rate.

The third modification illuminates the case of devaluation expectations. As we know from the market participants the devaluation fears had been much significant since April 1998. Also from (Aleksashenko, 1998) it is known that the Central Bank considered seriously the possibilities of changing the currency policy, loosely speaking, the possibility of the so-called mild devaluation. The modification suggests that in case of speculative attack government will let the currency to float freely for some period of time and then fix it again at some predetermined level that is higher then the current fixer exchange rate. The results imply again that crisis will be sooner and this depends also on the time of freely floating and the difference between two fixed exchange rates.

It is also possible to introduce the mixing of these modifications in this model to see the more real picture. It is done empirically with the last two modifications. Also there has been done massive empirical work using the financial data and all these three modifications were tried on the Russian case. Results are given in the 8th section of the Master Thesis and allow to suggest that these modifications generally fit the Russian case well.

As a supplement to the work in general there has been done also the "without-model" econometric estimation of financial market data. the main economic interpretation of this data lies in the fact that in order to understand the difference between yields on different assets (Russian and non-Russian) one should consider different risks. The full classification of risks that underlie two Russian assets – GKO and eurobonds – is provided.

The very general result is rather optimistic for the theory and states that it is possible to model such currency crisis in developing countries with a lot of outer factors besides described in the basic model without using very difficult and often notorious apparatus. Although it should be pointed out that at the same time it would be wrong to overestimate the good fitness of these modifications to the Russian case. It could be very well the fact that there is another explanation of the crisis (e.g., of an exchange rate jump or earlier crisis, etc.) that we do not consider. Nevertheless, if such another explanation exists it is argued that it could be possible to account for it in our model and to implement in some mixing modification.

This is a good portion of work for future investigations. Unfortunately (or fortunately, we do not know really), we could be sure that economic future will bring us inevitably to next financial crises including currency ones and these crises will have their own history, peculiarities, features, consequences, etc. But we do hope that with the help of the suggested model and modifications it is possible to start analysing future crises using the obtained results.

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Appendix A

Table 2

(all data in % to GDP)	1992	1993	1994	1995	1996	1997	1998 (Jan-Jul on a year basis)
Federal Budget							
Income	15.6	13.7	11.8	12.2	13.0	11.6	10.6
Expenditure	38.0	24.3	23.2	17.6	22.1	18.4	15.5
Balance[18]	-22.4	-10.6	-11.4	-5.4	-9.1	-6.8	-4.9
Consolidated Budget							
Income	38.3	36.2	34.7	31.9	32.1	33.0	32.8
Expenditure	56.7	45.6	45.1	37.6	41.5	40.5	38.1
Balance	-18.4	-9.4	-10.4	-5.7	-9.4	-7.5	-5.3

Table 3

(all data in % to GDP)	1992	1993	1994	1995	1996	1997	1998 (July)
Hard currency debt (in bln dollars)	83.6	95.0	110.2	120.4	125.0	123.4	136.3
Hard currency debt (as % of GDP)	182.3	69.1	65.9	35.2	31.6	28.3	31.1
Rouble debt (in bln dollars)	43.7	9.0	14.5	12.1	16.6	19.3	18.4
Rouble debt (as % of GDP)	56.1	11.8	19.7	16.7	24.0	28.6	29.5
All debt (in bln dollars)	103.6	107.4	134.4	161.6	190.8	207.3	217.0

[18] "-" stands for deficit.

All debt (as % of GDP)	226.0	78.1	80.3	47.3	48.2	47.6	49.5

Table 4

All data in bln roubles	1995 (June)	1996 (June)	1997 (June)	1998 (May)	Rate of growth 06.1995-05.1998, in %
Hard currency	62.1	92.5	131.3	66.7	7.5
Monetary base (M1)	68.7	129.4	167.0	162.9	137.1
Monetary base (M2)	156.7	266.9	352.0	369.4	135.7
GKO-OFZ nominal value	36.6	159.5	311.4	435.3	1089.4

