INVESTIGATING THE LIQUIDITY EFFECT IN THE UKRAINIAN INTERBANK MARKET

by

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Abstract

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This thesis studies the relationship between money and interest rate in Ukraine. First, theoretical explanation of a short-run negative response of interest rate to monetary expansion - the "liquidity effect"- is provided. Then, attention is paid to the development of empirical studies in the realm of money-interest rate relationship and to the failure of previous research to find strong empirical support to the simple theoretical notion of liquidity effect.

Two formal econometric tests for the information content of alternative interest rates in Ukraine reveal that the interbank interest rate is the best candidate for monetary policy studies. A semi-structural vector autoregression model (VAR) is constructed to monitor the dynamic response of the interbank interest rate to shocks in monetary policy variable. Thorough analysis of the operation procedure of the National Bank of Ukraine allows the author to suggest possible solution to the money endogeneity problem in Ukrainian context by taking total reserves of commercial banks as a policy variable. The paper presents strong evidence of the liquidity effect in Ukraine. The results are robust to the lag structure used in the VAR model as well as to the variations in the structural parameter that determines the fraction of the demand shock in total reserves offset by the National Bank.

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GLOSSARY

Liquidity effect - short-run decline of interest rate in response to monetary expansion

NBU – the National Bank of Ukraine: the central bank of Ukraine

OVDP – government discount bonds issued by the Ministry of Finance of Ukraine

"Covering" – a specific term from Ukrainian legislation that denotes the fraction of required reserves that must be held in the form of ("covered by") vault cash and/or government bonds

Chapter 1

INTRODUCTION

The ultimate effect of money on the real economy has always been of great concern to economists and monetary policymakers. However, the *transmission mechanism*, or channels through which changes in monetary aggregates affect real economic variables, is an issue of even greater importance. Channels of monetary transmission determine strength, duration, and direction of the effects brought into real economy by policy actions. As was perspicaciously noticed by Mishkin (1995) in his introduction to the symposium on monetary transmission mechanism "Monetary policy is a powerful tool, but one that sometimes has unexpected or unwanted consequences." Thus, the ability of central bank authorities to conduct monetary policy successfully depends substantially on the depth of their awareness of channels through which monetary shocks are transmitted into economy.

If we refer to monetary policy in transition economies, such as Ukraine, it is even more important for policymakers to be able to predict the consequences of their activity as precisely as possible. Under circumstances of unstable economic environment, undeveloped financial markets, and newly established institutional settings, any careless action may lead to very harmful results. Understanding of the mechanism through which changes in monetary policy pervade into real economy is crucial for Ukrainian policymakers.

The monetary transmission mechanism embraces a varied range of channels. A notion of a negative relationship between money and interest rates – the liquidity effect – is an important part of many of them. The liquidity effect is the first stage of monetary transmission through traditional interest rate, exchange rate and credit channels. The notion of the liquidity effect emanates from the conventional Keynesian theory of money with a vertical supply curve and downward sloping demand curve. According to this framework, increases in money supply leads to (at least) short-run declines of interest rates. Although the theoretical concept of the liquidity effect is quite old and simple, the empirical evidence is still puzzling. The econometric technique used to estimate the liquidity effect in the latest studies is much more sophisticated than it was four decades ago, when the first attempt to evaluate the money-interest rate relation was made. Nevertheless, there are still doubts among economists about the direction and persistence of the interest rate response to monetary expansion.

The inability of empirical studies to support the underlying theoretical concept suggests that the relation between money and interest rates is much more complex than a conventional economic textbook states. Simple models presented in textbooks are not able to explain how and through which channels the economy responds to policymakers' actions; thus, more advanced investigations are necessary to reveal the true picture of how the economy works. This thesis contributes to the literature by investigating the relation between money and the interest rate in Ukraine.

The rest of the paper proceeds as follows. Chapter 2 addresses the definition of the liquidity effect and basic theoretical concepts underlying this notion. Chapter 3 provides a review of previous empirical studies. It emphasizes the main problems faced by previous researchers and points out ways and methods that were adopted to overcome them. Chapter 4 deals with data analysis, verification and correction. Chapter 5 provides an econometric analysis that investigates the information content of the interbank interest rate. Chapter 6 focuses on the instruments, procedures, and institutional settings involved in the formation of monetary policy in Ukraine. It pays particular attention to the discussion of monetary policy tools and targets of the National Bank of Ukraine and briefly describes the development of Ukrainian interbank market. Chapter 7 is devoted to empirical modeling of the money-interest rate relation. The results of the semi-structural vector autoregression model developed here suggest that reaction of interest rate to monetary policy shock is strictly negative. The results are quite robust to the lag structure and to the value of model parameter. Chapter 8 concludes and suggests directions for further investigation.

C h a p t e r 2

THEORETICAL FRAMEWORK

The traditional definition of the liquidity effect is based on the partial equilibrium Keynesian model of money market with a downward sloping demand curve and vertical supply curve (Mishkin 2001). In this simple framework an increase in the money supply (*everything else remaining equal*) leads to a decline in interest rate (see Figure 1.A). This immediate (short-run) interest rate response to the monetary expansion was called the *liquidity effect*. However, in the long–run the effect of monetary expansion extends on other economic factors, which in turn influence interest rate. These "non-liquidity" factors can be classified as following:

1. *Income Effect*. Expansionary monetary policy leads to increase in national income and wealth, which affect demand for money. As a result, the demand curve shifts to the right and interest rate increases (see Figure 1.B).
2. *Price-level Effect*. Increase in money supply may lead to overall increase in prices. Since according to Keynesian framework people care about cash they hold only in real terms, when prices increase, more money is needed to leave the purchasing power at the sufficient level. As with income effect, demand curve shifts to the right and drives interest rate up (see Figure 1.B).
3. *Expected-inflation Effect* (or *Fisher effect*). Increase in money supply may affect people's expectations about future level of inflation, which in turn leads to increase in interest rate. The expected-inflation effect works through financial assets, such as government bonds or bank deposits[1]. When expected inflation increases the return on real assets

[1] Ukrainian government bonds (OVDP) have almost disappeared from circulation since crisis of 1998 (see Chapter 6 for more details). However, the same analysis can be applied to any financial assets held by public. Bank deposits are the most wide-spread financial assets in Ukraine; thus, we will demonstrate the expected-inflation effect in the context of bank deposits

also goes up, making bank deposits less desirable relative to real assets. The decreased demand for bank deposits drive the interest rate on them up. Two important points should be mentioned here:

(i) expected-inflation effect persists as long as the price level continues to rise

(ii) expected-inflation effect may operate rapidly, even at the same time when the liquidity effect comes into force.

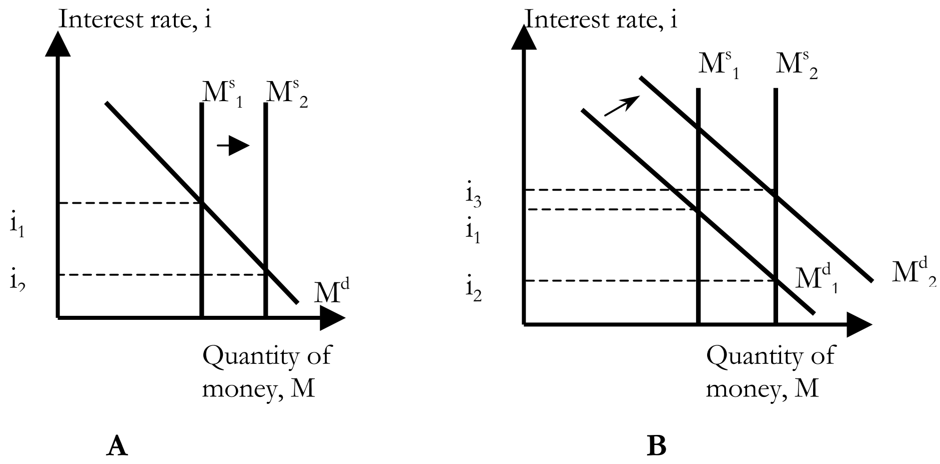

Figure 1. Interest rate response to increase in money supply
A - immediate response: liquidity effect; B - non-liquidity effects.
Note: i3 is not necessarily greater than i1.

Source: Mishkin 2001

Strength and persistence of monetary expansion effects are determined by current situation in the economy. Thus, the ultimate result of increase in money supply is ambiguous. Three typical scenarios of interest rate movements are possible (Figure 2):

a) liquidity effect dominates all other effects

b) liquidity effect is weak, expected-inflation effect comes into force later

c) liquidity effect is weak, expected-inflation effect comes into force immediately

Therefore, identifying which effect dominates has important implications for policymakers, since monetary expansion may lead to unexpected, or opposite to expected, consequences.

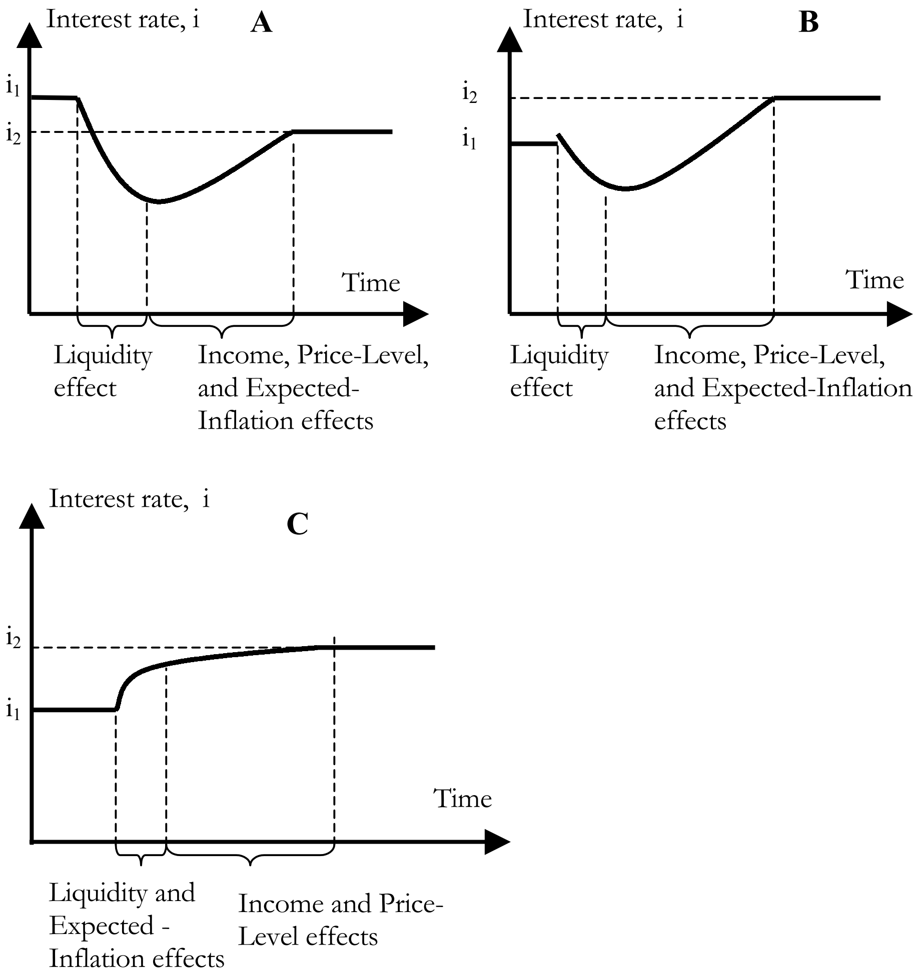

Figure 2. Ultimate interest rate response to increase in money supply A – liquidity effect is strong; B – liquidity effect is weak; C – expected inflation effect comes into force immediately.
Source: Mishkin (2001)

Chapter 3

PREVIOUS EMPIRICAL EVIDENCE

Though the relationship between money and the interest rate is straightforward in theory, empirical evidence on the liquidity effect has been puzzling since the earliest empirical research, and it is today. Historically, the theoretical explanation of the liquidity effect was treated as a plausible concept. In the earliest empirical studies the existence of a negative short-run relation between money and interest rate was taken for granted. As a general rule, researchers focused on the strength and persistence of interest rate decline in response to the money stock growth.

For example, Cagan and Gandolfi (1969) investigate the time pattern of the monetary effect on interest rates for monthly data spanning the period 1910-65. The equation presented in first differences relates the change in commercial paper rate during period *t* to M2 growth rates in period *t* and previous periods back to *t-n*. They found that, as theory predicts, the interest rate declines immediately after the increase in M2 growth rate and begins to rise later. To be precise, a 1% increase in M2 growth rate leads to a maximum 2.6% decline in commercial paper rate. In terms of the theoretical concepts outlined above, Cagan and Gandolfi have shown that the commercial paper rate behaves according to second scenario presented in Figure 2b: it reaches a trough seven month after an increase in money growth and then rises above its initial position.

Absolutely different results are obtained by Melvin (1983). He provides similar analysis for data drawn from the 1970s and finds that liquidity effect disappears during a month after the increase in money growth rate. In other words, Melvin's results conform to the last scenario (Figure 2c): the liquidity effect is immediately offset by other economic factors that drive interest rate up. Melvin himself infers that it is an anticipated inflation effect that dominates the liquidity effect in 1970s. Melvin's "vanishing liquidity effect" contributed to the development of monetary business cycle models that imply that persistent exogenous increase in money growth leads to a *rise* in the nominal interest rate. However, Cochrane (1989), using a spectral band pass filter technique, finds that the liquidity effect reemerges in 1979-82.

These earlier studies use a common, very simple technique – a distributed lag model - which implicitly assumes that no other variable affects the relation between money and interest rate. Because of this limitation, it is impossible to test which variable except money is responsible for the interest rate movements. In order to explore this possibility Gordon and Leeper (1992) estimate a four-variable vector autoregression (VAR) model that includes money growth rates, interest rates, CPI and industrial production. They assume that the endogenous component of the monetary base is small; with this assumption they use monetary base to model the exogenous innovations in monetary policy. They find that relation between monetary base and federal funds rate is never negative; that is, there is again no liquidity effect.

Subsequent empirical studies were revolutionary in the realm of monetary policy modeling. Christiano and Eichenbaum (1992) use the cross-correlation between the federal funds rate and different monetary aggregates to show that broad monetary aggregates such as monetary base (M0), M1 or M2 are inappropriate measures of exogenous monetary shock. They point out that correlation between M0 and *current and future* values of the interest rate is *positive*, whereas correlation between M0 and *past* values of the interest rate is negative. At the same time, the non-borrowed reserves (NBR) held by commercial banks are *negatively* related to the *past and future* values of the interest rate. Christiano and Eichenbaum (1992) argue that it is an understatement of the endogenous component in broad monetary aggregates by previous researchers that has led to poor empirical evidence of the liquidity effect. In reality, monetary aggregates are largely influenced by shocks that come from the demand for money. Thus, M0 or M1 contains large endogenous component and cannot serve as good measure of monetary policy shocks. On the contrary, the level of NBR is directly controlled by the Federal Open Market Committee (FOMC) through open market operations. Therefore, monetary policy shock can be measured by changes in the level of NBR. Christiano and Eichenbaum (1992) construct VAR model to support his cross-correlation analysis. When NBR is used as a measure of monetary shock the fed funds rate exhibits a sharp, persistent decline. This result is robust to the sample choice as well as to the identification assumption. Strongin (1992) uses somewhat different measure of exogenous monetary shock - the mix of borrowed and non-borrowed reserves. Performing two sets of VAR models for subsamples similar to those used by Gordon and Leeper (1992), he finds that the liquidity effect is highly significant and persistent in all cases.

Definitely VAR modeling opens a wider horizon for research than the lag distributed regressions do; however, it is also subject to criticism. Bernanke and Mihov (1998) summarize three common pitfalls of VAR: (i) failure to allow the instability in structure or parameters, (ii) uncertainty about the choice of policy indicators, and (iii) non-robustness of identification assumption. Bernanke and Mihov (1998) eliminate some of the pitfalls by constructing semi-structural VAR model and by using other specific methods, however new approach to model the liquidity effect was suggested recently. Hamilton (1997) pioneers the techniques of identifying the liquidity effect on the daily basis. "Rather than try to identify the effect of monetary policy over an entire month as earlier researchers have done", he investigates "the instantaneous consequences of an open-market purchase". His main argument against previous methods is that in most cases Federal Reserve changes its policy in response to changes in the level of output, inflation, exchange rate and other economic indicators. As a result, "the correlation between such a "policy innovation" and the future level of output of necessity mixes together the effect of policy on output with the effect of output forecasts on policy". In other words, identifying the liquidity effect on monthly basis, previous researchers did include endogenous component induced by Fed's forecasting procedure. Hamilton simulates the errors that Fed makes in forecasting the demand for reserves. He argues that these errors are responsible for fluctuations in bank reserves and, as a consequence, in fluctuations in the fed funds rate. Building quite complicated model of market for reserves, Hamilton finds the liquidity effect is present and significant, but only on the last two days of the maintenance period. Hamilton's methodology is criticized by Thornton (2001). Thornton shows that when Hamilton's model is applied to other data samples, there is no significant evidence of liquidity effect. He also suggests alternative model based on the Fed's operating procedure, however, this model doesn't give reliable results. Thornton concludes that the liquidity effect cannot be identified at daily frequency.

Researchers in other countries were also involved in solving the "liquidity puzzle". Fung and Gupta (1994) use structural VAR to investigate the response of output, interest rate, and exchange rate to shocks in monetary policy for Canadian economy. They find that positive monetary shocks measured by increases in excess cash reserves lead to declines in the interest rate, increases in output, and deprecation of the Canadian dollar. Fumio Hayashi's (2000) builds an elaborated econometric model of market for reserves to verify the existence of the liquidity effect in the Japanese interbank market for overnight loans.

