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Reserve Requirements and Monetary Management:
An Introduction

Prepared by Daniel C. Hardy ^{1/}

Authorized for distribution by Charles Enoch

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Abstract

Reserve requirements are widely used by central banks as a means to improve monetary control, an instrument for policy implementation, a source of revenue, and a safeguard of bank liquidity. The effectiveness of reserve requirements in fulfilling these functions is reviewed, and the detailed modalities of their use are examined. Reserve requirements in a sample of developing countries are described.

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^{1/} Daniel C. Hardy is an Economist in the Monetary and Exchange Affairs Department. Many colleagues provided preceptive comments; the author would like to thank in particular Tomás Baliño, Daniel Dueñas, Charles Enoch, Manuel Guitián, Carl Lindgren and V. Sundararajan. All errors are, of course, the responsibility of the author, and the views expressed do not necessarily reflect those of the Fund.

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Summary

Reserve requirements, which have been imposed by most central banks, can be rationalized on several grounds. First and foremost, they may help to stabilize the demand for base money and thus facilitate the use of other instruments in the implementation of monetary policy. In the absence of more flexible instruments, reserve requirements may themselves be varied as a means of implementing monetary policy. Reserve requirements have a fiscal impact insofar as they require banks to hold an asset that yields less than the market rate of return; they are an inefficient means of taxing financial services if alternatives are available. Finally, reserve requirements can be used to ensure that banks hold a prudent level of liquid assets.

The design of reserve requirements can strongly influence their effect on banks' behavior. It is normally most efficient to define the reserve base to include all and only those bank liabilities that are included in the targeted monetary aggregate. Most arguments suggest that the reserve base should be measured contemporaneously with the holding period, or designed to approximate a contemporaneous requirement, and that a bank's compliance with reserve requirements should be based on the average of its reserve holdings. For efficiency, the remuneration of reserves should be set close to their opportunity cost--that is, the safe lending rate--adjusted for the proportion of reserves held voluntarily. Assets eligible to fulfill the requirement may or may not include cash in vault. The penalty for non-compliance should be explicit: the penalty rate needs to be at least twice the opportunity cost to be effective.

I. Introduction

The state supplies "outside" money in the form of currency and reserve deposits with the central bank to serve as the ultimate means to settle transactions. Demand for outside, or base, money is generated not only by the convenience of currency in conducting everyday transactions and the liquidity of reserve deposits used in settlement between banks, but also, in most countries, by reserve requirements. The issue addressed here is how best to impose reserve requirements, given the objectives of monetary stability and microeconomic efficiency. ^{1/}

By way of definition, a reserve requirement is an obligation on a financial institution (referred to here as a bank) to hold deposits with the central bank or other eligible assets such as cash in vault. The requirement is specified as a function of the reserve base, normally a broader monetary aggregate such as the bank's deposit liabilities. The requirement is to be met over a maintenance period, failing which the bank normally has to pay a penalty; reserves may be remunerated through the payment of interest by the central bank. Liquid asset requirements (LAR), under which banks are obliged to hold a certain proportion of their portfolio in liquid assets such as reserve deposits and treasury bills, will not be discussed except insofar as they relate to reserve requirements proper.

In the next section general and fairly theoretical arguments in favor of imposing reserve requirements are laid out and criticized. As will become apparent, the usefulness of reserve requirements can depend on the details of their specification, which are discussed in Section III. Section IV contains a brief conclusion. Appendix I summarizes the reserve requirements in force in various developing countries, and Appendix II provides more detail on the implications of reserve requirements for bank behavior.

II. Arguments for Reserve Requirements

Several arguments can be made in favor of the imposition of reserve requirements. One argument is that reserve requirements improve the precision with which monetary policy can be conducted. Second, variations in reserve requirements can themselves be used to implement monetary policy. A third argument is that requiring banks to hold reserves that earn little

^{1/} As Fama (1980) puts it, when the government provides a pure nominal commodity, "the problem is to ensure that the nominal commodity...is subject to sufficiently well-defined demand and supply functions to give the unit in which it is measured determinate prices in terms of other goods." Reserve requirements help define demand for the nominal commodity, base money.

or no interest amounts to the levying of a tax, and is thus a useful addition to the set of fiscal policy instruments. Fourth, reserves may be needed to ensure that banks always have enough "good money" on hand to ensure their liquidity and the functioning of the clearing system, for unregulated banks may tend to hold too few reserves.

1. Reserve requirements and monetary control

The foremost argument for reserve requirements is that they enhance the ability of the monetary authorities to control the money supply, and thus further the public interest in stable monetary conditions. In the extreme, a 100 percent reserve requirement would ensure that the instrument, the monetary base, coincides with the targeted monetary aggregate, and the most direct transmission from instrument to target is achieved. Calls for a 100 percent reserve requirement have been heard at least since the 1930s, but seem almost never to have been acted on; the only experience with 100 percent reserve requirements seems to have been in Argentina during 1946-1957 and 1973-1976. 1/ Indeed, the recent tendency in industrialized countries has been to reduce reserve requirements. 2/

(a) Control of broad money

In this section, the use of reserve requirement in achieving a high degree of precision in controlling a monetary target are discussed. An illustrative model may help fix ideas (see Froyen and Kopecky, 1983, and also Kaminow, 1977). Demand for reserve, or base, money (B^d) is made up of required reserves (ρM , where ρ is the reserve requirement and M is the broad monetary aggregate that constitutes the reserve base), and banks' demand for excess reserves (E) (for simplicity, cash in circulation is ignored here, or subsumed under excess reserves):

$$B^d = \rho M + E^d. \quad (1)$$

Demand for excess reserves is assumed to be described by

$$E^d = a_1 M - a_2 i + \epsilon_1, \quad (2)$$

where i is the interest rate, and ϵ_1 is a zero-mean disturbance. Supply of reserve money from the central bank follows

$$B^S = P + \epsilon_2, \quad (3)$$

1/ The recommendation of 100 percent reserve requirements under the original "Chicago Plan" was part of a general scheme to separate deposit taking activity from investment financing.

2/ See Bingham (1985), Freedman (1991), and Weiner (1992).

where P is the central bank's intentional policy interventions; 1/ the disturbance to the supply of base money, ϵ_2 , may be due, for example, to variations in the balance on the government's accounts with the central bank or errors in the central bank's decision making. Ignoring constants, and allowing for a random shock (ϵ_3), an approximation of demand for broad money will be taken to be

$$M = -bi + \epsilon_3. \quad \underline{2/} \quad (4)$$

Combining these equations and using the equilibrium condition $B^d = B^s$, it is easy to show that

$$M = \frac{1}{A} \left\{ b(P + \epsilon_2 - \epsilon_1) + a_2 \epsilon_3 \right\} \quad (5a)$$

$$i = \frac{1}{A} \left\{ -(P + \epsilon_2 - \epsilon_1) + (\rho + a_1) \epsilon_3 \right\} \quad (5b)$$

$$A = b(\rho + a_1) + a_2.$$

It can be shown that the variance of M due to fluctuations in the demand for excess reserves and for broad money is lower, the higher is the reserve requirement ρ . A higher reserve requirement entails that disturbances and intervention in the market for reserve money have less leverage on broad money, and that disturbances to the demand for broad money can be better cushioned through fluctuations in demand for excess reserves. The argument for 100 percent reserve requirements relies on the assumption that the central bank cannot act to offset all disturbances, and that controlling the broad monetary aggregate is the sole objective of the central bank. 3/ Furthermore, according to equation (5b) of the illustrative model, the level of reserve requirements will affect the variance of the interest rate. A higher reserve requirement ratio ρ will increase the sensitivity of the interest rate to disturbances in demand for

1/ The intervention may be discretionary or rule-based, for example, through a refinance facility that defines a supply schedule of liquidity at increasing interest rates.

2/ It may be easier to think of all variables as defined in terms of deviations from their average values.

3/ Formally, the variance of M diminishes even with ρ greater than 1, that is, a reserve requirement greater than 100 percent. However, as ρ tends to unity, eventually banks will hold less excess reserves (banks would hold no excess reserves when faced with a 100 percent reserve requirement), so ' a_1 ' and ' a_2 ' will decline as ρ rises until reserve and broad money coincide.

broad money, and decrease variance caused by disturbances in the market for reserve money. 1/

However, the elementary model outlined above shows that positive reserve requirements are not necessary for monetary control if there is a stable demand for voluntarily held reserves. Even with a zero reserve requirement, the central bank could intervene in the market for reserve money so as to affect interest rates and thus, eventually, broad money. Indeed, if the central bank knows the parameters of the system, observes the various disturbances, and has available instruments for rapid and accurate intervention, it could eliminate all unwanted fluctuations in M . 2/ Furthermore, the hyperbolic form of equation (5a) implies that the marginal gain in monetary control for an increase in reserve requirements diminishes rapidly as ρ rises.

At issue, therefore, is whether the central bank has the information and capacities needed to achieve its monetary target accurately enough, even with a low reserve requirement. Circumstances will determine whether the gain in welfare from improved precision in controlling the money supply through higher reserve requirements will be economically significant and outweigh the costs of the concomitant distortions to portfolio allocation and the efficiency of intermediation (see below). The circumstances in which a central bank will have most difficulty conducting its discretionary interventions are also likely to be circumstances in which disturbances are large.

On the one hand, the behavior of financial markets is famously fickle, and estimated relationships tend to suffer from frequent structural breaks. The variances and covariances implicit in the disturbance terms in equation (5a) refer to the uncertainty in forecasting one period ahead. Forecast variance differs from the in-sample variance due to the presence of "estimation risk", that is, the uncertainty created by the necessity of estimating parameters from a finite sample, and of the risk that the historical sample is no longer fully relevant. Therefore, there may be important uncertainty concerning the money multiplier even over the very short term.

1/ Some central banks have aimed to control bank credit. From the simplified budget constraint $M = B + L$, where L is bank credit or lending, it follows that $L = M - P - \epsilon_2$. Therefore, reserve requirements have the same marginal effect on the variances of L and M --provided that demand for excess reserves and broad money are unchanged across policy regimes.

2/ Independent of ρ , M can be perfectly stabilized by choosing $P = \epsilon_1 - \epsilon_2 - a_2\epsilon_3/b$, that is, by fully accommodating shocks to demand for reserve money, exactly offsetting exogenous shocks to its supply, and counteracting shocks to demand for broad money in a proportion dictated by relative interest elasticities.