Table 5

Date	Event
27.10.97-28.10.97	Stock crisis in Asian markets, followed by European and American bourses
10.11.97	Decision to claim 3-year currency band for rouble, interest rate (refinance rate) is up to 28%
10.11.97	Central Bank increased interest rate from 21% to 28%
27.10-30.11.97	Central Bank spent 31 trln roubles on supporting GKO market
01.12.97	New Central Bank's policy started: supporting rouble, no supporting GKO market
09.01.98	IMF transferred another $670 mln to Russia
12.01.98	Another wave of crisis on Asian markets
Late Jan 98	Unsuccessful attack on GKO market/Russian rouble
02.02.98	Central Bank increased interest rate from 28% to 42%
16.02.98	Central Bank decreased interest rate from 42% to 39%
19.02.98	Camdessu said IMF and Russia had reconciled all programme on 1998
27.02.98	Central Bank decreased interest rate from 39% to 36%
Early March 98	First evidence of turning current account into deficit
13.03.98	Central bank decreased interest rate from 36% to 30%
23.03.98	Retirement of Chernomyrdin's government
24.04.98	Kirienko is appointed the prime-minister
13.05.98	New wave of crisis on Asian markets after political turmoil in Indonesia

Middle May 98	New unsuccessful attack on the Russian market
19.05.98	Central Bank increased interest rate from 30% to 150%
26.05.98	Ministry of Finance refuses from issuing OFZ series
05.06.98	Central Bank decreased interest rate from 150% to 60%
17.06.98	Ministry of Finance refuses from issuing of new GKO series
25.06.98	Central Bank declared its reserves decreased by $1 bln for one week to $14.7 bln.
26.06.98	Central bank increased interest rate from 60% to 80%
07.07.98-09.07.98	Chubais said IMF was ready to give massive bail out
20.07.98	IMF gives Russia massive financial bail out
24.07.98	Central bank decreased interest rate from 80% to 60%
17.08.98	Government and Central Bank 's decision on default (de-facto), new currency band (6-9 roubles), 90-day moratorium on payment to foreign creditors
Late August – Early September 98	Slump devaluing of rouble

Table 6

Variable	frequency
Balance of Payments	Monthly
World energy prices	Daily
GKO market data	Daily
Currency market data	Daily
Central Bank reserves	Monthly
Eurobond market data	Daily
Inflation	Quarterly
Rate of refinance	-
Debt (structure of overall debt)	Monthly

Table 7

Variable \ Test type	intercept	intercept and trend	none
DOLLAR	0.19022	-3.1202	3.6074
in levels	(-2.5742)***	(-3.1398)***	(-2.5756)*
	unit root	unit root	no unit root
DOLLAR	-7.1676	-7.1696	
in 1st differences	(-3.4636)*	(-4.0057)*	no unit root
	no unit root	no unit root	
EUROBOND	2.2887	1.4847	1.8516
in levels	(-2.5740)***	(-3.1396)***	(-1.9412)**
	unit root	unit root	unit root likely
EUROBOND	-5.3527	-5.6552	-5.1286
in 1st differences	(-3.4627)*	(-4.0045)*	(-2.5753)*
	no unit root	no unit root	no unit root
FUTURES	-0.47616	-2.9227	1.1125
in levels	(-2.5752)***	(-3.1415)***	(-1.6166)***
	unit root	unit root	unit root
FUTURES	-5.9208	-6.0697	-5.7709
in 1st differences	(-3.4678)*	(-4.0117)*	(-2.5770)*
	no unit root	no unit root	no unit root
GKO	-0.71535	-2.5227	0.64828
in levels	(-2.5742)***	(-3.1398)***	(-1.6165)***
	unit root	unit root	unit root
GKO	-6.4716	-6.6065	-6.3593
in 1st differences	(-3.4636)*	(-4.0057)*	(-2.5756)*
	no unit root	no unit root	no unit root
USBONDS	-2.9826	-3.2495	-0.80594
in levels	(-3.4627)*	(-3.4321)**	(-1.6165)***
	(-2.8753)**	(-3.1395)***	
	unit root possible	unit root likely	unit root
USBONDS	-7.0994	-7.0927	-7.0619
in 1st differences	(-3.4627)*	(-4.0045)*	(-2.5753)*
	no unit root	no unit root	no unit root

"*" stands for 1% critical value
"**" stands for 5% critical value
"***" stands for 10% critical value
critical value is the MacCinnon critical values for rejection of hypothesis of a unit root

Table 8

Sample: 10/24/1997 8/14/1998
Included observations: 181
Series: DOLLAR FUTURES
Lags interval: 1 to 4