Recently Ukrainian researchers have also become active in investigating the effects of monetary expansion on various economic variables. For example, Shevchuk (2001) employs a vector error correction model to reveal the relationship between money (measured by broad monetary aggregate M2), industrial production, inflation, and real exchange rate in Ukraine for 1994-2000. As usual, the reaction of other variables to monetary shock is measured in terms of impulse response function. Shevchuk finds that in response to one-standard deviation shock in M2 inflation initially decreases but then rises abruptly and reaches a peak half a year after monetary expansion. Not surprisingly the temporary appreciation of real exchange rate in response to monetary shock is found for periods when inflation is low. Strong and persistent real depreciation is observed in subsequent periods when inflation is high. Finally, an increase in M2 does not promote growth of industrial production. A tiny positive effect is observed only during the first 3 month, while in subsequent periods industrial production decreases substantially.

There are also some examples of successful and fruitful empirical research in the realm of monetary transmission for Ukrainian data (Kryshko 2000, Bolgarin, Mahadeva, and Sterne 2000). However, these studies neither investigate the interest rate response to monetary shock nor address the question of money endogeneity. To my present knowledge, the reaction of the interest rate to monetary policy shock has not yet been investigated in Ukraine. The present study is a first step toward filling the gap. It will contribute to the growing economic literature on monetary policy in Ukraine in two ways: by providing a deeper analysis of interest rate and its response to monetary policy shocks, and by attempting to solve the problem of money endogeneity for Ukrainian data.

DATA DESCRIPTION

Data used in the research are monthly, spanning 5 years: from January 1997 to September 2001. All variables, their short description, units of measurement, and sources are reported in Table 1. Auxiliary variables used in calculation and calculation procedure are presented of Appendix A. Tables A4 and A5 of Appendix A provide descriptive statistics of variables.

Table 1. Data description and sources

Variable	Description	Units	Source
Variables used to test the information content of interest rates			
IIR	Interbank interest rate	%, annual rate	UEPLAC quarterly issues of monthly update "Ukrainian Economic Trends"
DIR	Interest rate on deposits, weighted average	%, annual rate	NBU official site (www.bank.gov.ua)
LIR	Interest rate on loans to real sector, weighted average	%, annual rate	NBU official site (www.bank.gov.ua)
DR	Discount rate of the NBU, weekly average during a month	%, annual rate	www.Uabanker.net,
RRR	Reserve requirements ratio with corrections	%	Own calculations, see Appendix A for details
Variables used in semi-structural VAR model			
M	Monetary aggregate M1= currency in circulation + checkable deposits in national currency	mln. UAH	NBU official site (www.bank.gov.ua)
P	Inflation (CPI)	%, monthly rate	State Statistics Committee
I	Interbank interest rate	%, monthly rate	UEPLAC quarterly issues of monthly update "Ukrainian Economic Trends"
R	Total bank reserves (correspondent account + vault cash) with corrections	mln. UAH	Own calculations, see below

The reported amount of total reserves held by banking system includes funds on correspondent accounts and vault cash. Detailed analysis of data reveals a striking inconsistency between two variables, namely, required reserves, RR, and total reserves, TR[2]. As can be seen from Panel A of Figure 3, required reserves exceed total reserves over a period from January 1997 to September 1998. The explanation of such a suspicious situation comes from peculiarities of Ukrainian legislation. During 1996 – 1999 the Board of Governors of the National Bank of Ukraine initially allowed and then obliged commercial banks to hold certain fraction of their required reserves in government bonds (OVDP) or vault cash, so called "covering" (Stelmah et al. 2000). *OVDP "covering"* was established to increase the demand for OVDPs by commercial banks, especially after the foreign demand dried up in late 1997. Thereafter "covering" became an important tool of monetary policy, since it allowed the National Bank of Ukraine (NBU) to regulate demand for total reserves of commercial banks by changing the size of "covering" or abolishing it for some periods. However, after Ukrainian government defaulted on government bonds in August 1998 and froze almost all operations with government securities, "covering" became useless and was eventually abolished in January 1999. The timing and size of "covering" is presented in Table A2 in Appendix A.

Vault cash "covering" was not an obligatory measure. It was advantageous for banks to hold some fraction of required reserves in vault cash since otherwise they were forced to borrow funds at the interbank market paying interbank interest rate on them. Therefore, we can make a rather sensible assumption that banks held maximal permitted fraction of reserves in vault cash. Since the amount of total reserves reported by official sources includes funds on correspondent account and vault cash, vault cash "covering" cannot account for substantial part of inconsistency in the reported series. The reason of discrepancy in series lies in OVDP "covering". To correct data we need to add amount of reserves held in government bonds to total reserves in those periods when OVDP "covering" was established (1997-1998):

$$TR_t = TRrep_t + \text{OVDP "covering"}_t$$

[2] The amount of required reserves (RR) is calculated by the author. See Appendix A for details.

where subscript t denotes period. The corrected series is presented in Panel B of Figure 3.

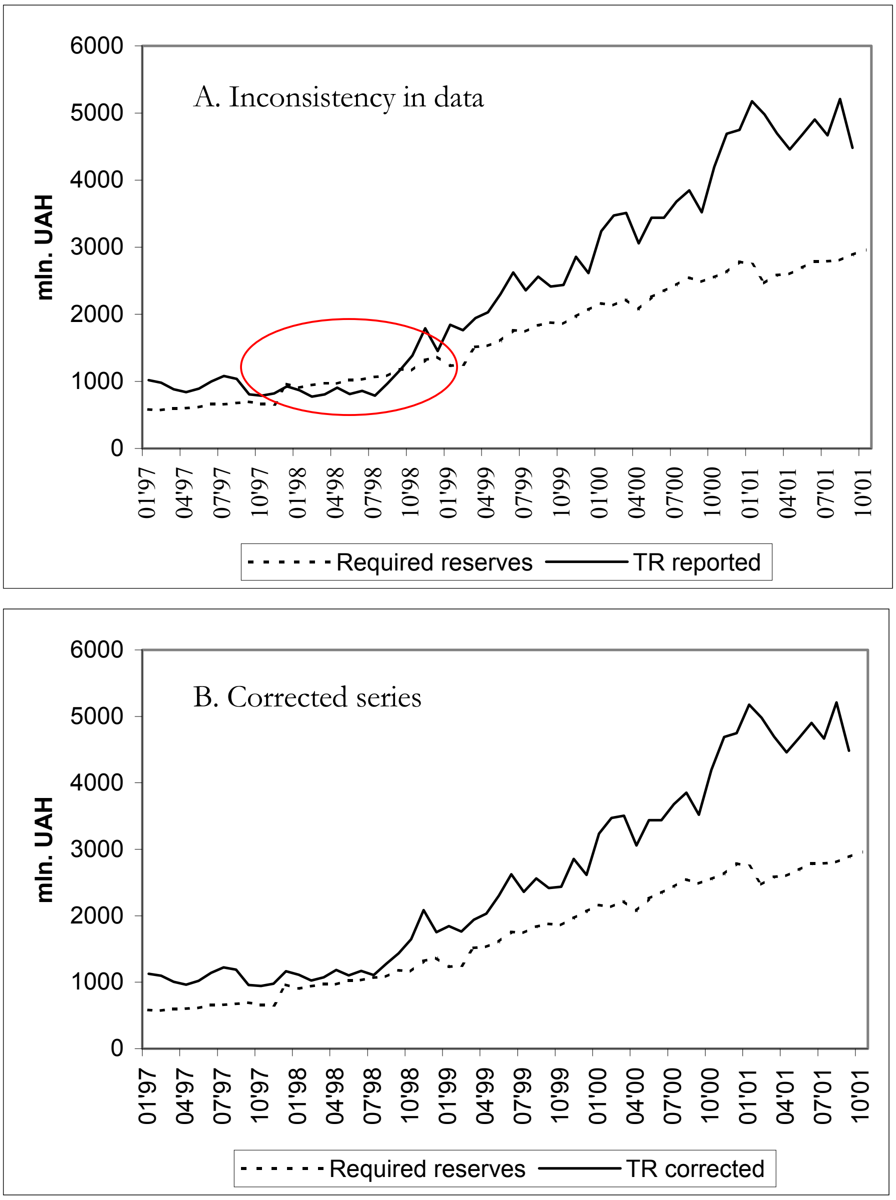

Figure 3. Data verification and correction

Chapter 5

INFORMATION CONTENT OF THE INTERBANK INTEREST RATE

The theoretical framework presented above shows the relation between money and interest rate. When turning to empirical investigations a natural question arises – which of the interest rates must be used in an empirical model? It is sometimes argued that the interbank interest rate serves as a "closely watched barometer of the …stance of monetary policy" (Mishkin 2001). The intuition behind this statement is that the interbank interest rate appears to be in closer connection with policy actions than other interest rates in the economy (Bernanke and Blinder 1992). This implies that interbank interest rate contains unique policy information. In order to be sure that the right variable was chosen for econometric model, one should test which of the interest rates *contains more information about monetary policy* than other market interest rates.

Grounding on the visual inspection of behavior of interest rates in Ukraine, some researchers suggest that interest rate on interbank loans determines the interest rate on loans to private sector (Gurski 1999). Indeed, as Figure 4 shows, while there is substantial spread between interbank interest rate and interest rate on loans to private sector, the change in the former induces the change in the latter. The same is seemed to be true for the behavior of interest rate on deposits. However, visual inspection is a rather subjective judgment. Therefore, we turn to formal econometric tests that help to discriminate among different interest rates. In performing such investigation, we basically follow the approach used by Garfinkel and Thornton (1995) and examine the information content of the interbank interest rate from two perspectives: (i) in the sense of Granger causality and (i) in the sense of responsiveness to policy actions.

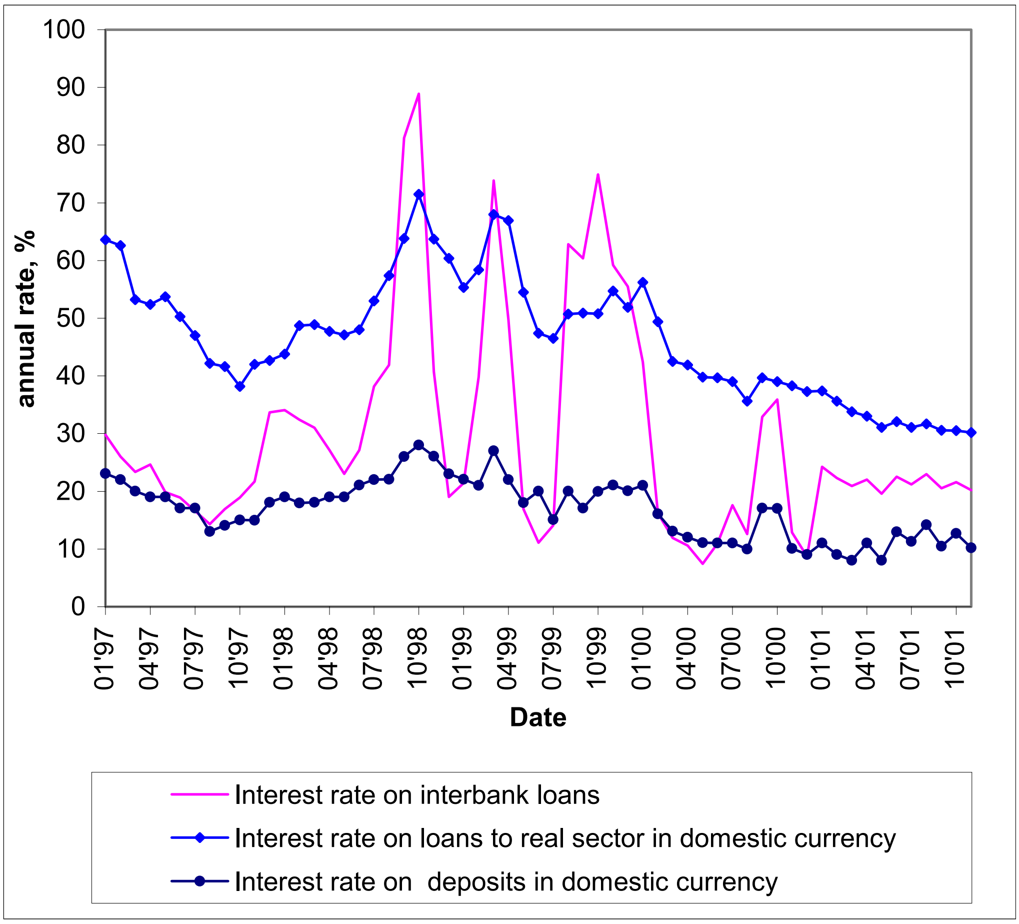

Figure 4. Interest rates on interbank loans, loans to real sector and deposits in Ukraine in 1997-2001
Data source: Bulletin of the National Bank, various issues; UEPLAC monthly update "Ukrainian Economic Trends", various issues

Granger causality test

The Granger causality test assesses whether lagged values of one variable help to explain variations in other variable. In other words, Y is said to be Granger caused by X, if lagged values of X improve on the explanation of Y obtainable from only lagged values of Y. The Granger causality test is usually performed by running the following regression:

$$Y_t = A_1 * Y_{t-1} + A_2 * Y_{t-2} + \ldots + A_k * Y_{t-k} + B_1 * X_{t-1} + B_2 * X_{t-2} + \ldots + B_k * X_{t-k}$$

where k is the maximum lag included.

Table 2. Marginal significance levels of Granger causality test

Lag (k)	DIR does not Granger Cause IIR	IIR does not Granger Cause DIR	LIR does not Granger Cause IIR	IIR does not Granger Cause LIR	LIR does not Granger Cause DIR	DIR does not Granger Cause LIR
2	0.0825	0.0497	0.5380	0.0051	0.2849	0.0201
3	0.0183	0.1043	0.5406	0.0172	0.3702	0.0196
4	0.0996	0.1376	0.8595	0.0447	0.5517	0.0215
5	0.2980	0.2387	0.9642	0.0226	0.5864	0.0059
6	0.3691	0.1725	0.9204	0.0160	0.6972	0.0370
7	0.3992	0.1518	0.8901	0.0502	0.4612	0.0364
8	0.4846	0.0430	0.9595	0.0556	0.5240	0.0432
9	0.4549	0.0804	0.4799	0.0650	0.0432	0.0429
10	0.1809	0.0367	0.3972	0.0702	0.1059	0.0574
11	0.2084	0.0845	0.4725	0.1046	0.1512	0.0694
12	0.3048	0.1490	0.4179	0.0344	0.1655	0.1153
10%	**0.27**	**0.45**	**0.00**	**0.91**	**0.09**	**0.91**
5%	**0.09**	**0.27**	**0.00**	**0.55**	**0.09**	**0.73**

If coefficients B1, B2, … , Bk are jointly significant, then X Granger causes Y. Hence, the null hypothesis of causality is simply the hypothesis that B1= B2= … =Bk=0. Rejection of the null hypothesis indicates that past realizations of X do contain information that helps to explain the behavior of Y. However, this result will be convincing evidence of unique information content of X only if the reverse causality is not observed.

We will analyze the Granger causality of the interbank interest rate (IIR), and two other interest rates, namely, the interest rate on loans to real sector (LIR) and the interest rate on deposits (DIR). All data are monthly and presented in annual rates. Data sample covers the period from January 1997 to September 2001. It is said that Granger test is often sensitive to the number of lags (k) used in the equation (Johnston and DiNardo 1997). To avoid misleading inference caused by arbitrary choice of k, the tests are performed for all lag lengths up to 12. Columns of Table 2 report the marginal significance levels for the hypothesis stated in the upper cell of the column. The second to last cell of each column shows the proportion of cases where the respective null hypothesis was rejected at 10% significance level. The last cell shows the same proportion, but for 5% significance level.

Although the results are somewhat sensitive to the choice of the critical significance level, two conclusions can be drawn from the table above:

(i) Both IIR and DIR Granger cause LIR and the opposite is not true.
(ii) The causality between DIR and IIR is in favor of IIR, but the relation is not unambiguously clear. Hence, additional tests of informational content should be performed.

Test for responsiveness to monetary policy actions

Using this type of test we check whether the reaction of the interbank interest rate to policy actions is different from the reaction of other interest rates. The test is based on the assumption of long-term relation (steady state) between alternative interest rates. In the short-run interest rates deviate from their long-run relation due to different shocks. If one of the interest rates contains unique information about monetary policy, its deviations from the steady state should be induced by innovations in monetary policy.

If two variables are integrated of order one, I(1), then the long-run relation between them can be addressed in a sense of cointegrating equation[3]. The results of Phillips-Perron test for unit root suggests that all three interest rates are I(1) series, thus we can look for cointegarting vector of the form [1; -µ] that satisfies:

$$IIR_t - \mu X_t = u_t^X \qquad X = DIR \quad or \quad LIR$$

where u_t^X is stationary series that represents the short-run dynamics.

The Johansen cointegration rank test reveals one cointegrating equation for both *X*. Namely, the cointegrating vector for IIR and DIR is [1; -1.751] and for IIR and LIR is [1; -0.0663]. The Phillips-Perron test for u_t^X rejects the hypothesis of unit root.

After u_t^X has been estimated one can check whether it is correlated with the monetary policy actions. In this chapter we use two variables that reflect monetary policy actions: (i) change in the discount rate, ΔDR, and (ii) change in the reserve requirements ratio, ΔRRR. Monthly data for changes in the discount rate is calculated as weekly average during a month with consequent differentiating. The reliable calculation of the required reserves ratio, RRR, requires more attention and is presented in Appendix A.

