BULGARIAN NATIONAL BANK

DISCUSSION PAPERS

DP/15/2000

Bank Reserve Dynamics under Currency Board Arrangement for Bulgaria

Boris Petrov

December 2000

DISCUSSION PAPERS

ISBN 954 – 9791 – 38 – 6

Accepted 25 July 2000.

Printed in BNB Printing Center.

Send your comments and opinions to:
Publications Division
Bulgarian National Bank
1, Alexander Battenberg Square
1000 Sofia, Bulgaria
Tel.: (359 2) 9145/1271, 1351, 1906
Fax: (359 2) 980 2425
e-mail: Dimova.L@bnbank.org
Website: www.bnb.bg

Contents

Summary. It is well known that under a monetary system based on currency board arrangements, financial system equilibrium is maintained by the interest rate. This study meets the need to explain bank reserve dynamics during the period of bank reserve maintenance. The study presents an empirical model of bank reserve demand and explains bank reserve supply shocks and adjustment of banks to these shocks. Finally, the author makes practical recommendations intended to smooth interest rate variance resulting from shocks.

JEL classification: E41; C22; E58

Keywords: currency board, demand for bank reserves, interbank money market

---

Special thanks are due to Nikolay Nenovsky, Kalin Hristov and the other colleagues from the BNB Monetary and Financial Research Division for their helpful comments and assistance, as well as to Prof. Hamilton and Prof. J. Campbell for sending their publications. The paper benefited from discussions with A. M. Gulde and M. Jones from the IMF technical mission. The author is also grateful to: M. Marinova and S. Ruicheva from the BNB Financial Markets Division, M. Strumnina from the BNB Treasury Directorate, and D. Ivanova from Bankservice Ltd. for sharing data and kind cooperation.

All errors and omissions remain the responsibility of the author. Views expressed are those of the author and do not necessarily reflect BNB policy.

Please contact us with your comments: BNB, Monetary and Financial Research Division, e-mail: Petrov.B@bnbank.org, bpetrov@mail.netplus.bg, tel. (+359 2) 9145 1814.

The Balancing Role of Reserve Money Market under a Currency Board

As it is known stable and long-lasting operation of the currency board is predetermined by the automatically functioning rules, the basis of the currency board. These rules are based on a monetary approach to the balance of payments which links balance of payments dynamics with reserve money dynamics. Since the exchange rate is employed as a nominal anchor, financial sector equilibrium is provided through money market prices and volumes, i. e. interbank market interest rates and reserve money.

Under a currency board any disequilibrium or imbalances in monetary and real sectors reflect finally on reserve money market. Attainment of rapid and automatic equilibrium between reserve money demand and supply is the major rule for maintaining currency board stability. Reserve money supply is predetermined by balance of payments dynamics which, in turn, is impacted by various factors. Reserve money demand consists of two major components: demand for currency in circulation (banknotes and coins) by the public and companies and commercial bank demand for reserve money. The study of the behavior of reserve money components of demand is of essential importance in case of a systemic risk. Irrespective of the origin of the initial shock and subsequent attack on the currency board (bank and/or foreign exchange), this attack will sharply reverse reserve money demand dynamics and affect currency board liabilities.

The study of reserve money market includes analysis of economy's liquidity or especially that part of liquidity which is vulnerable to the greatest extent to any possible shocks under a currency board.

With the introduction of currency board arrangements in Bulgaria in mid-1997, implementation of the anti-inflationary policy was transferred to the European Central Bank (ECB). This helped settle the problems associated with the inconsistent discretionary policy previously pursued, and hence public confidence in government abilities to pursue an anti-inflationary policy was partly restored.

With the introduction of a currency board monetary aggregate behavior reflects automatic adjustment to money demand changes, balance of payments dynamics, and to a smaller extent to government behavior. The impact of government behavior has been thoroughly studied and described by Nenovsky and Hristov (1999).

Nenovsky (1998) profoundly analyzes and advances arguments for the failure of traditional approaches to monetary policy implementation in transition economies. Behavior of currency outside banks under a currency board has been studied by Nenovsky and Hristov (2000). Therefore, the question of currency outside banks is beyond the scope of this paper. The study focuses on bank reserve behavior.

The goal of this paper is to propose a function of bank reserve demand and behavior model of average weighted interbank money market interest rate under a currency board. Further, construction of the model is associated with identification of various sources of shocks on bank reserves and changes in the behavior of various participants, and in interest rate dynamics correspondingly. The study will be made within the existing monetary system institutional structure.

This study is structured as follows. The first section includes a theoretical overview of the models of interbank market interest rate movements as well as models of bank reserve demand. The second section reviews institutional specificity of Bulgaria's minimum required reserve regulation system and payment system due to their importance in determining participants' behavior in the interbank deposit market. The third section of the paper includes a list of data used and major statistical test results which prove important for any further econometric processing. The fourth part of the study describes the model of bank reserve demand in levs and foreign currency.

This model can be used as a basis of future analysis of bank reserve dynamics and realization of an extremely short-term forecast (from one to several days). The model could be also instrumental in forecasting the impact of any institutional changes (e.g. a reduction of minimum required reserves) on interbank market rate dynamics.

Literature Review

Employment of a direct interest rate regulation of overnight deposits by a number of central banks in mid-90s as an operative target in monetary policy implementation made the study of interest rate movements extremely important.

The interbank deposit market is characterized by an interest rate with the shortest horizon. Consequently, the change in the interbank deposit market interest rate is considered indicative which automatically prompts changes in the interest rates of other financial market segments with longer maturity horizon. This way the influence on short-term interbank market rates spreads through economic agents' expectations on the whole yield curve. The hypothesis of rational expectations for the interest rate behavior in various yield curve points has been studied by Mankiw and Miron (1986), Fama (1984), Mishkin (1988), Hardouvelis (1988), Fama and Bliss (1987), Simon (1990), Rudenbusch (1995), etc. Any of these studies confirm the hypothesis that the spread between various yield rates can be used in forecasting the behavior of short-term interest rates, which in turn reflects economic agents' expectations of central bank behavior (Bernanke and Blinder*,* 1992).

In this study special attention is paid to short-term interest rate dynamics. Under a currency board interbank market rate movements reflect money supply adjustment to the changes in money demand. The adjustment is not an automatic process due to institutional specificity of payment and monetary systems. Some peculiarities are considered in the second part of the paper and other have been already described by *Nenovsky* and *Hristov* (1999).

Review of models describing interest rate dynamics in the interbank money market

Economists' interest in interest rate movements is associated with information about future changes in macroeconomic variables. This can be realized by forecasting an implicit function of central bank reaction under different circumstances and the impact of these changes on macrovariables through various transmission channels (Bernanke and Blinder, 1992).

Campbell (1987) proposes a two-period model of interest rate movement in the federal funds market. The martingale[1] hypothesis of interest rate dynamics has been rejected in this study. In accordance with this model interest rate fluctuations were explained partly by the effect of announcing money supply data by the US Federal Reserve. Spindt and Hoffmeister (1988) propose a model showing the impact of continuous trade and regulatory constraints on reporting minimum required reserves on interest rate variance in each day of the reserve maintenance period.

Feinman (1993) assesses the reaction function of the Federal Open Market Committee (FOMC). The proposed model successfully predicts 75% of FOMC reactions. Moreover, the author proves through this model not only the FOMC successful manipulation of money supply but also the signals it sends about monetary policy performance.

Hamilton (1996) tests the hypothesis of martingale in interbank market interest rate movements. Earlier Shiller, Campbell, Schoenholtz (1983) and Dyl and Hoffmeister (1985) considered the same hypothesis as doubtful. According to Hamilton (1996), the federal funds rate market follows a martingale within the 14-day maintenance period. On the first day of a new maintenance period interest rate dynamics is described by higher-order autoregression. This rejects the martingale hypothesis within the whole maintenance period.

[1] Martingale is first order autoregression.

Hamilton (1997a) measures the liquidity effect (the change in interest rates as a result of changes in bank reserve supply) by modeling budget accounts' behavior. Based on these accounts he derives unexpected exogenous shocks which affect bank reserve supply. Finally, the author confirms the existence of two different channels for emergence of liquidity effect. The first channel is a result of a temporary fall in bank reserves and the second one reflects a permanent shock which continues even after expiry of the maintenance period.

Hamilton (1997b) studies the factors affecting bank reserve demand and supply. For this purpose data from US Federal Reserve daily balance sheets was used. The author proposes a VAR model imposing a number of constraints on individual variables. The latter is predetermined by various institutional peculiarities. Impulse analysis of individual variables helped determine the effect of shock duration on bank reserve demand and supply.

Nautz (1998) further develops the model of bank reserve management created by Orr and Mellon (1931) to include an additional component influencing reserve demand: uncertainty as a result of shocks caused by an unclear central bank's monetary policy.

Furfine (1998) constructs a micromodel which formalizes the relationship between the activity of each bank in the payment process and interbank interest rate dynamics. According to Furfine (1998), the function of bank reserve demand consists of two separate components: required reserve demand and settlement demand. Total bank reserve demand in the monetary system is a sum total of individual functions of commercial bank demand.