Data Trend:	None	None	Linear	Linear	Quadratic
Rank or	No Intercept	Intercept	Intercept	Intercept	Intercept
No. of CEs	No Trend	No Trend	No Trend	Trend	Trend
	Log Likelihood by Model and Rank				
0	988.4495	988.4495	996.0455	996.0455	996.9368
1	996.3875	997.5283	1001.312	1001.833	1001.914
2	996.8870	1001.420	1001.420	1005.675	1005.675
L.R. Test:	Rank = 1	Rank = 1	Rank = 0	Rank = 0	Rank = 0

Table 9

Sample: 10/24/1997 8/14/1998
Included observations: 181
Series: DOLLAR USBONDS GKO FUTURES EUROBOND
Lags interval: 1 to 4

Data Trend:	None	None	Linear	Linear	Quadratic
Rank or	No Intercept	Intercept	Intercept	Intercept	Intercept
No. of CEs	No Trend	No Trend	No Trend	Trend	Trend
	Log Likelihood by Model and Rank				
0	1108.737	1108.737	1119.348	1119.348	1124.857
1	1126.315	1129.567	1139.692	1139.789	1143.497
2	1140.740	1147.005	1155.679	1155.777	1159.219
3	1145.332	1158.118	1161.652	1167.070	1170.069
4	1148.754	1162.639	1164.962	1173.042	1173.588
5	1150.915	1165.121	1165.121	1174.728	1174.728
L.R. Test:	Rank = 2	Rank = 3	Rank = 2	Rank = 2	Rank = 2

Table 10

Sample: 10/24/1997 8/14/1998
Included observations: 181
Test assumption: Linear deterministic trend in the data
Series: DOLLAR USBONDS GKO FUTURES EUROBOND
Lags interval: 1 to 2, 3 to 4

Eigenvalue	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value	Hypothesized No. of CE(s)
0.201314	91.54480	68.52	76.07	None **
0.161931	50.85822	47.21	54.46	At most 1 *
0.063869	18.88380	29.68	35.65	At most 2
0.035920	6.937740	15.41	20.04	At most 3
0.001748	0.316659	3.76	6.65	At most 4

*(**) denotes rejection of the hypothesis at 5%(1%) significance level
L.R. test indicates 2 cointegrating equation(s) at 5% significance level

Unnormalized Cointegrating Coefficients:

DOLLAR	USBONDS	GKO	FUTURES	EUROBOND
1.387105	0.441816	0.000373	-0.314007	0.072376
0.070408	-0.220778	0.025748	-0.592390	-0.185886
0.513972	0.076361	-0.012918	-0.014868	0.090608
-0.128134	0.514740	0.001106	0.046174	-0.026252
-0.878160	-0.075026	0.007101	-0.091777	0.004762

Normalized Cointegrating Coefficients: 1 Cointegrating Equation(s)

DOLLAR	USBONDS	GKO	FUTURES	EUROBOND	C
1.000000	0.318516	0.000269	-0.226376	0.052178	-6.951848
(0.06895)	(0.00318)	(0.06977)	(0.02212)		

Log likelihood 1139.692

Table 11

Cointegrating Eq:	CointEq1	CointEq2
DOLLAR(-1)	1.000000	0.000000
FUTURES(-1)	0.000000	1.000000
GKO(-1)	-0.006297	-0.043194
	(0.00401)	(0.01347)
	(-1.56964)	(-3.20576)
USBONDS(-1)	0.302088	0.377221
	(0.14374)	(0.48274)
	(2.10166)	(0.78142)
EUROBOND(-1)	0.081828	0.310600
	(0.05014)	(0.16841)
	(1.63185)	(1.84432)
@TREND	-0.000639	-0.000259
	(0.00072)	(0.00241)
	(-0.88960)	(-0.10744)
C	-8.229598	-10.39405