Results of the Phillips-Perron test for ΔDR and ΔRRR suggest that both series are stationary (see Table A4 in Appendix A), implying that inference procedures for OLS regression of u_t^X on policy innovations are valid. Thus, we can measure correlation between these variables and interest rate deviations from steady state in two ways: by conventional correlation coefficients and by significance of the slope in OLS regression. Correlation coefficients and P-value for the slope term are reported in Table 3.

Table 3. Correlation between policy innovation and u_t^X

		ΔDR	**ΔRRR**
u_t^{DIR}	Correlation	0.2179	0.3657
	P-value	0.0925	0.0056
u_t^{LIR}	Correlation	0.2541	0.4051
	P-value	0.0600	0.0027

Two conclusions can be drawn from the table. First, it is clearly seen that monetary policy actions and interest rate deviations from the long-run relation are positively correlated. Since variance of the interbank interest rate is the

[3] See for example Greene 2000, p.790

greatest among all interest rates[4], greater part of deviations from the steady state can be accounted for variations in IIR. This leads us to the first conclusion that interbank interest rate is more responsive to monetary policy innovations than other interest rates. Second, the slope coefficients on ΔRRR are significant at 1% level, while the slope coefficients on ΔDR only at 10%, meaning that deviations of interbank interest rate from the steady state are more closely correlated with changes in the reserve requirements ratio, than with changes in the discount rate. This may indicate that reserve requirements is more powerful instrument of monetary policy than the discount rate. Thus, the test provides some empirical support to the discussion of monetary policy instruments of the National Bank of Ukraine presented in the next chapter.

In summary, the results of the two tests suggest that interbank interest rate contains more information about monetary policy than other interest rates. The implication for this paper and for further research concerned with monetary policy in Ukraine is clear: the unique information content of the interbank interest rate should be exploited in econometric modeling.

[4] See Table A4 in Appendix A.

MONETARY POLICY TOOLS AND INTERBANK MARKET: UKRAINIAN CONTEXT

Interbank market

Interbank market provides the allocation of funds among banks. Hence, the interest rate that prevails in the interbank market serves as an indicator of availability of financial resources for banks. Although description of institutional settings, rules of trade and regulations of the Ukrainian interbank market is beyond the scope of this study, several facts from the history of its development would be useful.

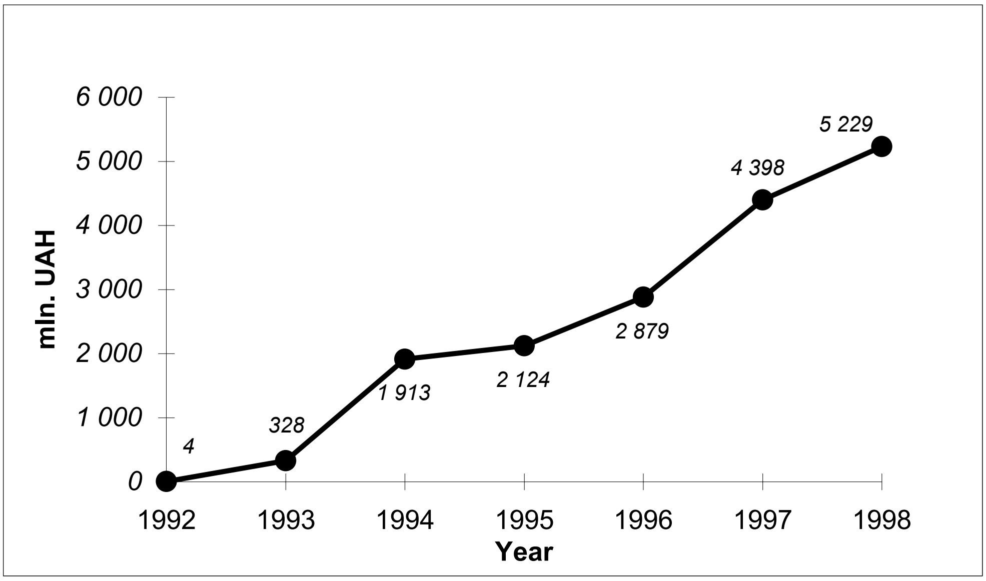

Figure 5. Volumes of trade in the Ukrainian interbank market in 1992-1998.
Data source: Herald of National Bank of Ukraine, #6,June 1999

Despite the significant increase in the volumes of interbank loans in 1992 - 1994 (see Figure 5), at the earliest stages of its development the ability of Ukrainian interbank market to allocate free funds efficiently was doubtful because of inefficient mechanism of funds redistribution adopted by the NBU (Gumen 1999). In 1995, the NBU changed the way of monetary policy implementation: the mechanism of centralized distribution of funds in the form of privileged loans was replaced by credit auctions based on market pricing. New methods of loans provision, such as "pawn-auctions"[5] and repurchase agreements, were also implemented during the next few years, namely in 1996 – 1997. These innovations led to relative stability in the interbank market, since the NBU became able to offset the excess demand for interbank loans by lending money through auctions. As a result, *only since 1997* it became possible to rely on the interbank interest rate as an indicator of availability funds for banking system and, consequently, as a barometer of monetary policy stance. For this reason, the starting point in the analysis of operation procedure of the NBU as well as the first point in the data set used for econometric modeling is January 1997.

Operation procedure of the National Bank of Ukraine

The activity of the National Bank of Ukraine is regulated by the Constitution of Ukraine and the Law of Ukraine "On the National Bank of Ukraine". According to the Law, the NBU is responsible for carrying out following functions: it determines and conducts monetary and credit policy, issues domestic currency, acts as a lender of last resort, determines the order and form of payments (including interbank payments), exercises banking regulation and supervision, and carries out other functions defined by the Law (clause 7). Clause 99 of the Constitution of Ukraine states that the long-run objective of the National Bank of Ukraine is to provide stability of national monetary unit, hryvnya.

While the role of the NBU in monetary policy design and conduct is clearly stated officially, it is much more obscure in practice. Kuznetsov (2002) describes comprehensively the "hierarchy" of legal entities involved in the

[5] There are two points in which "pawn-auctions" are different from conventional credit auctions: the funds (i) are lent on the security of government bonds and (ii) have to be used to support liquidity of the borrower.

monetary policy conduct in Ukraine. In contrast to developed countries where money growth is determined by the growth of production and savings, in Ukraine as well as in other transition economies monetary actions undertaken by local authorities are strongly dependent on the schedule of state debt repayment to international financial organizations, especially to the IMF. The activity of the NBU is restricted by its obligation to fulfill the efficiency criteria established by the IMF, the most important of which are requirements to net foreign reserves, net domestic assets and monetary base. In addition, despite the officially proclaimed political independence of the NBU from the government (clause 4 of the Law), the NBU must bring its policy in accordance with the indexes of socio-economic development, defined by the Ministry of Economy and on the Issues of European Integration, and take account of activity of the main borrower and accumulator of the state financial resources – the Ministry of Finance. Thus, balancing between external and internal constraints the NBU designs directions and goals of monetary policy in a form of the official document "The Main Monetary Policy Guidelines". This document determines tentative levels of objectives and intermediate targets, as well as describes major instruments that NBU plans to employ in order to achieve the projected levels of targets.

The most important forecasted macroeconomic variables are (Grebenyk 2000):

- Real GDP growth rate
- Government budget deficit
- Level of inflation

Taking into account this forecast, the NBU determines corresponding *intermediate targets* of monetary policy:

- Money supply, level and growth rate
- Monetary base, level and growth rate
- Amount of loans to real sector

To achieve intermediate targets National Bank uses administrative (direct) and non-administrative (market) instruments. The major *non-administrative instruments* of monetary policy of the NBU can be classified as follows (Stelmah et al. 2000):

- Required reserves
- Open-market operations
- Certificates of Deposit
- Discount rate policy

Since application of monetary policy instruments is the crucial part in the analysis of policy shock, the brief description of each instrument in Ukrainian context is provided below.

Reserve requirements

Reserve requirements policy is a powerful and administratively easily implemented instrument of monetary policy. Yet, frequent changes in reserve requirement policy as well as high reserve requirements ratio may appear very costly for banking sector and introduce distortions in interest rates formation (Eremenko 2001). For these reasons, and also due to availability of alternative instruments, central banks in developed countries use reserve requirements basically to support liquidity of commercial banks (Stelmah et al. 2000) and continue to show a tendency toward reduction of reserve requirements ratio to zero level (Eremenko 2001, Melnyk 2000). In contrast, central banks of transition economies lack effective instruments of monetary policy and use reserve requirements as a key tool of money market regulation. This is true for Ukrainian central bank too.

The National Bank of Ukraine uses required reserves to guarantee the stability of banking sector, to regulate money turnover and to combat inflation (Stelmah et al. 2000). In the end of 1996 the NBU took an important step toward establishing order and transparency in regulation of bank reserves - it adopted the Statute on accumulation of required reserves by the banking system of Ukraine. The Statute establishes a unified reserve requirements ratio and maintenance period for all types of deposits, describes the procedure of required reserves calculation, stipulates the possibility of government bonds and vault cash "covering", and institutes enforcement procedure and punitive sanctions[6]. Insufficient market reforms, lack of financial instruments, presence of structural and fiscal obstacles made reserve requirements the dominant instrument of monetary policy in Ukraine in 1997 – 1999. In the crisis periods of 1997, 1998, and 1999 the NBU actively used required reserves to slacken the pressure on foreign exchange market and to stabilize money market by increasing the reserve requirements ratio, shortening the maintenance period, and reducing or abolishing the amount of "covering" (Stelmah et al. 2000).

Open-market operations

In Ukraine the market for government bonds began to function in March 1995 when the Ministry of Finance issued government bonds (OVDP) to finance budget deficit. The NBU was responsible for distribution, storage and settlements servicing of OVDPs, so it acted as a chief agent between the Ministry of Finance and market participants. In addition, the NBU was eligible to buy OVDPs at its own expenses in primary or secondary market and sell them in secondary market (Stelmah et al. 2000).

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[6] To enhance the enforcement procedure and make other changes new versions of the Statute were designed in 1999 and 2001 (see Table A2 in Appendix A).

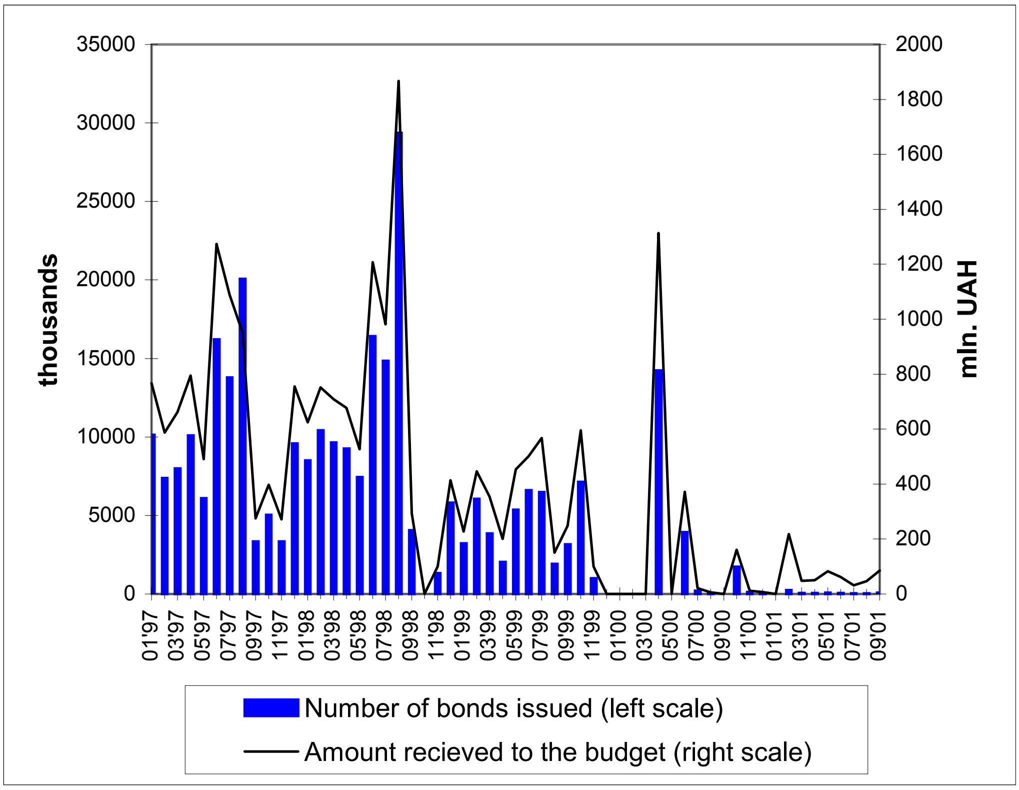

Figure 6. OVDP primary market in 1997 – 2001
Data source: Bulletin of the National Bank, various issues

Figure 6 depicts the dynamics of primary market for OVDPs. Till July 1997 domestic and foreign investors operated actively in the market since government bonds were highly profitable securities. This allowed Ukrainian government to increase number of bonds issued, thus, widening the market for government securities and raising sizeable amount of funds to the budget. Due to increased activity of traders and investors at that time, the NBU was able to conduct monetary policy through open-market operation successfully. However, the attitude of foreign investors toward financial markets of developing countries was negatively affected by consequences of the East Asian crisis at the end of 1997. As a result, large part of foreign portfolio investments was withdrawn from Ukrainian financial markets. Domestic investors (mainly commercial banks) followed this strategy and also reduced volumes of trade with government bonds. The NBU was deprived of possibility to implement open-market sales as effectively as before. In addition, it involuntary became the major participant in the OVDPs primary market (Stelmah et al. 2000). The situation became even worse in August 1998, when Ukrainian government defaulted on OVDPs and frozen all its payments on bonds till 2001-2004. With the collapse of secondary markets the NBU entirely lost the most effective instrument of monetary policy. Furthermore, in 1998 – 1999 it almost fully financed budget expenses by purchasing bonds in the primary market (i.e. directly from the Ministry of Finance), which inevitably led to the rapid money supply growth (Stelmah et al. 2000). In December 1999 the issue of government bonds was completely stopped. At the same time, according to the new version of the Law On the National Bank of Ukraine, the NBU became no longer eligible to buy government bonds in the primary market. Devoid of support of the central bank, Ukrainian government failed to restore confidence of commercial banks in government bonds. Thus, despite the promising start in April 2000, the revival of the government bonds market was far from success in 2000 - 2001.

Certificates of deposit

Inability to take advantage of open-market operations - the most efficient and quickly implemented monetary policy tool – compelled NBU officials to look for an alternative monetary policy instrument, that would substitute faithless government bonds. The search was crowned with success: in March 2000 the final version of the Statute On the Certificate of Deposits of the National Bank of Ukraine was adopted (Stelmah et al. 2000). The Certificate of Deposits (here and thereafter CD) is a debt security of the National Bank that can be traded, exchanged, and used as a collateral only by commercial banks (Grebenyk 1999). CDs are short-term securities (with the period to maturity no longer than 180 days), they are issued in electronic form and distributed among banks on special auction sessions. The frequency of sessions, quantity of CDs issued each session, face value and interest payments are determined by the NBU depending on the current development of the money market (Stelmah et al. 2000). Thus, the National Bank fully controls all aspects of CDs' circulation. The only thing beyond its control is the demand of commercial banks, which to great extent depends on the credibility of the issuer, the NBU. Despite this possible impediment, starting in January 2001 CDs became an actively used monetary policy tool (see Figure 7).

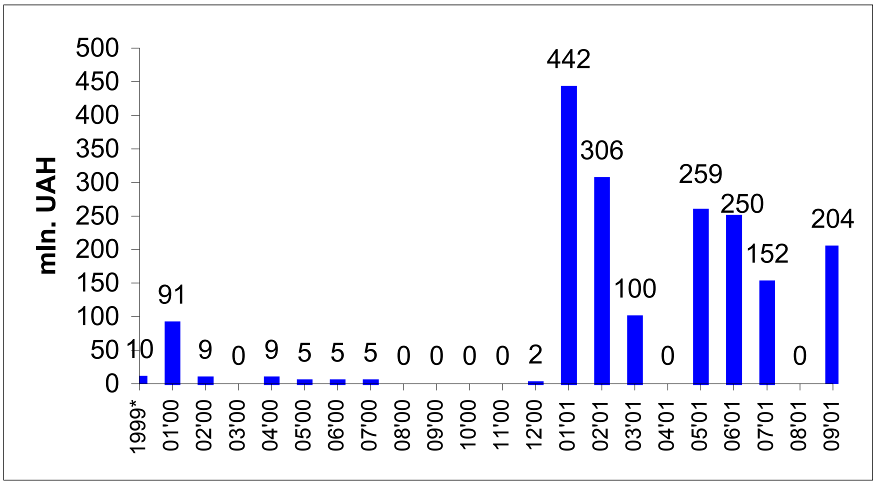

Figure 7. Certificates of Deposit issued by the NBU in 1999 – 2001
** during the whole year 1999*

Data source: Bulletin of the National Bank, various issues

Discount rate policy

Discount policy affects the money supply through the volume of discount loans supplied to the banking system. Change in the volume of discount loans affects monetary base and propagates further in money supply. Central bank regulates the volume of discount loans through the discount window or by setting the discount rate – interest rate that banks pay on funds borrowed from the central bank. When discount rate is low, compared to the market interest rate, commercial banks are ready to borrow from the central bank; therefore, the volume of discount loans increases. Analogously, when discount rate is high, the volume of discount loans decreases. Therefore, the simple logic predicts that, if the discount rate is an effective instrument of monetary policy, the volume of discount loans and the interest-rate spread (i.e. difference between the market interest rate and the discount rate) should be positively related. As Figure 8 shows, this does not hold true for Ukraine at least during 1997 - 2001.

