Anatomy of Liquidity Management

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The management of liquidity poses a major challenge to the conduct of monetary policy in an environment of financial liberalisation. Recent research has attempted to assess liquidity conditions in the market for bank reserves in terms of central bank balance sheet flows. This paper constructs the concepts of autonomous liquidity (AL) and discretionary liquidity (DL) in the Indian context and finds that there is a systemic response in the Reserve Bank's discretionary operations to offset 'autonomous' shocks to the market for bank reserves.

Introduction

The contemporary conduct of monetary policy has assumed a market orientation the world over, following financial liberalisation. A major challenge for any monetary authority today is to tune liquidity conditions in the financial markets consistent with the overall macroeconomic objectives, although monetary policy operating procedures vary according to the relative efficacy of the respective transmission channels. The key issue before central bank liquidity management is then to assess the demand in the market for bank reserves and initiate policy action in consonance with a targeted quantum or price of liquidity – or in many instances, a combination of both.

India, like several emerging market economies, embarked on a programme of financial liberalisation in the 1990s. This necessitated changes in the monetary policy framework to accommodate the resultant shifts in emphasis on monetary policy transmission channels and therefore, the information content of policy indicators (RBI, 1998). The contemporaneous evolution of inter-linked money, government securities and foreign exchange markets improved the efficiency of monetary management, but also posed challenges arising out of the possibilities of rapid contagion (Jalan, 2000). The need to ensure orderly conditions in the financial markets has intensified the quest for an effective liquidity assessment framework.

Recent research has attempted to assess liquidity by partitioning bank balances with the central bank in terms of central bank balance sheet flows emanating from discretionary policy liquidity operations and other “autonomous” factors (Borio, 1998; ECB 2001; Schaechter *et al*, 2001). This paper examines their applicability in the Indian context. Section I introduces the conceptual framework. Section II attempts to construct such measures from the Reserve Bank balance sheet. Section III reviews the recent Indian experience. Finally, Section IV sets out some concluding observations.

Section I
The Framework

The market for bank reserves evolves largely through the dynamic interaction between the central bank and the banks, which are the principal financial intermediaries in an economy and the most important participants in financial markets. Autonomous liquidity (AL) aggregates the primary liquidity available to banks, stemming from regular central banking functions as the

currency issuing authority and banker to banks and the government. In a stylised central bank balance sheet, this could comprise the claims on the Government and the rest of the world (RoW) netted for leakages from the banking system, such as currency. From Table 1,

$$AL = A1 + A3 – L1 – L3 \quad \ldots(1)$$

Discretionary liquidity (DL), the balance primary money flowing to the banking system, arises out of the central bank's money market operations and captures the reaction of the monetary authority to autonomous changes in market liquidity,

$$DL = A2 \quad \ldots(2)$$

Table 1 : A Stylised Central Bank Balance Sheet

	Component	Source
	1	2
L1.	Currency	A1. Credit to Government
L2.	Bank Reserves (=R)	A2. Credit to Banks
L3.	Net Other Liabilities	A3. Net Foreign Assets
	Total Liabilities	Total Assets

so that the supply of reserves (R^s) works out to

$$R^s = AL + DL \quad \ldots(3)$$

Central banks can - and often do - predict AL and the demand for bank reserves (R^d) (conventionally decomposed into required reserves (RR) and the demand for excess reserves (ER^d), inclusive of settlement balances, *etc.*). The net liquidity (NL), prior to central bank liquidity operations, could then be estimated, *ex ante*, as

$$NL = R^d (= RR + ER^d) - AL \quad ...(4)$$

If the central bank decides to maintain the existing liquidity conditions, it could bridge NL with DL (Bindseil, 2001). Alternately, interest rates would change to clear the market for bank reserves. For example, interest rates would harden (soften) if the central bank chose to 'short' (over-supply) the market. The realised liquidity in the market for bank reserves is simply the balances banks maintain with the central bank, in an *ex post* sense,

$$R = RR + ER = AL + DL = L2 \quad \ldots(5)$$

Employing the format of the central bank balance sheet presented in Table 1, suppose the Government draws Rs.100 as credit from the central bank to pay salaries to its employees who hold half the income in cash (Table 2). For the banking system, this results in a supply of funds of the order of Rs.50, since the currency component is a direct claim of the public on the Reserve Bank and therefore, does not impact bank liquidity (Table 3).

Table 2 : Autonomous and Discretionary Liquidity in a Central Bank Balance Sheet

	Component Flow	Rupees	Source Flow	Rupees
	1	2	3	4
L1.	Currency	50	A1. Credit to Government	100
L2.	Bank Reserves (=R)	0	A2. Credit to Banks	-50
L3.	Net Other Liabilities		A3. Net Foreign Assets	
	Total Liabilities	50	Total Assets	50

Memo Item

Δ AL = A1+A3-L1-L3 = 100-50=50 Δ NL = _ R^d (=0, by assumption) -
Δ DL = A2 = -50 Δ AL= 0-50 =(-) 50
Δ R = L2 = ΔAL + ΔDL = 50-50 = 0

Thus, AL amounts to Rs.50[1]. Assuming that the deposit is exempt from reserve requirements (RR) (without loss of generality) and that there is no change in the demand for settlement balances (*i.e.*, implicitly assuming that there is no mismatch between deposit mobilisation and credit offtake), there is, thus, an excess supply of bank reserves of Rs. 50. If the central bank contracts credit to banks, *i.e.*, DL, by the entire Rs. 50, there would be no change in liquidity (and hence interest rates) in the market for bank reserves. Note that in case of an incremental credit offtake of say, Rs. 50, which is fully held in cash, the AL generated by the Government's salary disbursement would be fully absorbed and therefore, the maintenance of existing liquidity conditions would not warrant central bank action. Secondly, in case of capital flows, of say Rs. 50, AL increases to Rs.100 and necessitates a withdrawal of Rs. 50 through DL to keep liquidity conditions intact. This discretionary action of the central bank to suck out liquidity can even take the form of imposing stricter reserve requirements.

Table 3 : Balance Sheet of the Banking System

	Source Flow	Rupees	Use Flow	Rupees
	1	2	3	4
1.	Deposits	50	1. Bank Reserves	
2.	Credit from Central Bank	-50	2. Bank Credit	
	Total	0	Total	0

The supply of bank reserves can be, alternatively, decomposed into borrowed reserves (BR), - essentially standing facilities available at the central bank rate - and non-borrowed reserves (NBR). The critical point of difference is that while the AL-DL classification bifurcates bank reserves on the basis of the central bank's control over its balance sheet in general, the BR-NBR categorisation splits it in terms of the commercial banks' ability to access primary money on own account (Table 4).

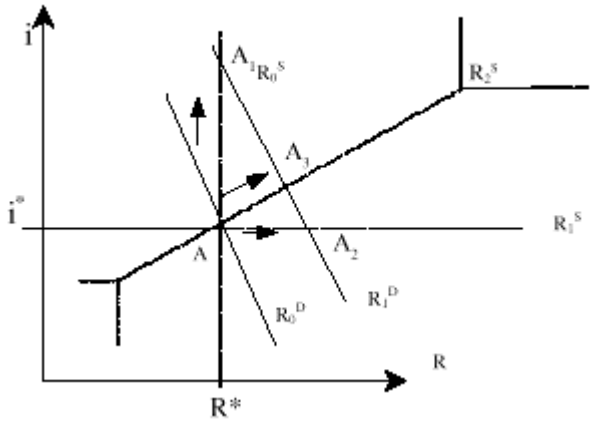
Table 4 : Analysis of Supply of Bank Reserves

Central Bank Action	Exogenous to liquidity operations of		Accounted in			
	Central bank	Banks	AL	DL	BR	NBR

1	2	3	4	5	6	7
Monetisation of deficit	√	√	√			√
Foreign exchange operations	√	√	√			√
Cash issuance	√	√	√			√
Open market operations	√ (Offtake)	√ (Amount/price)		√		√
Standing facilities	√ (Utilisation)	√ (limit & price)		√	√	

The AL-DL framework is intuitively more appealing from the practitioners' perspective in case of central banks which i) combine internal debt and monetary management, ii) perform development functions, and iii) operate in economies in which cash remains a major medium of transaction. The critical importance of the AL-DL construct lies in the fact that it is operable in case of both quantity and interest rate operating targets as well as the intermediate regimes (Chart 1).