Appenix B

Graph 1

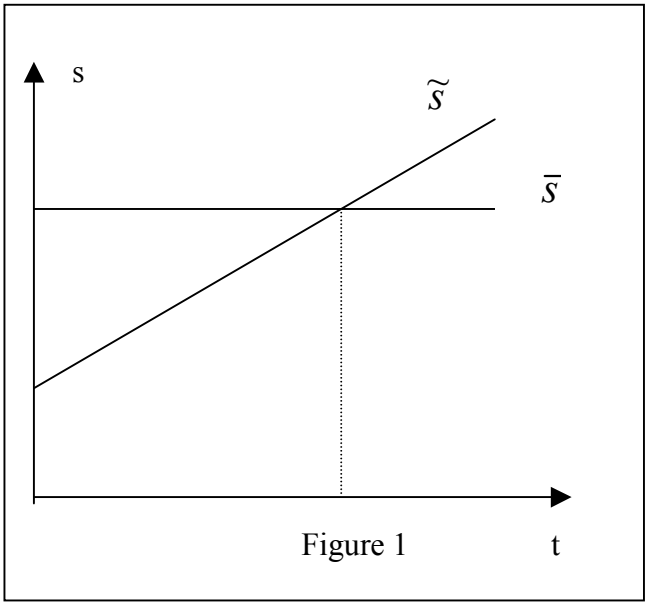


Figure 1

Graph 2

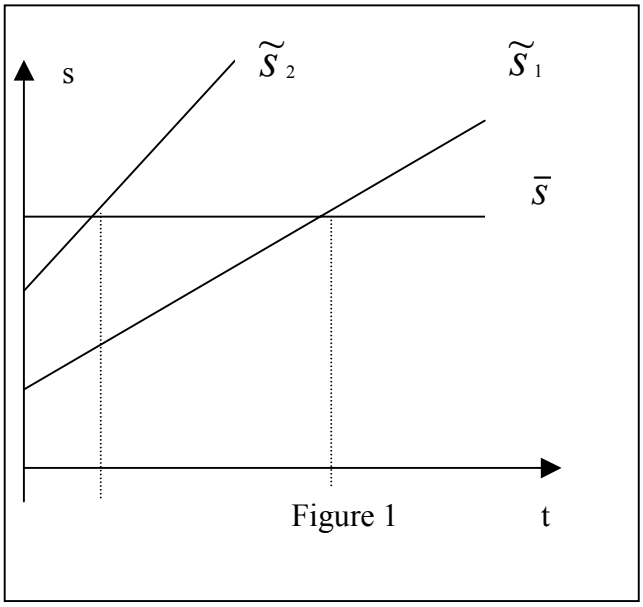


Figure 1

Graph 3