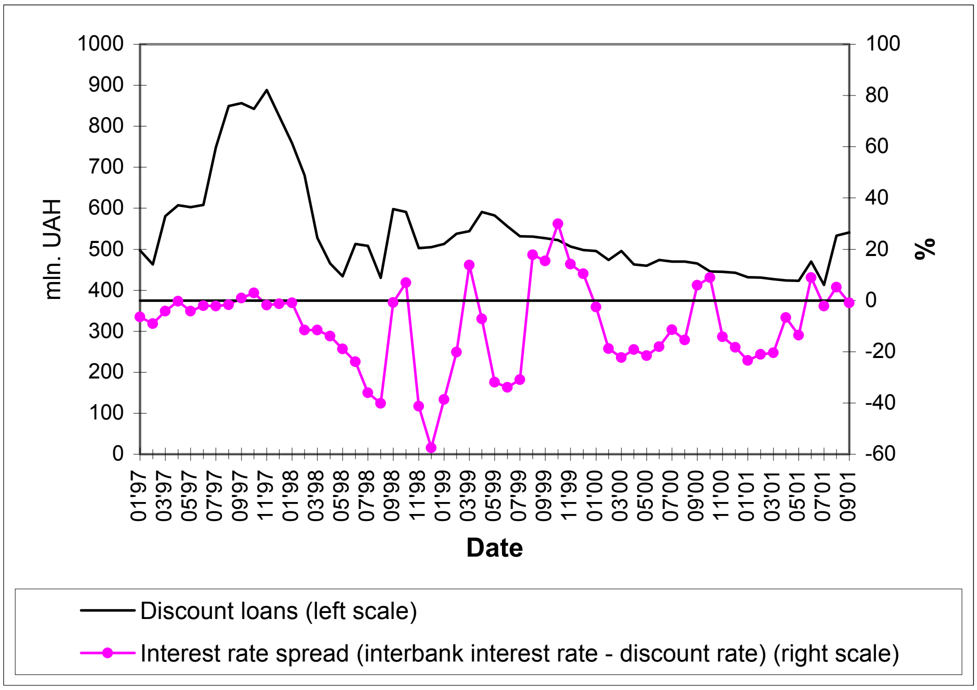

Figure 8. Interest rate spread and discount loans in 1997 – 2001
Data source: Bulletin of the National Bank, various issues; UEPLAC monthly update "Ukrainian Economic Trends", various issues

Several features of the discount rate policy can be inferred from Figure 8. First, most of the time during 1997 – 2001 the interest-rate spread was negative. Thus, with the interbank interest rate lower than the discount rate, it was less costly for commercial bank to borrow in the interbank market than from the NBU. Second, positive relationship between the interest rate spread and the amount of discount loans is observed in 1997 and to lesser extent in 1998. Since 1999 the volume of discount loans exhibits stable (slightly downward) trend despite the significant fluctuations in the interest-rate spread. These facts indicate that in 1999 - 2001 the discount rate was very weak and ineffective tool of monetary policy.

Several explanations are provided in economic literature. By interviewing Ukrainian commercial banks, Gurski (1999) finds out that banks are unwilling to borrow from the NBU due to complication and lack of transparency in the refinancing procedure. Banks complain that credit auctions, where discount loans are distributed, are held rarely and disorderly; furthermore, application process is usually prolonged and there is no guarantee that any reply will be received in time. There is no evidence that regulation concerning credit auctions changed much since 1999. If so, stable trend of volume of discount loans in 1999 – 2001 is readily explained. As to the earlier episode, Dzoblyuk (2000) points out that during the periods of rapid growth of market for government bonds banks were heavily engaged in speculative operations with OVDPs, so that relatively cheap discount loans might be easily reinvested in profitable government securities, rather than transmitted to the real sector. This observation explains why discount rate policy was hardly effective even in 1997 – 1998, when positive relationship between volumes of discount loans and interest-rate spread is detected. Under these circumstances, in 1997 - 2001 official discount rate functioned as an informative (or even declarative) index rather than the regulatory mechanism (Dzoblyuk 2000). Recall, that econometric test for the information content of the interbank interest rate in Chapter 5 also supports this conclusion implicitly.

Summary so far

Summarizing all above it can be concluded that during sub-periods of the period of investigation, January 1997 – September 2001, the leading place in money market regulations was attributed to different instruments: (i) reserve requirements, (ii) open market operations or (iii) certificates of deposit, whereas discount rate functioned mainly as an informative indicator. Two common features unite the first three instruments: first, they are under *direct* control and supervision of a *single* legal entity, the National Bank of Ukraine, an second, any action with this instruments is immediately reflected in the volume of total reserves held by commercial banks. These two features allows us two suggest that total reserves contain the major part of the exogenous policy shocks. Thus, taking total reserves as a policy variable is likely to be a plausible solution to money endogeneity problem described in the next chapter.

Chapter 7

MACROECONOMIC EVIDENCE

Econometric technique and identification assumption

Chapter 3 above has addressed various approaches that researchers used to investigate the liquidity effect. The variation is observed in two dimensions: econometric technique and procedure to isolate pure policy shock (identification assumption). This subsection provides brief summary and classification of the approaches employed by previous studies.

The most frequently used **econometric techniques** (apart from recent works using daily data) fall into three major groups.

a) Autodistributed lag (ADL) models. This type of model is the easiest one. It requires only two types of variables: interest rate and some measure of money (e.g. monetary aggregate). The first empirical work on liquidity effect was done in this fashion (Cagan and Gandolfi 1969). ADL model have two important limitations: (i) they are a-theoretical and (ii) do not allow one to control for other economic variables responsible for "non-liquidity" effects.

b) Vector autoregression (VAR) models avoid the latter limitation. Liquidity effect can be measured by means of impulse response function. The decline in interest rate in response to one standard deviation shock in monetary variable indicates that liquidity effect dominates other factors. When price level and income are included in the model, it is also possible to explore their reaction to policy shock. This approach was the most popular among economists despite its a-theoretical nature. The most widely cited studies include Gordon and Leeper (1992), Christiano and Eichenbaum (1992) and Strongin (1995).

c) Structural/semi-structural vector autoregression (SVAR) models. This approach combines advantages of structural equation models and simple VARs. In SVAR models the relationships between variables ground on theoretical concepts, while dynamic nature of a model allows one to monitor the response of interest rate to monetary policy shock by means of impulse response function. For this reason semi-structural model is used in this study. The well-known works on structural VAR include Leeper and Gordon (1994). Bernanke and Mihov (1995) develop semi-structural VAR model in order to measure monetary policy shock and apply it in further study to investigate the liquidity effect (Bernanke and Mihov 1998).

Empirical studies also differ in another dimension. There are debates among economists concerning the appropriate measure of monetary policy shock. The challenge economists confront in attempting to investigate monetary policy is that monetary actions reflect two types of shocks: policymakers' response to current development of the economy - endogenous component - and "pure" policy shocks - exogenous component (Christiano 1996). Thus, policymakers' actions can be expressed as a function (*feedback rule*) of a state of the economy. Policy actions result in changes of economic variables. The changes are induced partially by policymakers' actions and partially by previous situation in the economy. To evaluate the pure policy effect, one needs to identify only those changes that were not reactive to other variables - to separate exogenous and endogenous components of change in variables. The procedure of separating exogenous component is referred to as making an **identification assumption**. The analysis of monetary policy shock depends crucially on the plausibility of identification assumption.

Two general strategies for isolating monetary policy shock are exploited in empirical literature (Bernanke and Mihov 1998, Christiano, Eichenbaum and Evans 1998).

The first approach is nonparametric and grounded on policy makers' announcements about the future stance of monetary policy. The judgment is rather subjective and reveals only the date and direction of policy change, but does not provide information about quantitative characteristics. On the other hand, it does not require any modeling, making the measure of policy stance independent of model parameters.

The second approach involves econometric modeling. It requires making reliable assumptions in order to assess the feedback rule. The set of assumptions includes functional form of feedback rule, assumptions about variables that policy makers look at when deciding about the direction of future policy (information set), and assumptions about operating instruments that central bank uses in achieving its policy goals. In addition, one should assume the nature of interaction between policy shock and information set. The most widely used assumption is that policy shock is orthogonal to the information set (recursiveness assumption). More formally this strategy can be realized by estimating the following equation:

$$P = f(\Omega) + v^S$$

where P is an operating instrument (policy variable), Ω is a central bank information set, and v^S is an exogenous ("pure") policy shock.

While functional form and information set assumptions do not evoke disagreements among researchers, the choice of operating instrument, which would reflect all changes in policy stance, is quite controversial. Figure 9 shows why the money supply measured by M1 or a broader monetary aggregate cannot be used as a policy variable for investigating the liquidity effect. The key reason is that changes in M1 reflect both demand shocks and supply shocks. Let's assume that initially the money market is in equilibrium (M^*_1, i^*_1). Then a positive shock to money demand, induced, for instance, by changes in expectations, raises the demand for money from M^d_1 to M^d_2, and drives the interest rate up. Suppose also that policy-makers immediately observe these changes in demand for money, and for some reason they are unhappy with the high interest rate. The natural way to drive interest rate down to the initial position is to increase the money supply from M^s_1 to M^s_2 as in Figure 9.A. Since shifts in demand and supply take place almost simultaneously, we will observe increase in M1 over time and no change in interest rate, provided policy–makers were correct in their predictions of increase in money demand and calculations of necessary change of money supply. However, if increase in money demand was underestimated, we will see that monetary expansion drives the interest rate *up* as shown in Figure 9.B.

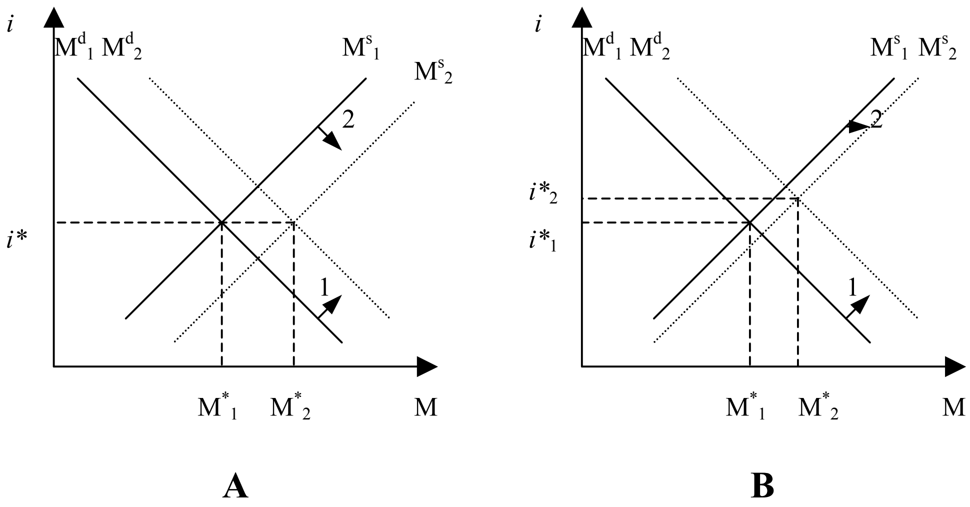

Figure 9. Interest rate reaction to endogenous monetary expansion.

Since economists agreed that broad monetary aggregates include a large endogenous component and both demand and supply shocks, several ideas about new policy variable have arisen. For example, Christiano and Eichenbaum (1992) argue that the quantity of nonborrowed reserves serves as the best indicator of the policy stance; Bernanke and Blinder (1992) suggest that the Fed (central bank of the United States) closely watches the fed funds rate and conclude that changes in the fed funds rate can be used as measure of policy shock; Strongin (1992) proposes using the proportion of nonborrowed reserve growth that is orthogonal to total reserve growth as policy measure. In any case, making a reliable identification assumption about policy instruments requires thorough knowledge of the central bank's operating procedure. From the analysis of the operation procedure of the National Bank of Ukraine sketched above it follows that quantity of total bank reserves is likely to reflect a lot of exogenous actions of the NBU. Therefore, innovations in total reserves may serve as measure of policy shocks.

Model

In this study we basically follow the general strategy of Bernanke and Blinder (1992), developed further by Bernanke and Mihov (1995), and applied by Bernanke and Mihov (1998) to investigate the liquidity effect. To be precise, we construct semi-structural four variable VAR model, that comprises two blocks: non-policy (macroeconomic) block and monetary policy block:

$$\mathbf{Y}_t = \sum_{i=0}^{p} \mathbf{B}_i \mathbf{Y}_{t-i} + \sum_{i=0}^{p} \mathbf{C}_i \mathbf{P}_{t-i} + \mathbf{A}^E \mathbf{v}_t^E \qquad (1)$$

$$\mathbf{P}_t = \sum_{i=0}^{p} \mathbf{D}_i \mathbf{Y}_{t-i} + \sum_{i=0}^{p} \mathbf{G}_i \mathbf{P}_{t-i} + \mathbf{A}^M \mathbf{v}_t^M \qquad (2)$$

Equations (1) and (2) describe an unrestricted linear dynamic macroeconomic model. Sticking to the notations of Beranake and Mihov, boldface letters are used to indicate vectors or matrices of variables or coefficients. In particular, **Y** is a vector of non-policy variables; **P** is a set (vector) of policy indicators. Thus, equation (2) may be interpreted as a policy block that defines relationships between primary indicators of monetary policy, whereas equation (1) is a non-policy block that describes a set of relationships in the rest of the economy. Vectors $\mathbf{v}^E$ and $\mathbf{v}^M$ are mutually uncorrelated "structural" error terms. Premultiplying them by matrices $\mathbf{A}^E$ and $\mathbf{A}^M$ respectively allows each shock to enter more than one equation in its block. Thus the assumption that elements of $\mathbf{v}^E$ or $\mathbf{v}^{\mathbf{M}}$ are uncorrelated is unrestrictive. It is also assumed that one component of $\mathbf{v}^M$, say v^s, represents pure policy shock. Note that each equation in the model contains *current* and lagged (up to lag *p*) values of all variables. Therefore, system (1)-(2) is not econometrically identified, i.e. it cannot be transformed into the standard VAR form with only lagged variables in the right-hand side, unless one imposes some specific structural restrictions. Bernake and Blinder (1992) show that in general case to transform the model into reduced form it is sufficient to assume that policy variables do not affect the rest of the economy within the given period, i.e. that $\mathbf{C}_0=\mathbf{0}$. Under this assumption equation (1) can be written as:

$$\mathbf{Y}_t = \sum_{i=0}^{p} \mathbf{B}_i \mathbf{Y}_{t-i} + \sum_{i=1}^{p} \mathbf{C}_i \mathbf{P}_{t-i} + \mathbf{A}^E \mathbf{v}_t^E =$$
$$= (\mathbf{I} - \mathbf{B}_0)^{-1} \sum_{i=1}^{p} \mathbf{B}_i \mathbf{Y}_{t-i} + (\mathbf{I} - \mathbf{B}_0)^{-1} \sum_{i=1}^{p} \mathbf{C}_i \mathbf{P}_{t-i} + (\mathbf{I} - \mathbf{B}_0)^{-1} \mathbf{A}^E \mathbf{v}_t^E \quad (3)$$

Using (3) to substitute $\mathbf{Y}_t$ in equation (2) allows one to write equation (2) in the reduced form:

$$\mathbf{P}_t = (\mathbf{I} - \mathbf{G}_0)^{-1} \sum_{i=1}^{p} \left[\mathbf{D}_i + \mathbf{D}_0 (\mathbf{I} - \mathbf{B}_0)^{-1} \mathbf{B}_i \right] \mathbf{Y}_{t-i} +$$
$$+ (\mathbf{I} - \mathbf{G}_0)^{-1} \sum_{i=1}^{p} \left[\mathbf{G}_i + \mathbf{D}_0 (\mathbf{I} - \mathbf{B}_0)^{-1} \mathbf{C}_i \right] \mathbf{P}_{t-i} + \quad (4)$$
$$+ \left[(\mathbf{I} - \mathbf{G}_0)^{-1} \mathbf{D}_0 (\mathbf{I} - \mathbf{B}_0)^{-1} \mathbf{A}^E \mathbf{v}^E + (\mathbf{I} - \mathbf{G}_0)^{-1} \mathbf{A}^M \mathbf{v}_t^M \right]$$

More compactly system (3)-(4) can be presented as:

$$\mathbf{Y}_t = \sum_{i=1}^{p} \mathbf{H}_i^E \mathbf{Y}_{t-i} + \sum_{i=1}^{p} \mathbf{H}_i^M \mathbf{P}_{t-i} + \mathbf{u}_t^E \quad (5)$$

$$\mathbf{P}_t = \sum_{i=1}^{p} \mathbf{J}_i^E \mathbf{Y}_{t-i} + \sum_{i=1}^{p} \mathbf{J}_i^M \mathbf{P}_{t-i} + [\mathbf{N}\mathbf{u}_t^E + \mathbf{u}_t^M] \quad (6)$$

where matrices of coefficients of system (5)-(6) correspond to matrices of coefficients of system (3)-(4) as follows:

$$\mathbf{H}_i^E = (\mathbf{I} - \mathbf{B}_0)^{-1} \mathbf{B}_i$$
$$\mathbf{H}_i^M = (\mathbf{I} - \mathbf{B}_0)^{-1} \mathbf{C}_i$$
$$\mathbf{J}_i^E = (\mathbf{I} - \mathbf{G}_0)^{-1} [\mathbf{D}_i + \mathbf{D}_0 (\mathbf{I} - \mathbf{B}_0)^{-1} \mathbf{B}_i]$$
$$\mathbf{J}_i^M = (\mathbf{I} - \mathbf{G}_0)^{-1} [\mathbf{G}_i + \mathbf{D}_0 (\mathbf{I} - \mathbf{B}_0)^{-1} \mathbf{C}_i]$$
$$\mathbf{N} = (\mathbf{I} - \mathbf{G}_0)^{-1} \mathbf{D}_0$$