Chart 1 : The Market for Bank Reserves



In case of quantum targets, central banks could supply a pre-determined level of reserves (R^*), so that the interest rate i^* would clear the market, given the reserves demand curve R_0^D. In case of a shift of reserves demand from R_0^D to R_1^D, interest rates would have to rise along R_0^S to A_1 for market clearing, if the central bank sticks to the same quantum of reserves. In case of interest rate targets, central banks would adjust the liquidity at A_2 along the desired trajectory say, R_1^S, so that the interest rate is maintained at i^*, and the supply of liquidity accommodates the shift in reserves demand. In many economies, especially the emerging markets, both quantity and rate transmission channels usually operate side by side, and so central bank policy spans both the quantum as well as price of the supply of bank reserves along R_2^S, inducing a shift in the market equilibrium from A to A_3. Only in the extreme cases, need the central bank give up one target for the other.

Recognising that discretionary operations often encompass changes in the policy rates, the initial framework can be extended to a simple model of the market for bank reserves in which the

central bank uses the entire array of instruments – quantum and rate - at its disposal for stabilising the price of liquidity. This is set out in Appendix I. In this scenario, the market interest rates depend on the autonomous liquidity generated and the discretionary operations of the central bank, including changes in policy rates. Given that i) an increase (decrease) in the quantum of discretionary liquidity softens (hardens) the market interest rate and that ii) an increase (decrease) in the price of discretionary liquidity similarly raises (lowers) the market interest rate, it is possible for the central bank to maintain orderly conditions in the financial markets through a policy of countervailing changes in the price and quantum of liquidity. This could, for example, include calibrated counterbalancing of i) changes in the reserve requirements and the policy rate, ii) open market operations (OMO) and the policy rate and iii) reserve requirements and open market operations. The common "sufficient" condition, requiring that the market interest rate sensitivity of discretionary operations should be greater than that of autonomous factors, is derived in the Appendix I. This underscores the potency of the central bank's discretionary use of policy instruments in fine-tuning liquidity. Central banks with a credible reputation would, thus, be able to influence market conditions with the signalling effect (which is consistent from the market perspective) reinforcing the liquidity impact of policy measures.

Cross-Country Experiences

Most central banks adjust market liquidity pro-actively in pursuance of either a quantum target or a price target, or a mix of both (Borio, 2001; Table 5). The most common operating procedure appears to be a two-step process of i) working out the net demand for bank reserves (through a forecast of AL), and then ii) undertaking discretionary operations, as determined by the estimated liquidity effect to maintain interest rates consistent with macroeconomic objectives (Ugolini 2002; and Appendix 2). The European Central Bank (ECB), for example, manages liquidity conditions through a policy mix of OMO (including repos), marginal refinance facilities (both deposit and lending facilities) and changes in the policy rates based on estimates of the autonomous liquidity[2] of the banking system. The US Federal Reserve targets the inter-bank federal funds rate essentially through OMO guided by its estimates of the demand of bank reserves and the technical factors[3] affecting bank reserves. The Bank of Japan (BoJ) targets the outstanding balance of the current accounts with it through money market operations which are based on its projections of the autonomous sources of bank reserves[4]. Operating procedures of monetary policy in emerging market economies are also coalescing into similar strategies of liquidity management (Kamin *et al,* 1998). A number of central banks, including the BoJ and the ECB, publish their forecasts of autonomous factors.

Table 5 : Operating Procedures Of Liquidity Management

Country	Operating Target	AL forecast horizon, if any	Frequency of Market Operations	Key Instruments of Discretionary Liquidity					
				Quantum				Rate	Others
				CRR	OMO	Repo	Standing Facilities		
Brazil	Overnight inter-bank rate	1 month	Daily	√	√	√			Financial assis-tance for liquidity
ECB		1 month	Once a week *plus* once addi-tionally a month, on a regular basis		√	√	√	Policy rate	

Indonesia	Monetary base and REER	1 week	Daily	√	√	√		Discount rate	Moral suasion
Japan	Bank reserves	1 day	More than one per day		√	√	√		
Malaysia	Intervention rates, inter-bank rates	1 day	Daily	√	√	√			Selective credit and moral suasion
Mexico		1 day	Daily		√	√			
South Africa	Repurchase rate	1 to 6 months	Daily	√	√	√	√	Repo rate	Foreign currency swaps
UK		1 day to 13 weeks	Daily		√	√		Repo rate	
USA	Federal Funds Rate	2 weeks	Typically one per day		√	√	√	Discount rate	

Section II
The Indian Context

The autonomous (ΔAL) and discretionary (ΔDL) liquidity flow measures adapt the standard literature with the caveat that the policy measures are "discretionary" and not "rule bound" (RBI 1999; RBI 2000a,b; RBI 2001a; RBI 2002a,b,c).

The ΔAL, in the Indian case, could be defined as the sum of the following:

i) the Reserve Bank's primary monetisation of the fiscal deficit, through a) ways and means advances (WMA), netted for the Government balances, b) net primary subscriptions to Treasury Bills, dated securities and non-marketable securities (such as *ad hoc* T-Bills funded into non-transferable special securities without any maturity, *etc.*) and c) holdings of rupee coins, (*i.e.*, the change in the net RBI credit to the Government, adjusted for secondary market operations);
ii) incremental claims on banks (other than credit to commercial banks);
iii) incremental claims on the commercial sector (other than credit to primary dealers (PDs), typically driven by development objectives;
iv) incremental net foreign assets;
v) *less* incremental liabilities (other than scheduled commercial bank and government balances with the RBI), which constitute a leakage from the banking system, comprising a) cash, governed by demand for transactions balances which, in turn, depends on the level of economic activity and on seasonal factors, such as harvests and festivals, b) balances maintained by co-operative banks, financial institutions and foreign central banks, and c) net non-monetary liabilities, mainly constituting the Reserve Bank's claims on itself.

The ΔDL, in quantum terms, could be the sum of i) the Reserve Bank's secondary market operations in the government securities market in the form of OMO (including repo), incremental credit to ii) commercial banks and iii) PDs at a pre-determined interest rate netted for iv) changes in reserve requirements.

The construction of _AL and _DL measures is judgemental and at best time-specific, especially in view of the on-going transition from direct to indirect instruments[5] of monetary control

(Appendix III). For instance, the Reserve Bank often accepts private placement and devolvement of Treasury Bills/government securities auctions during tight liquidity and offloads them to the market when conditions ease. As the Reserve Bank is entrusted with the dual responsibility of internal debt and monetary management, the first leg is classified as _AL and the second leg as _DL. Secondly, the critical difficulty in case of policy instruments such as OMO and standing facilities is that while the Reserve Bank often determines either the price or the potential quantum and, at times, both, the response really depends on banks and PDs. In this case, the precise utilisation levels, are viewed as a function of the "enabling" conditions, in both price and quantity terms, set by the Reserve Bank and are hence classified as _DL. Finally, while there usually exists an inverse relationship between bank reserves and short-term interest rates (*i.e.*, the liquidity effect), it is necessary to adjust bank balances with the Reserve Bank for changes in required reserves in a regime of frequent CRR changes. While the impact of CRR changes is actually dynamic and best captured by constructing a series for adjusted bank reserves, the first round release of resources on account of CRR changes is taken in _DL as a first approximation in absense of a time series on required reserves (RBI, 2001a).