Predictability may be most lacking in a situation where the financial system has undergone major structural disturbances, or where events and policy are already so unpredictable that expectations are highly volatile. For example, a major liberalization or rumors of a banking crisis may make it difficult for commercial banks to predict their cash flows, and so the banks are likely to hold large and variable excess reserves. These are also likely to be the times when the central bank has least capacity to formulate and implement discretionary policy, and so it may create much variance in the supply of reserve money through its own errors. Thus, the multiplier may become highly variable over short periods as a result of monetary instability, rather than fluctuations in the multiplier causing monetary disturbances.

These considerations suggest that the period-by-period variance of the components of base money could be important in some circumstances, and that the implementation of a money supply rule could be significantly facilitated by a relatively high reserve requirement.

On the other hand, the length of the period over which forecasts are needed should normally be short. In most industrialized countries, highly accurate estimates of financial variables are available to the central bank with a delay of only a few days, and even in developing countries the delay is rarely more than one month. The monetary authority should be able to monitor its own balance sheet almost continuously, and financial institutions normally have to report their deposit liabilities and cash in vault at least once a month. Once one has allowed for a few major sources of variation, such as seasonal and intra-month variations in the government accounts or the public's cash holdings, in most countries the money multiplier ought to be highly predictable over the short term. ^{1/}

Furthermore, just when the financial system is underdeveloped or severely disrupted, it may be difficult to trade large amounts of securities without large swings in interest rates. A high reserve requirement, that is, a low multiplier, may then be disadvantageous because larger open market operations, and thus larger changes in interest rates, will be needed to achieve any given change in the monetary aggregate. Put another way, when injecting or withdrawing liquidity is itself costly, a higher multiplier is desirable.

Certainly one cannot reasonably account for alternations between episodes of higher and lower inflation in terms of uncertainty over the money multiplier next week or next month. A higher reserve requirement may provide more insulation for the money stock against disturbances from period to period, but not against secular changes and shifts in the policy regime.

^{1/} Bomhoff (1977) uses simple autocorrelation methods to estimate that the mean absolute error in one-month ahead forecasts of the US multiplier is less than 0.5 percent. Presumably a central bank knows more than last month's multiplier.

(b) Central bank operations

One may go further and question whether even a "Friedmanite" monetarist should care about very short-term variance in the money supply, provided that the policy rule is maintained on average; the policy stance is not impaired if money is allowed to act as a "buffer" against small, zero-mean disturbances. Disturbances will be manifest elsewhere if they cannot be absorbed in the money stock, and a high reserve requirement may sacrifice control of other variables and the stability of the relationship between intermediate and ultimate targets for the sake of hitting a target for a monetary aggregate.

The higher the reserve requirement, the greater the distortion it imposes, and the greater the danger that the link between intermediate and ultimate targets will be eroded. If reserves are not adequately remunerated, a reserve requirement imposes an implicit tax on those financial assets to which it is applied. Economic agents will attempt to avoid this tax by developing alternative instruments and means of intermediating between borrowers and lenders. Even the concept of a "bank" may become hard to define. Therefore, the central bank may find it difficult to define a monetary aggregate on which to impose reserve requirements that remains in a stable relationship to prices and output. The more open and sophisticated the financial system, the faster will disintermediation develop.

Furthermore, a number of authors have described how reserve requirements can be set in order to minimize variation in prices (Siegel, 1981, Seideman and Siegel, 1981) or in excess demand (Baltensperger, 1983). In these models, the reserve requirement that minimizes the variance of the ultimate target is quite low precisely because the intermediate target, broad money, can then absorb some of the disturbances. 1/

Over a period of days or weeks, it seems plausible to assume that normally only interest rates, rather than excess demand or the general price level, react to central bank operations. Even when the monetary authority is committed to a simple monetary growth rule, it may desire to reduce the short-term variance of interest rates. The money supply is a statistical construct that stands in an uncertain relationship to ultimate objectives, and its definition may be subject to frequent revision. The stock of money in an economy, even if well defined, is not observed by individual agents. 2/ Interest rates, in contrast, are prices that are publicly posted, and players in financial markets can normally trade some assets at the posted rates at least once a day. Therefore, interest rates may be more useful as day-to-day indicators of the state of financial markets and

1/ Siegel recommends a 7 percent reserve requirement to minimize price variability in the US.

2/ This is one reason why individual banks may voluntarily hold reserves even if there are no shocks in aggregates.

expectations than are monetary aggregates. The monetary authorities may wish to improve the "signalling" effect of interest rate movements by reducing the "noise" created by short-term variance. ^{1/} Indeed, interest rates could also be used by the central bank as indicators of the appropriate policy response to disturbances, and an optimal feedback rule may make the level of reserve requirements irrelevant (Horrigan, 1988, Dotsey, 1989).

The trade-off between the variance of short-term interest rates and that of money is implicit in equations (5a) and (5b). The nature of this trade-off depends on the instruments and information available to the central bank, on commercial banks' demand for reserves, and on the magnitude of different disturbances. In the extreme, if the central bank can learn of the various disturbances and has the instruments to react rapidly, it could choose P to determine either the money stock or short-term rates, but not both; minimizing the variance of the one maximizes the variance of the other.

Central banks have differed in how they have balanced these considerations. The U.S. Federal Reserve's operating procedure based on targeting borrowed reserves seems to represent a compromise between the objectives of short term interest rate and money supply smoothing (Dotsey, 1989). Under the current operating system in the U.K. (and soon in Canada), with minimal (or zero) reserve requirements, the central bank concentrates on varying the supply of reserves very finely to control the short-term money market rate, because demand for reserves is very stable and interest-inelastic (Freedman, 1990). Other central bank have been content to have relied more on reserve requirements and preferred to leave financial markets free of day-to-day official intervention.

Measures may be available that reduce the variance of the system as a whole and that improve the trade-off faced by the authorities, although their implementation may involve direct costs. Even if, say, the central bank aims to stabilize the short-term interest rate from day to day, the financial system can be designed to minimize the variance of reserve money. First, the variance of the exogenous disturbances may be diminished. For example, shocks to demand for reserves might be reduced through the establishment of a clearing and settlement system with short and predictable lags.

Second, improved monitoring and forecasting may allow the central bank to offset shocks more accurately. The component of uncertainty due to

^{1/} In a model with interest rate restrictions or informational asymmetries that prevent credit markets from clearing, raising reserve requirements will transfer variance from the money stock to the extent of rationing and the magnitude of distortions.

estimation risk and forecasting errors may be diminished through better collection and analysis of information. For example, the central bank might gain advance warning from the Ministry of Finance of variations in government expenditures and receipts, which in many countries dominate day-to-day monetary fluctuations. The design of the central bank's instruments is very important in allowing it to react to such information. For example, in Canada the system of next-day settlement allows the Bank of Canada to intervene on the morning of day two to offset variations in clearing balances generated on day one, with the proximate aim of controlling money market interest rates (see Clinton, 1991).

Third, the design of the reserve requirements may themselves affect the incentives to hold excess reserves or alter their interest sensitivity (see Section III). According to equations (5a) and (5b), a lower average ratio of excess reserves to broad money (a lower ' a_1 ') or lower interest rate elasticity of demand for excess reserves (a lower ' a_2 ') increases the sensitivity of both M and i to shocks to the supply and demand for base money. A lower a_1 decreases the variance of i caused by fluctuations in demand for broad money, and increases that of M ; a lower a_2 has the reverse effect.

2. Reserve requirements as a monetary instrument

Reserve requirements may not only enhance the precision of other monetary instruments, but may also themselves be varied to inject or withdraw liquidity. An increase in requirements forces banks to purchase temporary liquidity from the central bank, raising their costs, and reduce their lending activity, leading to a reduction in the public's deposits. Conversely, a reduction allows an expansion in deposits for any given monetary base.

Varying reserve requirements to affect the aggregate money supply is considered a crude and inefficient means of implementing monetary policy. Even small changes in requirements could entail large adjustments in banks' portfolios, and so some forewarning is needed. Whereas open market operations, for example, involve the voluntary exchange of securities, whereby prices adjust automatically to clear the market, a change in reserve requirements is a unilateral action by the central bank. Changes in reserve requirements cannot readily be used to offset short-term monetary fluctuations, if only because of lags in defining the reserve base and the length of the holding period.

Furthermore, if requirements are changed very frequently and without lengthy warning, banks will have a greater incentive to hold excess reserves to use as a buffer, and to invent substitutes for deposits that are not subject to this uncertain imposition. Hence the money multiplier may become less sensitive to variations in reserve requirements, and the link to ultimate targets will be weakened.

Put more formally, the other arguments for reserve requirements suggest that they should be set at some optimal level that depends on the parameters of the economy, such as variances and interest elasticities. This level, which might be termed the steady state optimum, will be constant so long as there is no structural change. To use reserve requirements to implement monetary policy means allowing them to deviate arbitrarily far from that steady state optimum, and thus large costs in terms of the inefficiencies created may be incurred. Therefore, variations in reserve requirements are usually used to implement monetary policy as a second best approach when other instruments are unavailable or very costly to use, say, because there are no well-developed securities markets in which to conduct open market operations.

However, under these conditions, when the central bank has no alternative to varying reserve requirements to manage liquidity, an important asymmetry may emerge. It is normally easy to inject liquidity, for example, by granting central bank advances to government or others. Typically it is much more difficult to withdraw liquidity, to continue the example, by running a fiscal surplus that can be sterilized. It is often tempting to raise reserve requirements to tighten monetary conditions, but few occasions will be found to reduce them, so reserve requirements will tend to drift upwards, increasing their cost in terms of the inefficiencies created. A point may be reached where any further increase is prohibitively costly, and even this instrument becomes unusable. There is no obvious solution to this problem, except to anticipate it, accept any increase in requirements with reluctance, and to use the time before the limit is reached to develop alternative instruments.

3. Reserve requirements as a fiscal instrument

Required reserves, as a component of the monetary base, contribute to the seigniorage revenue generated by monetary expansion, and they may yield income directly if the central bank invests the funds in earning assets, as is usually the case when the central bank earns interest on its holdings of treasury bills and government advances. By the same token, reserve requirements not only affect the reaction of banks to disturbances, but also reduce their profits insofar as reserves are remunerated at less than their opportunity cost. The tax burden implicit in the under-remuneration of reserves will be passed on to the banks' customers, namely borrowers and creditors, in the form of a spread between lending and deposit rates. ^{1/}

In the simple case where banks are competitive, operate under constant returns to scale, and would not hold any reserves in the absence of a requirement, the spread between lending and deposit rates created by

^{1/} The cost of under-remunerated reserve requirements may be borne in part by banks' shareholders if the banks have monopoly profits, but this is not a well-targeted approach to dealing with a lack of competition in the financial sector.

unremunerated reserves will be simply ρi . In general the spread will be positively related to the reserve requirement and negatively related to the level of their remuneration (see Appendix II for a simple exposition of how this tax affects banks' portfolios).