The relationship between observable VAR residuals $\mathbf{u}^E$ and $\mathbf{u}^M$ and unobservable structural disturbances $\mathbf{v}^E$ and $\mathbf{v}^M$ is:

$$\mathbf{u}_t^E = (\mathbf{I} - \mathbf{B}_0)^{-1} \mathbf{A}^E \mathbf{v}^E = \tilde{\mathbf{H}} \mathbf{v}^E \quad (7)$$

$$\mathbf{u}_t^M = (\mathbf{I} - \mathbf{G}_0)^{-1} \mathbf{A}^M \mathbf{v}_t^M = \tilde{\mathbf{J}} \mathbf{v}_t^M \quad (8)$$

Note that since we assumed that $\mathbf{v}^E$ and $\mathbf{v}^M$ are mutually uncorrelated, $\mathbf{u}^E$ and $\mathbf{u}^M$ are also uncorrelated; therefore, $\mathbf{u}^M$ is a constituent of the residual of (6) that is orthogonal to the residual of (5), $\mathbf{u}^E$. Recall that one component of vector $\mathbf{v}^M$ is a pure policy shock v^s we are interested in. Therefore, provided matrix $\tilde{\mathbf{J}}$ of equation (8) is known, the dynamic response of all variables in the system to a policy shock can be measured by the impulse response function[7]. It is also useful for further exposition to rewrite equation (8) in a form:

$$\mathbf{u}_t^M = \mathbf{G}_0 \mathbf{u}_t^M + \mathbf{A}^M \mathbf{v}_t^M \quad (8')$$

Monetary policy and market for bank reserves

The market for bank reserves in the form of innovations, that is in a form of equation (8'), can be described by the following system of equations:

$$u_{TR}^d = -\alpha u_{IIR} + v^d \quad (9)$$

$$u_{TR}^s = \varphi v^d + v^s \quad (10)$$

Equation (9) determines the commercial banks' demand for reserves, expressed in innovation form. It states that innovation (i.e. component that is not explained by relationships with other variables in VAR model (5)-(6)) in demand for reserves depends negatively on the innovation in the interbank interest rate (opportunity cost of holding reserves) and on an exogenous demand disturbance v^d. Equation (10) describes the behavior of the central bank. It is assumed here that central bank observes and responds to the exogenous disturbance in demand for reserves. The strength of the response is given by coefficient φ. The assumption that the National Bank of Ukraine observes the demand for reserves is quite reasonable, since the NBU and its branches closely monitor banks on a daily basis. Whether the NBU responds to the shocks in demand for reserves is

[7] See Appendix B for technical details.

an open question that will be discussed below. The second item in the supply equation is a disturbance term v^s - the policy shock we are interested in.

To solve system (9)-(10) one should impose condition of supply and demand equilibrium in the market for reserves. Solving the system in terms of innovation gives following expression:

$$\begin{bmatrix} u_{IIR} \\ u_{TR} \end{bmatrix} = \begin{bmatrix} \frac{1-\varphi}{\alpha} & -\frac{1}{\alpha} \\ \varphi & 1 \end{bmatrix} \begin{bmatrix} v^d \\ v^s \end{bmatrix} \qquad (11)$$

Thus, we presented system (9)-(10) in a form of equation (8) that can be easily incorporated in the reduced form VAR model. We also can express policy shock v^s as a function of observable VAR residuals:

$$v^s = \alpha \left[-\varphi u_{IIR} + \frac{1-\varphi}{\alpha} u_{TR} \right] \qquad (12)$$

When the reduced form VAR model (5)-(6) is estimated by conventional methods, one can calculate variance-covariance matrix of residuals $\mathbf{u}^M$ and $\mathbf{u}^E$.[8] Since vector $\mathbf{u}^M$ consists of two components, three coefficients of variations for this vector are available. However, to calculate the impulse response function of the policy shock v^s four variables should be estimated: parameters α and φ of matrix $\mathbf{J}$ plus two variances of structural shocks, σ_d^2 and σ_s^2 ($cov(v^d,v^s)=0$ by assumption). Now it is apparent that system (11) is under-identified by one restriction. If additional restriction is imposed on some of the parameters, the system becomes exactly identified. It seems reasonable to make some assumptions of the NBU's willingness or ability to offset shocks in demand for total reserves and thus to restrict coefficient φ of the supply equation (10).

<u>Case1.</u> As an extreme case we assume that the NBU does not offset any disturbances in the demand for total reserves, this implies $\varphi=0$. In this situation demand shock does not affect the quantity of reserves, i.e. supply of reserves is perfectly inelastic with respect to interest rate as shown in Figure 10.A. This case resembles real situation when the National Bank of Ukraine was providing such

[8] The procedure of variance-covariance matrix calculation is described in Appendix B

policy some period of time after the Ukrainian government had defaulted on government bonds in August 1998. After default the NBU was deprived of possibility to implement open-market operations, certificates of deposits were not in use yet, and the amount of discount loans also didn't change much in spite of a sharp increase in demand for reserves. So, the NBU simply had no instrument to respond to the increased demand.

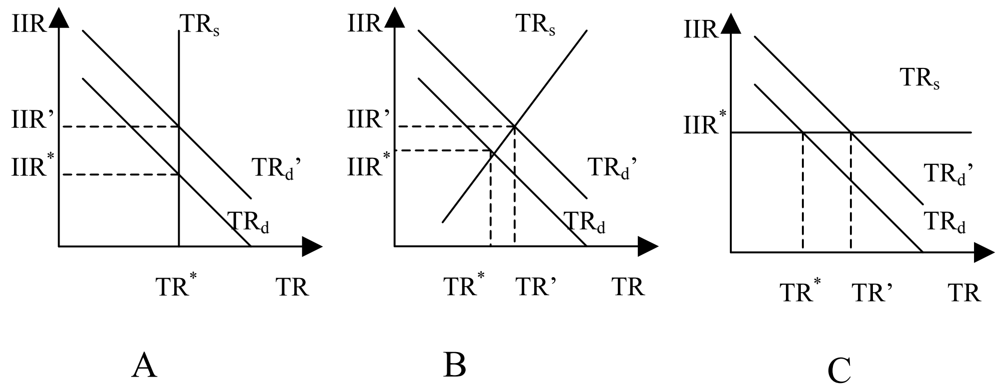

Figure 10. Supply and demand in the market for reserves.

Under this assumption matrix relating the VAR residuals to structural shocks takes a form:

$$\mathbf{J} = \begin{bmatrix} \frac{1}{\alpha} & -\frac{1}{\alpha} \\ 1 & 1 \end{bmatrix}$$

and the policy shock v^s is simply the residual u_{TR}.

<u>Case 2.</u> Here we assume that the NBU offsets some fraction, namely one half, of demand shock. In this case the supply curve is positively sloped (Figure 10.B) and structural demand disturbances change the equilibrium level of reserves. The assumption corresponds to real situation before the government bonds default or to the period of 2001 when certificates of deposit were actively used by the NBU. Under assumption $\varphi=1/2$ matrix relating the VAR residuals to structural shocks is:

$$\mathfrak{J} = \begin{bmatrix} \frac{1}{2\alpha} & -\frac{1}{\alpha} \\ \frac{1}{2} & 1 \end{bmatrix}$$

and the policy shock is

$$v^s = \alpha\left[-\frac{1}{2}u_{IIR} + \frac{1}{2\alpha}u_{TR}\right].$$

Case3. To make the picture complete we should assume that φ is equal to 1, i.e. the supply curve is perfectly elastic as shown in Figure 10.C. This is possible when central bank targets the interbank interest rate. Under this assumption matrix $\mathfrak{J}$ takes the form:

$$\mathfrak{J} = \begin{bmatrix} 0 & -\frac{1}{\alpha} \\ 1 & 1 \end{bmatrix}$$

Policy shock can be expressed as:

$$v^s = -\alpha u_{IIR}$$

Econometric specification and estimation

Standard form VAR model (5)-(6) has an alternative plausible interpretation. Components of vector **Y** can be regarded as variables of the central bank's information set or as a set of monetary policy targets. Thus, equation (5) describes relationships between monetary policy targets, while equation (6) describes behavior of policy variables as before. With this interpretation in mind we can proceed to the estimation procedure that consists of several steps.

First step is to estimate the reduced form VAR model (5)-(6). Four variables are used in the analysis. While they were already described in Chapter 4, here we provide brief explanation why exactly these variables are chosen.

Monetary policy block (equation (6))

In order to investigate liquidity effect at least two variables should be included in the structural block: interest rate and policy variable that reflects exogenous monetary policy shocks. The econometric analysis of Chapter 5 suggests that interbank interest rate contains unique information about monetary policy and helps to explain movements in other interest rates. From the discussion of the operation procedure of the National Bank of Ukraine it follows that monetary policy tools, used by the NBU, directly affect amount of total reserves of commercial banks; therefore, total reserves contain significant exogenous component of policy actions. Thus, the best candidates for this block are:

- interbank interest rate (I) and
- total reserves held by commercial banks (R).

Macroeconomic block / Information set (equation (5))

Recall from the description of the operation procedure of the National Bank of Ukraine provided in Chapter 6 that the set of forecasted macroeconomic variables includes: (i) real GDP growth rate, (ii) government budget deficit and (iii) level of inflation. Grounding on the forecast, the NBU determines intermediate targets of monetary policy: (a) money supply (level and growth), (b) monetary base, and (c) amount of loans to real sector. Ideally, macroeconomic block should include all these variables to grasp as much information about central bank's activity as possible. However, taking into account small sample size of data at my disposal (57 observations), we can't afford including more than two variables in this block. It seems reasonable to take one variable from the forecasted set and the other from the set of intermediate targets.

As was mentioned in Chapter 6, the officially established long-run goal of the National Bank of Ukraine is the national currency stability, with low level of inflation as an essential component of stabilization. Furthermore, theoretical model described in Chapter 2 predicts that the speed of inflation is responsible for existence or absence of the liquidity effect in the short-run. Therefore, among the forecasted indicators, inflation is the most important for study of the liquidity effect.

As to the intermediate targets, monetary base would be the best choice, since requirements to the monetary base is one of the IMF efficiency criteria that the National Bank is obliged to fulfill. However, monetary base is simply the sum of currency in circulation and total bank reserves and, therefore, is highly correlated with variable already included in the monetary policy block of the model. Hence, some measure of money supply would be an appropriate candidate for inclusion in the macroeconomic block. For this purpose we take monetary aggregate M1, which represents supply of "narrow" money, or money for transactions.

Thus, information set of the NBU is represented by:

- level of inflation (P) and
- money supply measured by monetary aggregate M1 (M).

The results of Phillips – Perron test for unit root, shown in Table A5 in Appendix A, suggest that all series are integrated of order one. To obtain correct estimators one should look for cointegrating equations and construct vector error correction (VEC) models[9]. VAR models are also characterized by the ambiguity in number of lags included. To avoid misspecification due to lag structure and, at the same time, to save for the degrees of freedom we include up to 3 lags in the model. Table 4 presents results of Johansen cointegration test – the number of cointegrating equations for each lag structure.

Table 4. Cointegration rank test

Number of lags in VEC model	1	2	3
Number of cointegrating equations revealed by the Johansen cointegration test	3	1	1

[9] In VEC model first differences of the variables are used; therefore, some transformation of coefficients is required. See Appendix B for technical details.

Next step in the estimation procedure is calculation of the impulse response function. The dynamic response of variables to VAR residuals is of little importance. The reaction to one standard deviation increase in *policy shock* is our prime interest in this research. Under additional restrictions imposed on parameter φ the variance-covariance matrix of policy disturbances can be calculated using the formula:

$$\begin{bmatrix} s_d^2 & 0 \\ 0 & s_S^2 \end{bmatrix} = \tilde{\mathbf{J}}^{-1}\Omega_M(\tilde{\mathbf{J}}^{-1})' \qquad (13)$$

where Ω_M is a variance-covariance matrix of policy block VAR residuals $\mathbf{u}^M$:[10]

$$\Omega_M = \begin{bmatrix} \sigma_I^2 & \sigma_{I,R} \\ \sigma_{I,R} & \sigma_R^2 \end{bmatrix}$$

Now impulse response function can be estimated by setting $v^s = s_S$ and all other structural shock equal to zero. In VAR models impulse responses are often supplemented by decomposition of forecast variance. In the present context, however, calculation of variance decomposition requires additional restrictions on components of matrix $\tilde{\mathbf{H}}$, for which economic explanation hardly exists. Therefore, we confine ourselves to the analysis of impulse responses for different values of parameter φ and for different lag structure that are provided in the next subsection.

[10] Because of structure of the model the calculation of $\mathbf{\Omega}^M$ is not straightforward and is described in detail in Appendix B.

Results

Estimation output of vector error correction models are presented in Appendix C. Table 5 reports the estimates of the slope coefficient of the demand for total reserves, α, and the standard deviation of structural disturbance v^S for different values of offset parameter, φ, and for different lag structure. Positive sign of estimated α indicates that the estimated demand curve is (correctly) downward sloping.

Table 5. Estimates of parameter α and standard deviation of v^S

	1 lag		2 lags		3 lags	
	α	s_S	α	s_S	α	s_S
φ=0	2 280.00	240.34	35 850.00	219.01	8 429.00	223.48
φ=1/2	243.42	178.79	217.31	155.33	258.82	160.43
φ=1	25.99	25.66	1.32	1.33	7.95	6.86

The impulse responses of the interbank interest rate (I) to one standard deviation policy shock grouped by different values of parameter φ are presented in Figure 11. Panel A shows the dynamic response under assumption that the NBU does not offset the demand shock in bank reserves (φ=0). While quantitative results are somewhat sensitive to the number of lags included in specification, qualitatively we observe that interest rate reduces immediately after policy shock, reaches minimum and then increases slightly. The conformity to the first scenario described in Chapter 2 is apparent.

Change in the responsiveness parameter does not affect the dynamic response substantially. As Panel B of Figure 11 shows, under assumption that the NBU offsets some part of the demand shock, φ=1/2, the pattern of the interbank interest rate response is extremely robust to the number of lags used in specification. Again the behavior of the interbank interest rate is similar to Scenario 1: it sharply decreases immediately after positive policy shock, reaches minimum point 2 months later, and eventually rises to the long-run (negative) level.

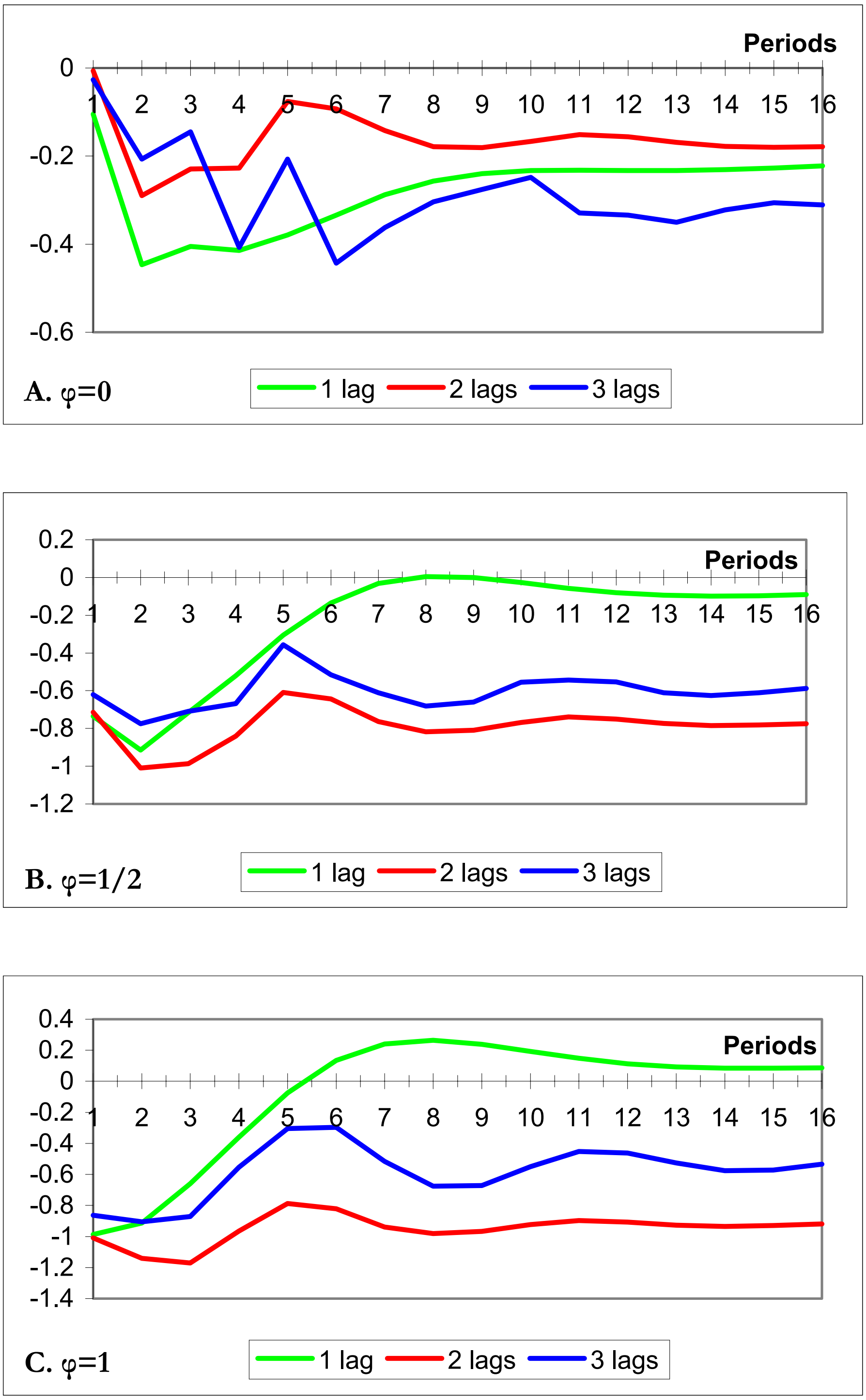

Figure 11. Impulse responses of interbank interest rate (I) to one standard deviation policy shock grouped by variations in responsiveness parameter φ

Panel C of Figure 11 depicts dynamic reaction of interbank interest rate when φ=1, i.e. under assumption of interest rate targeting. While with only 1 lag included, we observe a picture similar to scenario 2: interest rate eventually rises to the level higher than the initial position, specifications with 2 and 3 lags give results similar to scenario 1. Again the minimum level is reached 2 or 3 month after the policy shock.