Section III
The Indian Experience

The Reserve Bank faces the monetary policy dilemma of funding both the Government and the commercial sector at reasonable cost without stoking inflationary pressures and at the same time maintaining exchange rate stability (RBI, 1998a). The Reserve Bank announced a multiple indicator approach in April 1998 to accord itself the necessary flexibility for drawing policy perspectives in the face of financial liberalisation. The array of indirect instruments of monetary control has been simultaneously expanded to ensure orderly conditions in the money and foreign exchange markets.

Table 6 : AL and DL - Select Operational Cases

Autono-Mous Factors	AL	Likely Liquidity Operations					Adjusted Bank Reserves	Monetary Conditions	
		CRR	OMO (inc. repos)	Standing Facilities	DL	Bank Rate		Interest Rates	Exchange Rates (Re/US$)
1	2	3	4	5	6	7	8	9	10
Cash demand	↓		↑	↑	↑		↔	↔	↔
Government demand	↑		↓		↓		↔	↔	↔
Capital outflows	↓	↑	↓@	↑#	↓#	↑	↓	↑	↓
On reversal,	↔	↓	↑$	↓*	↑*	↓	↑	↓	↔

@ Especially higher cost repos. # At higher cost. $ At higher prices. * At lower cost.

The liquidity management is now carried out by OMO (including repo operations) supplemented by direct interest rate signals through changes in the policy rates such as the bank rate and the

Liquidity Adjustment Facility (LAF) rates, besides the traditional reserve requirements and standing facilities (Vasudevan, 1998; Reddy, 2001, 2002; Table 6). It is in this *milieu* of multiple objectives, indicators and instruments that partitioning bank reserves on the basis of liquidity management provides a useful tool for analysing central bank operations.

There are four stylised facts. First, ΔDL, more or less, offsets ΔAL[6] (Chart 2 and Table 7). Secondly, the Reserve Bank has operated through different instruments[7] - quantum and rate – at different points of time to ensure orderly conditions in the money markets.

Chart 2 : AL & DL Flows and the Call Rate

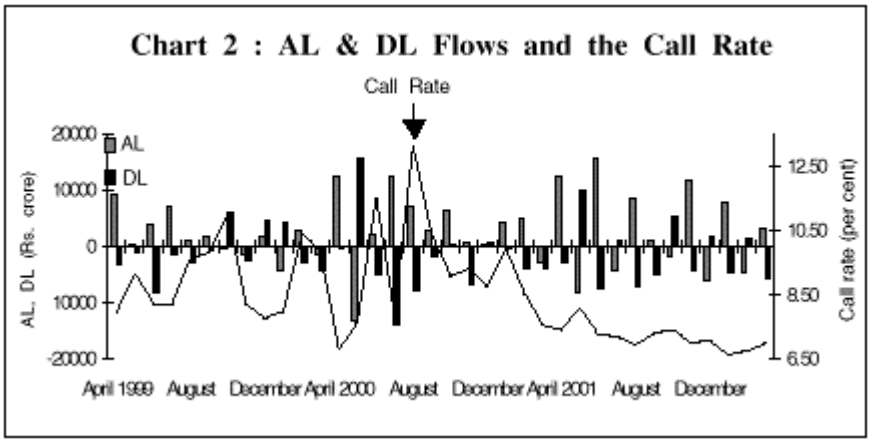
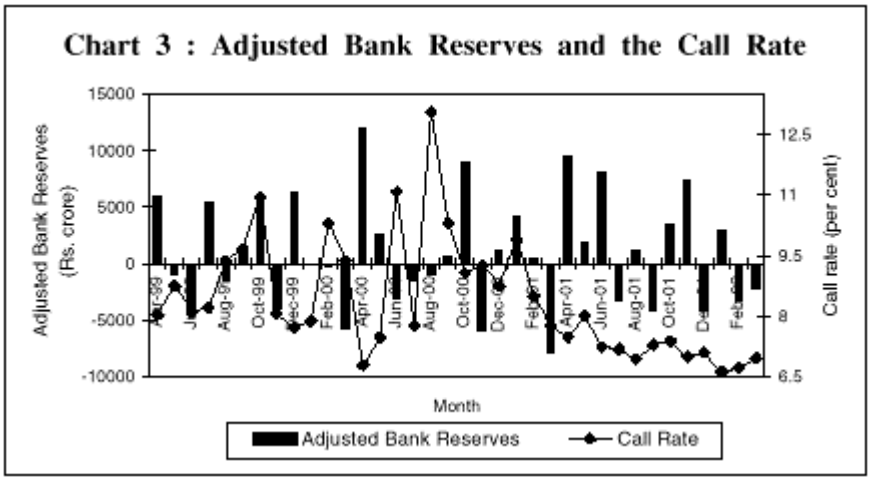


Table 7 : Measures of Volatility

Variable		Monthly Flow Average (Rs. crore)	Co-efficient of Variation
1		2	3
AL		2,502	2.5
Currency in circulation		2,010	2.2
Monetisation of the Centre's Fiscal Deficit		2,223	3.1
Net foreign assets of the RBI		3,507	1.1
DL		-1,510	-3.8
Memo Item:			
Variable/Co-efficient of Variation	1999-2000	2000-01	2001-02
Adjusted bank reserves (R^a)	0.06	0.07	0.07
Call rate	0.12	0.19	0.05
Exchange rate (Re/US $)	0.01	0.02	0.01

Thirdly, there has been a gradual reduction in the volatility in the inter-bank call rates, without any appreciable change in the variability of bank reserves, adjusted for first-round CRR changes (Chart 3). Finally, ΔAL (and consequently ΔDL) is heavily influenced by seasonalities in cash demand and government payments.



The Anecdotal Evidence

The recent monetary experience is best analysed in terms of phases of easy and tight monetary conditions (Chart 4 and Table 8). The fiscal year 1999-2000 provides a good starting point since the present operating procedure of liquidity management was, by and large, in place. The foreign exchange market saw excess demand conditions by early 1999-2000 emanating from a mix of domestic uncertainties, border tensions and bulk crude oil imports, depleting the foreign exchange reserves. This gap was funded by refinance drawals by commercial banks and PDs at the Bank Rate, which pushed up inter-bank call rates above central bank lending rate. The Reserve Bank continued its policy of private placements/ devolvements combined with subsequent OMO to deflect the pressures of Government borrowing. As a result, while ΔAL amounted to Rs. 14,228 crore, DL declined by Rs. 8,354 crore during June-October 1999 to constrain average monthly change in bank reserves (adjusted for CRR changes) (ΔR^a) to Rs.1,175 crore. During this period, the discretionary operations were essentially quantum based, in the absence of any change in the policy rates.

Capital flows revived after November, adding to the foreign exchange reserves. Given seasonal cash demand, AL increased by Rs. 12,603 crore during November 1999 to April 2000.