Clouse and Dow (1999) propose an equilibrium model. This model explains significant deviations of federal funds rates from the operative target. According to the authors, the reasons behind the significant deviations are fixed transactions expenses in finding nonmarket bank reserve sources. Chung and Hung (2000) explain interbank market rate movements by a single factor model.

The common feature of all mentioned models is the relationship between interbank market rate as a central bank's operative target and open market operations. In other words the size of the interest rate reflects the central bank's decision and the manner of its fulfillment through the interbank money market.

Under a currency board interest rate dynamics does not depend on central bank decisions. The interest rate reflects the interaction between demand and supply of bank reserves which are impacted by various factors. In this case the central bank could influence commercial bank behavior only indirectly by changing minimum required reserves. It should be noted that employment of minimum required reserves is considered a disadvantage of the currency board rather than an advantage due to the adverse effect of the retained monetary policy instrument on currency board credibility, a fact highlighted by Hanke and Schuler (1994) and Nenovsky and Hristov (1999). Since no changes in minimum required reserves were made during the reviewed period, interest rate dynamics was entirely a result of changes in bank reserve demand and institutional specificity of the financial system.

The trend towards a reduction or even removal of minimum required reserves prompts a change in determinants of commercial bank reserve demand, and hence in the interest rates in interbank deposit market. Sellon and Weiner (1996) focus on the role of transactions demand which remains the core of the function of bank reserve demand in the absence of minimum required reserves. The authors focus on increased interest rate volatility as a direct effect of reducing minimum required reserves. Clinton (1996) makes practical recommendations in respect of monetary policy implementation in Canada under zero minimum reserves. Clouse and Elmendorf (1997) explain the increased interest rate volatility and show the change in this relationship as a result of changes in banks' behavior. Di Giorgio (1999) studies the interdependence between the reduction of minimum required reserves and the degree of financial mediation development. According to Di Giorgio, the degree of financial mediation development depends on financial agents' expenses for borrower monitoring.

Henckel, Ize and Kovanen (1999) propose a simplified model of bank reserve demand adjusted to uncertainty in payments which should be made by the respective bank. They find an interdependence between the interbank market interest rate, central bank supply of bank reserves and idiosyncratic shocks on money supply.

Study of bank reserve demand

Pool (1968) constructs a fundamental micromodel of bank reserve management deriving the optimal value of reserves a bank should maintain in order to maximize expected profit.

Ho and Saunders (1985) develop a micromodel of the interbank deposit market, including major institutional characteristics. The economists derive the determinants of demand for deposits by any individual participant and explain why big banks are net consumers of interbank deposits and small banks are net providers of resources.

Nautz (1998) studies bank reserve demand under the conditions of uncertainty of future monetary policy of Deutsche Bundesbank. Based on results obtained by using ARCH-M model, the Nautz concludes that the central bank can influence money market, announcing its monetary policy explicitly or implicitly. This impacts the expected variance in bank reserve demand.

Jahnsen (1998) analyzes reserve money demand in Great Britain using quarterly data which covers a 20-year period. The author uses in his study a cointegration model with error adjustment.

Bartolini, Bertola and Prati (1999) analyze the effect of Federal Reserve behavior on bank reserve demand. In accordance with this econometric model interbank market rates volatility reflects market participants' confidence in Federal Reserve commitment to manipulating rigidly or softly the interest rate. The authors propose a specific theoretical model of the federal funds market microstructure.

Institutional Specificity of the Money Market in Bulgaria

Parameters of minimum required reserve system adopted in April 1998

The present minimum required reserve system replaced the former regulation system which had operated with certain modifications between 1990 and 1998. The change was intended to make commercial banks more flexible in executing minimum required reserves and to avoid maintenance of excess reserves.

Any required reserve system has specific parameters outlining its institutional character. For example, the period of reporting the deposit base required for minimum required reserve formation is called a base period. In Bulgaria this period covers one calendar month. Within this period banks must compute daily their deposit base. The deposit base includes all borrowed funds with the exception of funds borrowed from commercial banks. The deposit base is reported on a daily basis during the base period. Minimum required reserves account for 11% of the reported daily amount of the deposit base during the base period[2]. The average daily amount of minimum required reserves in the maintenance period is computed by reducing 60% of the average cash balances in levs from the total amount of minimum required reserves during the base period. The maintenance period begins on the fourth day of each month and finishes on the third day of the following month. During this period banks must cover minimum required reserves. Banks are allowed to use up to 50% of the minimum required reserves.

[2] 8% since July 2000.

The required reserves are estimated according to the following formula:

$$\frac{1}{K}\sum_{\kappa=1}^{K} R_k \geq \theta,$$

where

k has values from 1 … *K*, where *K* is the number of days during the maintenance period, i. e. 30 or 31 dependent on the corresponding month,

q is the average daily amount of minimum required reserves.

If banks fail to fulfil the minimum required reserves during the maintenance period, a penalty interest is to be paid to the BNB in the amount of 150% of the average interbank market rate for the days of default.

The opportunity to maintain both lev and foreign currency reserves with the BNB is another specific feature of the minimum required reserve system. This is predetermined by the significant share of foreign currency deposits in commercial bank liabilities and the need to offset foreign exchange risk by maintaining foreign exchange assets. It should be noted that forex reserves are in the form of noninterest-bearing deposits. Although forex reserves may not be used in transactions, they may be withdrawn and changes in balances are allowed through the whole maintenance period.

The analysis of the foreign exchange structure of these deposits indicates that banks use foreign exchange denominations to save opportunity costs. These are currencies on which low interest rate is applied (e. g. the Swiss franc).

Institutional specificity of the BISERA settlement system

BISERA is a system for gross settlement operating in a particular time period. The value date of payments is *t+1*. Payments are processed after the end of the business day and final balances resulting from settlement are recorded on commercial bank accounts in the beginning of the next business day.

Since banks do not have information about other participants' payments initiated to them, they are unable to manage effectively their liquidity, and when more sizable payments are to be effected, commercial banks have to provide excess reserves (if smaller) or use the admissible 50% of paid reserves to effect payments through BISERA.

Supply of bank reserves under a currency board

The supply of bank reserves under a currency board may have several exogenous sources. First, these are commercial bank net foreign assets denominated in reserve currency. These funds appear to be a source of liquidity for commercial banks' sales of reserve currency to the BNB. The term of delivery is minimum *t+3* as in reserve currency transactions an external (foreign) payment system is used. Consequently, the banking system direct source of liquidity within a 24-hour time horizon is limited. As a result the banking system is unable to react to any idiosyncratic[3] shocks. Minimum required reserves in foreign currency maintained with the BNB appear to be one of the accessible liquidity channels. Where necessary commercial banks sell a portion of these reserves to the BNB, thus providing spot liquidity (as forex transactions with the BNB are effected only with a spot value date). This limits banks' immediate sources of liquidity. Under these conditions money market proves to be the only source of lev liquidity within 24- and 48-hour time horizons.

The Ministry of Finance issuing policy is the second systemic source of liquidity. Given the matching of maturity and new issue dates and maintenance of an issuance schedule, the Ministry of Finance issuing policy cannot be a source of unexpected shocks on the money market. Therefore, it can be assumed that market participants' behavior adjusts more or less to this shock in advance.

On the other hand, the Ministry of Finance appears to be a net exogenous source or absorber of liquidity from the banking system through cash flows from and to the budget accounts with the BNB. As these flows are serviced through BISERA, which operates with a value date *t+1*, commercial banks meet flows to the BNB by maintaining higher balances on their reserve accounts by the end of a particular business day.

Theoretical Model of the Demand for Bank Reserves

Money demand in transition economies has been thoroughly studied. In contrast to developed countries where money demand is relatively stable and its behavior predictable, in transition economies it is characterized by a number of specific features. For example, Nenovsky (1998) points out the high degree of foreign currency substitution and lack of confidence in monetary authorities as major factors behind the disturbed stability of the function of money demand. Similar arguments in favor of instability in the function of broad money demand have been also pointed out by Blishev (1997). Calvo and Vegh's (1992) arguments are based on the study of Arrau, De Gregorio, Reinhart and Wickham (1991). In this study money demand instability is

[3] A shock affecting a particular participant and not the whole system. In this case this is an individual commercial bank.

considered as a result of 'financial innovation' approximating the process of dollarization.

However, bank reserves are a relatively narrow segment of money in the economy. Therefore, bank reserves are characterized by a certain behavioral stability provided by the transaction and institutional specificity of payment and reserve systems. Employment or absence of minimum required reserves is part of the institutional specificity of bank reserve demand. Major factors ensuring stability of bank reserve demand are described below.

Motives for bank reserve demand

Commercial banks use their reserves with the central bank due to two major reasons. First, commercial banks need adequate balances on their current accounts at any time in order to be able to effect payments on their own account or on the client's account due to the banks' specific role of payment mediators in the economy, or the so-called liquidity buffer role of bank reserves. Transactions demand for bank reserves is predetermined by the need of maintaining a liquidity cushion.