Figure 12 shows the same impulse responses but grouped by the lag structure. Such exposition allows us to compare shapes of impulse responses obtained for the same specification but for different values of the responsiveness parameter, φ. It can be inferred from Figure 12 that, in general, the reaction of interbank interest rate under assumption φ=0 is rather smoothed: the trough is shallow and stable steady state is reached rapidly. Economic interpretation is straightforward: φ=0 means that the National Bank is not willing (or not able) to respond to demand shocks; therefore, fluctuations in interest rate are mainly induced by shocks in demand and little is explained by pure policy shock. In contrast, under assumption that φ=1/2 or φ=1, interest rate response is characterized by deeper immediate decline and larger amplitude of consequent fluctuations. In other words, policy actions have much stronger effect when central bank reacts to shifts in demand.

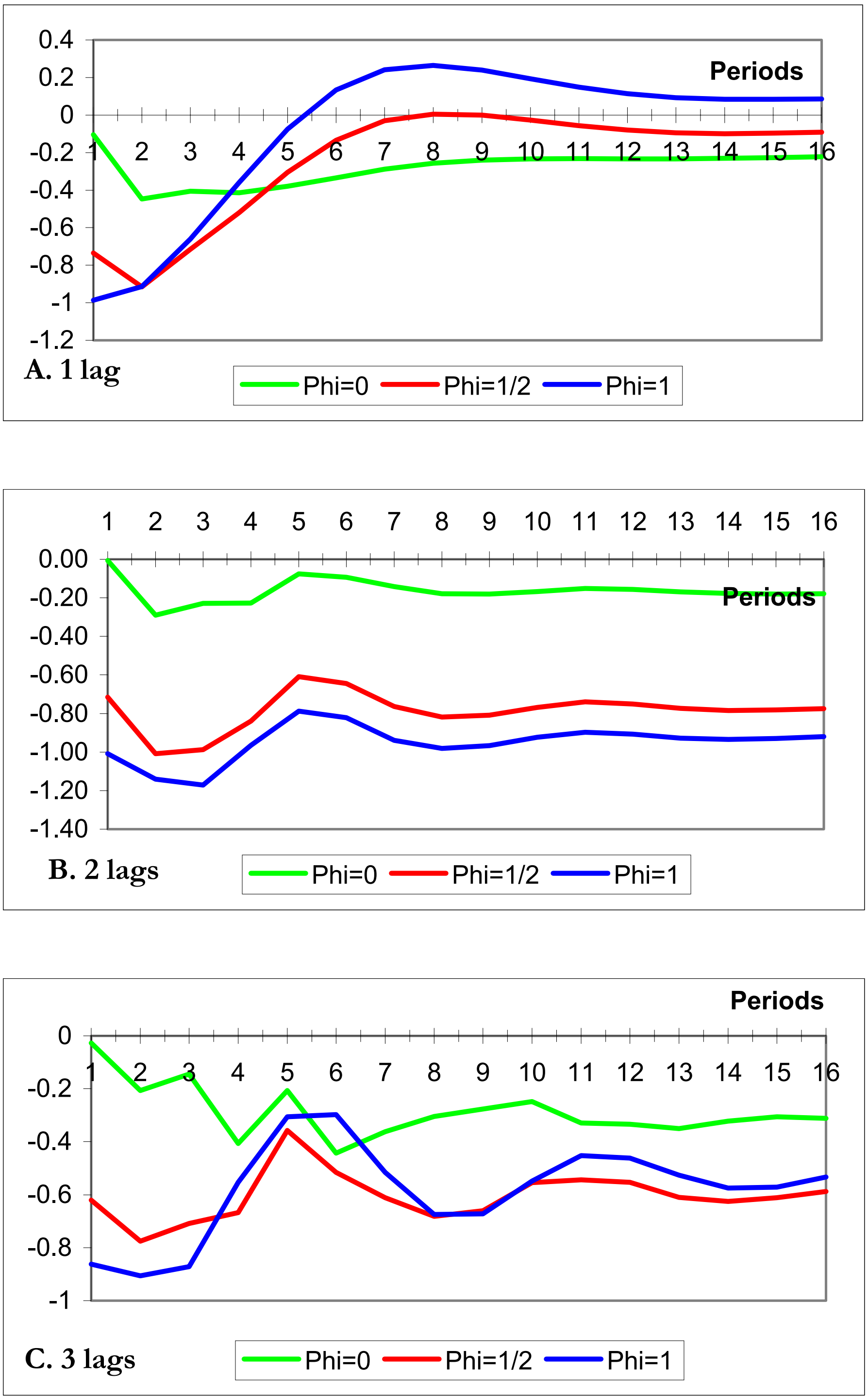

Figure 12. Impulse responses of interbank interest rate (I) to one standard deviation policy shock grouped by lag structure.

Robustness of the model and possible drawbacks

The robustness of the results to the number of lags included in the specification was already verified. In order to check whether change in some variables would affect the results, we estimated several different versions. To make comparison easier, we will refer to the specification described in the previous section as the benchmark case.

First, specification with both M1 and total reserves *logged* was estimated in the same manner as the benchmark model. In the log-linear case main findings are not affected. Namely, estimates of parameter α are positive (ensuring that the demand for reserves is downward-sloping) and behavior of the interbank interest rate resembles scenario 1 with minimum value reached 2 months after the policy shock. Further, we tried to use *growth rates* of M1 and total reserves instead of levels. This exercise was not so successful as the previous one: occasionally negative values of α were obtained. This should not be very surprising taking into account that structural model of the market for reserves (9)–(10) loses its convenient economic interpretation when model is estimated in growth rates. Nevertheless, the impulse responses are again shaped according to the scenario 1.

Second, one may reasonably object that since monetary aggregate M1 contains only quickly adjustable checkable deposits, the process of multiple (checkable) deposit creation is quite fast and changes in total bank reserves may induce changes in M1 even within a month. So, assumption that policy indicators do not affect information set in the current period does not hold. To respond to the objections of this type, M1 was substituted by broader monetary aggregate M2, which includes more sluggish time deposits, and new specification was estimated in levels and in logs as before. The estimates of α and impulse responses are very similar to those obtained from the benchmark specification and, hence, consistent with the hypothesis of liquidity effect.

Finally, seasonally adjusted real GDP was introduced in the model instead of M1. But here results appear to be inconclusive to some extent: we again obtain negative estimates of α, although impulse responses resemble mainly scenario 1. It is worthwhile to note that there is no official statistics of real GDP on monthly basis, since only quarterly figures of GDP deflator are reported by the State Statistics Committee. In this study widespread proxy of monthly real GDP was used: real figures were calculated as nominal values divided by CPI. Therefore, implausible estimates of parameters may be caused by shortcomings of data set.

While rather strong empirical evidence of the liquidity effect is presented here, our promising findings may be undermined by several drawbacks of the model. Among them could be:

- Assumption that variables from the information set affect policy indicators within the current period. In other words, we implicitly assume that policymakers of the National Bank observe current developments of the economy and immediately respond to them. This assumption may be subject to some critique, since not all information becomes available to policymakers quickly enough and their response may be delayed due to, for example, bureaucratic impediments.
- In some specifications residuals of the interest rate equation are not normal. Non-normality is likely to be caused by abnormally high values of the interbank interest rate in crisis periods.
- Total bank reserves may not be the best possible measure of monetary policy shock. While choice of proper policy variable has been grounded on the analysis of operation procedure of the National Bank of Ukraine, it is still subject to some subjective judgment. Alternative measure may give more robust results.
- The model does not allow us to examine which "non-liquidity" factors are responsible for increase in interest rate after the liquidity effect has slackened. This question leaves space for additional detailed examination.

Notwithstanding listed limitations, we can conclude that our data and chosen econometric technique have succeeded in proving hypothesis of the liquidity effect in the Ukrainian interbank market.

Chapter 8

SUMMARY AND CONCLUSIONS

This study has been devoted to the investigation of money-interest rate relationship in Ukraine. In particular, it has questioned the plausibility of negative interest rate reaction to exogenous monetary expansion - the concept known as the liquidity effect – in the Ukrainian context. From the simple theoretical model of money market, described in the first place, it appears that the interest rate response to the expansionary monetary shock may follow three typical scenarios depending on the current situation in the economy. Identifying which of the theoretical scenarios holds in practice has important implications for policymakers, since monetary policy actions may lead to unexpected consequences. Hence, the dynamic response of interest rate to monetary policy shock requires solid and careful exploration.

Before turning to formal econometric investigation of the liquidity effect, the question of interest rate choice should be addressed. Two formal tests are employed in this research to reveal the information content of the alternative interest rates in Ukraine. The lag robust Granger causality test shows that the interbank interest rate Granger causes interest rate on loans to private sector, but "causality" between the interbank interest rate and interest rate on deposits is not clear. Another test for responsiveness to change in the discount rate and reserve requirements ratio shows that the interbank interest rate is more reactive to monetary policy action compared to the interest rate on loans and on deposits. Results of two tests suggest that interbank interest rate contains unique information about monetary policy stance and, therefore, is the best choice for econometric research in the realm of monetary policy.

Another key problem that researchers face when investigating monetary policy is the money endogeneity problem and related question of proper measure of monetary policy shock. Since economists agree that monetary aggregates cannot serve as a measure of policy shock due to large endogenous component, some another policy variable, one that would reflect mainly exogenous monetary policy action, should be found. From the discussion of the operation procedure of the National Bank of Ukraine it follows that amount of total reserves held by commercial banks is a good candidate for such variable in Ukraine. Detailed analysis of total reserves time series revealed considerable inconsistency in data, emanating from the peculiarities of Ukrainian legislation. The measurement error was corrected and, thus, correct estimation of model parameters was ensured.

The macroeconomic evidence of the liquidity effect presented in this study is based on a semi-structural four variable VAR model, that consists of a macroeconomic block, representing the information set of the National Bank, and structural monetary policy block, describing the relationship between two monetary policy indicators – interbank interest rate and total bank reserves. Two assumptions are made to assure identification of the model. First, policy indicators do not affect the rest of the economy in the current period. Second, when supplying reserves to commercial banks the National Bank of Ukraine offsets structural shocks in the demand for reserves to some certain extent. By varying the value of the parameter, which determines the fraction of demand shock offset by the National Bank, three typical cases of total reserves supply schedule are modeled. To test the robustness of results to the lag structure of VAR model, different specifications with 1 to 3 lags were estimated.

In all cases the impulse response of the interbank interest rate to a one standard deviation policy shock was strongly negative. Qualitatively the result is robust to the lag structure used in VAR model as well as to the variations in the responsiveness parameter, while quantitatively some sensitivity is observed. Nevertheless, in the majority of cases interbank interest rate exhibits typical behavior: it decreases immediately after the policy shock, reaches a trough approximately 2 month later, then increases slightly, and, finally, settles down to a new steady state, which is lower than the initial position. Therefore, the main finding of this research is that the behavior of the interbank interest rate is consistent with the hypothesis of dominance of the liquidity effect over other "non-liquidity factors" that affect interest rate after innovation in monetary policy. Albeit, the question of very factor responsible for interest rate increase requires additional examination.

By providing empirical support to the first link in a chain of monetary transmission, this study signals that money expansion is likely to propagate into real economy through the channels that include interest rate reaction as an important part. Wide horizon for further research in the realm monetary transmission in Ukraine is opened. Especially important would be to explore the next link: behavior of those interest rates that are essential for real sector agents. This would allow policymakers of the National Bank to assess the effect of monetary policy actions not only on performance of interbank market, but also on the real sector.

BIBLIOGRAPHY

Bernanke, Ben S., and Alan S. Blinder. 1992. The federal funds rate and the channels of monetary transmission. *The American Economic Review,* Vol. 82, Issue 4 (September):901-921

Bernanke, Ben S., and Ilian Mihov. 1995. Measuring monetary policy. *NBER Working Paper 5145* (June)

_______, and ______. 1998. The Liquidity effect and long-run neutrality. *NBER Working Paper 6608* (June)

Bolgarin, I., Mahadeva L., and G. Sterne. 2000. Some methodological aspects of building and exploiting model of monetary transmission mechanism in Ukraine. *Visnyk NBU #11* (November): 4-6 (Деякі методологічні аспекти побудови та використання моделі механізму монетарної трансмісії в Україні, *Вісник НБУ*, №11, 2000)

Cagan, P., and A. Gandolfi. 1969. The lag in monetary policy as implied by the time pattern of monetary effects on interest rates. *The American Economic Review* (May):27-84

Christiano, Lawrence J. 1996. Identification and the liquidity effect: A case study. Federal Reserve Bank of Chicago. *Economic Perspectives*(May):2-13

_________, and Martin Eichenbaum. 1992. Identification and the liquidity effect of a monetary policy shock. In *Business Cycles, Growth and Political Economy*, edited by L. Hercowitz and L. Leiderman, Cambridge (MA):MIT Press. Quoted in Lawrence J. Christiano. Identification and the liquidity effect: A case study. Federal Reserve Bank of Chicago *Economic Perspectives* (May 1996):2-13

_________, _________, and Charles L. Evans. 1998. Monetray policy shock: What have we learned and to want end? . *NBER Working Paper 6400* (February)

Cochrane J. H. 1989. The return of the liquidity effect: A study of the short-run relation between money growth and interest rates. *Journal of Business and Economic Statistics 7* (January):75-83

Dzoblyuk, O. 2000. Peculiarities of implementation of discount rate policy as an instrument of regulation of monetary relationships. *Banking #3*: 39-42 (Особливості застосування політики облікової ставки як інструмента управління грошово-кредитними відносинами, *Банківська справа,* №3, 2000)

Eremenko, I. 2001 Reserve requirements and implicit taxation of commercial banks in Ukraine. In *Fostering Sustainable Economic Growth in Ukraine*, edited by Cramon-Taubadel, Stephan von and Iryna Akimova, Heidelberg - Berlin – New-York: Physica-Verlag.

Fung, Ben, and Rohit Gupa. 1994. Searching the liquidity effect in Canada. *Bank of Canada Working Paper* #94-12

Garfinkel, Michelle R., and Daniel L. Thornton. 1995. The information content of the federal funds rate: Is it unique? *Journal of Money, Credit and Banking*, Vol.7, Issue 3 (August):838-847

Gordon, David B., and Eric M. Leeper. 1992. In search of the liquidity effect. *Journal of Monetary Economics 29*: 341-370.

________, and _________. 1994. The dynamic impact of monetary policy: Exercise of tentative identification. *The Journal of Political Economy*, Vol.102, Issue 6 (December) : 1228-1247.

Grebenyk N. 1999. The Certificate of Deposit of the National Bank of Ukraine. *Visnyk NBU*, #12 (December):7 (Депозитний сертифікат Національного банку України, *Вісник НБУ*, №12, 1999)

Grebenyk N. 2000. Main target is the stability of national currency. *Visnyk NBU*, #6 (June):2-3 (Головна мета – стабільність національної валюти, *Вісник НБУ*, №6, 2000)

Greene, William H. 2000. *Econometric analysis*. 4th ed. Upper Saddle River, New Jersey: Prentice-Hall, Inc.

Gumen,I. 1999. The formation of Ukrainian market for interbank loans. *Visnyk NBU*, #6 (June):58-61 (Становлення ринку міжбанківських кредитів в Україні, *Вісник НБУ*, №6, 1999)

Gurski, Urban. 1999. Ukrainian interbank market. Preliminary results of research. (Украинский межбанковский рынок. Предварительные результаты исследований). *Studies and Analyses* #148 (January)

Hamilton, James D. 1997. Measuring the liquidity effect. *The American Economic Review*, Vol.87, Issue 1 (March):80-97

Hayashi, Fumio. 2000. Is there a liquidity effect in the Japanese interbank market? *Harvard Institute of Economic Research Discussion Paper* #1898 (May)

Johnston, Jack, and John DiNardo. 1997. *Econometric Methods*. 4th ed. New-York: The MCGraw-Hill Companies, Inc.