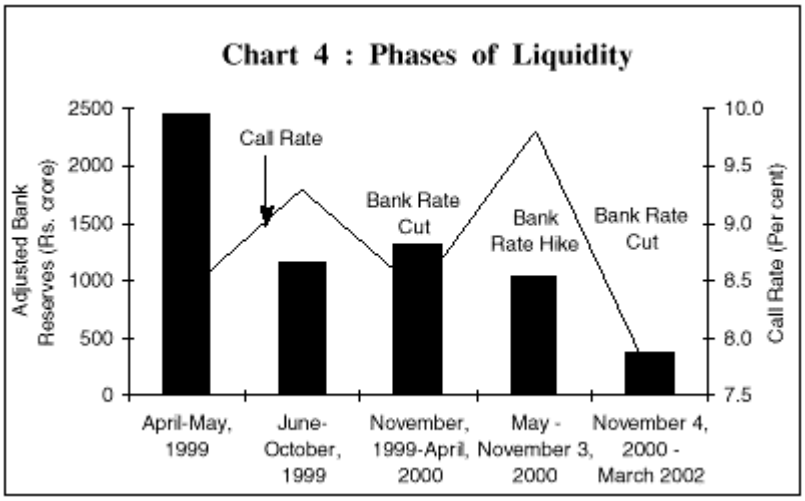


Table 8 : AL and DL – Phase-wise Analysis

Variable	April-May 1999	June-October 1999	November 1999-April 2000	May-November 3, 2000	November 4, 2000-March 2002
1	2	3	4	5	6
1. AL (1+2+3+4-5-6-7-8)	**9,184**	**14,228**	**12,603**	**7,804**	**44,103**
1.1 Net RBI credit to Government (other than OMO)	16,528	15,789	12,890	21,378	15,198
1.1.1 Primary subscription to dated GoI securities	16,000	11,000	0	30,149	26,679
1.2 RBI's claims on banks (other than credit to commercial banks)	-1,064	1,060	-224	383	337
1.3 RBI credit to commercial sector (other than PDs)	-36	-267	94	-367	-1,121
1.4 RBI's net foreign assets (NFA)	9,250	599	23,171	-4,581	97,811
1.4.1 net of revaluation	9,047	-2,893	27,554	-10,545	89,760
1.5 RBI's net non-monetary liabilities	1,678	4,757	6,329	2,554	28,735
1.6 Notes in circulation	14,894	-2,119	16,440	6,421	37,063
1.7 "Other" deposits with the RBI	-1,138	30	98	-262	-151
1.8 Bankers' deposits with the RBI (other than commercial banks)	61	285	462	296	2,475
2. DL (1+2+3+4)	**-4,234**	**-8,354**	**-4,722**	**-1,040**	**-37,613**
2.1 Open Market Operations	-11,301	-12,385	-12,749	-5,815	-47,717
2.1.1 Repo operations#	702	256	-1,984	0	-4,022
2.2 RBI's credit to commercial banks	2,066	2,382	-2,274	820	-2,272
2.3 RBI's credit to primary dealers	1,751	1,649	-3,155	4,155	-4,224
2.4 Release of resources through changes in CRR on NDTL of commercial banks	3,250	0	13,456	-200	16,600
3. Bank Reserves (adjusted for CRR) (R^a) (1+2 = 3.1+2.4)	**4,950**	**5,875**	**7,881**	**6,763**	**6,491**
3.1 Commercial bank deposits with the RBI	1,700	5,875	-5,575	6,963	-10,109
Memo item					

Average Inter-bank Call Rate	8.4	9.3	8.4	9.8	7.7

: Pertains to the LAF since June 2000.

The Reserve Bank eased monetary conditions, reducing the CRR in November 1999 and April 2000 and cutting the Bank Rate and the fixed repo rate effective April 1, 2000, to ease average call rates to 8.4 per cent. The surplus liquidity enabled banks and PDs to redeem their drawals from the Reserve Bank and revived interest in gilts, reducing DL by Rs. 4,722 crore. The average monthly _R^a amounted to Rs. 1,313 crore.

The foreign exchange market again saw excess demand pressures due to an increase in the oil import bill and the drying up of capital inflows, draining the Reserve Bank's foreign exchange reserves. The Reserve Bank initially conducted high-cost reverse repos under the newly-introduced LAF to bridge the liquidity gap and at the same time, stabilise the foreign exchange market. As the rupee continued to depreciate, the Reserve Bank raised the Bank Rate and the CRR and halved the refinance facilities available to banks on July 21, 2000. The Reserve Bank accepted private placements/devolvements of government paper (Rs. 20,151 crore during end-July-November 3) and simultaneously conducted aggressive repo operations (averaging Rs. 9,267 crore during August-October 2000) at attractive interest rates (14.5 per cent on August 14). During May-November 3, 2000, ΔAL worked out to be Rs. 7,804 crore while DL declined by Rs. 1,040 crore, on a point to point basis, limiting average ΔR^a to about Rs. 1,000 crore. The adjustment of liquidity was reinforced by strong interest rate signals, especially in terms of sharp changes in LAF repo rates.

Capital flows revived in November 2000, initially with the proceeds of India Millennium Deposits (IMDs), followed by strong portfolio inflows, resulting in an accretion of Rs. 89,760 crore (adjusted for revaluation) to the Reserve Bank's foreign currency assets between November 2000 and March 2002, enabling the Reserve Bank to ease monetary conditions pulling the average inter-bank call rates down to 7.7 per cent. During November 4, 2000-March 2002, _AL amounted to Rs. 44,103 crore while DL was tightened by Rs. 37,613 crore. As a result, average monthly ΔR^a amounted to about Rs. 400 crore.

An Empirical Exercise

We examine the dynamic inter-relationships among ΔAL, ΔDL and the changes in the call money rate (i_{mr}), through an unrestricted vector auto regression (VAR) model, over the period April 1996 - March 2002. The exercise has been undertaken in two steps. First, the monthly interaction between ΔAL and ΔDL has been examined along with the policy rate (i_{pr}), proxied by the Bank Rate, as exogenous, in Model 1. Second, the interaction between ΔR^a and changes in the call money rate (Δi_{mr}) has been examined along with Δi_{pr} and a dummy representing the South-East Asian crisis as exogenous in Models 2 (on monthly basis) and 3 (on weekly basis). We follow the standard VAR methodology of model estimation, block-causality, impulse response and variance decomposition.

The underlying variables were first examined for stationarity with the lag length chosen by the appropriate model selection, *viz.*, Akaike Information (AIC) and Schwarz Bayesian (SBC) criteria. In the monthly data, all the series were found to be stationary at levels both in terms of

DF and ADF tests (Table 9). In the weekly data, except for the call money rate, which is stationary at levels, all other series were found to be stationary at first-differences, *i.e.*, I(1).

We first test the causality between ΔAL and ΔDL (Table 10). It will be noted that the x^2-tests, which measure the statistical significance of lags of other variables in predicting the left-hand side variables, in addition to own lagged variables, are equivalent to Granger (1969) causality involving non-stationary variables in a VAR framework.

Table 9 : Unit Root Tests

Variable	Monthly Models I and II		Weekly Model III	
	Without Trend	With Trend	Without Trend	With Trend
1	2	3	4	5
ΔAL	-3.56 (4)	-3.80 (4)		
ΔDL	-3.52 (4)	-4.13 (4)		
R^a	-5.59 (10)	-5.59 (10)	-0.91 (1)	-9.73 (1)
I_{mr}	-5.25 (1)	-5.25 (1)	-8.87 (1)	-9.62 (1)
I_{pr}	-6.41 (2)	-6.37 (2)	-1.28 (1)	-2.88 (1)

Note: Based on Akaike Information Criterion (AIC). In case of the monthly models, the 95% critical value for the ADF statistic is –2.9023 for the regression without a trend and –3.4730 with a trend. In case of weekly data, the 95% critical value for the ADF statistic is –2.8710 for the regression without a trend and –3.4258 with a trend both at levels and first differences.