In addition to payments maintenance of commercial bank reserves is required by the central bank. Although the reasons for maintaining required reserves are beyond the scope of this study, it should be noted that employment of minimum required reserves helps stabilize demand for reserves within a particular period, thus contributing to highly efficient monetary policy. Under a currency board the monetary policy is based on a simple rule, in contrast to discretionary policy which can influence the amount of a particular monetary aggregate. Therefore, under a currency board employment of minimum required reserves cannot and should not be justified by the need to regulate the demand for bank reserves. Existence of minimum required reserves distorts the information generated by the money market about motives for bank reserve demand. For example, in case of an attack against the fixed exchange rate in absence of minimum required reserves, enhanced demand for bank reserves will prompt a faster increase in interest rates than in a situation when banks are required to maintain minimum reserves. A liquidity crisis with a certain lag may also occur if a system of averaging minimum required reserves is employed.

On the other hand, minimum required reserves ensure less interest rate volatility in the interbank market which may occur as a result of significant deviations in banks' payment activity within the maintenance period. This thesis is well grounded and studied by Clouse and Elmendorf (1997).

Since the interbank market rate reflects the opportunity cost of maintained reserves on a particular day of the maintenance period, the banks' ability to average their positions allows, in the event of liquidity squeeze, to avoid borrowing from the interbank market. This step should be initiated provided banks fail to fulfil their reserve positions. In the absence of an averaging system and insufficient liquidity, enhanced demand for bank reserves will prompt an increase in interbank market rates.

Another argument in favor of maintaining minimum required reserves ensure high commercial bank liquidity. High liquidity can be provided by introducing liquidity requirements. In Argentina, for instance, minimum required reserves were gradually replaced in 1995 by a requirement to maintain a portfolio of high-liquid and low-risk forex assets, with the amount of these assets dependent on the deposit base of an individual commercial bank. Furthermore, the accepted liquid assets entirely comply with currency board rules. For more details regarding the institutional arrangement of liquidity requirements in Argentina, see Escude (1999) and *Main features …* (2000).

Consequently, employment of minimum required reserves as an argument for maintaining bank liquidity is not well grounded. Moreover, Argentina's experience during the Asian crisis and later in the Russian and Brazilian forex crises evidenced that this technique works well.

Determinants of transactions demand for bank reserves

Transactions demand for bank reserves results from economic agents' preference for making noncash payments. With a view to better security of claims, financial mediators prefer the central bank as a clearing center between commercial banks. This is also in line with the recommendation of the Payments and Settlement System Committee at the Bank for International Settlements (BIS Report, 2000).

In technical aspect, the mediation function of commercial banks in payments is effected in a manner allowing any agent who has initiated payment through its bank to generate demand for reserve money (central money on the condition that the final recipient's account is outside the payer bank). Therefore, the increase in commercial bank demand for bank reserves is quite natural in the periods of concentrated payments, and *vice versa*: transactions demand decreases with reduced payment activity. Transactions demand is measured by the volume of effected noncash payments.

Bank reserve demand is in direct proportion to the monetary equivalent of transactions:

$$R^d = f(Q), \tag{1}$$

where

Q is the monetary equivalent of effected noncash payments of bank-to-bank type in the entire banking system.

Noncash payments are an accidental quantity dependent on bank customers' behavior. All outgoing customer payments which are not channeled to the BNB appear to cause an idiosyncratic shock on money demand by an individual bank. The sum total of such shocks for all commercial banks is equal to zero. Consequently, if such shocks affect only the individual function of demand for bank reserves, the effect will not reflect on total commercial bank demand for reserves.

Precautionary Demand Predetermined by the Specificity of the Payment System

Transactions demand for bank reserves is predetermined by the institutional specificity of the payment system. The efficiency of any payment system is measured through the ratio of used reserves and the volume of effected payments. To improve the efficiency of the payment system, it is necessary to use less liquidity in effecting a greater number of payments. Under less effective payment systems the above ratio is higher. Maintenance of significant minimum required reserves reflects the inefficiency of the present payment system.

While the number of payments is a natural factor determining demand for bank reserves, inclusion of the number of payments as a second factor needs an explanation. Initially, it seems that demand for bank reserves might not be determined by the number of payments, but under a system of noncash payment operating in gross settlement regime in a particular period *(t+1)*, the number of payments factor generates uncertainty regarding the time period required for processing. Therefore, for the purpose of security, banks maintain greater reserves. Consequently, precautionary demand for bank reserves should be proportional to the number of payments registered by BISERA for the entire system. The number of these payments is denoted with N_t.

$$R^d = f(N_{t-i1}), \tag{2}$$

where

$i1$ (1. . .m) is the number of lags.

Transactions demand for bank reserves in Bulgaria includes an additional component due to the specificity of the Bulgarian payment system (BISERA). This is a settlement system in a particular moment operating with a value date *t+1*. The system is designed to service both small payments of client-to-client type and payments between commercial banks. Within BISERA banks are unable to obtain information about incoming payments. They can forecast incoming cash flows on the basis of previous information.

This specificity of the system induces precautionary demand. It occurs as a result of banks' enhanced demand for reserves necessary to guarantee the realization of all payments against uncertainty of incoming payments. Since all payments through BISERA are effected on behalf and on the account of the client, precautionary demand covers only this segment of payments. Payments on foreign currency transactions as well as interbank market payments of bank-to-bank type are entirely controlled by commercial banks and do not prompt precautionary demand. These payments are considered a component of transactions demand for bank reserves.

Reserve Demand for Covering Minimum Required Reserves

The third component of demand for bank reserves reflects the need of covering minimum required reserves. This component is associated with the institutional specificity of the system of maintaining minimum required reserves.

Besides uncertainty of incoming cash flows, precautionary demand is also predetermined by the requirement for a particular balance of minimum required reserves at the end of each maintenance period to be covered by any individual commercial bank. Bank reserve demand for covering minimum required reserves is a function of compliance with required reserves from the previous day and the opportunity cost for maintaining these reserves. Correspondingly, the variables include the amount of total commercial bank reserves R_t, maintained in the review period t, and opportunity costs it for maintaining these reserves. The formula of bank reserve demand for covering minimum required reserves is as follows:

$$R^d = f(R_{t-i2}, i_{t-i3}), \tag{3}$$

where

$i2$ and $i3$ are the lags of the effect on respective variables.

The values of these variables are determined empirically.

In addition, the closer the end of the maintenance period, the more difficult the compensation for noncompliance with the requirements. This makes demand and correspondingly supply of minimum required reserves inelastic in the last day of the maintenance period. Therefore, interest rate volatility on this day is expected to be higher. This fact has been noted and explained by Hamilton (1996). Consequently, besides compliance, respectively noncompliance with the requirements for minimum reserves, the proximity of a particular day to the end of the maintenance period should also be taken into account in modeling expected variance. Logically, if at the moment of reporting banks maintain excess reserves, reserve demand in the next few days will decrease, and *vice versa*, if banks need to cover deficits, the demand will increase. This reveals the essence of the behavior under the martingale hypothesis.

Speculative Demand for Bank Reserves

Speculative demand for bank reserves reflects banks' ability to generate income from arbitrage transactions. This depends on the opportunity of placing abroad funds borrowed in the interbank market and *vice versa*. Consequently, demand for bank reserves is a function of the opportunity profitability of these funds.

The covered interest rate differential is traditionally used as a measurement of arbitrage transactions in national or foreign currency. Given the assumed full credibility of BGN/EUR fixed exchange rate in the future, the interest rate parity between these currencies will be permanently covered. Consequently, the amount of the interest rate differential plays a key role. Profitability of assets denominated in foreign currency is used by Giovannini and Turtelboom (1992) and Cuddington (1983) in modeling money demand. The DEM/USD exchange rate and/or the covered interest rate differential between lev interbank market rates and LIBOR on USD-denominated deposits can be used as a major variable in determining the speculative demand for bank reserves. The formula of speculative demand for bank reserves is as follows:

$$R^d = f\,(I_{t\text{-}j3}, \mathbf{DIF}_{t\text{-}j2}),$$

where

$\mathbf{DIF}_{t\text{-}j2}$ is the uncovered interest rate differential between weekly LIBOR on EUR-denominated deposits and the interbank average daily interest rate;

$I_{t\text{-}j3}$ the average weighted interbank market rate in levs;

$j2$ and $j3$ the lags of corresponding variables.

Peculiarities of the Bulgarian Money Market

Since the institutional characteristics of the currency board in Bulgaria have been already extensively studied (Nenovsky and Hristov, 1999) I will not consider in detail this issue. I would like to note, however, that unlike the monetary regime with a classical currency board, under the quasi-currency board in Bulgaria the function of the lender of last resort continues to exist institutionally within the central bank, though under strictly formulated preconditions. In practice, this function can be used only in a situation of a systemic liquidity crisis.

Commercial banks therefore do not rely on the central bank in managing their liquidity, as is the normal situation in industrialized countries with classical central banks where access to the lender of last resort is seen rather as a privilege than a right.