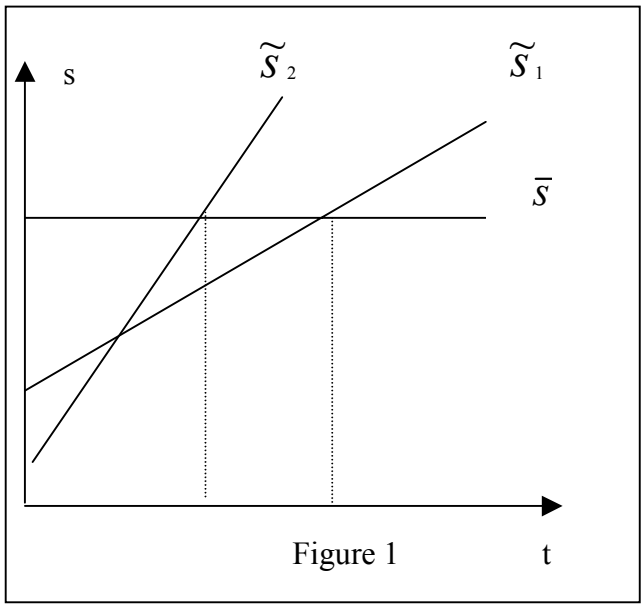


Figure 1

Graph 4

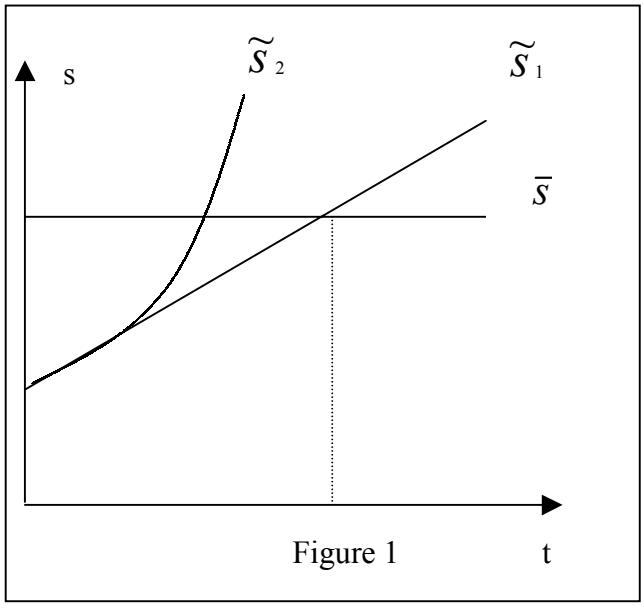
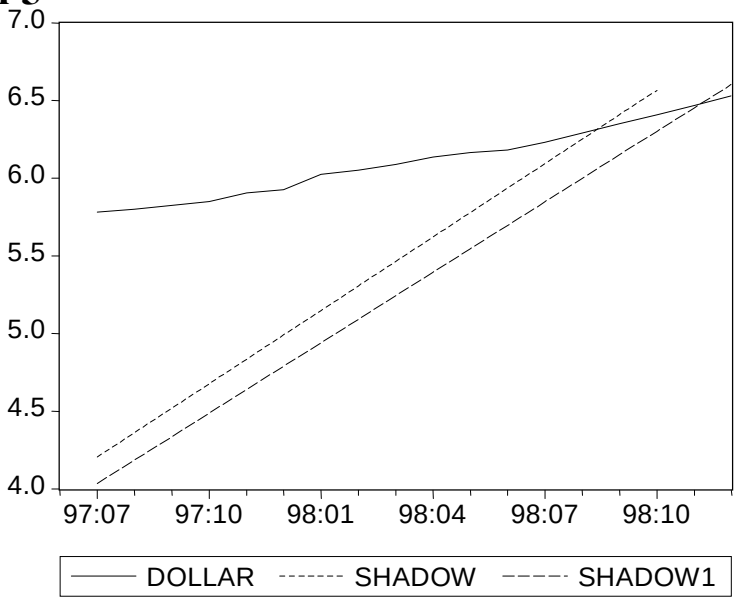
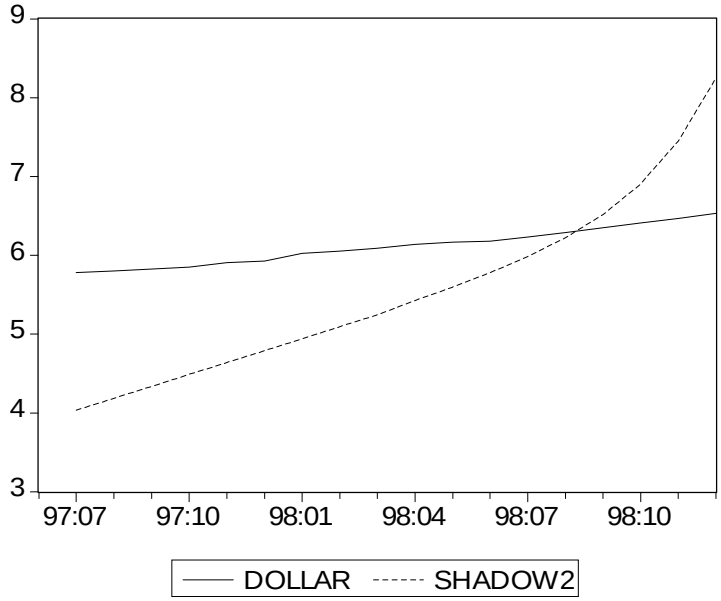