Reserve requirements are popular with governments as a way to raise revenue. The Bank of England admits that the sole purpose of the very low reserve requirements imposed (currently 0.35 percent of deposits) is to finance its operations. From a political point of view, an advantage of reserve requirements as a fiscal instrument is that the tax is usually obscure; the incidence of the tax is sufficiently complex, that the central bank can generate revenue for itself and the central government without directly hurting any particular group of voters. Furthermore, by law central banks often have discretion over the imposition of reserve requirements and the determination of their remuneration, at least within certain bounds. Therefore requirements can be imposed and varied for fiscal reasons without a great deal of public scrutiny, under the mantle of the central bank's independent pursuit of monetary stability. Indeed, the availability to the central bank of an autonomous source of revenue may contribute to its independence. 1/

Besides the considerations of Realpolitik, reserve requirements may be a means to tax financial services that otherwise would be privileged under the conventional tax system. The transaction services provided by banks to their customers are often paid for by below-market interest rates on deposits (or premiums on loan rates) and are thus free of explicit taxes. Furthermore, in some countries such as the U.K., bank service charges are free of Value Added Tax. Generally one would want to tax these services to some extent so that the fiscal system is not biased in favor of bank intermediation. Given the difficulty of measuring the value added in the banking sector, reserve requirements may be an acceptable approximation to a tax on them.

In addition, reserve requirements are almost costless to administer. Banks would have to report to the central bank and monitor their own liquidity in any case, the normal prudential supervision of banks can detect evasion, and reserve deposits take the form of mere book entries. There can be few conventional sources of revenue that can be exploited with such ease, speed, and reliability.

Given the need to raise a certain amount of revenue and the availability of other tax instruments, it becomes a conventional problem in public finance to work out the optimal tax implicit in reserve requirements (Baltensperger, 1982). Consideration of the negligible cost of

1/ However, central bank profitability will be negatively related to the level of the reserve requirement when the central bank has to issue its own securities to absorb liquidity, because the higher the requirement, the larger the open market sales needed to absorb a given amount of liquidity.

administering reserve requirements suggest a higher rate, while the production technology in the financial sector and the ease of disintermediation suggest prime facie that the implicit tax should be low. Liquid financial instruments usually have a low marginal cost of production, and it is easy to find substitutes for any one instrument, so the elasticity of demand is likely to be high. In an open economy, an important source of disintermediation may come from foreign financial institutions, which no redefinition of the coverage of reserve requirements will bring under the jurisdiction of the central bank.

An implication of the above is that the taxation effect of reserve requirements will impinge on monetary policy implementation. Disintermediation induced by a high implicit tax may weaken the link between the central bank's intermediate targets and ultimate objectives. More positively, adjustment in the implicit tax may be used to shift the equilibrium composition of the public's portfolio, and thereby to influence financial flows. For example, the currency substitution that often occurs in a high inflation environment can be discouraged by imposing a more costly reserve requirement on foreign currency deposits. Of course, this is a second best approach which does not address the ultimate causes of the problem.

Note that setting reserve requirements involves two decisions, determining their level and the function describing their remuneration. For a given level of reserve requirements, the magnitude of the tax effect can be varied by varying the spread between their remuneration and the opportunity cost borne by banks, which is approximately the riskless lending rate. There is no reason to suppose that the optimal rate of tax on banks' transaction services will vary one for one with the level of nominal interest rates when inflation is imperfectly controlled. Hence, the optimal rate of remuneration is likely to be described by a positive function of the nominal rate. A fixed zero rate of remuneration on reserves is unlikely to be optimal, especially if the authorities cannot consistently achieve the optimal inflation rate (see also Section III).

The use of reserve requirements as a fiscal instrument may be put in greater doubt when the comparison is made, not between reserve requirements and familiar direct or indirect taxes, but between reserve requirements and other forms of taxation targeted at the financial sector (Romer, 1985, and Freeman, 1987). In particular, taxing deposits, when administered at the level of banks, may well be a superior approach. Whereas the cost of reserve requirements is somehow distributed between borrowers and depositors, a tax on deposits would be directed at those receiving transaction services from banks. Furthermore, a reserve requirement, unlike a deposit tax, entails a quantity constraint on the public's portfolio. A tax to be paid by each bank in proportion to its total deposits would be as easy to administer as a reserve requirement.

4. Reserve requirements and liquidity

In some countries reserve requirements seem to have originated as a prudential measure designed to maintain the liquidity of the banking system. The argument was presumably that, even if any individual bank could rely on inter-bank loans to cover an unforeseen outflow of liquidity, the banking system as a whole needs some reserves to act as a buffer. Besides the general need for liquidity, the clearing system may require a bank to have "good money", that is, deposits with the clearer, immediately available to make payments (Garber and Weisbrod, 1990). Reserves may need to be regulated because, first, the interconnected nature of financial relationships creates the externality of systemic risk, and, second, the willingness of the central bank to act as lender of last resort may lead to a moral hazard problem. Even when remunerated, banks may tend to less highly liquid reserves than is socially optimal.

This line of reasoning, however, points to the need for prudential liquidity requirements, not reserve requirements as they are conventionally implemented. Liquidity requirements typically take into account many liquid assets and liabilities. For example, in the U.S. treasury bills are barely less liquid than deposits with the Federal Reserve since a bank can sell bills in a matter of moments. Indeed, one could envisage a system where settlement between banks was conducted in bills: if a bank for some reason does insist on being paid with central bank money, it should be willing to pay for the privilege, much as some retail stores offer lower prices to those paying cash (Black, 1975).

In a sophisticated environment, liquidity may be guaranteed according to a "cash flow approach" based on projections of net fund flows under different scenarios, rather than by a requirement specified in relation to stocks. In a less developed financial system, liquid instruments may be scarce, so that the liquidity requirement binds before the reserve requirement; the latter may be almost irrelevant.

If reserve requirements are imposed in order to maintain bank liquidity, their specification must be carefully designed to allow them to fulfill their function. Ill-designed reserve requirements can even reduce bank liquidity by impounding banks' reserves, stunting the development of financial markets, or creating fluctuations.

III. The Specification of Reserve Requirements

Having presented the general arguments in favor of reserve requirements, the various means to implement them can be evaluated. As indicated above, the details of the specification of reserve requirements can have an important influence on their usefulness. Decisions are needed on the definition of the reserve base, that is, the set of banks' liabilities (or assets) that are subject to the requirements; on the

remuneration of reserves and on the related issue of which assets are eligible to serve as reserves; and on the measurement of the reserve base and reserve holdings.

1. The reserve base

Typically, reserve requirements are defined as a proportion of banks' deposit liabilities. This rule can be justified by all arguments for reserve requirements.

When a certain monetary aggregate is being targeted, one would want to include all and only deposits that are included in the definition of that aggregate, and to treat them all equally. Shifts in the composition of the aggregate are deemed unimportant, but the central bank will want to offset changes in the public's portfolio that increase or decrease the target monetary mass. If the reserve base is defined more narrowly than the target aggregate, control is impaired as the aggregate can change independent of movements in reserves. For the same reason the base should not be wider than the target. If low remuneration of reserve deposits results in disintermediation and the growth of "near money", the response should be to expand the definition of both the reserve base and the target, and/or to remunerate reserves appropriately.

If considerations of monetary targeting motivate the imposition of reserve requirements, the reserve base should not be defined in terms of banks' assets. In a perfectly efficient market, banks will be readily able to raise funds by means other than deposits, so fluctuations in credit outstanding will bear little or no relationship to movements in monetary aggregates (Black, 1975). In a more realistic setting, loans are typically of longer maturity and less liquid than deposits--such a transformation is one of the primary purposes of banks--so if loans form the reserve base, an injection or withdrawal of base money will be more disruptive and take effect more slowly than if deposits form the base. The question of whether the central bank should be more concerned with credit than money goes beyond the scope of this paper.

The fiscal role of reserve requirements may suggest a somewhat different definition of the reserve base. At issue is the empirical question of which deposits yield transaction services that are inadequately taxed by other means or are subject to some other distortion. If required reserves serve to ensure that banks have a stock of "good money" on hand to settle transactions, intuition suggests that the reserve base should consist of a fairly broad range of liquid liabilities, which can be the source of involuntary outflows of cash from banks.

No matter which arguments are used, the definition of the set of liabilities that form the reserve base cannot be decided a priori. For example, it is an empirical issue whether foreign currency deposits are such close substitutes for domestic currency deposits that they should all be included in one aggregate to be targeted, or all be subject to the same

implicit tax. One would also need to investigate whether deposits abroad are significantly closer substitutes for foreign currency deposits with home banks than are domestic currency deposits.

All theoretical arguments suggest that in some circumstances reserve requirements should not be uniform across the reserve base. Many countries have targeted more than one monetary aggregate, in which case it is optimal to have differentiated requirements on the narrower and broader aggregates depending on the weights placed on the various targets, the variance and covariance of demand for them, etc. (Sherman, Sprenkle and Stanhouse, 1979, Laufenberg, 1979). Similarly, it may be felt that certain types of deposits should bear a higher tax than others, perhaps because interest elasticities differ. And short-term deposits are more likely than long-term deposits to create an unexpected need for cash for settlement purposes.

However, in practice differentiated reserve requirements are likely to complicate monetary management by obscuring the links between a change in reserves and changes in aggregates, and it may be difficult to monitor components of the aggregates. Furthermore, multiple reserve requirements on similar liabilities will most likely be undermined by disintermediation and various redefinitions and devices. Even in quite unsophisticated banking systems, people will rapidly invent means to exploit what are clearly less heavily taxed financial instruments. Thus, differentiated requirements are likely to lessen the degree of monetary control, create distortions, and be ineffectual in safeguarding liquidity.

One form of differentiation that has sometimes been recommended is a marginal reserve requirement, whereby the requirement R_t in period t on deposits D_t is defined by

$$R_t = \rho D_t + \beta(D_t - D_{t-1}). \quad (6)$$

A marginal reserve requirement can serve as an automatic stabilizer, encouraging banks to reverse any sudden increase in deposits or releasing liquidity when money demand falls. The feedback mechanism can be "tuned" by varying the parameter ' β '. ^{1/} (There does not seem to be a fiscal or prudential rationale for a marginal requirement).