The choice of liquidity managers is reduced to attracting funds from the interbank markets or to liquidation of assets. Big banks with established record are net borrowers from the money market (M. Stigum, 1990, and Ho and Saunders, 1985). Small and medium-sized banks are net investors in the money market. In managing their liquidity they use mostly their own assets while big banks rely on creating and refinancing of liabilities.

The situation in the Bulgarian interbank money market is different. Small banks have no access to attracting funds through deposits due to their low confidence level (a fact easy to explain given the number of failed banks of similar size in 1996 and the lack of publicly accessible information on their financial state[4]). The only way to accumulate funds is through repo agreements in government securities and at a higher interest rate than that on interbank deposits. It is difficult to check this assertion as observations on the interest rate differential between unsecured deposits and repo agreements indicate that the average difference between them is a mere -0.13% for the period May 1998 – May 2000, but final fluctuations are -1.93 and 1.91. This assertion is based on the fact that distribution of interest rate differential is slightly shifted to the left (see Chart 1 in the appendices) indicating a greater possibility for higher repo agreement rate. Therefore we may argue that the Bulgarian interbank market is segmented. Despite the existence of a positive interest rate differential between interest rates on repo agreements and interbank deposits, they are cointegrated. This shows that there is a stable long-term relationship between them and they move in one direction. This signals that though being segmented in the short run, banks use this differential in the long run to effect arbitrage operations, thus providing the cointegration relationship.

Sources of Providing Bank Reserves

Commercial banks have several sources of providing liquidity. In terms of assets, forex reserves are most commonly used. Big commercial banks

[4] The initiative of the BNB to publish commercial banks' balance sheets and income statements is laudable and deserves appreciation, but is not sufficient. The whole information collected by the BNB on a bank should be made public. Thus creditors of any bank will have equal access to information. This will also facilitate money market operations.

use unsecured deposits in the interbank market as a source of liquidity while small banks employ repo agreements. Maturing government securities are a source of liquidity due to the negative net issue reflecting a reduced budget deficit and domestic debt after currency board introduction. Similarly, but in the opposite direction, auctions for new government securities can be a channel of absorbing liquidity.

Inflows and outflows to and from the BNB are a major source of liquidity. They reflect daily revenue and expenditure on the cash service of budget-supported organizations. This is the so-called unconscious channel of monetary policy pursuit, extensively described by Nenovsky and Hristov (1999). It affects directly liquidity in the banking system. Although this effect is accidental, it is of systemic significance.

Therefore this channel should not be assumed as being capable of affecting money supply in any form whatsoever. On the contrary, our thesis is that creating rules for budget spending should restrict the impact of this channel of affecting liquidity. By way of early public announcing of the shocks on money supply caused by the impact of the cash execution of the budget transparency will be achieved which will allow commercial banks to anticipate the overall impact on money market liquidity. Better knowledge will help all participants to anticipate the impact of the shock.

Modeling Interest Rate Dynamics in the Interbank Deposit Market

The Data

Undoubtedly the best way of modeling interest rate dynamics in the interbank market is to use daily data.

One of the problems with daily data is that BNB has available information from daily balance sheets since early 2000 and this is a very short period for a statistical study. Therefore no information from BNB balance sheet has been used. Since banks base their behavior on statistics maintained for the purposes of minimum required reserves, in this study we use such data. It includes information on the amount of required reserves (*R*), reserves maintained in levs (*TRL*) and foreign currency (*TRV*), the average-weighted interest rate in the interbank money market (*I*), and the interest rates on repo agreements (*RR*) and on operations in unsecured deposits (*DR*).

As statistics on minimum required reserves requires reporting of their maintenance on holidays when the money market does not operate, the values of the effective interest rate for the preceding business day are used to report the values of the interest rate for such periods.

Data on LIBOR for the euro (*EL*) and the US dollar have a seven-day term and are derived from the Reuters database.

Bankservice supplied data on the number (*N*) and total amount of payments (*Q*) via BISERA.

The period of the sample is from May 1998 to early June 2000 and includes 761 observations.

Test for Integration and Lags

The integration test is the first step in processing time series, which enables us to choose an appropriate econometric model. We apply both tests, the Dickey – Fuller test and the Philips – Perron test, in order to achieve high assurance of the results obtained.

In line with theory the data series on bank reserves is stationary as the existing system of averaging minimum reserves warrants this. All the other series shown in Table 1 are also stationary. Nonstationarity occurs only in the exchange rate of the lev to the US dollar. Both tests (DF and PP) with first differences indicate first order integration of the exchange rate. Because of the nonstationarity of the US dollar exchange rate we will not use it in modeling the demand for bank reserves.

Stationarity of the data series used warrants valid results in applying the OLS and ARCH econometric models.

Table 1

TEST OF INTEGRATION OF TIME SERIES USED[5]

Variables	Dickey – Fuller Test		Philips – Perron Test		Integration and Lags	
Daily data	Levels	1Δ	Levels	1Δ	1	Lags
Q	-18.6		-15.03		0	3
A	-20.5		-24.5		0	3
P2	-14.93		-17.28		0	3
R	-4.06		-4.14		0	2
I	-3.93		-4.75		0	3
ER**	1.54	-26.13	1.52	26.11	1	0
Dif2	-3.49		-4.24		0	3
Dif1	-2.81		-3.45		0	3
TRL	-3.57		-3.69		0	3
TRV	-3.29*	-10.62*	-3.03*	-23.79*	0	4

* With trend and level: -3.9749 at 1%, -3.4180 at 5%, -3.1311 at 10%.
** The hypothesis for order stationarity can be assumed at 75.8% confidence probability.

[5] McKinnon's critical values for DF and PP tests – without trend: -3.4415 at 1%, -2.8657 at 5% and -2.5690 at 10%.

General Description of ARCH Models

The base of the model is the autoregressive conditional heteroskedasticity (ACRH) of the time series. The reason to choose this model is the fact that, according to Hamilton (1996), in this type of daily data the interest rate variance is different. In essence, the autoregressive conditional heteroskedasticity means that the model specifies not only the mean, but also the variance in the series, the latter being conditionally dependent on variance displayed in past periods. Engle (1982), later generalized as GARCH (generalized ARCH) by Bollerslev (1986), introduced the ARCH models to econometrics. ARCH and GARCH models are widely applied in the analysis and modeling of high-frequency financial series.

The general equation of the GARCH model with one lag is:

$$Y_t = a + Y_{t-1} + \varepsilon_t \tag{1}$$

$$\sigma_t^2 = \omega + \alpha\sigma_{t-1}^2 + \beta\varepsilon_{t-1}^2. \tag{2}$$

Equation (1) describes the behavior of the interest mean and equation (2) describes the behavior of the conditional variance of the mean. Conditional, because it refers to the whole set of information on the interest accessible till moment *T-1*. In these models the conditional variance is assumed not as a constant but as a variable whose values in *t* depend on the available information in the preceding period *t-1*. This model is applicable in studying interest rates because, as *Hamilton* points out (1996), interest dynamics follows a high level of heteroskedasticity.

Conditional variance σ_{t-1}^2 represents a GARCH component or projected variance in the penultimate period, and ε_t is an ARCH component and represents a change in the variance based on available information at the end of period *t-1*. The number of lags *t* in the conditional variance formula shows the duration of the impact of shocks on volatility.

GARCH models assume normal distribution of the conditional variance. This means that irrespective of the direction of the mean's movement volatility remains unchanged.

However, practice shows that there is a case where it is different depending on the direction of movement of the mean. For example, in high-frequency financial series movement of the price of a particular asset in a certain direction (most often downwards) is coupled with higher volatility. In modeling time series with asymmetrical behavior of the conditional variance TARCH (threshold autoregressive conditional heteroskedasticity) and EGARCH (exponential general autoregressive conditional heteroskedasticity) econometric models are used.

Glosten, L. R., R. Jagannathan and D. Runkle (1993) and Zakoian, J. M. (1990) introduced the TARCH model of variance independently of each other. The equation of conditional variance used in modeling is:

$$\sigma_t^2 = \omega + \alpha\varepsilon_{t-1}^2 + \gamma\varepsilon_{t-1}^2 d_{t-1} + \beta\sigma_{t-1}^2 .$$

Nelson (1991) proposes the original EGARCH model of behavior of the conditional variance. The variance equation in it is:

$$\log(\sigma_t^2) = \omega + \beta \log(\sigma_{t-1}^2) + \alpha\left|\frac{\varepsilon_{t-1}}{\sigma_{t-1}}\right| + \gamma\frac{\varepsilon_{t-1}}{\sigma_{t-1}} \ .$$

Hamilton (1996) uses this EGARCH model, slightly modified, in modeling the behavior of the conditional variance of federal funds rate. This prompted us to apply this approach to the modeling of the conditional variance of the function of the demand for bank reserves in Bulgaria.