Figure 1

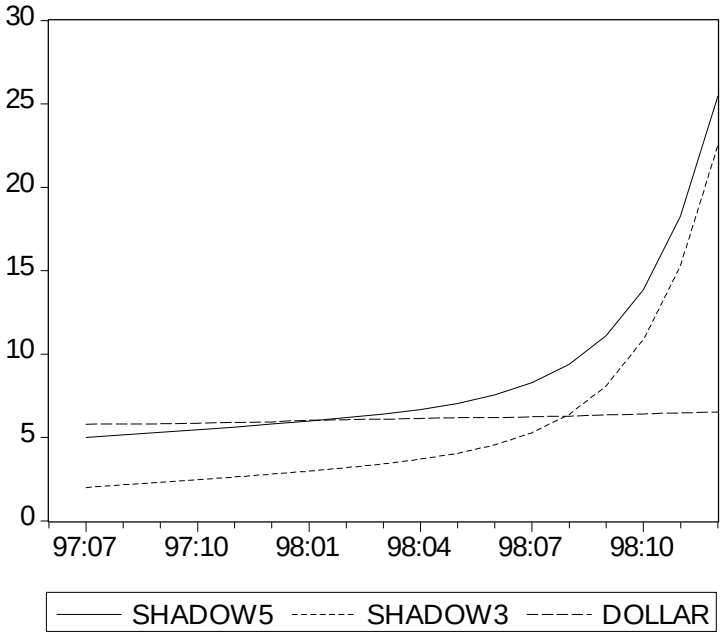
Graph 5



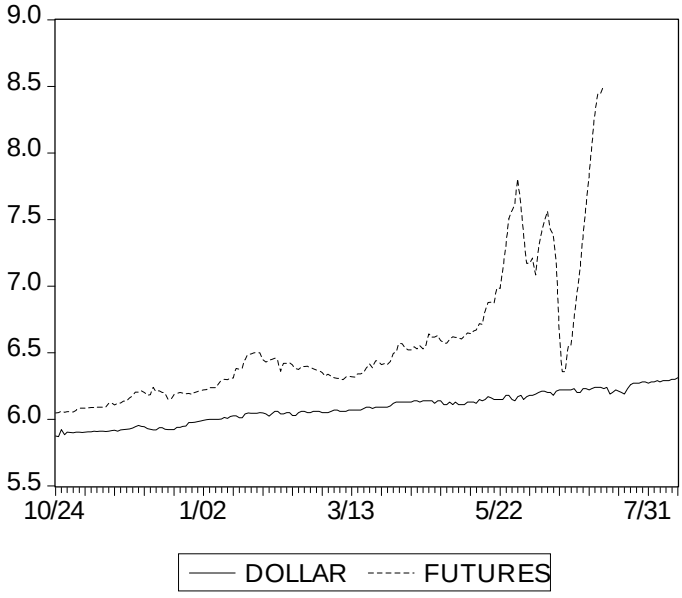
Graph 6



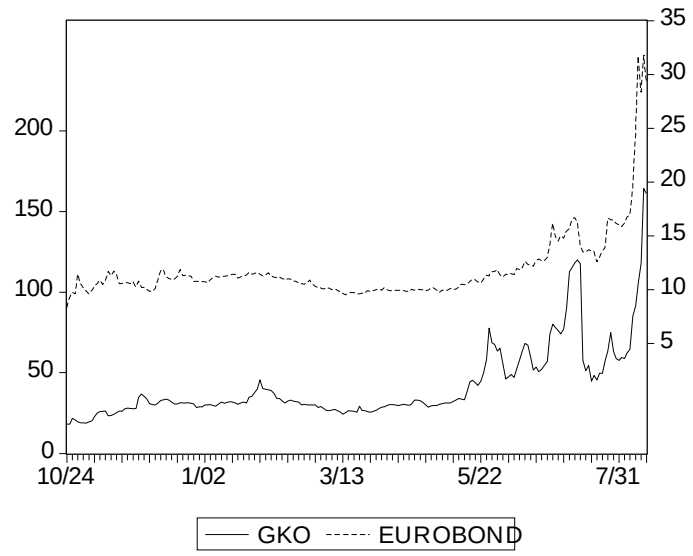
Graph 7