However, a marginal reserve requirement may diminish competition among banks, because a bank that offers better returns and services and sees its market share grow will be penalized; this brake on the evolution of the banking sector could be especially harmful in an economy in transition where

^{1/} Poole (1976) recommends setting $\rho + \beta = 1$ and $0 < \beta\rho < 1$, so

$$R_t = \rho D_{t-1} + (D_t - D_{t-1}).$$

the financial sector is dominated by a few large, inefficient institutions. 1/ Equally importantly, for a marginal reserve requirement to have a stabilizing influence, the parameter ' β ' must be chosen appropriately, which requires considerable knowledge of the economic system. For example, if exogenous shocks to the demand for deposits have low or negative serial correlation, a high value of ' β ' will create variance. In general a central bank would do better to make its money supply rule contingent on market conditions, notably the information contained in interest rates, than to follow a very rigid rule and rely on a marginal reserve requirement. A marginal requirement may be appropriate only when the central bank lacks timely information and flexible instruments.

A stronger argument in favor of marginal reserve requirements applies when the central bank wishes to change the level of reserve requirements substantially, but for some reason does not wish to adjust the stock of base money very rapidly. The new reserve requirement could be applied to the change in each bank's deposits after some cut-off date, and the old reserve requirement applied to its stock of deposits at that date. Interbank competition would not be discouraged by such a rule because marginal reserves are defined relative to a fixed base. In equation (6), D_{t-1} would be replaced by the stock of deposits at the cut-off date, ρ would be the old required reserve ratio, and ' β ' would be the new required ratio minus the old. 2/

Another issue in the definition of the reserve base concerns the treatment of interbank deposits. Since total interbank deposits and loans sum to zero, monetary control is unaffected by their inclusion or exclusion, provided that under the former rule lending banks are allowed to deduct their loans from their reserve base. Nor will their inclusion or exclusion affect the fiscal impact of reserve requirements, provided that the interbank rate is free to adjust. If, say, interbank deposits are included in the reserve base, then the borrowing banks must hold the corresponding reserves, but they will offer a suitably lower rate of interest. Since interbank deposits are normally highly liquid, they should be included when reserve requirements are imposed to preserve bank liquidity.

2. Contemporaneous reserve requirements and the measurement of the reserve base

In more developed financial systems it is practical to measure the reserve base contemporaneously with the reserve maintenance period. A contemporaneous reserve requirement more closely links the targeted monetary aggregate to base money (see McCallum and Hoehn, 1983), or it allows the

1/ The Supplementary Special Deposit scheme, or "corset," in force in the U.K. during the 1970s was similar to a marginal reserve requirement. It seems to have induced large-scale disintermediation with little gain in monetary control.

2/ I am thankful to Daniel Dueñas for suggesting this point.

payment of the "tax" on the provision of financial services to coincide with their delivery, or it ensures that a bank's reserve requirements vary together with its liabilities. A contemporaneous requirement does prevent banks from knowing their reserve requirements exactly until the end of the period, but they may become adept enough at forecasting their liabilities and managing their liquidity that this is not a problem, especially if the central bank is quick to respond to any emerging reserve shortage. 1/

However, the disadvantages of a lagged reserve requirement may be small, especially if the central bank takes offsetting measures or if informational lags are long. A lagged requirement may complicate the dynamics of the relationship between the monetary aggregate and base money, but it should be possible to adjust monetary policy accordingly. If information on banks' positions is available only with delay, it may be more efficient to accept a lag between the measurement period and the maintenance period in order to let banks know their reserve requirements more precisely, or to make averaging of the reserve base more practical. A lagged requirement can also be useful to the central bank in the planning of policy implementation by facilitating the forecasting of aggregate liquidity.

At the same time, the rule for measuring the reserve base can be designed so that a lagged requirement approximates a contemporaneous one. A lagged reserve requirement will have few drawbacks if past observations of the reserve base are in effect used to forecast the base during the maintenance period. In order to form the basis for a good forecast, the measurement rule must balance two considerations: observations should be recent, to capture innovations, and the observations should be drawn from a sufficiently long period that banks' typical positions can be estimated. The weights to be given to these considerations will depend on the particular characteristics of the financial system in question. The measurement period is typically one to four weeks or a month.

Generally it is preferable to measure the reserve base as an average of daily positions over the period, because a representative measure of banks' positions is desirable no matter what the motivation for imposing reserve requirements. Averaging smooths banks' positions, which on any given day are likely to be strongly influenced by the pattern of transactions in the economy, for example, by the habit of paying wages on a certain day of the week or month. Furthermore, averaging prevents banks attempting to reduce their reserve requirements by temporarily reducing their reservable liabilities, for example, by shifting some deposits off balance sheet through repurchase operations, or by accelerating or delaying the settlement of transactions. Such tax avoidance measures will make the imposition of the optimal reserve requirement more difficult, and create distinct intra-period fluctuations in financial markets.

1/ Roley (1986) provides a discussion how operating procedures and lags in the reserve requirement system interact.

If lack of information dictates that the reserve base be measured on individual days, some of the problems alluded to can be mitigated by taking the measurement on a "typical" day, often mid-week. Taking measurements on mid-week days is also less likely to be disrupted by holidays.

In addition, the accuracy of a contemporaneous reserve requirement can be approximated by letting the measurement and maintenance periods overlap (Kopecky, 1983). The measurement period could be made longer than the maintenance period, so that requirements can be based on more information, but banks will have scope to react gradually to new developments. Suppose that the measurement period is two weeks and the maintenance period is one week: an inflow of deposits in week two of the first measurement period, for example, will raise reserve requirements only little in the first maintenance period, and more in the second and subsequent periods only if the shock turns out to be persistent.

3. Reserve maintenance

Normally, reserves must be held above requirements either on every day of the maintenance period, or as an average of daily positions. A day-to-day maintenance requirement has little to recommend it. On the positive side, a day-to-day requirement forestalls the accumulation of reserve shortfalls during part of the maintenance period, and accelerates the transmission of policy interventions to monetary aggregates (if this is desirable). However, a day-to-day requirement will compel banks to hold substantial excess reserves to act as a buffer against unforeseen shocks, and therefore monetary control is worsened (in equation (2), the variance of ϵ_1 increases, and therefore the variance of the target M increases). Furthermore, a day-to-day maintenance requirement can reduce the interest elasticity of demand for excess reserves (a smaller ' a_2 ' in equation (2)), increasing the variability of money market interest rates and, possibly, broad money. At the same time, the required reserves fail to provide liquidity. ^{1/} Enforcing day-to-day maintenance requires the same information as an average requirement, so there is no argument for the former on the basis of administrative convenience. Day by day maintenance is difficult to reconcile with a contemporaneous requirement.

When, in a sophisticated financial system, banks are able to manage their liquidity positions very precisely and the central bank can react quickly, reserves will never deviate far from their required levels; banks have an incentive to place excess liquidity in interest bearing deposits, and they will avoid reserve shortfalls so as not to have to hold excess reserves later. In contrast, averaging will be especially important in less sophisticated financial systems, where thinness in the interbank market and long and variable lags in the clearing and settlement system lead to

^{1/} Frost (1975) provides a simple model of the determination of excess reserves under a day to day maintenance requirement, and Angeloni and Prati (1992) provide a model of behavior under reserve averaging.

involuntary variations in bank liquidity. Put another way, when large variations in the supply of reserve money is unavoidable, say, because of inadequacies in banks' information systems or uncertainties in clearing and settlement, one wants to make demand for reserves more interest elastic through averaging, and thus stabilize money market interest rates (raising parameter 'a₂' in equation (2)).

However, in these circumstances large intra-period variations in banks' reserve holdings may complicate monetary management. A compromise is to shorten the maintenance period. In some regards an average requirement functions more like a day-to-day requirement, the shorter the maintenance period: when there is less time to compensate for a large reserve shortfall early in the period, banks will be more motivated to meet or exceed their reserve requirements every day, but those requirements will adjust frequently to market conditions.

Variation in banks' positions within a given maintenance period can be moderated by penalizing excess reserves, that is, by adding an explicit cost on top of the opportunity cost of excess reserves. In Bolivia, banks are fined an amount proportional to the "average" shortfall

$$\sum_1^T [U_t - \alpha E_t], \quad 0 < \alpha < 1,$$

where, on each day t of the T -day maintenance period, a bank's reserve holdings are either U_t under the requirement, or in excess by E_t . 1/ The parameter ' α ' can be tuned to determine the degree of smoothing, for as ' α ' tends to 0, the system approaches a day-to-day reserve requirement, and as ' α ' tends to unity, the system approaches an average maintenance requirement. In the case of Bolivia, $\alpha = 0.2$.

Alternative methods are available to smooth intra-period fluctuations in banks' reserve positions. It would be possible to weight more heavily large deviations from the average requirement, especially large shortfalls, in calculating the average shortfall; to set minimum reserve holdings below the average requirement; or to impose an explicit penalty on all deviations beyond some margin. Often a bank will be charged an exceptional penalty if it overdraws its account with the central bank (in equation (1), a 'kink' is introduced at $B^d = 0$). Sometimes banks are allowed to carry over some of their average excess reserves from one period to the next (as is the practice in the U.S.), or to make up for a shortfall by holding higher

1/ More formally, if the reserve requirement is ρD and H_t is a bank's holdings of eligible assets on some day t , then $U_t = \min(0, H_t - \rho D)$ and $E_t = \max(0, H_t - \rho D)$. Since $\sum(U_t - \alpha E_t) = \sum(U_t - E_t) + (1 - \alpha)\sum E_t$, the "average" shortfall under this system equals the usual measure of the bank's mean position, plus a non-negative term.

reserve in the next period; allowing carry-overs effectively amounts to a lengthening of the averaging period.

4. Remuneration of reserves

The remuneration of required reserves allows the separation of their monetary from their fiscal effects. The amount of revenue raised for a given requirement can be varied at will by varying the remuneration. The easier is disintermediation in the domestic financial system or through foreign competition, the less revenue will one want to raise by this means. If the remuneration is well designed, the imposition of reserve requirements may have no effect on banks' profitability or their demand for deposits (see Appendix II). The practical complications of conducting the book-entries needed to remunerate reserves seem rather minor.