Table 10 : Test of Granger's Block Causality in a VAR Framework

	Null Hypothesis		Test Statistic *x*2	Accept/ Reject Null Hypothesis	Inference
1			2	3	4
I.	ΔAL does not Granger cause	ΔDL	8.10*	Reject	ΔAL Granger
	ΔDL does not Granger cause	ΔAL	1.91	Accept	causes ΔDL
II.	ΔR^a does not Granger cause	Δimr	5.42**	Reject	Bi-directional
	Δi_{mr} does not Granger cause	ΔR^a	8.69*	Reject	causality
III.	ΔR^a does not Granger cause	Δi_{mr}	16.6*	Reject	ΔR^a Granger
	Δi_{mr} does not Granger cause	ΔR^a	2.37	Accept	causes Δi_{mr}

Note : Models 1-2 and 3 are estimated with 12 and 4 lags of the endogenous variables, respectively.

* Significant at 1 per cent level. ** Significant at 5 per cent level.

As expected, ΔAL causes ΔDL, without evidence of reverse causation, which is consistent with previous research (RBI, 2001). Note that the computed $\_^2$ test-statistic for the null hypothesis of no-causation running from ΔAL to ΔDL is highly significant at 1 per cent level.

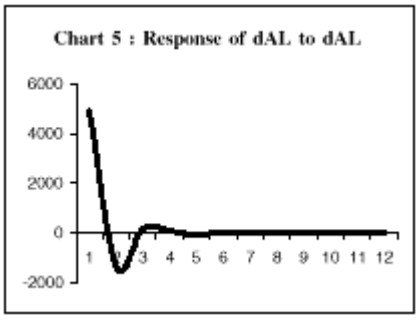
We then turn to the causal relationship between market interest rates (i_{mr}) and adjusted bank reserves (R^a) to extend the existing research. We find that there exists bi-directional causality

between ΔR^a and $\Delta\ i_{mr}$ in terms of monthly data in Model II. An empirical verification of the liquidity effect in the Indian context is subject to a number of limitations of the data. For example, while the liquidity numbers are point-to-point flows between the monthly last reporting Fridays, the call money rate is taken as the weighted average lending rate of the month. Thus, in as much ΔR^a affects Δi_{mr} , intra-month Δi_{mr} influences the monthly ΔR^a[8]. It is difficult to match the periodicity between the two series since i) time series data on daily bank reserves are not available and ii) it would be inappropriate to work with point call data since call rates used to fall to very low levels on reporting Fridays earlier. To reduce the gaps in the information content of the data, an exercise was also conducted on a weekly basis. In this case, a strong block Granger causality running from ΔR^a to Δi_{mr} is evident, while at the same time, the causality running from Δi_{mr} to ΔR^a has been rejected. The i_{pr} is taken as an exogenous variable and its presence in the model has been vindicated by a significant x^2 statistic.

We used the unrestricted VAR model for analysing the impulse responses and forecast error variance in each of the three cases. In each equation, iterations are made till 12 lag periods by imposing a one-standard deviation shock to each variable in a generalised impulse response approach. This has the advantage of circumventing the problem of the dependence of the orthogonalised impulse responses on the ordering of the variables in the VAR (Koop *et al*, 1996).

In Model 1, in terms of impulse response, the response of ΔDL to ΔAL is immediate and pronounced in the first and second months, although the tendency to react continues up to 5-6 months (Charts 5-8). On the other hand, in Model II, the response of Δi_{mr} to ΔR^a is immediate and more pronounced with the impact lasting up to 8-9 months (Charts 9-12). In Model III, the response of Δi_{mr} to ΔR^a is similarly immediate and strong with the effect persisting for 8-10 weeks (Charts 13-16).

In terms of variance decomposition, in the Model I, about one-third of the total variation in _DL is due to the innovations in ΔAL. Similarly, about half of the total variation in Δi_{mr} is due to the innovations in ΔR^a in the monthly data. In terms of weekly data, almost the total variation in i_{mr} is due to the innovations in ΔR^a



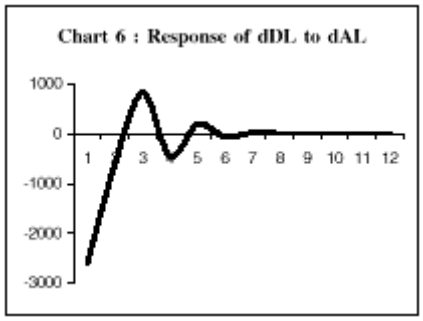


Chart 7 : Response of dAL to dDL

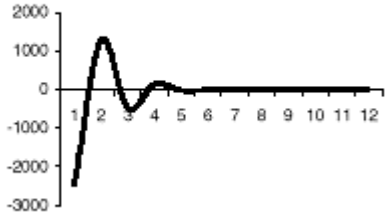


Chart 8 : Response of dDL to dDL

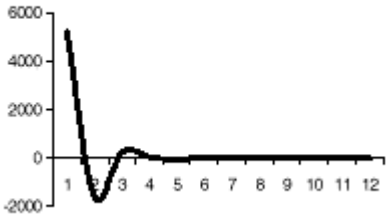


Chart 9 : Response of dR^{a} to dR^{a} (Monthly)

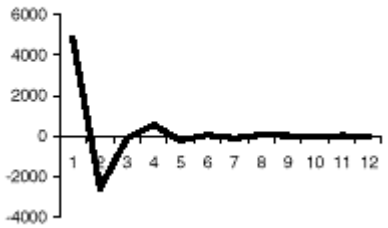


Chart 10 : Response of di_{ar} to dR^{a} (Monthly)

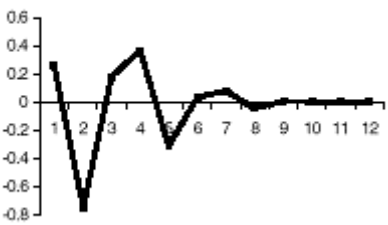


Chart 11 : Response of dR^{a} to di_{ar} (Monthly)

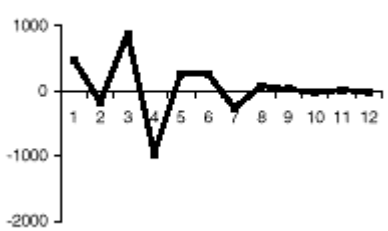


Chart 12 : Response of di_{ar} to di_{ar} (Monthly)

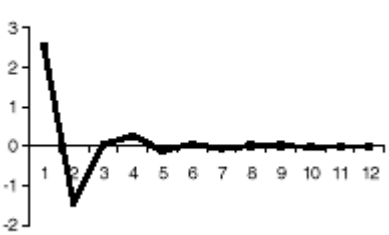


Chart 13 : Response of dR^{a} to dR^{a} (Weekly)