Basic Models of the Demand for Bank Reserves

Demand for bank reserves denominated in levs

In modeling the demand for bank reserves in levs we follow the above-described theoretical model. The first variable used is the amount of bank reserves in the previous day. Thus we record the demand for reserves to satisfy required reserves or the martingale hypothesis in the dynamics of bank reserves. As simple testing of the significance of this relationship shows, in the first model in Table 2 over 90% of the value of daily average reserves is determined by their amount at the end of the previous day.

The test of the hypothesis of dependence of the demand for bank reserves on the number N of payments via BISERA indicates the existence of a statistically significant direct relationship (see the second model in Table 2) with a coefficient of elasticity at about 5%. The test for significance of the impact of the relative change in the interbank interest rate (the opportunity cost of maintaining minimum required reserves in levs) shows the theoretically assumed statistically significant inverse relationship with a coefficient of elasticity at 42% (third model). The last variable, independently tested in the fourth model, is the interest rate differential between the average interbank interest rate in levs and the average LIBOR for the euro. The hypothesis of existence of inverse relationship between bank reserve demand and the percentage change in the interest rate differential is confirmed.

The fifth model presents a generalized model of the demand for bank reserves in levs. An equation for variance modeling is used because after the

OLS[6] model was applied the LM test for autoregression in the residual value of the error was confirmed (see Table 4 in the appendices). This entailed the use of different versions of the ARCH models.

In modeling variance some of the variables in the equation of the mean began to lose some of their statistical significance and we had to include them in the equation of the conditional variance and then add variance itself in the equation of the mean. In other words, by including variance of demand in modeling the mean demand we check the hypothesis of the mean value being affected by the expected variance of demand.

To check the hypothesis we use a version of the ARCH-M (ARCH in the average value) model. This type of model is introduced by Engle (1987) and is used by Nautz (1998) in modeling the demand for bank reserves. The basic equation of the mean under ARCH-M using the standard deviation (σ) in modeling the mean under uncertainty is:

$$Y_t = x_t' \gamma + \sigma_t^2 \bar{\gamma} + \varepsilon_t$$

where

x' is vector of exogenous variables, which determine the behavior of the mean.

Results obtained from the application of this model did not confirm the hypothesis of a relationship between the average value of the demand for bank reserves and the expected variance or the expected standard deviation.

As we noted, Hamilton (1996) confirmed the existence of asymmetrical reaction of the expected variance to the direction of the impact of interbank market innovations in a similar study. This provoked us to test the hypothesis of asymmetrical impact on the demand for bank reserves using the available data.

To this end we used EGARCH model and assessed its efficiency by comparing the LogL values obtained from applying the ordinary ARCH model (see Table 2).

Sprindt and Hoffmeister (1998), Balduzzi (1993) and Robertds (1994) extensively describe dependence of variance on the day within the period of maintenance. It is higher in days coinciding with the end of the maintenance period, on Fridays and other days preceding holidays.

Based on the available information for the preceding and the current period market agents can form their preliminary expectations of variance on the respective day of the maintenance period.

[6] The method of least squares.

We use dummy variables in modeling the expected behavior of the variance in different days of the maintenance period. For example, *D1* to reflect the impact of the last day of the maintenance period on the expected volatility. According to Hamilton (1996), volatility should be higher at the end of the maintenance period. The dummy variable *D3* reflects business days preceding holidays, when volatility should be higher. *D4* reflects the first day of a new maintenance period, when volatility should be lower.

In addition to dummy variables in the equation of the conditional variance we include variables relating to payments via BISERA, their number and amount respectively. This should be done because, in our opinion, banks would expect greater volatility in the demand for bank reserves if payments on the respective day are active and *vice versa*. We should note that in period *t* banks have information only on the number and amount of their own payments.

Table 2

MODELS OF DEMAND FOR BANK RESERVES IN LEVS

Model	**I**	**II**	**III**	**IV**	**V**
	Mean modeling – Log(TRL)				
Level	0.47 (0.52)	12,2 (47,2)	13,3 (487)	12.6 (994)	0.16 (3.14)
LTRL(-1)	0.96 (98.4)				0.99 (241.2)
L(P)		0,05 (2.5)			
L(I)			-0.42 (-15.7)		
L(DIF1)				-0.17 (-5.68)	-0.007 (-7.5)
L(Q1)					-0.0005 (-2.92)
L(DIF1(-2))				-0.09 (-3.10)	

(continued)

(continued)

Conditional variance modeling					
C					-0.83 (-8.19)
ABS(RES)/SQR[GARCH](1, 1)					0.61 (13.2)
RES/SQR[GARCH](1, 1)					-0.16 (-5.59)
EGARCH(1)					0.82 (44.3)
LOG(Q1)					-0.23 (-9.9)
LOG(P1)					0.24 (6.41)
D3					3.55 (17.9)
D1					-0.44 (-2.1)
D4					-0.49 (-2.0)
Sample	Complete	Business days	Business days	Business days	Complete
R^2 adj.	0.93	0.01	0.32	0.45	0.93
DW	1.75	0.04	0.12	0.13	1.78
Loglikelihood	1120	85	184	240	1348

Results and Conclusions from Modeling Bank Reserve Dynamics Using Basic Models

Inclusion of the interbank interest rate in the overall model proved to be of lower statistical significance compared with the interest rate differential. This shows that banks model their demand giving preference to interest rate differential because this enables them to perform arbitrage between operations in the domestic and international money markets.

Existence of a lag in the conditional variance is indicative of the fast adaptation of the demand for bank reserves in lev terms to shocks external to the model. The effect of innovations on conditional variance is asymmetrical, which coincides with the conclusions of Hamilton (1996). In terms of dummy variables, *D3* (the days preceding holidays) had the strongest positive impact on conditional variance, which coincides with the conclusions of Hamilton (1996).

The test shows that dummy variables *D1*, *D3* and *D4* have statistically significant effects on expected variance. The effect of *D3* causes an increase in expected variance in the days preceding holidays. This result is consistent with the behavior of the conditional variance in other countries with similar institutional scheme of maintaining minimum required reserves. As far as the other two dummy variables *D*1 and *D*4 are concerned, they have little impact and in the opposite direction, contrary to the conclusions of Hamilton (1996). This can be explained by the fact that banks do not wait the last day to compensate their minimum required reserves, but achieve this earlier. Similarly banks disregard fulfillment of minimum required reserves in the beginning of a new maintenance period due to the long outstanding period during which they can offset the shortfall.

The variables reflecting active payment operations via BISERA (*Q1* and *P1*) indicate a statistically significant impact on the conditional variance. An increase in the number of payments causes an increase in the variance of the demand for reserves, while an increase in the total amount of payments effected through BISERA causes a decrease in the demand variance. The latter reflects the fact that the largest number of payments is effected to transfer revenues to budget accounts from commercial banks (which are agents on the cash basis execution of the budget) into the BNB. As in the previous days these funds have been received by agent banks on their current accounts with the BNB, they use them only to meet their minimum required reserves, keeping them until the day of transfer. Therefore on the transaction day to the BNB commercial banks do not look for additional bank reserves, which leads to a decrease in the aggregate demand in the banking system.

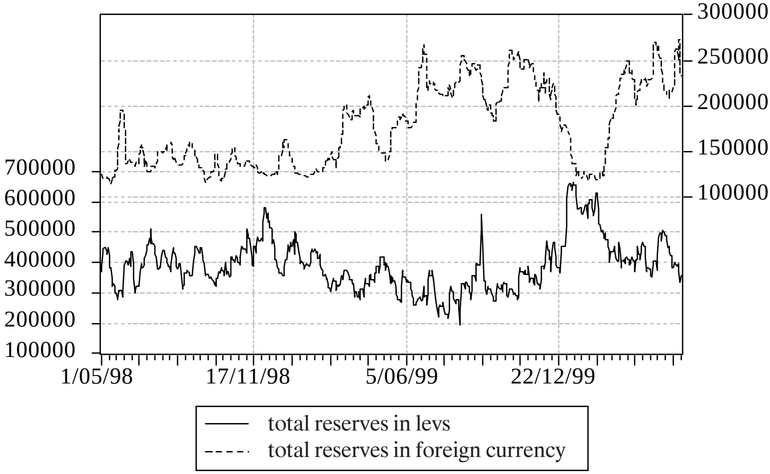
Demand for bank reserves denominated in foreign currency

Since bank reserves denominated only in levs are used in settlements, a transaction component of the demand for bank reserves denominated in foreign currency is absent. Therefore transaction components are not present in the function of demand for bank reserves.