In the simple case with no excess reserves and constant returns to scale, banks' profits will not be affected by a requirement to hold reserves that earn interest at the safe nominal lending rate, which equals the opportunity cost of the funds locked up in deposits with the central bank. This nondistortionary level of remuneration is independent of the interest rate paid on deposits and of the administrative costs of banks. ^{1/} Of course, a change in reserve requirements implies an adjustment elsewhere in the banks' balance sheet, which may ultimately affect interest rates.

If banks would hold reserves even in the absence of requirements, the nondistortionary level of remuneration is the relevant riskless lending rate scaled down by the proportion of reserves that are voluntarily held, provided that required reserves can be used during the maintenance period. When reserve requirements are equal to the average level of reserves banks would hold voluntarily, zero remuneration would be appropriate; such requirements would not be redundant if their design served to stabilize the demand for reserve money.

Central banks sometimes provide various services free of charge to commercial banks, for example, through the supply of bank notes and the operation of the clearing system; the rate of remuneration may be adjusted for the cost of those services that are provided in proportion to banks' deposits if for some reason explicit charges are not levied.

If some amount of revenue has to be raised through reserve requirements, the least distortionary form of the implicit tax normally requires that the remuneration of reserves be a function of the relevant nominal lending rate. The function will depend on the amount of revenue to be raised, the level of the requirements, the proportion of reserves held voluntarily, and the definition of eligible assets. Remuneration at the riskless rate minus a fixed number of percentage points ensures that the tax

^{1/} However, it is sometimes hard to identify the safe nominal interest rate, in which case a short-term deposit rate might serve as a proxy.

is constant in real terms. 1/ From a fiscal perspective, zero remuneration is (almost) certainly not optimal: zero remuneration implies a tax that varies with the nominal interest rate, which is at best imperfectly controlled and cannot readily be set at the level that is optimal from an efficiency point of view. 2/

Note that it is feasible to have the same required reserve ratio on all components of the reserve base, so the money multiplier is largely unaffected by fluctuations in the composition of targeted broad money, while remuneration is differentiated to reflect differences in tax treatment or other distortions. 3/ For example, required reserves could be a fixed proportion of all deposits, but reserves corresponding to foreign currency deposits could earn less relative to their opportunity cost so as to discourage currency substitution if it is deemed undesirable. Also opportunity costs may differ: whereas the alternative use of reserves denominated in domestic currency might be investment in treasury bills, the relevant alternative for reserves in foreign currency might be investment in the Eurodollar market (but see Section III.5 below).

The case for remunerating excess reserves is very weak. One might argue that the liquidity services of base money are costless to produce, and that therefore there should be no incentive to economize on its use. Hence all its components (reserve deposits and cash) ought to earn at least a non-negative return, i.e., that the optimal rate of inflation is at most zero. However, this argument ignores the need to earn seigniorage revenue, and the separate issue of why it is so difficult to achieve the optimal rate of inflation. Remunerating excess reserves will in effect reduce the interest elasticity of demand for excess reserves. In the extreme, if excess reserves are always remunerated at their opportunity cost (the safe lending rate), demand for excess reserves will be perfectly inelastic because reserves are not costly. 4/ Therefore monetary control could be weakened and interest rates made more variable.

An important consideration is that the remuneration of reserves will entail a steady increase in base money in the absence of off-setting sterilization, say, through bill sales or central bank profits earned on other activities. The remuneration of reserves may force the central bank to use its other instruments more intensely, which may be costly. When

1/ One implication of such a rule is that remuneration may have to be negative if the level of the requirement is low enough.

2/ Much of the literature in this area, such as Romer (1985), assumes that the government can effortlessly set the rate of inflation at its optimum level.

3/ There could still be variations in the multiplier if demand for excess reserves deferred across components of the aggregate.

4/ In equation (2), the term 'i' could be replaced by the difference between 'i' and the rate of remuneration. Full remuneration reduces this difference to zero.

inflation, and thus nominal interest rates, are high, the strong feedback into monetary base growth through the remuneration of reserves could be very dangerous if the central bank lacks instruments to absorb liquidity. However, in a low-inflation environment the remuneration of reserves may be a reasonable means of allowing money to grow in line with real activity.

5. Eligible assets

The tax implicit in reserve requirements can be varied by redefining the set of eligible assets. While deposits with the central bank are always counted towards the fulfillment of reserve requirements, the correct treatment of banks' vault cash is more debatable, and some countries include government securities among eligible assets.

It is sometimes argued that the inclusion of vault cash among eligible assets is "fairer" because it does not penalize banks that have to hold much vault cash to conduct their retail business. However, the marginal cost of reserve requirements equals the product of their opportunity cost (the nominal lending rate) and the quantity of deposits, and does not depend on how much cash a bank chooses to hold relative to its deposits. So, while the inclusion of vault cash does reduce the cost of under-remunerated reserve requirements, the argument in favor of making cash an eligible asset can be turned around: of two banks with the same amount of deposits, there is no reason to favor the one that chooses to engage in cash-intense business to obtain deposits (see Appendix II). If reserve deposits are remunerated at the lending rate and banks would hold no reserve deposits voluntarily, bank profits are independent of whether or not cash is an eligible asset.

A stronger argument in favor of including vault cash among eligible assets depends on the feasibility of banks using vault cash to avoid some of the reserve requirement tax. If vault cash is not included, and positions at the central bank are measured, say, at the close of business, banks may be able to use their vault cash for normal business transactions during the day and transport it back to the central bank to be redeemed for reserve deposits. Such machinations increase the "noise" in monetary conditions and the tax incidence by adding another random element. Furthermore, banks with more branches located near the central bank will be more able to avoid the reserve requirement tax, giving them a competitive advantage.

When vault cash is an eligible asset, procedures for its measurement must be carefully designed to prevent banks finding other ways to avoid the reserve requirement tax. If vault cash and reserve deposits are measured on an average basis, or if banks themselves cannot track their vault cash very precisely, there is little danger; the central bank could allow banks to report estimates of vault cash, with subsequent adjustment of reserve

requirements for revisions to the estimates. 1/ However, if data on cash holdings are reported to the central bank only periodically and with a lag, banks could be tempted to count vault cash in fulfillment of their reserve requirement at one time, ship it back to the central bank, and let the same asset fulfil the reserve requirement again in the guise of a reserve deposit.

When foreign currency deposits are included in the reserve base, the issue arises of whether the corresponding reserve deposits should be denominated in domestic or foreign currency. The complex issue of whether foreign currency deposits should be included in the targeted aggregate will not be addressed here.

Matching the currency denomination of eligible assets and the corresponding deposit liabilities helps limit banks' exposure to capital gains or losses due to exchange rate movements, and does not force banks to find extra reserves (or actively reduce deposits and call in loans) when a depreciation increases their deposit liabilities. These considerations will be most important when the exchange rate is subject to periodic large adjustments, and when foreign currency deposits are concentrated in just one or two banks.

The counter-argument is that denominating some reserves in foreign currency implies that base money can vary independent of the central bank's actions as the exchange rate varies, and in an especially dangerous manner: any depreciation will be automatically accommodated to some degree as reserve deposits (in local currency terms) expand. With a simple monetary model of the exchange rate and in the absence of offsetting central bank intervention, the system could become explosive. Denominating reserves on foreign currency deposits in domestic currency places the onus of adjustment in case of depreciation on banks, but the central bank could at its discretion ease the transition by temporally increasing reserve money.

Furthermore, as a prudential matter the central bank could impose an additional regulation limiting or even eliminating banks' net foreign exchange positions, so they are not exposed to undue risk of capital losses. Note, however, that even if a bank does not have an open foreign exchange position, the flow of its profits will be affected by the level of the exchange rate if reserves are denominated in domestic currency and under-remunerated; until adjustment occurs, a depreciation increases its requirement to hold under-remunerated reserve deposits on its foreign currency liabilities.

Sometimes banks are allowed to satisfy at least a part of their reserve requirement with central bank or government securities, so the reserve

1/ The central bank will be able to judge whether estimates are provided in good faith by verifying that average revisions are insignificantly different from zero.

requirement takes on some of the character of an LAR. The rationale for this practice seems to be that such securities are highly liquid, and they provide some remuneration on required reserves. However, reserves could equally well be remunerated directly, and including securities among eligible assets greatly complicates monetary control, because banks could expand their deposit liabilities independent of movements of base money.

6. Penalties

Central banks can normally achieve a high degree of compliance with reserve requirements by moral suasion alone. However, it is still advisable to have explicit penalties that allow banks to formulate a definite liquidity management strategy.

To create a real deterrent, penalties must be such that reserve deposits do not form the marginal source of financing for bank lending; penalties are ineffective if it is more expensive on average for banks to raise funds in the interbank market than to run down their reserves with the central bank. The penalty rate should be twice the opportunity cost of reserves, that is, the riskless lending rate, if banks are to target exactly zero excess reserves; half the time a bank will end the holding period with unremunerated excess reserves, and half the time pays a penalty on a shortfall, which, however, corresponds to an investment. A higher penalty rate would induce a rational bank to hold on average higher excess reserves, so that unavoidable fluctuations in its position with the central bank result less often in reserve shortfalls.

The level and design of penalties can be used to alter the shape and position of the curve describing demand for reserve money (equation (2)). Sometimes it may be useful to include some gradation in penalties according to the size of the shortfall so as to discourage very large swings in reserve positions, if only for prudential reasons. The same purpose could be achieved by penalizing frequent or large reserve shortfalls on individual days during the reserve maintenance period.

Nonpecuniary or indirect penalties, such as restrictions on participation in the clearing system (as in Paraguay) or limitations on access to central bank refinancing (as once used in Costa Rica and Nepal), obscure the true cost of reserve shortfalls, and may be disruptive to other parts of the financial system. Sometimes reserve shortfalls, and other breaches of central bank regulations such as liquid asset requirements, have been penalized by supplementary reserve requirements (this practice was used for example in Madagascar, Paraguay, and Venezuela). Using reserve requirements to impose penalties seems unnecessary, as direct fines could as well be used, and complicates monetary policy implementation by varying the multiplier.

IV. Conclusions

Reserve requirements can be justified as a means to enhance or implement monetary policy, as a fiscal instrument, or as a guarantee of banks' liquidity. These purposes are not mutually exclusive: generally the optimum policy is to set the level of reserve requirements according to the needs of monetary policy considerations, and to remunerate them as dictated primarily by efficiency considerations.

The level of reserve requirements that most enhances the use of other monetary instruments depends on the importance of short-term shocks affecting the system, and on the available trade-off between accuracy in controlling a monetary aggregate and the stability of other relevant variables. In particular, given the allocative and informational role of interest rates, fairly low reserve requirements would normally be desirable. Varying reserve requirements to implement policy directly is generally a crude instrument, and can bear a heavy cost in terms of the inefficiencies created.