Kryshko, Maxim. 2001. Bank lending channels and monetary transmission mechanism in Ukraine. *EERC MA Thesis Paper*, NaUKMA

Kuznetsov, A. 2002. Strategic choice of NBU. *Newsletter of the Center for Monetary Policy within the NBU Council*, Vol.1: 3-10

Melnyk, O. M. 2000. Legislative fundamentals and the most important parameters of monetary policy. *Finance of Ukraine*, *#7*: 34-44 (Законодавчі основи та найважливіші параметри грошово-кредитної політики, *Фінанси України,* №7, 2000)

Melvin, Michael. 1983. The vanishing liquidity effect of money on interest: Analysis and implications for policy. *Economic Inquiry*, Vol. XXI (April): 188-202

Mishkin, Frederic S. 1995. Symposium on the monetary transmission mechanism. *The Journal of Economic Perspectives,* Vol. 9, Issue 4 (Autumn):3-10

Mishkin, Frederic S. 2001. *The Economics of Money, Banking and Financial Markets.* 6th ed. Boston, San Francisco, New-York: Addison-Wesley

Pagan, Adrian R., and John C. Robertson. 1995. Resolving the liquidity effect. *Federal Reserve Bank of St. Louis Review* 77 (May-June):33-54

Shevchuk V. 2001. The effect of monetary policy on industrial production, inflation and real exchange rate in Ukraine during 1994-2000. *Visnyk NBU*, #1 (January):12-15 (Вплив монетарної політики на промислове виробництво, інфляцію та реальний обмінний курс в Україні у 1994-2000 роках, *Вісник НБУ*, №1, 2001)

Stelmah et al. 2000. *Monetary and credit policy in Ukraine.* (Грошово-кредитна політика в Україні), ed. Mischenko. Kyiv: Znannya

Strongin, Steven. 1995. The identification of monetary policy disturbances: Explaining the liquidity puzzle. *Journal of Monetary Economics 35* (August):463-97

Thornton, Daniel L. 2001. Identifying the liquidity effect at the daily frequency. *Federal Reserve Bank of St. Louis Review* (July-August):59-78

APPENDIX A. DESCRIPTIVE STATISTICS AND CALCULATIONS

Table A1. Auxiliary variables used for corrections and other calculations

Variable	Description	Units of measurement	Source
Dep_i	Amount of deposits of type *i*	mln. UAH	NBU, www.bank.gov.ua
CPI	Consumer price index 97'01=100	--	UEPLAC monthly update "Ukrainian Economic Trends", own calculations
RRRrep	Reserve requirements ratio reported	%	Legislative acts, www.rada.gov.ua
TRrep	Amount of total reserves held by commercial banks (correspondent account +vault cash) reported	mln. UAH	UEPLAC monthly update "Ukrainian Economic Trends", "Bulletin of the National Bank"
RR	Required reserves	mln. UAH	Own calculations, see below

Table A2. Main legislative acts that regulated required reserves in 1997 – 2001

Document name and number	Date of adoption	Date of implementation
Statute of NBU №333 on accumulation of required reserves by the banking system of Ukraine	26.12.1996	01.04.1997
Enactment of NBU №332 on ratification of Statute on rules of obligatory reservation of funds by the banking system of Ukraine	09.07.1999	01.09.1999
Enactment of NBU №244 on ratification of Statute on the procedure of required reserves formation for banks of Ukraine	27.06.2001	21.07.2001

Source: www.rada.gov.ua

Table A3. Legislative acts concerning bank reserves in 1997 – 2001

Document name and number	Date of adoption	Date of implementation	Type of Deposits	Reserve requirements ratio, %	Req res held in vault cash, % of total reserves	Government bonds "covering", % of deposits of households
Statute of NBU №333 on accumulation of required reserves by the banking system of Ukraine	26.12.1996	01.04.1997	All	11	30	
Enactment of NBU №76 on changes and addenda to Statute №333	31.03.1997	01.04.1997				voluntary <=11%
Enactment of NBU №211 on changes and addenda to Statute №333	04.07.1997	04.07.1997				mandatory =11%
Letter of NBU №14-110/3408-8333	14.11.1997	15.11.1997			20	
Enactment of NBU №385 on situation on monetary and credit market	20.11.1997	01.12.1997	All	15		mandatory =15 %
Enactment of NBU №333 on changes and addenda to Statute №333	31.08.1998	01.09.1998	All	16.5		mandatory =16.5 %
Letter of NBU № 14-011/2906-6292	06.09.1998	07.09.1998			abolished	
Letter of NBU № 14-011/4193-9804	30.12.1998	01.01.1999	All	15	20	
Enactment №513 on some issues of monetary and credit market regulations	04.12.1998	01.01.1999				abolished
Letter of NBU № 14-011/155-559	21.01.1999	01.02.1999			abolished	
Letter of NBU №14-011/319-1188	10.02.1999	20.02.1999	All	17		
Letter of NBU № 14-011/208-547	27.01.2000	01.02.2000	All	16		
Letter of NBU № 14-011/936-2256	10.04.2000	11.04.2000	All	15		
Letter of NBU № 14-011/3759	29.12.2000	15.01.2001	ST, leg ent, UAH	14		
			ST, leg ent, fcur	14		
			ST, housh, UAH	12		
			ST, housh, fcur	13		
			LT, leg ent, UAH	13		
			LT, leg ent, fcur	13		
			LT, housh, UAH	11		
			LT, housh, fcur	13		
Letter of NBU № 14-012/1399-2131	05.04.2001	15.04.2001	ST, leg ent, UAH	14		
			ST, leg ent, fcur	14		
			ST, housh, UAH	12		
			ST, housh, fcur	13		
			LT, leg ent, UAH	*11*		
			LT, leg ent, fcur	13		
			LT, housh, UAH	*9*		
			LT, housh, fcur	13		
Letter of NBU № 14-011/4948-7383	05.12.2001	11.12.2001	ST, leg ent, UAH	12		
			ST, leg ent, fcur	12		
			ST, housh, UAH	10		
			ST, housh, fcur	12		
			LT, leg ent, UAH	8		
			LT, leg ent, fcur	10		
			LT, housh, UAH	6		
			LT, housh, fcur	10		

Note: LT = long term, ST= short term, leg ent = legal entity, housh = household, fcur = foreign currency
Example: *ST, leg ent, fcur* means short-term, foreign currency deposits of legal entities
All documents are available at www.rada.gov.ua

Table A4. Descriptive statistic of variables used in tests of information content of the interbank interest rate

	IIR	DIR	LIR	ΔDR	ΔRRR
Mean	28.16368	17.06526	47.26789	-0.429825	0.119643
Median	21.4	18	47.4	0	0
Maximum	88.92	28.02	71.5	23.25	3.6
Minimum	4.2	8.02	30.6	-16.5	-1.8
Std. Dev.	20.32883	5.106572	10.42032	5.325301	0.890438
Skewness	1.267447	0.010191	0.312762	1.356577	2.328186
Kurtosis	3.903898	2.154505	2.30705	9.807041	9.501933
Jarque-Bera	17.20147	1.698784	2.069714	127.5304	149.2329
Probability	0.000184	0.427675	0.355277	0	0
Observations	57	57	57	57	56
Phillips-Perron test statistic for levels	-2.59137 (-3.5478)*	-2.06339 (-3.5478)	-1.213041 (-3.5478)	-4.654934 (-3.5478)	-7.272260 (-3.5523)
Phillips-Perron test statistic for 1st differences	-33.17807 (-3.5478)	-9.583116 (-3.5478)	-6.21681 (-3.5478)	--	--

** 1% MacKinnon critical values for rejection of hypothesis of a unit root are in parentheses*

Table A5. Descriptive statistic of variables used in semi-structural VAR model

	M	P	I	R
Mean	13235.72	1.282456	2.382368	2537.105
Median	11434	1	1.891667	2301
Maximum	25884	6.2	7.41	5209
Minimum	6433	-1.7	0.3	942
Std. Dev.	5402.964	1.478673	1.676651	1426.687
Skewness	0.757984	0.864594	1.262912	0.481816
Kurtosis	2.353237	4.06629	3.942204	1.775454
Jarque-Bera	6.451598	9.801772	17.2604	5.766735
Probability	0.039724	0.00744	0.000179	0.055946
Observations	57	57	57	57
Phillips-Perron test statistic for levels	5.796151 (-3.5478)*	-3.921985** (-3.5478)	-2.565851 (-3.5501)	-0.116551 (-3.5501)
Phillips-Perron test statistic for 1st differences	-7.864119 (-3.5478)	-12.88998 (-3.5478)	-46.14091 (-3.5523)	-9.265309 (-3.5523)

** 1% MacKinnon critical values for rejection of hypothesis of a unit root are in parentheses*

*** While Phillips-Perron test rejects the hypothesis of a unit root for inflation, ADF test statistics is very sensitive to the number of lags included. Taking into account small sample size, we are inclined to suspect that inflation is a non-stationary series.*

Calculation of required reserves (RR)

As can be seen from Table A3, prior to January 2001 required reserves are product of reserve requirements ratio and the total amount of deposits of all types held by banking system. In January 2001 the required reserves ratio became differentiated. Therefore, for the period January 2001 to September 2001 required reserves are calculated according to the formula

$$RR = \sum_i RRRdep_i * Dep_i \qquad \text{(A1)}$$

where $RRRdep_i$ is reserve requirements ratio for deposits of type *i*, Dep_i is amount of deposits of type *i* held by commercial banks.

Calculation of required reserves ratio (RRR)

Under assumptions made in Chapter 4 the calculation of RRR for the period of OVDP "covering" (April 1997 – January 1999) can be performed using the formula:

$$RRR_t = (\text{Official } RRR_t * Dep_t - \text{ max OVDP "covering"}_t)/Dep_t \qquad \text{(A2)}$$

As can be seen from Table A3, the National Bank of Ukraine established diversified reserve requirements ratio for different types of deposits in January 2001. Therefore, for the period from January to September 2001 RRR is calculated as an average weighted on the amount of deposits of a given type. For the rest of the sample RRR equals the officially established rate.

APPENDIX B. TECHNICAL DETAILS OF THE ESTIMATION PROCEDURE

This appendix provides technical details of the part of estimation needed to calculate the impulse response function for a semi-structural model described in Chapter 7. The starting point is a set of coefficients of the vector error correction (VEC) model and variance-covariance matrix of VEC residuals. Step-by-step transformation of coefficients necessary to calculate the impulse response to exogenous policy shock is shown below. All transformation can be easily performed in MathCad software or any other mathematical software package.

Transformation of VEC model coefficients to coefficients of a standard reduced form VAR representation

Consider an estimation output of (*p-1*)-lagged vector error correction model with *m* linearly independent cointegrating equations:

$$
\begin{aligned}
\Delta \mathbf{y}_t &= \begin{pmatrix} k_{11} \\ \vdots \\ k_{1n} \end{pmatrix} (coin\_eq\_1) + \cdots + \begin{pmatrix} k_{11} \\ \vdots \\ k_{1n} \end{pmatrix} (coin\_eq\_m) + \mathbf{Q}_1 \Delta \mathbf{y}_{t-1} + \cdots + \mathbf{Q}_{\text{p-1}} \Delta \mathbf{y}_{t-(p-1)} = \\
&= \begin{pmatrix} k_{11} \\ \vdots \\ k_{1n} \end{pmatrix} \left(w_{11} y_{1,t-1} + \cdots w_{n1} y_{n,t-1} \right) + \cdots + \begin{pmatrix} k_{11} \\ \vdots \\ k_{1n} \end{pmatrix} \left(w_{1m} y_{1,t-1} + \cdots w_{nm} y_{n,t-1} \right) + \\
&+ \mathbf{Q}_1 \Delta \mathbf{y}_{t-1} + \cdots + \mathbf{Q}_{\text{p-1}} \Delta \mathbf{y}_{t-(p-1)} = \\
&= \mathbf{KW} \mathbf{y}_{t-1} + \mathbf{Q}_1 \Delta \mathbf{y}_{t-1} + \mathbf{Q}_2 \Delta \mathbf{y}_{t-2} + \cdots + \mathbf{Q}_{\text{p-1}} \Delta \mathbf{y}_{t-(p-1)}
\end{aligned}
\tag{B1}
$$

Here small and capital boldface letters denote vectors and matrices respectively. Thus, **y** is a vector of *n* variables, **K** is a *m*n* matrix of estimated coefficients <u>on</u> cointegrating equations, **W** is a *m*n* matrix of estimated coefficients of cointegrating equations, $\mathbf{Q}_1,\ldots,\mathbf{Q}_{p-1}$ are $n*n$ matrices of estimated coefficients on first differences. The constant term in cointegrating equations was omitted for the simplicity of exposition.

The corresponding standard reduced form VAR representation can be written as:

$$\mathbf{y}_t = \mathbf{F}_1\mathbf{y}_{t-1} + \cdots + \mathbf{F}_p\mathbf{y}_{t-p} \qquad \text{(B2)}$$

The reduced form VAR representation has one more lag than VEC representation (p lags in (B2) versus p-1 lags in (B1)), because VEC model is estimated in first differences. Our first task is to find coefficients of matrices $\mathbf{F}_\mathrm{i}$.

The correspondence of coefficients in equations (B1) and (B2) are determined by the following system of equations:

$$\mathbf{Q}_{p-1} = -\mathbf{F}_p$$
$$\mathbf{Q}_j = -\sum_{i=j}^{p}\mathbf{F}_i \quad for \quad j \in [1, p-2]$$
$$\mathbf{KW} = \sum_{i=1}^{p}\mathbf{F}_i - \mathbf{I}$$

Solution to the system gives matrices of coefficients $\mathbf{F}_\mathrm{i}$ that we were searching for.

Transformation of variance-covariance matrices

To make further exposition less obscure we will turn to the special case of semi-structural VAR system (5-6) that was estimated in this research.

$$\mathbf{Y}_t = \sum_{i=1}^{p}\mathbf{H}_i^E\mathbf{Y}_{t-i} + \sum_{i=1}^{p}\mathbf{H}_i^M\mathbf{P}_{t-i} + \mathbf{u}_t^E \qquad (5)$$

$$\mathbf{P}_t = \sum_{i=1}^{p} \mathbf{J}_i^E \mathbf{Y}_{t-i} + \sum_{i=1}^{p} \mathbf{J}_i^M \mathbf{P}_{t-i} + [\mathbf{N}\mathbf{u}_t^E + \mathbf{u}_t^M] \tag{6}$$

The system includes 4 variables: money aggregate, *M*, and inflation, *P*, are variables of macroeconomic block marked by superscript ^{E} (for economic); interest rate, *I*, and bank reserves, *R*, are variables of monetary policy block marked by superscript ^{M} (for monetary). This small system can be presented in a form of equation (B2):

$$\begin{pmatrix} M_t \\ P_t \\ I_t \\ R_t \end{pmatrix} = \mathbf{F}_1 \begin{pmatrix} M_{t-1} \\ P_{t-1} \\ I_{t-1} \\ R_{t-1} \end{pmatrix} + \cdots + \mathbf{F}_p \begin{pmatrix} M_{t-p} \\ P_{t-p} \\ I_{t-p} \\ R_{t-p} \end{pmatrix} + \begin{pmatrix} u_t^1 \\ u_t^2 \\ u_t^3 \\ u_t^4 \end{pmatrix} \tag{B3}$$

where

$$\mathbf{F}_i = \begin{pmatrix} \mathbf{H}_i^E & \mathbf{H}_i^M \\ \mathbf{J}_i^E & \mathbf{J}_i^E \end{pmatrix} \quad for \quad i = 1..p$$

Estimated residuals of system (B3) and their variance-covariance matrix ($\tilde{\mathbf{\Omega}}$) are of little interest. Instead, we need to find a variance-covariance matrix ($\mathbf{\Omega}$) of vector $\begin{pmatrix} \mathbf{u}^E \\ \mathbf{u}^M \end{pmatrix}$. From equations (5) and (6) it follows that

$$\begin{pmatrix} u_t^1 \\ u_t^2 \\ u_t^3 \\ u_t^4 \end{pmatrix} = \begin{pmatrix} \mathbf{u}_t^E \\ \mathbf{N}\mathbf{u}_t^E + \mathbf{u}_t^M \end{pmatrix} = \begin{pmatrix} \mathbf{I} & \mathbf{0} \\ \mathbf{N} & \mathbf{I} \end{pmatrix} \begin{pmatrix} \mathbf{u}_t^E \\ \mathbf{u}_t^M \end{pmatrix} = \begin{pmatrix} \mathbf{I} & \mathbf{0} \\ \mathbf{N} & \mathbf{I} \end{pmatrix} \begin{pmatrix} u_t^L \\ u_t^P \\ u_t^I \\ u_t^R \end{pmatrix} \tag{B4}$$

It would be useful to split the estimated variance-covariance matrix of residuals of system (B3) into four smaller matrices:

$$\tilde{\mathbf{\Omega}} = \left(\begin{array}{cc|cc} \sigma_1^2 & \sigma_{12} & \sigma_{13} & \sigma_{14} \\ \sigma_{21} & \sigma_2^2 & \sigma_{23} & \sigma_{24} \\ \hline \sigma_{31} & \sigma_{32} & \sigma_3^2 & \sigma_{34} \\ \sigma_{41} & \sigma_{42} & \sigma_{43} & \sigma_4^2 \end{array}\right) = \begin{pmatrix} \mathbf{E} & \mathbf{L'} \\ \mathbf{L} & \mathbf{Z} \end{pmatrix}$$

Since $\mathbf{u}^{\mathrm{E}}$ and $\mathbf{u}^{\mathrm{M}}$ are uncorrelated by assumption their variance-covariance matrix $\mathbf{\Omega}$ has a form:

$$\mathbf{\Omega} = \begin{pmatrix} \sigma_L^2 & & & \\ \sigma_M & \sigma_P^2 & & \\ 0 & 0 & \sigma_I^2 & \\ 0 & 0 & \sigma_{IR} & \sigma_R^2 \end{pmatrix} = \begin{pmatrix} \mathbf{\Omega_E} & \mathbf{0} \\ \mathbf{0} & \mathbf{\Omega_M} \end{pmatrix}$$