Bank reserves denominated in foreign currency play the role of a liquidity source in case of necessity for a specific commercial bank. Therefore they represent liquidity buffer that can be used always when there is a shortfall in lev bank reserves. This assumes a negative correlation between reserves denominated in levs and reserves denominated in foreign currency (see Chart 1). Given the liquid role of bank reserves in foreign currency, to estimate their demand we will use the amount of bank reserves in levs at the end of the previous day TRL_{t-1}. We assume reverse relationship between the two variables:

$$R^d = f(TRL_{t-1}).$$

Chart 1



The second function of the reserves in foreign currency is that of a store of bank reserves' real value. By store of real value we mean minimizing the opportunity cost of maintaining noninterest-bearing reserves which has a two-sided effect: missed interest income and missed income due to devaluation of the lev/euro exchange rate to the US dollar. This suggests a direct positive relationship between demand for bank reserves in foreign currency and the exchange rate ER_t:

$$R_d = f(TRL_{t-1}, ER_t).$$

Since theory assumes existence of autocorrelation, in the function of the demand for reserves we also include reserves in foreign currency at the end of the previous day TRV_{t-1}:

$$R_d = f(TRL_{t-1}, ER_t , TRV_{t-1}).$$

To estimate the function of the demand for bank reserves in order to preserve their value we also add the logarithm of the interest rate differential between lev money market and the weekly LIBOR on deposits denominated in US dollars $DIF2_t$:

$$R_d = f(TRL_{t-1}, ER_t , TRV_{t-1}, DIF2_t).$$

Summarized results are shown in Table 3.

ARCH-LM test of the model presented in the fourth model of Table 3 does not show evidence of residual autocorrelation (see appendices).

Table 3

DEMAND FOR BANK RESERVES IN FOREIGN CURRENCY

Model	I	II	III	IV	V
		Log(TRV)			
Level	0.1 (1.79)	19.2 (37.4)	10.7 (163)	1.11 (7.51)	0.94 (7.96)
LTRL(-1)		-0.56 (-13.98)		-0.05 (-6.16)	-0.04 (7.54)
LTRV(-1)	0.99 215			0.95 (114.5)	0.96 (155)
L(ER)			2.27 (21.3)	0.14 (4.98)	0.09 (4.91)
L(DIF2)				0.006 (1.90)	
		Conditional variance modeling			
Level					0.0006 (14.97)
ARCH(1)					0.28 (10.02)
GARCH(1)					0.13 (3.45)
D4					-0.0007 (-16.54)
Sample	Complete	Complete	Complete	Complete	Complete
R2 adj.	0.98	0.2	0.37	0.99	0.99
DW	1.66	0.04	0.03	1.70	1.71
Loglikelihood	1533	48	138	1559	1599

Results and Conclusions from Modeling Bank Reserve Dynamics Using ARCH, EGARCH and TARCH Models

Modeling of the average value of bank reserves denominated in foreign currency, including all independent variables, shows that the amount of reserves at the end of the preceding day and the exchange rate have the strongest impact on the mean. The interest rate differential has no statistical significance together with the other variables. The amount of reserves denominated in levs is with a reverse sign, which coincides with the conclusion that banks use a portion of their reserves in foreign currency as a liquidity buffer.

In modeling expected variance the test for asymmetrical impact of innovations by using EGARCH and TARCH did not confirm. Therefore the

ARCH (1,1) model used yielded the best result. The dummy variable *D*4, which reflects the beginning of the new maintenance period, shows that expected variance of forex reserves decreases in this model. The other dummy variables used in the model of demand for bank reserves denominated in levs have no statistical significance.

Sources of Shocks on Bank Reserve Supply

Constructed models of the demand for bank reserves in levs and foreign currency enable us to estimate banks' expected reserves on day t of the maintenance period using the information available to them at the end of that period. This can be based on checking the models by using the redundant variable test, which rejects the hypothesis of the availability of such information. Therefore the difference between demand for bank reserves and their actually reported value in the model gives an idea of the amount and dynamics of unexpected shocks.

The possibility of exerting unexpected shocks on commercial bank reserves is one of the institutional peculiarities of the Bulgarian monetary system. The most typical unexpected shock on supply is the spending policy of the Ministry of Finance. Although within a month the Ministry of Finance injects and withdraws liquidity, there is neither a clear calendar of the amounts of these payments nor any form of preliminary announcing of these payments. As most of them are effected through the settlement system, banks get information on amounts received on their accounts on the next working day.

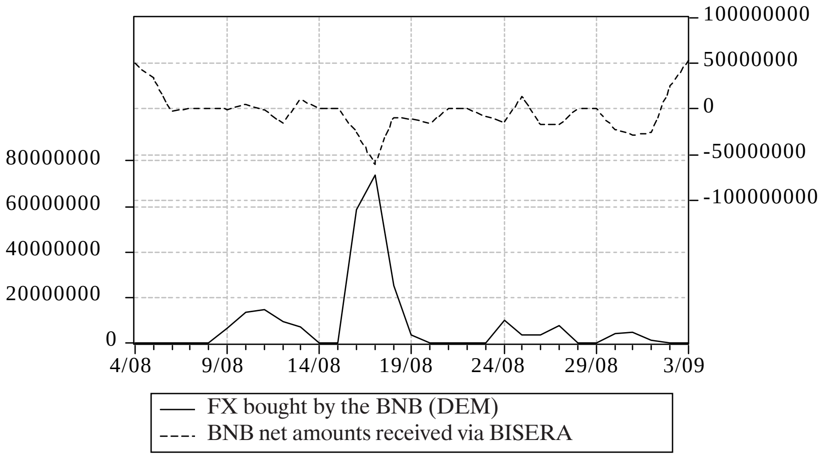
Decisions on daily allocation of amounts are taken exclusively discretionary by the finance ministry administration and are not subject to any rules and regulations. This creates an unexpected positive shock on liquidity in the banking system, which has an immediate impact on interest rate variance.

In the middle of each calendar month (on the 15th and 16th day of the month) tax offices transfer budgetary revenues into the BNB. This exposes the banking system to an unexpected liquidity shock. The size of the shock depends on the amount of revenues from taxpayers. The presence of such unexpected shocks on bank reserves explains the deviation between bank reserve demand and supply, as observed in the model. The size of this deviation for the period of the sample is 7%. The impact of unexpected shocks is accommodated through forex sales by the BNB. These are effected within the standard spot value date and therefore banks are adapting to the shock till the day after tomorrow by reducing their available reserves (see Chart 2). This causes a contraction in supply and hence affects the behavior of the interest rate in the interbank market, which is the main reason for its short-term deviation from the interest rate on euro-denominated deposits abroad.

Variance in the supply of bank reserves in the conditions of lacking alternative sources of liquidity is undesirable, because it heightens volatility of the interbank market interest rate in period $t+1$. This makes banks cautious in using it as a source of liquidity regulation. Arbitrage is possible only within the $t+2$ horizon due to the fact that the BNB effects spot forex operations. Higher volatility of interest rates in the interbank market is one of the reasons for the larger margin between deposit and lending rates. Saunders and Hausman (1998) have come to a similar conclusion in studying the high margin between deposits and credits in Mexico.

Chart 2

PAYMENTS VIA BISERA AND BNB FOREX OPERATIONS (AUGUST 1999)



Possibilities of Introducing More Flexible Solutions To Lower Interest Rate Volatility

Interest rate volatility in the Bulgarian interbank market (23.2%), measured through the ratio between the standard deviation and the mean for the period of the sample, is higher than that of the seven-day LIBOR for the euro (18.9%). Therefore banks in Bulgaria assume higher interest risk borrowing from the domestic interbank market than in the interbank market for eurodeposits in London.

To reduce interest rate volatility and hence limit the risk of investing and borrowing in the Bulgarian interbank market, the impact of shocks on the supply of bank reserves need to be offset. This can be achieved in several ways.

First, commercial banks should receive daily comprehensive information on the amounts the Ministry of Finance withdraws and injects into the banking system for the purposes of cash budget execution. Asymmetrical behavior of expected variance shows that variance increases with withdrawal of liquidity. This means that lack of information on the amount of liquidity withdrawn from banks creates higher uncertainty in commercial banks' demand for money. Therefore information on projected amounts to be withdrawn by the MF should be announced.

The second possibility of reducing interest rate volatility is to shorten the value date of BNB operations for forex purchases. Thus the banking system will be capable of flexibly responding to unexpected supply shocks by accommodating demand.

The third possibility is accelerated infrastructure integration of the Bulgarian payment system into TARGET to help avoid limitations on arbitrage between the two money markets imposed by the difference in value dates between payments in lev and euro.

The fourth possibility is suggested by Nenovsky and Hristov (1998) and refers to rechanneling and depositing budget resources from the BNB to commercial banks. It has already been resolved to centralize MF funds at the BNB, the direct result of which is twice as high interest rate volatility in the interbank market: for example, from 0.487 for the period from May 1998 till June 1999 before the centralization of budget funds it reached 0.89 for the period June 1999 – June 2000 after almost complete centralization.

The fifth possibility of constraining variance of demand for bank reserves is by providing the banks with information on their incoming payments from BISERA.

Conclusion

In this study we present an empirical model of the demand for bank reserves denominated in levs and foreign currency in Bulgaria for the period May 1998 – May 2000. In the course of the study the role of bank reserves is presented as a liquidity buffer absorbing part of the impact of shocks on the supply of bank reserves. Major shocks on the supply of bank reserves have been identified as well as the sources of their offsetting.