Consideration of the efficiency of the banking sector suggest that reserve requirements will be a poor way to impose a tax, albeit a politically convenient one. The optimal remuneration of reserves will generally be close or equal to the level of the nominal riskless lending rate. It is difficult to defend the zero remuneration of reserves.

What reserve requirements cannot do is resolve any of the most central problems associated with monetary policy, namely, the uncertainties concerning the linkage between financial variables and the ultimate targets of policy such as output and inflation, and the difficulties encountered by governments in achieving credibility and consistency. Reserve requirements are at most a facilitating device, which function best when these more fundamental problems are addressed directly.

Reserve Requirements in Developing Countries

In this appendix the reserve requirements imposed in a number of developing countries are described. ^{1/} The descriptions are taken from various sources and discussions with national officials over a number of years (the date is reported in parentheses), so some may no longer be current. Insofar as generalizations can be made based on this sample, it seems that Latin American countries are prone to imposing highly complex reserve requirements. Former British colonies often have a simpler system of reserve requirements, but they tend to have a liquid asset requirement (LAR) in addition. In many countries, nonbank financial institutions (NBFIs) enjoyed low or zero reserve requirements on liabilities that were close substitutes for bank deposits. In several countries measurement of the reserve base and monitoring of compliance was hindered by practical difficulties.

Reserve requirements in the Bahamas (1991) were uniform, at 5 percent of average bank deposits. Both the measurement and the holding period were one month. Unusually, excess reserves at the start of a holding period could be used to offset shortfalls later, but the reverse was not possible. Banks were charged an effective penal interest rate on reserve shortfalls. Reserves were not remunerated, and up to one fifth of the requirement could be satisfied by holdings of vault cash.

Banks in Bangladesh (1993) were formerly required to hold reserves in the form of central bank deposits equal to 10 percent of their deposit liabilities, including gross interbank deposits, and reserve deposits above a 5 percent statutory minimum were remunerated at 5 percent. The requirement is now 5 percent. Some NBFIs that take deposits do not bear any reserve requirements. Measurement of the reserve base is contemporaneous with the one-month holding period, and reserves are to be maintained day to day. Reserve shortfalls bore a penalty interest rate 3 to 5 percentage points above the bank rate.

Reserve requirements on time deposits in Bolivia (1991) were 10 percent, while those on most deposits are 20 percent and some deposits incurred a 100 percent reserve requirement. Measurement and maintenance periods were contemporaneous and followed a two-week cycle, with the "shortfall" measured according to a certain formula (see main text). All reserves on domestic currency liabilities were remunerated, whereas only half of reserves on foreign currency liabilities earned interest.

In Burundi (1992), sight deposits formerly carried a 10 percent reserve requirement, while other bank deposits carried a 5 percent requirement. NBFIs had significant liabilities that were close substitutes for bank deposits but were free of reserve requirements. Requirements were based on

^{1/} For a description of practices in industrialized countries, see Bingham (1985).

end-of-month positions and were to be maintained from mid-month to mid-month on a day-to-day basis. Only deposits with the central bank were eligible assets and they earned no interest. The penalty rate was equal to the refinance rate, so reserve requirements were enforced largely by moral suasion. In 1992 reserve requirements were made uniform and applied to all comparable liabilities of financial institutions, averaging was introduced into the measurement and maintenance of the requirements, and the penalty for noncompliance was set at 8 percentage points above the refinance rate.

Due to the size of the country and poor communications, reserve requirements on banks in China (1991) were calculated by branch at 13 percent of domestic currency deposits (excluding interbank deposits) plus a 5 to 7 percent "additional" or "supplementary" reserves requirement introduced in 1998 to absorb the excess liquidity of some banks. The reserve base was measured, with some lag, on end of month data, though previously different liabilities had different measurement days. Reserves in the form of deposits with the local branch of the central bank had to be held at the end of the month, but the supplementary reserves requirements were frozen. Reserves were remunerated at about 6 percent. Banks were charged a penal interest rate on reserve shortfalls.

In October 1992, the reserve requirement in Costa Rica (1993) on domestic currency demand deposits was raised from 30 to 34 percent, and those on time deposits from 10 to 14 percent; substitutes for bank deposits provided by NBFIs carried low or zero reserve requirements. Short-term foreign currency deposits bear a 20 percent reserve requirement; a 100 percent requirement is applied to long-term foreign currency deposits existing prior to February 1993, and 10 percent on deposits mobilized thereafter. At least 60 percent of reserves on foreign currency deposits earned market rates of interest. The high level of reserve requirements are estimated to add about 3 percentage points to banks' spreads. Measurement and maintenance were contemporaneous over a half-monthly period. Vault cash and central bank deposits were eligible assets. A bank failing to meet reserve requirements may suffer a denial of central bank refinancing and the suspension of some of its operations.

In Ecuador (1992), demand deposits carried a 32 percent reserve requirement, deposits at the National Development Bank carried a 10 percent requirement, and foreign currency deposits with domestic banks bore a 35 percent requirement; while foreign currency demand deposits with foreign banks and other deposits including those with NBFIs bore an 8 percent requirement. The reserve base was measured weekly. Excess reserves could be "carried over" from period to period, and penalties for reserve shortfalls began after two weeks, as verified by the Superintendency with a lag of two weeks. Banks could use central bank deposits and, to some extent, vault cash to satisfy their reserve requirements, while NBFIs could satisfy them only with central bank deposits. Reserve shortfalls were charged interest at a penal rate (1.5 times the average 90-day lending rate). Previously, a bank which persistently failed to meet its reserve

requirement could be prohibited from making new loans until the deficiency was made good.

Until 1990, domestic currency deposits with maturity less than two years attracted a 25 percent reserve requirement in Egypt (1993); because some specialized banks were not subject to reserve requirements, the reserve base constituted approximately 75 percent of all bank deposits. The base was measured and reserves held on a contemporaneous, average, monthly basis, although there was a lag of at least five days in reporting. Reserves were not remunerated, but vault cash was an eligible asset. Since then, banks have been required to deposit the equivalent of 15 percent of all domestic currency deposits with the central bank (specialist banks face a reserve requirement on deposits in excess of their capital and reserves). Reserve deposits, which are not remunerated, must be maintained on an average basis over a week, and the measurement lag is two weeks. The penalty for non-compliance is twice the discount rate. Required reserves of 15 percent on foreign currency deposits must themselves be in foreign currency.

In 1987 the central bank of The Gambia (1992) introduced reserve requirements of 24 percent on demand deposits and 8 percent on term deposits. In addition, there is a 30 percent LAR on all deposits. A bank must satisfy at least 80 percent of its reserve requirements with unremunerated deposits at the central bank, and the rest in vault cash. Reserves are to be maintained on an average basis over two weeks, and the penalty rate is five percentage points above the rediscount rate.

The central bank of Ghana (1992) introduced in 1989 a 30 percent reserve requirement on demand deposits (excluding interbank liabilities) and 10 percent on time deposits, resulting in an average requirement of about 22 percent and wide variations between banks. In addition there was a 15 percent LAR. Reserves were to be maintained contemporaneously and day to day, but reserves and the reserve base were measured only once a week. Vault cash and the unremunerated central bank deposits were eligible assets. Reserve shortfalls were charged 0.1 percent interest per day (44 percent per year), and a bank with a persistent shortfall could be prohibited from new lending. Reserve requirements were unified at 22 percent in 1990, and the LAR was raised to 20 percent. In 1991, the reserve requirement was reduced to 18 percent but the LAR increased to 24 percent.

Guinea's (1993) system of reserve requirements was introduced in February 1991. A bank's required reserves equal 2 percent of residents' domestic currency deposits with terms up to three months, plus 5 percent of the difference between short-term credits and 2.5 times medium- and long-term credits. Requirements are based on end-of-month data reported with a two-week lag. The holding period is from mid-month to mid-month. Eligible assets include unremunerated deposits with the central bank and 75 percent of the bank's vault cash averaged over the previous six months.

Commercial banks in India (1992) were subject to a 15 percent reserve requirement on demand and time liabilities (except for certificates of

deposit), a 10 percent marginal requirement having been abolished. A LAR with a 30 percent marginal rate was also in effect. The reserve requirement on cooperative banks was between 3 and 6 percent. The reserve base included interbank liabilities less interbank loans, if the difference was non-negative. The base was measured on a Friday before the start of the two-week holding period, but data were available with a lag of 7 to 10 days. Reserves, in the form of central bank deposits, were to be maintained on an average basis (the LAR was to be maintained day by day). Reserve deposits were remunerated, though the marginal remuneration was zero.

Formerly, most domestic and foreign currency deposits carried a 15 percent reserve requirement in Indonesia (1992). The requirement was only 10 percent on time deposits with state banks, foreign banks and the state development bank, and 5 percent on those with regional development banks. Reserves were calculated on the weekly average of banks' positions, and the holding period was contemporaneous. At least a third of reserves on domestic currency accounts had to be held as central bank deposits. At least one third of reserves on residents' foreign currency accounts, and all reserves on nonresidents' accounts, had to be held as U.S. dollar deposits with the central bank. Required reserves were not remunerated, but, as of 1984, excess domestic currency reserve deposits earned interest at 13 percent, and excess foreign currency reserves earned 10 percent interest. In 1984 the remuneration of excess reserves was eliminated. In 1988 reserve requirements were reduced progressively to 2 percent of all deposits.

Reserve requirements in Jamaica (1992) have been varied as an instrument of monetary policy and reached 25 percent of deposits (their statutory limit), less interbank deposits, averaged over four end-of-week observations. In the early 1980s the system of average maintenance was replaced by a day by day requirement. Requirements had to be fulfilled with central bank deposits. A LAR was also in effect.

Reserve requirements in Kenya (1993) are uniform (currently 8 percent), but important NBFIs were free of requirements. Reserves have to be held day by day, the requirement being determined on the basis of net deposit liabilities measured at the end of the previous month; net deposit liabilities exclude government, nonresident, and export retention account deposits. Vault cash is not an eligible asset, and reserves are not remunerated. Reserve shortfalls are charged 0.1 percent interest per day (44 percent per year), and a bank with a persistent shortfall can be prohibited from new lending. A 20 percent LAR is applied to banks.