Graph 8

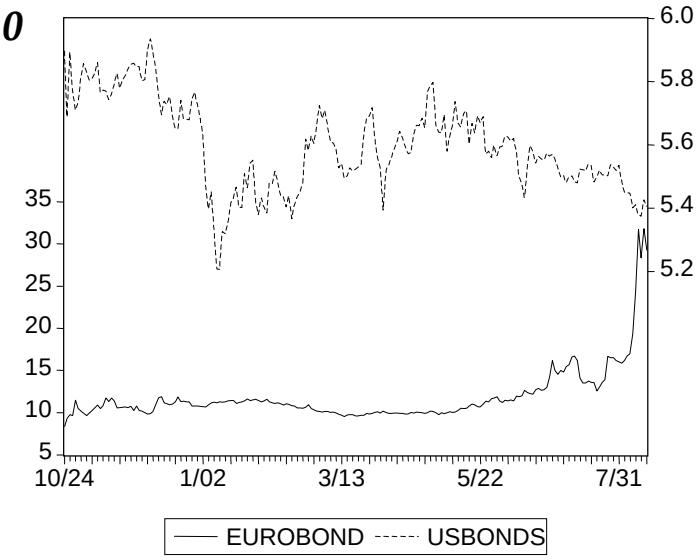


Graph 9



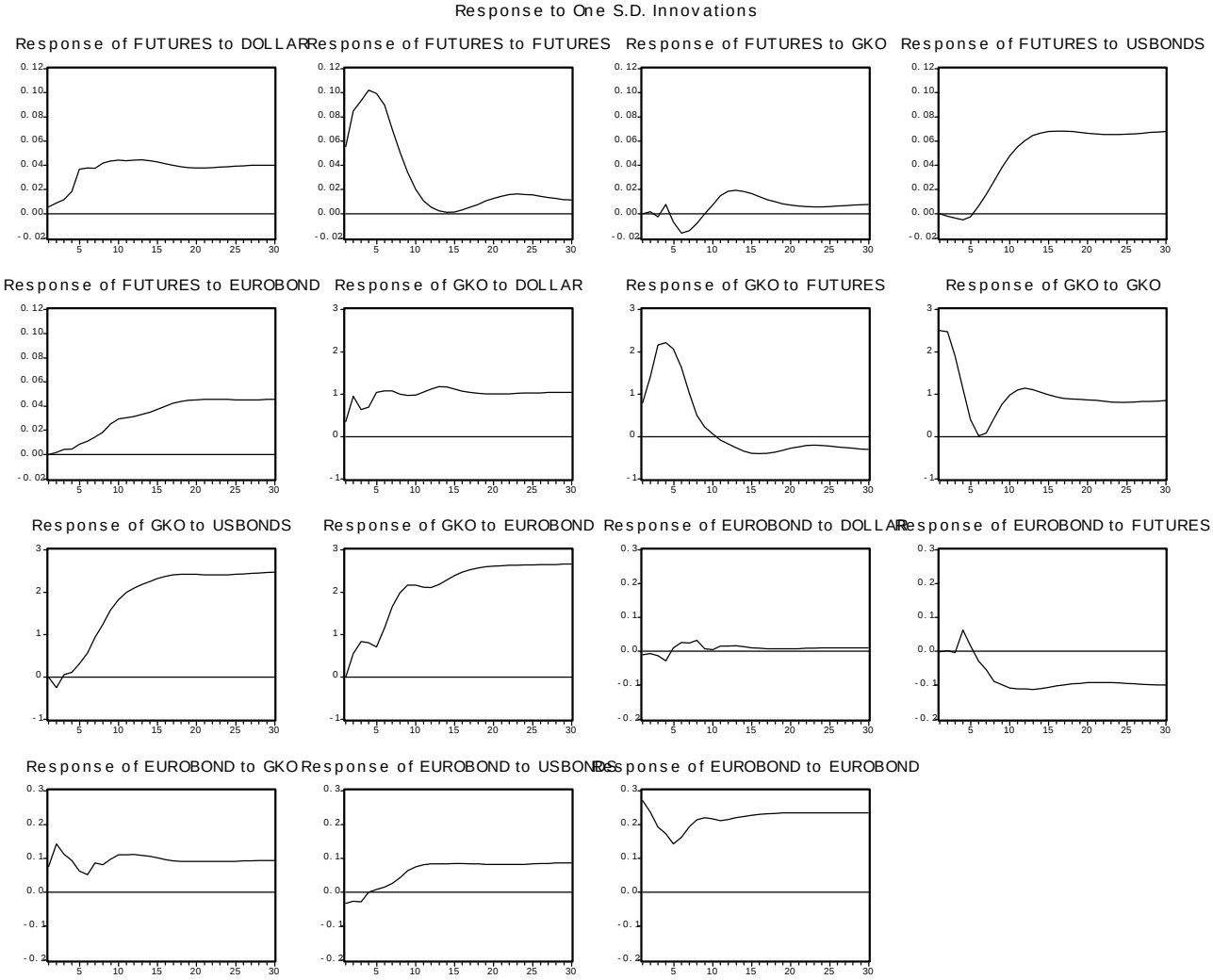
(EUROBOND scale on the left, GKO scale on the right)