The proposed model shows that demand for bank reserves denominated in levs is dependent on demand in the preceding period, on the interest rate differential between domestic money market and the London interbank euro deposit market, as well as on the amount of payments made through BISERA. Expected variance of demand for bank reserves in levs is modeled using the asymmetrical EGARCH (1.1) model. It includes dummy variables reflecting the different level of volatility in the demand for bank reserves in different days of the maintenance period. The major reason for asymmetrical variance is the different impact of positive and negative shocks on the supply of bank reserves in levs.

Based on the difference between demand and supply the impact of shocks is identified, which are caused by transfers from and to the BNB associated with state budget cash execution.

In this regard and with a view to limiting the impact of asymmetrical shocks on volatility of the demand for bank reserves and hence on the volatility of interbank interest rate, several steps have been proposed, including pursuit of a policy of transparency by the MF. This policy should include preliminary announcing of expected liquidity to be withdrawn from the banking system in certain critical moments for the revenue in the state budget. Solutions for avoiding higher variance in demand for reserves by undertaking other practical measures, including improving the infrastructure of the money market and the payment system, have also been recommended.

As a starting point for future study the model of the demand for bank reserves can be used for projecting any possible influence that the reduction in bank reserves could have on the volatility of the interest rate in the interbank money market.

Appendices

Table 4

DEPENDENCE BETWEEN THE NUMBER OF BISERA PAYMENTS AND NET AMOUNTS RECEIVED AT BNB

Dependent Variable: B

Method: Least Squares

Date: 07/03/00 Time: 11:00

Sample(adjusted): 4/05/1998 19/05/2000 IF D5=0

Included observations: 513 after adjusting endpoints

Variable	Coefficient	Std. error	t-statistic	Prob.
C	1852449.	675771.0	2.741237	0.0063
P	28.02809	10.24797	2.734990	0.0065
R-squared	0.014427	Mean dependent var		3489792.
Adjusted R-squared	0.012498	S.D. dependent var		7144831.
S.E. of regression	7100041.	Akaike info criterion		34.39299
Sum squared resid	2.58E+16	Schwarz criterion		34.40952
Log likelihood	-8819.802	F-statistic		7.480169
Durbin-Watson stat	1.055176	Prob (F-statistic)		0.006455

Table 5

ERROR AUTOCORRELATION TEST IN MODEL V OF TABLE 2

ARCH Test

F-statistic	3.517827	Probability	0.061096
Obs*R-squared	3.510825	Probability	0.060969

Test Equation:

Dependent Variable: STD_RESID^2

Method: Least Squares

Date: 07/04/00 Time: 17:00

Sample (adjusted): 3/05/1998 1/06/2000

Included observations: 761 after adjusting endpoints

Variable	Coefficient	Std. error	t-statistic	Prob.
C	0.932257	0.085745	10.87249	0.0000
STD_RESID^2(-1)	0.067926	0.036216	1.875587	0.0611
R-squared	0.004613	Mean dependent var		1.000215
Adjusted R-squared	0.003302	S.D. dependent var		2.147351
S.E. of regression	2.143803	Akaike info criterion		4.365665
Sum squared resid	3488.282	Schwarz criterion		4.377845
Log likelihood	-1659.135	F-statistic		3.517827
Durbin-Watson stat	1.986478	Prob(F-statistic)		0.061096

Table 6

ERROR AUTOCORRELATION TEST IN MODEL IV OF TABLE 3

ARCH Test

F-statistic	6.84E-05	Probability	0.993405
Obs*R-squared	6.86E-05	Probability	0.993394

Test Equation:

Dependent Variable: STD_RESID^2

Method: Least Squares

Date: 07/04/00 Time: 16:52

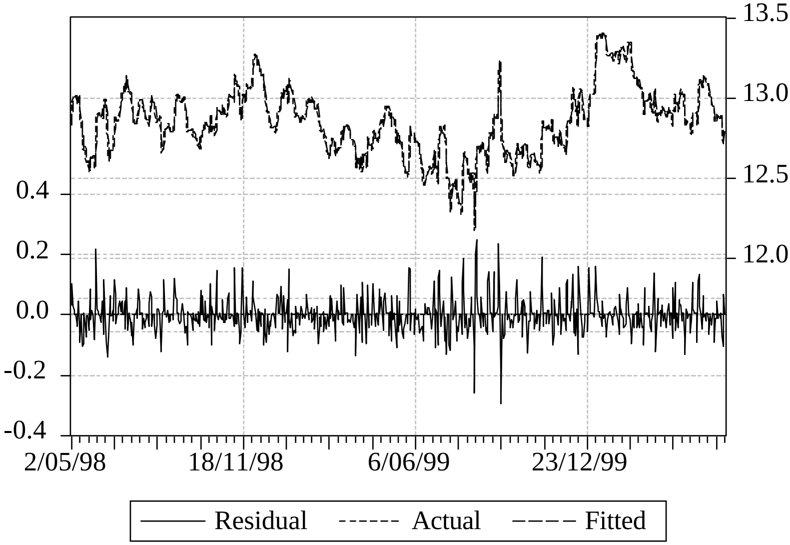
Sample(adjusted): 3/05/1998 1/06/2000

Included observations: 761 after adjusting endpoints

Variable	Coefficient	Std. error	t-statistic	Prob.
C	1.000742	0.109843	9.110651	0.0000
STD_RESID^2(-1)	0.000300	0.036299	0.008269	0.9934
R-squared	0.000000	Mean dependent var		1.001042
Adjusted R-squared	-0.001317	S.D. dependent var		2.857604
S.E. of regression	2.859485	Akaike info criterion		4.941785
Sum squared resid	6206.082	Schwarz criterion		4.953965
Log likelihood	-1878.349	F-statistic		6.84E-05
Durbin-Watson stat	1.999220	Prob(F-statistic)		0.993405

Chart 3

ESTIMATED DEMAND FOR BANK RESERVES IN LEVS AND RESIDUAL ERROR



References

Arrau, P., J. De Gregorio, C. Reinhart, P. Wickham (1991) Financial Innovation and Money Demand in Developing Countries: Assessing the Role of Financial Innovation, *Working Paper 91/45*, International Monetary Fund.

Astley, M. and A. Haldane (1995) Money as an Indicator, *Bank of England Working Paper* No. 35.

Balduzzi, P., G. Bertola, S. Foresi (1993) A Model of Target Changes and the Term Structure of Interest Rates, *National Bureau of Economic Research Working Paper* No. 4347, April 1993.

Bartolini, L., G. Bertola, A. Prati (1999) Day-To-Day Monetary Policy and the Volatility of the Federal Funds Interest Rate, http://www.ny.frb.org/rmaghome/economist/bartolini/day2day.pdf.

Bartolini, L., G. Bertola, A. Prati (2000) Banks' Reserve Management, Transaction Costs, and the Timing of Federal Reserve Intervention, http://www.ny.frb.org/rmaghome/economist/bartolini/tcosts.pdf.

Bernanke, B., A. Blinder (1992) The Federal Funds Rate and the Channels of Monetary Transmission, *American Economic Review*, September 1992, pp. 901 – 921.

Blishev, G. (1997) Reliability of the Exchange Rate as a Monetary Target in an Unoptimal Currency Area-Macedonian Case, *Working Paper No. 5*, National Bank of the Republic of Macedonia.

BIS Report (2000) Committee on Payment and Settlement Systems, Core Principles for Systematically Important Payment Systems. Report of the Task Force on Payment System Principles and Practices.

Bollerslev, Tim (1986) Generalized Autoregressive Conditional Heteroskedasticity, *Journal of Econometrics* 31, pp. 307 – 327.

Breedon, F. J. and P. G. Fisher (1993) M0: Causes and Consequences, *Bank of England Working Paper* No. 20.

Calvo and Vegh (1992) Currency Substitution in Developing Countries, *IMF Working Paper* 92/40, May, 1992.

Campbell, J. Y. (1987) Money Announcement, the Demand for Bank Reserves and the Behavior of the Federal Funds Rate within the Statement Week, *Journal of Money, Credit and Banking*, Vol. 19, No. 1, pp. 56 – 67.

Chung, C. F.-, M. W- Hung (2000) A General Model for Short-term Interest Rates, *Applied Economics,* 32, pp. 111 – 121.

Clinton, K. (1997) Implementation of Monetary Policy in a Regime with Zero Reserve Requirements, *Bank of Canada Working Paper* 97 – 8.

Clouse, J. A. and D. W. Elmendorf (1997) Declining Required Reserves and the Volatility of the Federal Funds Rate, *Board of Governors of the Federal Reserve System*.

Clouse, J. A., J. P. Dow (1999) Fixed Costs and the Behavior of the Federal Funds Rate, *Journal of Banking and Finance,* 23, pp. 1015 – 1029.

Cothren, R. and R. Waud (1994) On the Optimality if Reserve Requirements, *Journal of Money, Credit, and Banking*, Vol. 26, No. 4, pp. 827 – 838.

Cuddington (1983) Currency Substitution: A Critical Survey from a Portfolio Balance Perspective, *Proceedings of Sixth West Coast Academic/Federal Reserve Economic Research Seminar*, November 1982, Published by the Federal Reserve Bank of San Francisco, November 1983.