Madagascar (1989) operated a system whereby banks had to hold reserves equal to 6 percent of their nonpreferential credit, based on an average of end-of-month stocks, on a day-to-day basis over three months. In addition, they had to hold reserves equal to 20 percent of their average deposits with the central bank over the previous quarter. In November 1990, reserve requirements were redefined as 6 percent of all deposits, measured at the end of each month. Reserves were to be maintained over the second following month, half in a blocked account and half as a daily average.

Surplus reserves could be carried over for one month. The penalty rate equaled the money market rate plus two percentage points, and in addition a bank with a reserve shortfall would have to hold an equal amount of excess reserves next month.

Reserve requirements in Nepal (1993) are 12 percent on deposits. The system was meant to be contemporaneous, but in practice data on the two test dates per month used to verify compliance become available with a lag of six or seven weeks. A penal interest rate is charged on reserve shortfalls. Formerly, the main penalty for noncompliance was a restriction on refinance credit, and at least two thirds of reserves were to be held as central bank deposits.

Nicaragua (1993) operated a highly complex system of reserve requirements prior to December 1992, but enforcement seems to have been poor. Currently, reserve requirements are 10 percent on sight and index linked deposits, and 25 percent on foreign currency deposits. The measurement period is two weeks, and the maintenance period is contemporaneous but verified with a lag of three days. At least two thirds of requirements are to be met with central bank deposits. Reserves are not now remunerated. Up to two periods of shortfall are permitted per quarter, and the penalty rate equals the highest lending rate plus one percent. The penalty rate seems to be too low to enforce compliance.

In Oman (1992), reserve requirements amounted to five percent of all deposits, excluding local interbank deposits. The requirement could be met with central bank deposits, vault cash, and 5 percent of foreign currency deposits with the central bank; this last earned market rates of interest. In addition, up to 3 percentage points of the requirement could be met with interest-bearing treasury bills and development bonds.

Banks in Papua New Guinea (1991) bore a LAR rather than a reserve requirement. Vault cash, reserve deposits and government securities were to equal to 11 percent of all deposits; the base was measured each Wednesday, and assets were to be held day to day from the following Thursday through Wednesday in two weeks.

Paraguay (1993) formerly operated a complex scheme, whereby, for example, sight and savings deposits incurred a marginal reserve requirement of 30 percent, and time deposits had a 20 percent marginal requirement. Verification of compliance was subject to long delays, and the effective penalty was exclusion from the daily clearing. Until 1990, banks were obliged to make 50 percent of loans to priority sectors; a shortfall in lending to priority sectors was to be matched by unremunerated reserve deposits. Currently, reserve requirements are 30 percent on all bank deposits except certificates of deposits, which carry a 15 percent requirement. Deposits mobilized since April 1992 by NBFIs carry a marginal reserve requirement of 30 percent. The penalty rate for noncompliance is 2.5 times the discount rate.

Reserve requirements in Peru (1991) were also complex. Marginal requirements had been brought down from 80 percent in 1990 to 15 percent in March 1991, and the effective requirement on domestic currency deposits fell from 59 percent to 25 percent, while the effective rate on foreign currency deposits is 35 percent. Most interbank deposits were exempt. The measurement period was two weeks, with a two-week lag. Eligible assets comprised central bank deposits, vault cash, and, previously, government bonds. Up to 104 percent of required reserves were remunerated at 4 percent per month on domestic currency reserves, and at LIBOR minus one percent on foreign currency reserves. Foreign cash in vault was remunerated.

Reserve requirements in Sierra Leone (1993) are set at 10 percent of banks' deposits. Demand deposits also carry a 40 percent LAR, and savings deposits carry a 20 percent LAR. Central bank deposits and vault cash are eligible assets. Reserves and the reserve base are measured on the last business day of the week. The penalty rate is 5 percentage points above the prevailing 91-day treasury bill yield.

Reserve requirements in Sri Lanka (1992) have been altered frequently, and, in practice, have remained well above the 5 percent statutory minimum. Reserve requirements were unified in 1988 at 10 percent of all bank deposits; in mid-1992 they were 12 percent. During 1984-1986, a marginal reserve requirement was in effect. Requirements could be fulfilled by holding unremunerated central bank deposits or, up to a limit, treasury and other bills; vault cash was not an eligible asset after 1977. Shortfalls were penalized at a high rate of interest. During 1991-1992, treasury bills were rendered ineligible, while vault cash was made an eligible asset. Foreign currency deposits, which were formerly excluded, were brought under the requirement in mid-1992.

Reserve requirements were reintroduced in Tunisia (1992) in May 1989. The requirement was set at two percent of deposits, plus some marginal requirements--which were in effect during September 1989-December 1990-- , as measured at the end of each month. Reserves, in the form of unremunerated central bank deposits only, were to be held as a monthly average of daily positions.

Banks in Uganda (1992) were obliged to maintain unremunerated central bank deposits equal to 10 percent of their deposits. The 20 percent LAR does not seem to be enforced. Reserve requirements were meant to be contemporaneous, but in practice they were measured and held on a weekly basis with one-week lag. Reserve shortfalls were charged 0.1 percent interest per day (44 percent per year). Reserve requirements have seldom been varied, despite a lack of other monetary policy instruments.

Reserve requirements in Venezuela (1993) were unified at 12 percent in 1990 and extended to cover deposits at all banks and finance houses. Two thirds of required reserves were to be held over a week in a blocked account with the central bank, and one third as cash in vault or deposits in a clearing account. Reserves were not remunerated, and a penalty rate was

applied to shortfalls, but enforcement was reported to be intermittent. Shortfalls in the requirement that banks make 22.5 percent of loans to the agricultural sector were penalized by a matching reserve requirement. Reserve requirements were gradually raised to 25 percent during 1990-1991. In September 1992 the central bank introduced a uniform marginal reserve requirement of 15 percent on the change over the August stock of deposits. The increase in reserve requirements for public sector deposits from 15 percent to 80 percent in 1991 was reversed in 1992.

Yugoslavia (1990) had reserve requirements even under the socialist system. Banks were obliged to hold deposits with the central bank equal to 17 percent of demand deposits and 5 percent of other deposits, plus central bank bills equal to 5.5 percent of demand deposits. Many financial sector liabilities, notably those of NBFIs, were free of reserve requirements. The reserve base was measured on three days each month, with a ten-day delay, and reserves were held from the 11th of one month to the 10th of the next. Reserve deposits were remunerated at 30 to 70 percent of the central bank discount rate. Occasional shortfalls were not penalized, and the penalty rate was below the interbank rate.

Remuneration of Reserves and Vault Cash

Most industrialized countries include banks' cash in vault among eligible assets with which banks can fulfill their reserve requirements. Cash is treated on a par with reserves on deposit with the central bank, as both provide finality of payment. In several countries, however, cash in vault is excluded from eligible assets, sometimes for the purely practical reason that banks' holdings of cash are difficult to monitor in a timely and verifiable manner.

A number of questions arise concerning the treatment of vault cash. Would its exclusion from eligible assets increase distortions caused by reserve requirements? Or should the opportunity cost of holding vault cash be regarded as a normal business expense which should not be effectively subsidized by treating vault cash as an eligible asset? How would the remuneration of central bank deposits, or vault cash, affect the answers to these questions? Do reserve requirements affect banks differently according to the amount of cash they willingly hold?

Here an attempt is made to answer these questions in a simple way by using a stylized representation of a bank's profit maximization problem. The analysis is partial equilibrium; in particular, interest rates are taken as given. Therefore, and because the behavior of nonbanks is represented only implicitly, welfare considerations cannot be addressed directly. General questions concerning the optimal quantity of liquid assets go beyond the scope of this note. Also neglected are any questions concerning dynamics, such as the best way to introduce a new or revised reserve requirement.

The bank makes loans (L), holds vault cash (V), and keeps reserve deposits (R) with the central bank. Its liabilities consist of its capital (K) and deposits (D). The bank is a price taker, in the sense that it takes the lending rate i_L and the deposit rate i_D as given. However, it can attract more deposits by offering better customer services. Holdings of vault cash will be treated as a proxy for the provision of such retail transaction services; the supply schedule for deposits will be written $D = D(V)$ ($D' > 0$). Providing customer services and handling cash is costly, so the bank faces a cost function $C = C(V)$ ($C' > 0$). 1/ If banks differ in the deposit supply schedules or cost functions that they face, they will be more or less specialized in the provision of retail services.

In addition, the holding of reserves on deposit with the central bank may provide transaction services to the bank, principally by ensuring that "good money" is available immediately as a buffer against fluctuations in

1/ The problem could be reformulated in various ways, for example, by making the bank's desired cash holdings a function of the deposit base. The cost function specified can be thought of as a reduced form that incorporates also the costs of making loans and taking deposits.

inflows and outflows. Because the absolute magnitude of these fluctuations can be expected to vary with the size of the bank's balance sheet, the value of transaction services is described by a function $T(R/D)$, $T' \geq 0$, $T'' \leq 0$.

1. No transactions balances

Initially it will be convenient to assume away the motivation to hold transaction balances with the central bank, i.e., to assume that $T(r) = 0$ for all r .

a. The unconstrained case

In an unregulated environment the bank's problem is to maximize profits Π :

$$\Pi = i_L L - i_D D(V) - C(V),$$

given the budget constraint

$$L + V + R = D + K .$$

The budget constraint can conveniently be substituted into the profit function, so that the problem is to solve

$$\max_V i_L [D(V) + K - V - R] - i_D D(V) - C(V) . \quad (1)$$

Clearly no reserves with the central bank will be held, as they merely reduce the funds available for lending. The bank chooses V according to the first order condition

$$[i_L - i_D] \cdot D' - C' = i_L . \quad (2)$$

It is assumed that the second order condition is met. The solution to the bank's maximization problem is illustrated in Figure 1, assuming $D'' < 0$, $C'' < 0$; a superscript 'u' denotes an unconstrained value. If the bank forgoes one extra dollar of lending to hold vault cash, it loses i_L in interest income and bears a cost C' , but it generates an additional D' in deposits, which yield $[i_L - i_D]$. At the solution, marginal cost and revenue are just equal. The shape and position of the functions $D(\cdot)$ and $C(\cdot)$ together determine how much vault cash the bank wants to hold, and what deposits it will generate.