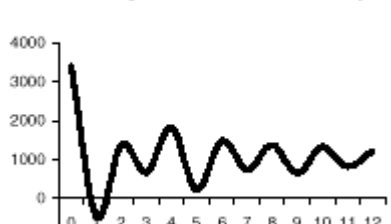
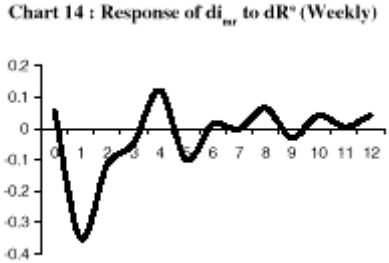
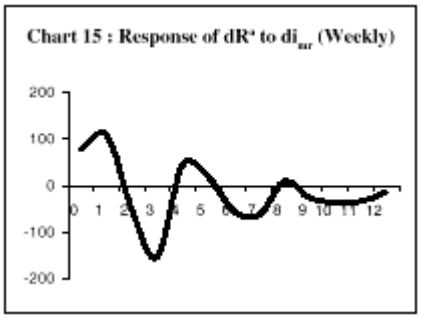
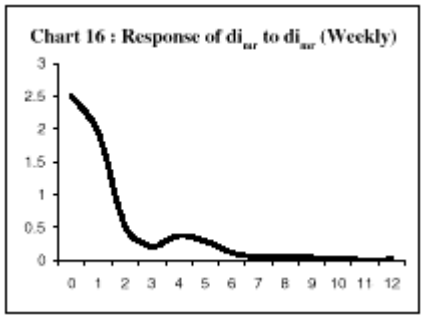


Chart 14 : Response of di_{ar} to dR^{a} (Weekly)







Conclusion

The management of liquidity in financial markets has emerged as a key policy issue in central banking. Given the large size of the fiscal deficit, sudden switches in capital flows and the seasonal character of cash demand, the Reserve Bank steers short-term liquidity conditions by a policy mix of adjustments in market liquidity through changes in reserve requirements, standing facilities and open market operations, reinforced by interest rate signals *via* changes in policy rates. This paper simply formalises this natural partition of sources of primary liquidity into the emerging reserve concepts of autonomous and discretionary liquidity. Given the empirical result that changes in bank reserves impact short-term interest rates, especially in the short run, we believe that the AL-DL dissection provides a reasonably good analytical framework for mapping the interaction of the central bank and participant banks in the market for bank reserves. This is buttressed by the fact that DL is empirically found to capture the policy response to the autonomous factors in the AL.

Further research could essentially proceed in two directions. First, there is a need to forecast autonomous liquidity. Second, it may be apposite to explore the impact of combinations of policy instruments on the stability of liquidity conditions to evolve useful feedback rules for monetary policy formulation. Empirical work, beyond the present modest attempt, is constrained by the shifts in the relationship between the money market rates and the instruments of DL, such as, refinance and repo operations, as a result of frequent changes in regulations in respect of average reserve requirements, on the one hand, and the lack of an acceptable representative policy rate in view of the infrequent changes in the Bank Rate and the intermittent character of repo auctions, especially in the pre-LAF years, on the other. These limitations of quantification, natural in transition, are likely to be ironed out with the evolution of the LAF as a principal operating instrument of monetary policy and the recent CRR stipulation of a daily minimum maintenance of 80 per cent of required reserves for commercial banks.

Notes

1. Following the Reddy Working Group, we divide the economy into six sectors, *viz.*, households (A), the Reserve Bank (B), the banking system in India (C), other financial corporations (D), general government (E) and the non-financial commercial sector (F), which interact within themselves and with the rest of the world (RoW) sector. It may be useful to work out the numerical example through the sectoral balance sheets of the economy, including the Government and the commercial sector, which comprises the other agents of the domestic economy. In case of the Government, the monetisation of the deficit to fund employees' salaries expands the balance sheet by Rs.100, generating an AL of a like amount in the first instance (Tables 2 and 11).

Table 11 : Balance Sheet of the Government Sector

Income Flow	Rupees	Expenditure Flow	Rupees
1	2	3	4
1. Credit from the Central Bank	100	1. Salaries	100
Total	100	Total	100

The net impact on AL, however, depends on the public demand for cash, which is a leakage from the banking system. In this case, since the commercial sector splits the salary evenly into cash and bank deposits, net AL increases by Rs.50 (Tables 3 and 12). It is useful to mention that if there was an increase in the public's demand for currency, irrespective of the Government's salary disbursement, there would have been a drainage of liquidity from the banking system as deposits would have been drawn down and been substituted for by currency.

Table 12 : Balance Sheet of the Commercial Sector

Income Flow	Rupees		Expenditure Flow	Rupees
1	2	3		4
1. Salaries	100	1.	Currency with the Public	50
2. Bank Credit to Commercial Sector		2.	Deposits	50
				100
Total	100		Total	

2. Defined as the sum of the liquidity-injecting factors such as the purchases of net foreign assets by the Eurosystem, netted for liquidity-absorbing factors such as issuance of bank notes in circulation, government deposits with the Eurosystem and other factors (net) The ECB has published weekly forecasts of autonomous factors since June 2001, with a view to providing the counter-party public and private credit institutions in the Eurosystem a reliable basis for assessing its allotment decisions in variable tender auctions for central bank support.

3. Includes shifts in cash demand, size of treasury balances at Federal Reserve Banks and the volume of the Federal Reserve float.

4. Includes net issuance of bank notes and changes in treasury funds. The Bank of Japan releases projections of sources of changes in current account balances with it and market operations a day in advance.

5. For instance, the 14-day Treasury Bills (introduced June 1997) emerged as a key instrument for mopping up surplus liquidity generated by capital inflows during the first half of 1997-98 because they were more attractive than repos. In the latter half of the year, when external pressures on account of the South-Asian crisis warranted monetary tightening, the Reserve Bank raised the repo rates but left the 14-day T-Bill rates unchanged since the Government borrowing programme had already been completed (RBI, 1998a). The EPW Research Foundation adjusts the autonomous liquidity for Treasury Bill auctions in its monthly money market review in the Economic and Political Weekly.

6. The empirical test of the strategy of the AL-DL framework should ideally involve a verification of the relationship between the market liquidity gap (*i.e.*, net liquidity in (4)) and discretionary operations. The computation of net liquidity, however, is difficult given the lack of data on required reserves (or net demand and time liabilities relevant for CRR) necessary for a forecast of the demand for bank reserves (R^d). While this is undoubtedly a limitation, the difference may not be as material given the secular trend in long-run NDTL growth and adjustment of bank reserves for changes in CRR.

7. For instance, the Reserve Bank has adjusted liquidity (*i.e.*, rejected bids) 143 times and adjusted rates 20

times in the operation of the 1-day auctions under the LAF between June 2000-March 2002.

8. For instance, once the Reserve Bank tightened monetary policy on January 16, 1998, in the wake of the South-Asian crisis, inter-bank call rates shot up from 6 per cent on the reporting Friday of January 16, 1998 to 30 per cent per cent on January 17 and 70 per cent on January 24 before returning to 7 per cent on the next reporting Friday on January 30.

References

Bindseil, Ulrich (2001): "Central Bank Forecasts of Liquidity Factors: Quality, Publication and the Control of the Overnight Rate", *ECB Working Paper*, No. 70.

Borio, Claudio E.V. (1997): "The Implementation of Monetary Policy in Industrialised Countries", *BIS Economic Papers*, No. 47.

Borio, Claudio E.V. (2001): "A hundred ways to skin a cat: comparing monetary policy operating procedures in the United States, Japan and the euro area", *BIS Policy Paper*, No. 9.

European Central Bank (2001): *The Monetary Policy of the European Central Bank.*

Granger, C.W.J. (1969): "Investigating Causal Relations by Econometric Models and Cross-Spectoral Models", *Econometrica*, 37.

Jalan, Bimal (2000): "Finance and Development – Which Way Now?", *RBI Bulletin*, February.

Kamin, Steven, Philip Turner and Jozef Van't Dack (1998): "The Transmission Mechanism of Monetary Policy in Emerging Market Economies: An Overview", *BIS Policy Paper*, No. 3.

Koop, G., M.H. Pesaran and S.M. Potter (1996): "Impulse Response Analysis in NonLinear Multivariate Models", *Journal of Econometrics*, 74.