Equation (B4) implies that estimated matrix $\tilde{\mathbf{\Omega}}$ and unknown matrix $\mathbf{\Omega}$ are linked by equation:

$$\mathbf{\Omega} = \begin{pmatrix} \mathbf{I} & \mathbf{0} \\ \mathbf{N} & \mathbf{I} \end{pmatrix}^{-1} \tilde{\mathbf{\Omega}} \begin{pmatrix} \mathbf{I} & \mathbf{N'} \\ \mathbf{0} & \mathbf{I} \end{pmatrix}^{-1}$$

The block-diagonal structure of $\mathbf{\Omega}$ allows calculating $\mathbf{\Omega_E}$ and $\mathbf{\Omega_M}$ separately:

$$\mathbf{\Omega_M} = \mathbf{Z} - \mathbf{L'}(\mathbf{E}^{-1})'\mathbf{L}$$
$$\mathbf{\Omega_E} = \mathbf{E}$$

Now we proceed further and see how variance-covariance matrix $\mathbf{\Omega}$ of observable VAR residuals $\mathbf{u}^{\mathrm{E}}$ and $\mathbf{u}^{\mathrm{M}}$ is related to the variance-covariance matrix $\mathbf{\Sigma}$ of unobservable structural disturbances $\mathbf{v}^{\mathrm{E}}$ and $\mathbf{v}^{\mathrm{M}}$. Recall that equations (7) and (8) can be written as

$$\begin{pmatrix} u_t^L \\ u_t^P \\ u_t^I \\ u_t^R \end{pmatrix} = \begin{pmatrix} \mathbf{u}_t^E \\ \mathbf{u}_t^M \end{pmatrix} = \begin{pmatrix} \tilde{\mathbf{H}} & \mathbf{0} \\ \mathbf{0} & \tilde{\mathbf{J}} \end{pmatrix} \begin{pmatrix} \mathbf{v}_t^E \\ \mathbf{v}_t^M \end{pmatrix} = \begin{pmatrix} \tilde{\mathbf{H}} & \mathbf{0} \\ \mathbf{0} & \tilde{\mathbf{J}} \end{pmatrix} \begin{pmatrix} v_t^L \\ v_t^P \\ v_t^d \\ v_t^s \end{pmatrix}$$

Therefore,

$$\mathbf{\Omega} = \begin{pmatrix} \mathbf{\Omega_E} & \mathbf{0} \\ \mathbf{0} & \mathbf{\Omega_M} \end{pmatrix} = \begin{pmatrix} \tilde{\mathbf{H}} & \mathbf{0} \\ \mathbf{0} & \tilde{\mathbf{J}} \end{pmatrix} \mathbf{\Sigma} \begin{pmatrix} \tilde{\mathbf{H}}' & \mathbf{0} \\ \mathbf{0} & \tilde{\mathbf{J}}' \end{pmatrix} =$$
$$= \begin{pmatrix} \tilde{\mathbf{H}} & \mathbf{0} \\ \mathbf{0} & \tilde{\mathbf{J}} \end{pmatrix} \begin{pmatrix} s_L^2 & & & \\ 0 & s_P^2 & & \\ 0 & 0 & s_d^2 & \\ 0 & 0 & 0 & s_S^2 \end{pmatrix} \begin{pmatrix} \tilde{\mathbf{H}}' & \mathbf{0} \\ \mathbf{0} & \tilde{\mathbf{J}}' \end{pmatrix} \tag{B5}$$

where $\mathbf{\Sigma}$ is a variance-covariance matrix of structural disturbances. Since all components of vector $\mathbf{v}=\begin{pmatrix} \mathbf{v}^E \\ \mathbf{v}^M \end{pmatrix}$ are uncorrelated by assumption, $\mathbf{\Sigma}$ is a diagonal matrix. We are interested in value of only one component of $\mathbf{\Sigma}$ – standard deviation s_S of policy shock v^S. So, only bottom right submatrix of $\mathbf{\Omega}$ is needed:

$$\mathbf{\Omega_M} = \tilde{\mathbf{J}} \begin{pmatrix} s_d^2 & 0 \\ 0 & s_S^2 \end{pmatrix} \tilde{\mathbf{J}}' \tag{B6}$$

Inverting (B6) and substituting $\tilde{\mathbf{J}}$ from equation (11) gives

$$\begin{pmatrix} s_d^2 & 0 \\ 0 & s_S^2 \end{pmatrix} = \tilde{\mathbf{J}}^{-1} \begin{pmatrix} \sigma_I^2 & \sigma_{IR} \\ \sigma_{IR} & \sigma_R^2 \end{pmatrix} \tilde{\mathbf{J}}'^{-1} =$$
$$= \begin{bmatrix} \alpha & 1 \\ -\alpha\varphi & 1-\varphi \end{bmatrix} \begin{pmatrix} \sigma_I^2 & \sigma_{IR} \\ \sigma_{IR} & \sigma_R^2 \end{pmatrix} \begin{bmatrix} \alpha & -\alpha\varphi \\ 1 & 1-\varphi \end{bmatrix} \tag{B7}$$

Now it is apparent that system (B7) is not identified: only three elements of variance-covariance matrix Ω_M are given, and four variables should be calculated. For this reason we assign different values for parameter φ. The dynamic response of all variables to one standard deviation exogenous shock is calculated by assigning value s_S to disturbance v^S, while taking all other components of $\mathbf{v}$ to be zero. Since

$$\begin{pmatrix} u_t^1 \\ u_t^2 \\ u_t^3 \\ u_t^4 \end{pmatrix} = \begin{pmatrix} \mathbf{I} & \mathbf{0} \\ \mathbf{N} & \mathbf{I} \end{pmatrix} \begin{pmatrix} u_t^M \\ u_t^P \\ u_t^I \\ u_t^R \end{pmatrix} = \begin{pmatrix} \mathbf{I} & \mathbf{0} \\ \mathbf{N} & \mathbf{I} \end{pmatrix} \begin{pmatrix} \tilde{\mathbf{H}} & \mathbf{0} \\ \mathbf{0} & \tilde{\mathbf{J}} \end{pmatrix} \begin{pmatrix} v_t^M \\ v_t^P \\ v_t^d \\ v_t^s \end{pmatrix} = \begin{pmatrix} \tilde{\mathbf{H}} & \mathbf{0} \\ \tilde{\mathbf{H}}\mathbf{N} & \tilde{\mathbf{J}} \end{pmatrix} \begin{pmatrix} v_t^M \\ v_t^P \\ v_t^d \\ v_t^s \end{pmatrix}$$

this corresponds to assigning

$$\begin{pmatrix} u_t^1 \\ u_t^2 \\ u_t^3 \\ u_t^4 \end{pmatrix} = \begin{pmatrix} \tilde{\mathbf{H}} & \mathbf{0} \\ \tilde{\mathbf{H}}\mathbf{N} & \tilde{\mathbf{J}} \end{pmatrix} \begin{pmatrix} 0 \\ 0 \\ 0 \\ s_S \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ j_{12} s_S \\ j_{22} s_S \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ \frac{-s_S}{\alpha} \\ s_S \end{pmatrix}$$

Vector error correction model, 1 lag

Date: 03/26/02 Time: 14:26
Sample(adjusted): 1997:03 2001:09
Included observations: 55 after adjusting endpoints
Standard errors & t-statistics in parentheses

Cointegrating Eq:	CointEq1	CointEq2	CointEq3	
M1(-1)	1.000000	0.000000	0.000000	
INFL(-1)	0.000000	1.000000	0.000000	
IIRM(-1)	0.000000	0.000000	1.000000	
TR(-1)	17.79161	0.002556	0.012017	
	(84.9013)	(0.01114)	(0.04720)	
	(0.20956)	(0.22941)	(0.25460)	
Error Correction:	**D(M1)**	**D(INFL)**	**D(IIRM)**	**D(TR)**
CointEq1	-0.010976	-0.000165	0.000137	-0.018090
	(0.02882)	(6.2E-05)	(6.0E-05)	(0.01368)
	(-0.38079)	(-2.66986)	(2.26847)	(-1.32200)
CointEq2	-38.12222	-0.854593	-0.269546	45.38579
	(74.9677)	(0.16115)	(0.15654)	(35.5883)
	(-0.50852)	(-5.30326)	(-1.72187)	(1.27530)
CointEq3	40.22717	0.493669	-0.174624	24.43021
	(61.0586)	(0.13125)	(0.12750)	(28.9855)
	(0.65883)	(3.76137)	(-1.36961)	(0.84284)
D(M1(-1))	-0.171799	6.26E-05	-0.000457	-0.029823
	(0.13662)	(0.00029)	(0.00029)	(0.06486)
	(-1.25749)	(0.21310)	(-1.60118)	(-0.45984)
D(INFL(-1))	-76.60723	0.221701	0.069648	-15.52223
	(68.0976)	(0.14638)	(0.14220)	(32.3270)
	(-1.12496)	(1.51458)	(0.48980)	(-0.48016)
D(IIRM(-1))	-59.07361	-0.253440	0.061735	10.52444
	(75.5604)	(0.16242)	(0.15778)	(35.8697)
	(-0.78181)	(-1.56041)	(0.39127)	(0.29341)
D(TR(-1))	0.395412	-0.000407	-0.001122	-0.438878
	(0.34625)	(0.00074)	(0.00072)	(0.16437)
	(1.14199)	(-0.54739)	(-1.55124)	(-2.67007)

R-squared	0.267987	0.404154	0.340848	0.187569
Adj. R-squared	0.176485	0.329674	0.258454	0.086016
Sum sq. resids	14348937	66.29876	62.56588	3233608
S.E. equation	546.7506	1.175255	1.141690	259.5512
Log likelihood	-421.0174	-83.17947	-81.58581	-380.0403
Akaike AIC	12.72640	0.441383	0.383432	11.23632
Schwarz SC	12.98188	0.696862	0.638911	11.49180
Mean dependent	352.4364	-0.014545	-0.017273	61.50909
S.D. dependent	602.4950	1.435453	1.325803	271.4899

Determinant Residual Covariance	1.72E+10
Log Likelihood	-850.2225
Akaike Information Criteria	23.92931
Schwarz Criteria	24.29428

Vector error correction model, 2 lags

Date: 03/26/02 Time: 14:29
Sample(adjusted): 1997:04 2001:09
Included observations: 54 after adjusting endpoints
Standard errors & t-statistics in parentheses

Cointegrating Eq:	CointEq1
M1(-1)	1.000000
INFL(-1)	36046.41 (3040768) (0.01185)
IIRM(-1)	-10719.52 (830534.) (-0.01291)
TR(-1)	411.0808 (35621.3) (0.01154)

Error Correction:	D(M1)	D(INFL)	D(IIRM)	D(TR)
CointEq1	0.000448 (9.9E-05) (4.53465)	3.50E-08 (2.4E-07) (0.14357)	1.42E-07 (2.2E-07) (0.65909)	7.62E-05 (4.6E-05) (1.66450)
D(M1(-1))	-0.212013 (0.14020) (-1.51221)	-1.71E-05 (0.00035) (-0.04927)	-0.000605 (0.00031) (-1.97496)	0.010050 (0.06499) (0.15464)
D(M1(-2))	-0.235498 (0.13610) (-1.73033)	-0.000219 (0.00034) (-0.65288)	0.000120 (0.00030) (0.40432)	-0.006842 (0.06309) (-0.10845)
D(INFL(-1))	-101.7739 (55.4794) (-1.83444)	-0.247107 (0.13701) (-1.80356)	-0.221000 (0.12118) (-1.82366)	26.65044 (25.7172) (1.03629)
D(INFL(-2))	-61.41721 (57.9140) (-1.06049)	-0.511859 (0.14302) (-3.57887)	-0.459965 (0.12650) (-3.63601)	96.94317 (26.8457) (3.61113)
D(IIRM(-1))	-58.11566 (65.1173) (-0.89248)	0.100529 (0.16081) (0.62513)	0.131950 (0.14224) (0.92768)	8.167554 (30.1848) (0.27059)
D(IIRM(-2))	112.7215 (60.5417) (1.86188)	0.392624 (0.14951) (2.62604)	0.007660 (0.13224) (0.05792)	7.236072 (28.0638) (0.25784)
D(TR(-1))	0.318018 (0.32882) (0.96714)	0.000137 (0.00081) (0.16818)	-0.001351 (0.00072) (-1.88086)	-0.412471 (0.15242) (-2.70608)

D(TR(-2))	-0.135597	-0.000909	0.000232	0.066670
	(0.35578)	(0.00088)	(0.00078)	(0.16492)
	(-0.38113)	(-1.03489)	(0.29824)	(0.40425)
R-squared	0.363597	0.309257	0.373086	0.322858
Adj. R-squared	0.250458	0.186458	0.261635	0.202478
Sum sq. resids	12466275	76.02895	59.47987	2678672
S.E. equation	526.3348	1.299820	1.149685	243.9796
Log likelihood	-410.0604	-85.86000	-79.23215	-368.5424
Akaike AIC	12.68289	0.675463	0.429987	11.14518
Schwarz SC	13.01438	1.006961	0.761485	11.47668
Mean dependent	350.3148	0.005556	-0.013534	64.37037
S.D. dependent	607.9449	1.441097	1.337960	273.2008

Determinant Residual Covariance	1.51E+10
Log Likelihood	-831.3921
Akaike Information Criteria	23.81116
Schwarz Criteria	24.17949

Vector error correction model, 3 lags

Date: 03/26/02 Time: 14:31
Sample(adjusted): 1997:05 2001:09
Included observations: 53 after adjusting endpoints
Standard errors & t-statistics in parentheses

Cointegrating Eq:	CointEq1			
M1(-1)	1.000000			
INFL(-1)	-2529.564 (5506.13) (-0.45941)			
IIRM(-1)	-101.4437 (2227.51) (-0.04554)			
TR(-1)	-12.02154 (11.2781) (-1.06592)			
Error Correction:	**D(M1)**	**D(INFL)**	**D(IIRM)**	**D(TR)**
CointEq1	-0.028819 (0.00617) (-4.67368)	7.16E-06 (1.5E-05) (0.47830)	3.16E-06 (1.3E-05) (0.23969)	-0.004571 (0.00305) (-1.50082)
D(M1(-1))	-0.265540 (0.14933) (-1.77815)	-0.000154 (0.00036) (-0.42517)	-0.000312 (0.00032) (-0.97722)	-0.002109 (0.07375) (-0.02859)
D(M1(-2))	-0.183118 (0.14393) (-1.27228)	-0.000357 (0.00035) (-1.02251)	0.000214 (0.00031) (0.69363)	-0.012930 (0.07108) (-0.18190)
D(M1(-3))	-0.144130 (0.13734) (-1.04942)	0.000190 (0.00033) (0.56948)	0.000314 (0.00029) (1.06893)	-0.022914 (0.06783) (-0.33781)
D(INFL(-1))	-196.4328 (66.7543) (-2.94263)	-0.308125 (0.16211) (-1.90069)	-0.185095 (0.14283) (-1.29594)	7.950385 (32.9690) (0.24115)
D(INFL(-2))	-94.77535 (63.9230) (-1.48265)	-0.640599 (0.15524) (-4.12661)	-0.415293 (0.13677) (-3.03645)	84.87667 (31.5707) (2.68847)
D(INFL(-3))	-52.79991 (78.9084) (-0.66913)	-0.197599 (0.19163) (-1.03116)	-0.101262 (0.16883) (-0.59978)	-26.48238 (38.9718) (-0.67953)
D(IIRM(-1))	-24.43236 (70.4773) (-0.34667)	0.065731 (0.17115) (0.38404)	0.042813 (0.15079) (0.28392)	7.799968 (34.8078) (0.22409)

D(IIRM(-2))	66.37172	0.499976	-0.025152	4.727427
	(65.0086)	(0.15787)	(0.13909)	(32.1068)
	(1.02097)	(3.16696)	(-0.18083)	(0.14724)
D(IIRM(-3))	56.44422	0.291792	-0.227564	16.28124
	(69.4320)	(0.16861)	(0.14856)	(34.2915)
	(0.81294)	(1.73052)	(-1.53184)	(0.47479)
D(TR(-1))	0.179123	0.000526	-0.000765	-0.398577
	(0.36694)	(0.00089)	(0.00079)	(0.18123)
	(0.48815)	(0.58997)	(-0.97428)	(-2.19931)
D(TR(-2))	-0.363074	-0.000344	0.000317	0.061905
	(0.37311)	(0.00091)	(0.00080)	(0.18427)
	(-0.97310)	(-0.37913)	(0.39682)	(0.33594)
D(TR(-3))	-0.843596	0.001823	-0.001140	-0.062682
	(0.37172)	(0.00090)	(0.00080)	(0.18359)
	(-2.26942)	(2.01939)	(-1.43293)	(-0.34142)
R-squared	0.446092	0.416214	0.476559	0.329255
Adj. R-squared	0.279919	0.241079	0.319527	0.128031
Sum sq. resids	10846758	63.96946	49.65479	2645781
S.E. equation	520.7389	1.264609	1.114168	257.1858
Log likelihood	-399.2743	-80.18857	-73.47583	-361.8855
Akaike AIC	12.71965	0.678680	0.425369	11.30875
Schwarz SC	13.20293	1.161959	0.908648	11.79203
Mean dependent	351.8113	-0.007547	-0.015818	66.35849
S.D. dependent	613.6623	1.451637	1.350657	275.4206

Determinant Residual Covariance	8.57E+09
Log Likelihood	-800.9139
Akaike Information Criteria	23.39996
Schwarz Criteria	23.92042