Graph 10

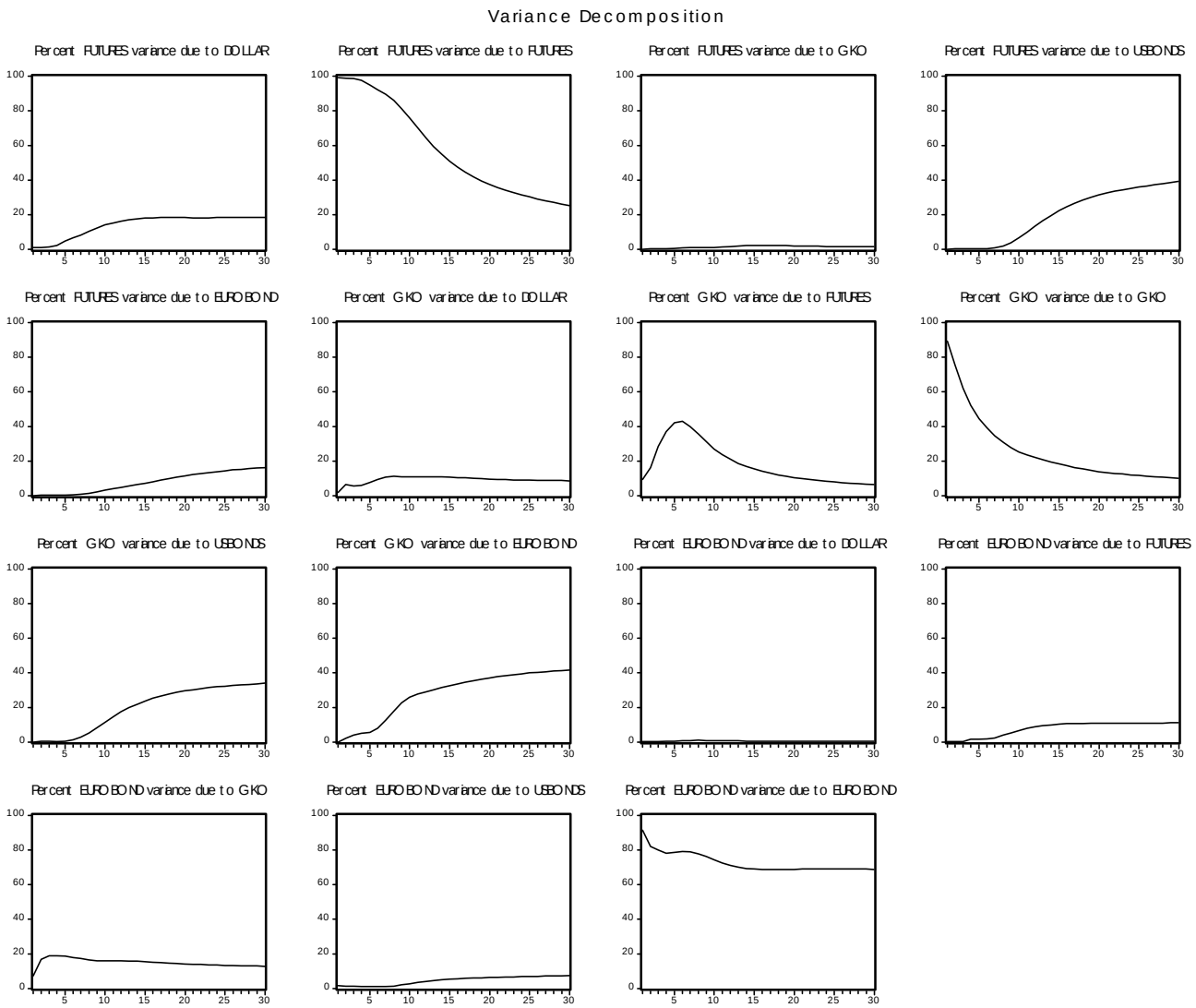


(EUROBOND scale on the left, USBONDS scale on the right)

Graph 11


Response to One S.D. Innovations
Response of FUTURES to DOLLAR
Response of FUTURES to FUTURES
Response of FUTURES to GKO
Response of FUTURES to USBONDS
Response of FUTURES to EUROBOND
Response of GKO to DOLLAR
Response of GKO to FUTURES
Response of GKO to GKO
Response of GKO to USBONDS
Response of GKO to EUROBOND
Response of EUROBOND to DOLLAR
Response of EUROBOND to FUTURES
Response of EUROBOND to GKO
Response of EUROBOND to USBONDS
Response of EUROBOND to EUROBOND

Graph 12


Variance Decomposition
Percent FUTURES variance due to DOLLAR
Percent FUTURES variance due to FUTURES
Percent FUTURES variance due to GKO
Percent FUTURES variance due to USBONDS
Percent FUTURES variance due to EUROBOND
Percent GKO variance due to DOLLAR
Percent GKO variance due to FUTURES
Percent GKO variance due to GKO
Percent GKO variance due to USBONDS
Percent GKO variance due to EUROBOND
Percent EUROBOND variance due to DOLLAR
Percent EUROBOND variance due to FUTURES
Percent EUROBOND variance due to GKO
Percent EUROBOND variance due to USBONDS
Percent EUROBOND variance due to EUROBOND