Di Giorgio, G. (1999) Financial Development and Reserve Requirements, *Journal Banking and Finance,* 23, pp. 1031 – 1041.

Dyl, E. A., J. R. Hoffmeister (1985) Efficiency and Volatility in the Federal Funds Market, *Journal of Banks Research* 15 (Winter 1985), pp. 234 – 239.

Engle, Robert F. (1982) Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of U. K. Inflation, *Econometrica*, 50, pp. 987 – 1008.

Engle, Robert F., David M. Lilien, and Russell P. Robins (1987) Estimating Time Varying Risk Premia in the Term Structure: The ARCH-M Model, *Econometrica* 55, pp. 91 – 407.

Escude, G. (1999) Coping with External Shocks under a Currency Board, *Presentation in the Center for Central Banking Studies*, Bank of England, April 19 – 23, London.

Fama, E. F. (1984) The Information in the Term Structure, *Journal of Financial Economics,* 13, pp. 509 – 528.

Fama, E. F., R. R. Bliss (1987) The Information in Long-maturity Forward Rates, *American Economic Review,* 77, pp. 680 – 692.

Feinman, J. (1993) Estimating the Open Market Desk's Daily Reaction Function, *Journal of Money, Credit and Banking*, Vol. 25, Issue 2 (May, 1993), pp. 231 – 247.

Freixas, X., B. Parigi and J. Rochet (1999) Systemic Risk, Interbank Relations and Liquidity Provision by the Central Bank, *CEPR Discussion Paper* 2325.

Furfane, C. (1998) Interbank Payments and the Daily Federal Funds Rate, *Board of Governors of the Federal Reserve System*.

Glosten, L. R., R. Jagannathan and D. Runkle (1993) On the Relation between the Expected Value and the Volatility of the Normal Excess Return on Stocks, *Journal of Finance*, 48, pp. 1779 – 1801.

Giovannini and Turtelboom (1992) Currency Substitution, *NBER Working Paper* 4332

Griffiths, M. D., D. B. Winters (1995) Day-of-the Week Effects in Federal Funds Rates: Further Empirical Findings, *Journal of Banking and Finance,* 19, pp. 1265 – 1284.

Hafer, R. W. and D. Jansen (1991) The Demand for Money in the United States: Evidence from Cointegration Tests, *Journal of Money, Credit and Banking*, Vol. 23, No. 2, pp. 155 – 168.

Hamilton, J. (1996) The Daily Market for Federal Funds, *Journal of Political Economy*, Vol. 104, No. 1, pp. 26 – 56.

Hamilton, J. (1997a) Measuring the Liquidity Effect, *The American Economic Review*, Vol. 87, No. 1, pp. 80 – 97.

Hamilton, J. (1997b) The Supply and Demand for Federal Reserve Deposits, *UCSD Discussion Paper, pp*. 97 – 27.

Hardouvelis, G. A. (1988) The Predictive Power of the Term Structure During Recent Monetary Regimes, *Journal of Finance,* 43, pp. 553 – 566.

Hardy, D. C. (1993) Reserve Requirements and Monetary Management: An Introduction, *IMF Working Paper* 93/35.

Hanke, S., K. Schuler (1994) Currency Boards for Developing Countries: a Handbook (An International Center for Economic Growth Publications), *ICS Press*, San Francisco, California.

Henkel, T., A. Ize, A. Kovanen (1999) Central Banking without Central Bank Money, *IMF Working Paper* 99/92.

Ho, T. and A. Saunders (1985) A Micro Model of the Federal Funds Market, *The Journal of Finance*, Vol. XL, No. 3.

Janssen, N. (1998) The Demand for M0 in the United Kingdom Reconsidered: Some Specification Issues, *Bank of England Working Paper,* No. 83.

Main Features of the Regulatory Framework of the Argentine Financial System (2000) Banco Central de la Republica Argentina, http://www.bcra.gov.ar/english/e_english.htm.

Mankiw, N. G., Miron J. A. (1986) The Changing Behavior of the Term Structure of Interest Rates, *Quarterly Journal of Economics,* 101, pp. 211 – 228.

Mishkin, F. (1988) The Information in the Term Structure: Some Further Results, *Journal of Applied Econometrics,* 3, pp. 307 – 314.

Nautz, D. (1998) Banks' Demand for Reserves When Future Monetary Policy is Uncertain, *Journal of Monetary Economics*, Vol. 42, pp. 161 – 183.

Nelson, Daniel B. (1991) Conditional Heteroskedasticity in Asset Returns: A New Approach, *Econometrica*, 59, pp. 347 – 370.

Nenovsky, N. (1998) Is Money Supply in Bulgaria Controllable?, *Economic Thought*, No. 2, pp. 139 – 162.

Nenovsky, N., K. Hristov (1998) Financial Repression and Credit Rationing under Currency Board Arrangement for Bulgaria, *Discussion Papers* No. 2, Bulgarian National Bank, 1998.

Nenovsky, N., K. Hristov (1999) Monetary Policy under the Currency Board: the Case of Bulgaria, paper presented at International Workshop on Currency Boards: Convertibility, Liquidity Management and Exit, Hong Kong Baptist University, October 1999, web site: http://www.hkbu.edu.hk/~econ/99wsNenovsky.PDF.

Nenovsky, N., K. Hristov (2000) Currency Circulation after Currency Board Introduction in Bulgaria (Transactions Demand, Hoarding, Shadow Economy), *Discussion Papers* No. 3, Bulgarian National Bank, 1998.

Pool, W. (1968) Commercial Bank Reserve Management in a Stochastic Model: Implications for Monetary Policy, *Journal of Finance,* 23, pp. 769 – 791.

Rudebusch, G. (1995) Federal Reserve Interest Rate Targeting, Rational Expectation, and the Term Structure, *Journal of Monetary Economics* 35, pp. 245 – 274.

Saunders A., R. Hausman (1998) The Determinants of Bank Interest Rate Margins in Mexico's Post-Privatization Period (1992 –1995), *Inter-American Development Bank Working Paper Series* R-333.

Sellon, G. H., S. E. Weiner (1996) Monetary Policy without Reserve Requirements: Analytical Issues, *Federal Reserve Bank of Kansas City Economic Review*, 4th Quarter.

Shiller, R. J., J. Y. Campbell, K. L. Schoenholtz (1983) Forward Rates and Future Policy: Interpreting the Term Structure of Interest Rates, *Broodings Papers Econ. Activit*, No. 1, pp. 173 – 217.

Spind, P. A., J. R. Hofmeister (1988) The Micromechanics of the Federal Funds Market: Implications for Day-of-the-week Effects in Funds Rate Variability, *Journal of Financial and Quantitative Analysis*, 23:4, pp. 401 – 416.

Stigum, M. L. (1990) The Money Market, 3-rd ed., *New York: Irwin Professional*.

Zakoian, J. M. (1990) Threshold Heteroskedastic Models, manuscript, CREST, INSEE, Paris.

DISCUSSION PAPERS

DP/1/1998 **The First Year of the Currency Board in Bulgaria**
Victor Yotzov, Nikolay Nenovsky, Kalin Hristov, Iva Petrova, Boris Petrov

DP/2/1998 **Financial Repression and Credit Rationing under Currency Board Arrangement for Bulgaria**
Nikolay Nenovsky, Kalin Hristov

DP/3/1999 **Investment Incentives in Bulgaria: Assessment of the Net Tax Effect on the State Budget**
Dobrislav Dobrev, Boyko Tzenov, Peter Dobrev, John Ayerst

DP/4/1999 **Two Approaches to Fixed Exchange Rate Crises**
Nikolay Nenovsky, Kalin Hristov, Boris Petrov

DP/5/1999 **Monetary Sector Modeling in Bulgaria, 1913 – 1945**
Nikolay Nenovsky, Boris Petrov

DP/6/1999 **The Role of a Currency Board in Financial Crises: The Case of Bulgaria**
Roumen Avramov

DP/7/1999 **The Bulgarian Financial Crisis of 1996 – 1997**
Zdravko Balyozov

DP/8/1999 **The Economic Philosophy of Friedrich Hayek (The Centenary of his Birth)**
Nikolay Nenovsky

DP/9/1999 **The Currency Board in Bulgaria: Design, Peculiarities and Management of Foreign Exchange Cover**
Dobrislav Dobrev

DP/10/1999 **Monetary Regimes and the Real Economy (Empirical Tests before and after the Introduction of the Currency Board in Bulgaria)**
Nikolay Nenovsky, Kalin Hristov

DP/11/1999 **The Currency Board in Bulgaria: The First Two Years**
Jeffrey B. Miller

DP/12/2000 **Fundamentals in Bulgarian Brady Bonds: Price Dynamics**
Nina Budina, Tzvetan Manchev

DP/13/2000 **Currency Circulation after Currency Board Introduction in Bulgaria (Transactions Demand, Hoarding, Shadow Economy)**
Nikolay Nenovsky, Kalin Hristov

DP/16/2000 **A Possible Approach to Simulate Macroeconomic Development of Bulgaria**
Victor Yotzov