Reddy, Y.V. (2001): "Developments in Monetary Policy and Financial Markets", *RBI Bulletin*, May.

Reddy, Y.V. (2002): "Parameters of Monetary Policy in India", *RBI Bulletin*, February.

Reserve Bank of India (1998): *Report of the Working Group on Money Supply: Analytics and Methodology of Compilation* (Chairman: Dr. Y.V. Reddy), June.

Reserve Bank of India (1998a): *Annual Report*.

Reserve Bank of India (1999): *Annual Report*.

Reserve Bank of India (2000a): *Macroeconomic and Monetary Developments*.

Reserve Bank of India (2000b): *Annual Report*.

Reserve Bank of India (2000c): *Report on Currency and Finance*.

Reserve Bank of India (2001a): *Annual Report*.

Reserve Bank of India (2001b): *Report on Currency and Finance*.

Reserve Bank of India (2002a): *Monetary and Credit Policy Statement 2002-03*. Reserve Bank of India (2002b): *A Short-term Liquidity Forecasting Model for India*. Reserve Bank of India (2002c): *Annual Report*.

Schaechter, Andrea (2001): "Implementation of Monetary Policy and the Central Bank's Balance Sheet", *IMF Working Paper*, No. 149.

Schaechter, Andrea *et al* (2001): "Forecasting Liquidity", *IMF Working Paper*.

Ugolini, Peiro (2002): "Development of Money Markets and Co-ordination with Monetary Policy Operations", *Workshop on Developing Government Bond Markets in Eastern Europe*, Istanbul, April.

Van't dack, Jozef (1999): "Implementing Monetary Policy in Emerging Market Economies: An Overview of Issues", *BIS Policy Paper*, No. 5.

Vasudevan, A. (1998): "Analytical Issues of Monetary Policy in Transition", *RBI Bulletin*, January.

Appendix I :
A Model of Autonomous and Discretionary Liquidity

We develop a simple model of the market for bank reserves using the AL-DL framework in which the central bank uses the array of instruments – both quantum and rate - at its disposal for stabilising the price of liquidity. The demand for reserves is based on required reserves ($\bar{R}^a$), immunised for changes in reserve requirements (r) (and hence, constant in the short run, *i.e.*, $d\bar{R}^a=0$) and "excess" reserves (inclusive of settlement balances), usually maintained as a precautionary buffer for unforeseen contingencies, depending on the opportunity cost, *i.e.*, the market interest rate (i_{mr}) and the cost of avoiding default, linked to the central bank policy rate (i_{pr}). Accordingly, the demand for adjusted bank reserves (R^{ad}) can be written as:

$$R^{ad} = R^{ad} (i_{mr}, i_{pr}, \bar{R}^a), \text{ where } R^{ad'}_{imr} < 0 \qquad \ldots (A.1)$$

DL depends on both the liquidity adjustment either through changes in r or open market operations (dQ), and the price (i_{pr}) at which funds are made available from the central bank, *i.e.*,

$$DL = DL\ (i_{pr},\ r,\ Q) \quad DL'_{ipr} < 0,\ DL'_{r} < 0,\ DL'_{Q} > 0 \quad ...(A.2)$$

(Q is liquidity support arising out of open market (including repo) operations).

The supply of bank reserves (R^s), by definition, thus, works out to

$$R^s = AL + DL\ (i_{pr},\ r,\ Q) \quad ...(A.3)$$

Since the central bank stabilises the price of liquidity, the DL trajectory is determined by its reaction to the liquidity conditions in the market, *i.e.,*

$$DL\ (i_{pr},\ r,\ Q) = f[R^{ad}\ (i_{mr},\ i_{pr},\ \bar{R}^a) - AL] \quad ...(A.4)$$

The market interest rate, consistent with market clearing conditions, can, thus, be written as a function of i_{pr}, AL, $\bar{R}^a$ and DL, as

$$i_{mr} = g\ (i_{pr,}\ AL,\ DL\ (i_{pr},\ r,\ Q),\ \bar{R}^a) \text{ where } g'_{ipr} > 0,\ g'_{AL} < 0,\ g'_{DL} < 0,$$
$$g'_{\bar{R}^a} = 0 \text{ [as } \bar{R}^a = \text{constant]} \quad ...(A.5)$$

The total change in market interest rates can be worked out by totally differentiating (A.5),

$$di_{mr} = (g'_{ipr} + g'_{DL}DL'_{ipr})\ di_{pr} + g'_{DL}DL'_{r}\ dr + g'_{AL}dAL + g'_{DL}DL'_{Q}dQ \quad ...\ (A.6)$$

The following derivatives delineate the partial impact of changes in the determinants of liquidity conditions on the market interest rate. Besides, the possible alternative policy mixes of discretionary operations are analysed, which could be used for interest rate stabilisation.

From (A.6), the partial impact of i_{pr}, r, AL and Q on i_{mr} work out to:

$$(\delta i_{mr}/\delta i_{pr}) = (g'_{ipr} + g'_{DL} DL'_{ipr}) > 0 \text{ [assuming } dAL = dr = dQ = 0] \ldots (A.7)$$

which implies that an increase in the central bank policy rate, *ceteris paribus*, pushes up the market interest rate. Note that i_{pr} impacts on i_{mr} in two ways, *viz.*, the direct signalling effect (g'_{ipr}), which is instantaneous and the indirect liquidity effect ($g'_{DL} DL'_{ipr}$) as a result of the change in the cost of liquidity available from the central bank;

$$(\delta i_{mr}/\delta r) = g'_{DL} DL'_{r} > 0 \quad [\text{assuming } dAL = di_{pr} = dQ = 0] \ \ldots (A.8)$$

i.e., an increase in reserve requirements, *ceteris paribus*, hardens the market interest rate by impounding liquidity and reducing the supply of funds in the inter-bank market;

$$(\delta i_{mr}/\delta AL) = g'_{AL} < 0 \quad [\text{assuming } dr = di_{pr} = dQ = 0] \ldots (A.9)$$

so that an increase in autonomous liquidity, *ceteris paribus*, softens the market interest rate by augmenting the supply of reserves; and finally,

$$(\delta i_{mr}/\delta Q) = g'_{DL} DL'_{Q} < 0 \quad [\text{assuming } dr = di_{pr} = dAL = 0] \ \ldots (A.10)$$

which implies that an infusion (absorption) of liquidity through open market purchases (sales), *ceteris paribus*, softens (hardens) the market interest rate.

We now turn to the mechanics of interest rate stabilisation in the market for bank reserves. If the central bank offsets AL with a compensating DL, *i.e.*,

$$\text{if } dDL = -dAL \Rightarrow dR^s = 0 \qquad \ldots (A.11)$$

the impact on i_{mr} can be derived from (A.6) using (A.11),

$$di_{mr} = [g'_{ipr} + (g'_{DL} - g'_{AL}) DL'_{ipr}] di_{pr} + (g'_{DL} - g'_{AL}) DL'_{r} dr + (g'_{DL} - g'_{AL}) DL'_{Q} dQ \qquad \ldots (A.12)$$

This expression (A.12) can be used to analyse the impact of various combinations of changes in r, i_{pr} and Q on the stability of i_{mr} (market interest rates are stable when $di_{mr} = 0$).

Case I : Policy mix of changes in reserve requirements and policy interest rate

The central bank could, *ceteris paribus*, stabilise i_{mr} by changing r and i_{pr} in opposite directions, *i.e.*,

$di_{pr} = [(g'_{DL} - g'_{AL})DL'_r / \{g'_{ipr} + (g'_{DL} - g'_{AL})\ DL'_{ipr}\}](-dr)$…(A.13, from A.12, assuming no OMO, *i.e.,* $dQ = 0$)

iff […] is positive. Given $g'_{ipr} > 0$, $DL'_r < 0$ and $DL'_{ipr} < 0$, a sufficient condition for […] to be positive is $(g'_{DL} - g'_{AL}) < 0 \Rightarrow |g'_{DL}| > |g'_{AL}|$ as $g'_{DL} < 0$ and $g'_{AL} < 0$, *i.e.*, if market interest rates are influenced to a greater extent by DL than by AL. Thus, central banks could stabilise liquidity conditions with a policy mix of injecting (withdrawing) liquidity by lowering (raising) reserve requirements and at the same time increasing (reducing) the cost of primary money by raising (lowing) the policy rate.

Case 2 : Policy mix of changes in OMO and policy interest rate

The central bank could stabilise i_{mr} through a combination of changes in i_{pr} and Q, *i.e.*,

$dQ = [\{g'_{ipr} + (g'_{DL} - g'_{AL})\ DL'_{ipr}\}/\{(g'_{DL} - g'_{AL})\ DL'_Q\}](-di_{pr})$ …(A.15, from A.12, assuming $dr = 0$, *i.e.*, there is no change in reserve requirements)

iff […] is negative. Given $g'_{ipr} > 0$, $DL'_{ipr} < 0$ and $DL'_Q > 0$, […] is negative if the sufficient condition mentioned above holds, *i.e.,* $|g'_{DL}| > |g'_{AL}|$, implying once again that the interest rate effect of DL should be stronger that of AL.

Thus, the central bank could influence market liquidity through a policy mix of open market purchases (sales) and a hike (reduction) in the policy rate.

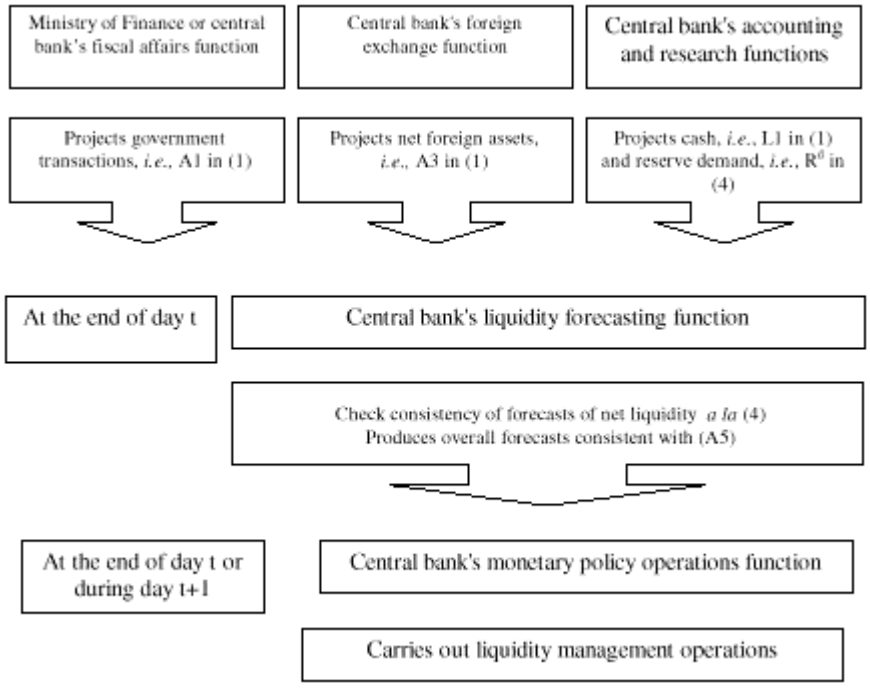
Case 3 : Policy mix of changes in reserve requirements and OMO

The central bank would be able to stabilise i_{mr} if changes in r and Q are unidirectional, *i.e.*,

$dQ = [(g'_{DL} - g'_{AL})\ DL'_r / \{(g'_{DL} - g'_{AL})\ DL'_Q\}](-dr)$ …(A.14, from A.12, assuming $di_{pr} = 0$, *i.e.*, policy rate is left unchanged)

iff […] is negative. Given $DL'_r < 0$ and $DL'_Q > 0$, the above condition is sufficient for the [.. ..] expression to be negative, Hence, the central bank could ensure orderly conditions in the money market with a policy combination that pares reserve requirements (perhaps with a view to phase out a "blunt" instrument) and neutralises the resultant liquidity through open market sales.

Appendix 2 : An Operational Scheme of Liquidity Management



Appendix 3 : Classification of Autonomous and Discretionary Liquidity Flows in the Reserve Bank Balance Sheet

Account	Nature of Flow AL	Nature of Flow DL	Claim of/on Sector	Select Remarks

1	2	3	4	5
Issue Department: Liabilities				
Notes held in Banking Department	√		B	
Notes in Circulation	√		Other Than B	
Issue Department: Assets				
Gold Coin and Bullion	√		Sovereign asset	
(a) Held in India				
(b) Held outside India				
Foreign Securities	√		RoW	
Rupee Coin	√		E	
Government of India Rupee Securities	√		E	Secondary market transactions classified DL.
Internal Bills of Exchange and other Commercial Paper	√		A+D+F	
Banking Department: Liabilities				
Capital paid up	√		E	
Reserve Fund	√		B	
National Industrial Credit (Long Term Operations) Fund	√		B	
National Housing Credit (Long Term Operations) Fund	√		B	
Deposits				
(a) Government			E	
(i) Central Government	√			
(ii) State Governments	√			
(b) Banks			C	
(i) Scheduled Commercial Banks				Changes in required reserves for scheduled commercial banks under Section 42(1) classified DL.
(ii) Scheduled State Co-operative Banks	√			
(iii) Other Scheduled Co-operative Banks	√			
(iv) Non-scheduled State Co-operative Banks	√		C	
(v) Other Banks	√			
(c) Others	√		A+D+F	
Bills Payable	√		A+D+F	
Other Liabilities	√		B	
Banking Department: Assets				
Notes	√		B	
Rupee Coin			E	
Small Coin				
Bills Purchased and Discounted				
(a) Internal	√		A+D+F	
(b) External	√		RoW	
(c) Government of India Treasury Bills			E	
Balances held Abroad	√		RoW	
Investments				
Investments in Subsidiaries/ Associate Institutions	√		C+D	
Foreign Securities	√		RoW	

Government Securities	√		E	Secondary market transactions classified DL.
Loans and Advances to				
(i) Central Government	√		E	
(ii) State Governments	√		E	
Loans and Advances to				
(i) Scheduled Commercial Banks		√	C	
(ii) Scheduled State Co-operative Banks	√			
(iii) Other Scheduled Co-operative Banks			C	
(iv) Non-Scheduled State Co-operative Banks				
(v) NABARD	√		D	
(vi) Others		√	D	Liquidity support to primary dealers classified DL.
Loans, Advances and Investments from National Industrial Credit (Long Term Operations) Fund	√		D	
(a) Loans and Advances to				
(i) Industrial Development Bank of India	√		D	
(ii) Export Import Bank of India				
(iii) Industrial Investment Bank of India				
(iv) Others				
(b) Investments in bonds/ debentures issued by				
(i) Industrial Development Bank of India				
(ii) Export Import Bank of India				
(iii) Industrial Investment Bank of India				
(iv) Others				
Loans, Advances and Investments from National Housing Credit (Long Term Operations) Fund				
(a) Loans and Advances to National Housing Bank				
(b) Investments in bonds/debentures issued by National Housing Bank				
Other Assets	√		B	Includes gold.

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