The bank's behavior in this unregulated environment will serve as a benchmark, as there each bank can choose its portfolios according to its comparative advantage without constraint. The aim is to design reserve requirements in such a way that the bank holds as much cash, and, thus, take as much in deposits, as in the unregulated environment.

b. Reserve requirements

Suppose now that the central bank imposes a requirement that the bank hold deposits at the central bank equal to ρ 100 percent of their deposits, so that $R = \rho D$. It is assumed that banks can manage their cash flow so well that no systematic reserves excess or shortfall occurs. Deposits at the central bank may be remunerated at a rate i_R , $i_R \geq 0$. The bank's problem now can be stated as

$$\max_V i_L [D(V) + K - V - \rho D(V)] + i_R \rho D(V) - i_D D(V) - C(V) . \quad (3)$$

The optimal holdings of vault cash, V^b , satisfies the first order condition

$$[i_L - i_D - \rho(i_L - i_R)] D'(V^b) - C'(V^b) = i_L . \quad (4)$$

The new first order condition is illustrated in Figure 2. The marginal cost of an extra dollar in vault cash is unchanged, but the marginal revenue schedule has been rotated counter-clockwise (if $i_L > i_R$). The change in profits for a marginal increase in the reserve requirement is just $[i_R - i_L]D(V^b)$, which depends only on the position of the deposit supply schedule, rather than on the bank's involvement in cash-based operations.

The sensitivity of V^b to the imposition of the reserve requirement can be judged by differentiating equation (4) with respect to ρ , giving the expression

$$\frac{dV^b}{d\rho} = \frac{[i_L - i_R]D'}{[i_L(1-\rho) + i_R\rho - i_D]D'' - C''} \quad (5)$$

evaluated at $V = V^b$. Note that the denominator in equation (5) must be negative by the second order condition of the maximization problem.

Clearly, if deposits with the central bank are remunerated at the same rate as the bank earns on its loans ($i_R = i_L$), then equation (4) reduces to equation (2), profits are unchanged, and $dV^b/d\rho = 0$; the bank's holdings of cash and deposits are unaffected by the reserve requirement. Independent of how reliant the bank is on obtaining deposits by offering customer services and the costs associated with those services (as expressed by $D(\cdot)$ and $C(\cdot)$), adequate remuneration of reserves removes any distortion to banks' demand for deposits or cash. Of course, by the budget constraint, the bank's loans must be reduced or its capital increased by the amount of reserves. In general equilibrium, interest rates would then change to distribute the necessary adjustment between all loans and deposits.

If $i_L > i_R$, then $dV^b/d\rho < 0$ and the imposition of a reserve requirement discourages the bank from holding vault cash. Therefore the bank also takes fewer deposits and makes fewer loans. It does not seem possible to say in general whether V/D will increase or decrease relative to its unconstrained level.

Figure 1. Demand for vault cash

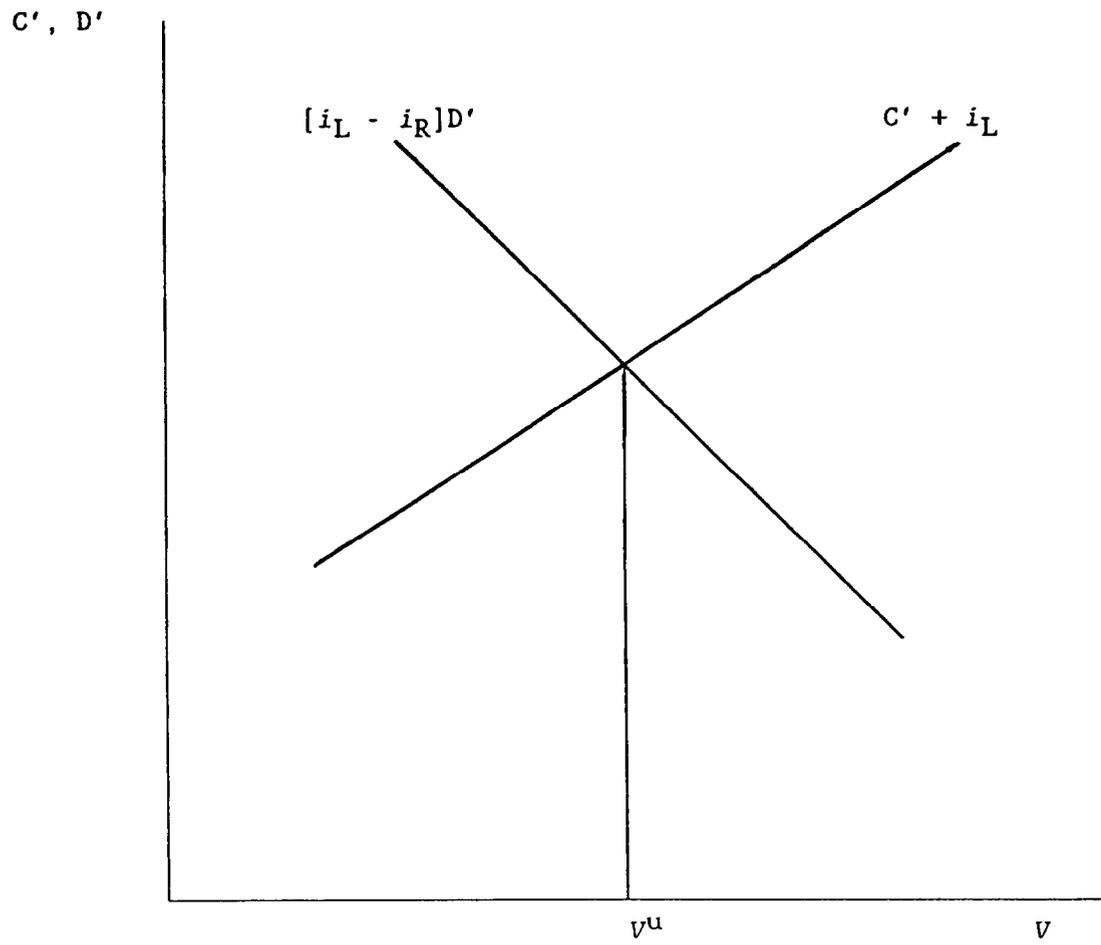
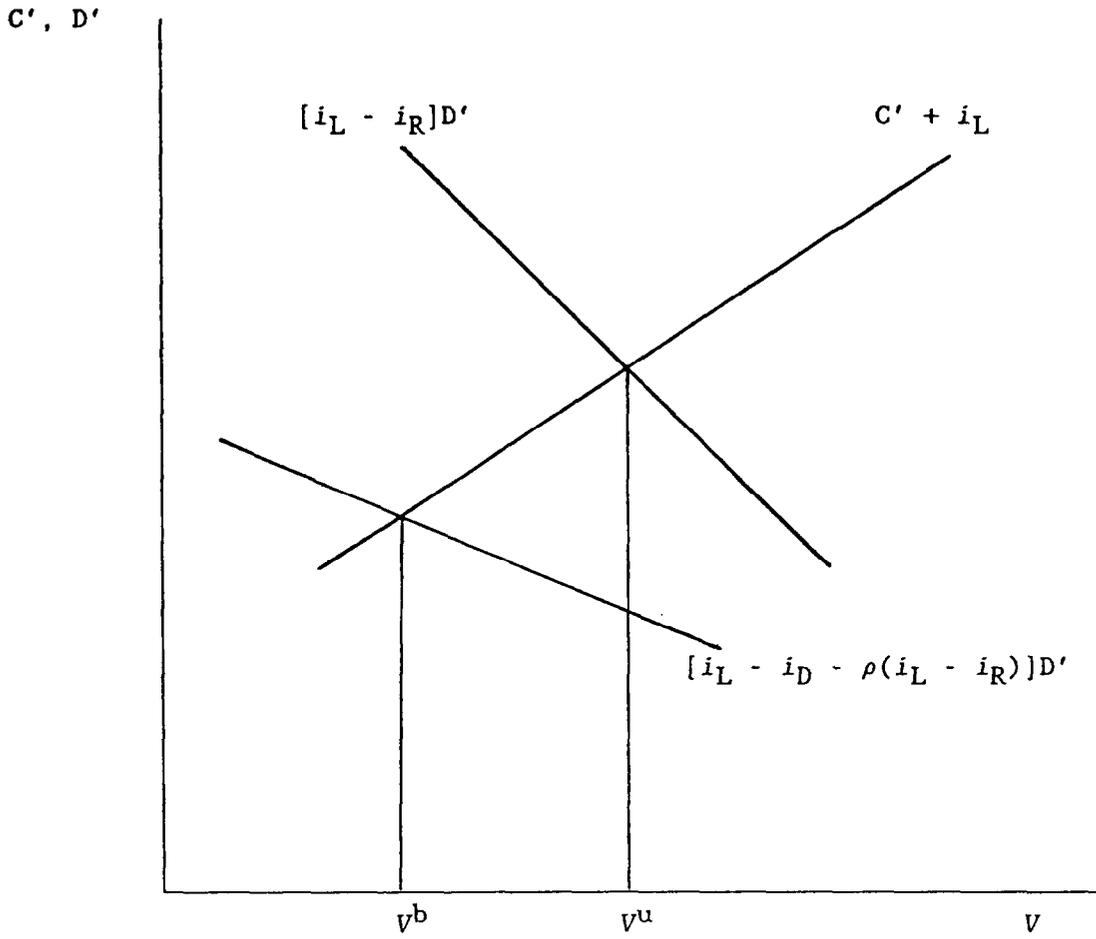


Figure 2. Vault cash and reserve requirements



c. Vault cash as an eligible asset

Suppose now that vault cash is declared an eligible asset; the reserve requirement can be expressed as $R + V = \rho D$. Only deposits with the central bank may be remunerated. The bank has to solve

$$\begin{aligned} \max_V \quad & i_L [D(V) + K - V - (\rho D(V) - V)] \\ & + i_R (\rho D(V) - V) - i_D D(V) - C(V). \end{aligned} \quad (6)$$

Let V^c satisfy the relevant first order condition

$$[i_L - i_D - \rho(i_L - i_R)]D'(V^c) - C'(V^c) = i_R. \quad (7)$$

The derivative $dV^c/d\rho$ is still given by equation (5), and the change in profits for a marginal increase in the reserve requirement is still $[i_R - i_L]D(V^c)$.

If reserves are remunerated at the lending rate, equation (7) reduces to equation (2), and the bank's vault cash and deposits are again unaffected by the reserve requirement. Whether or not vault cash is an eligible asset, remunerating reserve deposits at the lending rate eliminates any effect on the cash-intensity of the bank's operations. Even when vault cash is needed as an input to the "production" of deposits and it is costly to hold, the opportunity cost of reserves in any form is the lending rate.

The left-hand sides of equations (4) and (7) describe the same negatively sloped function; equations (4) and (7) differ only by the interest rate term on the right. Hence, if $i_L > i_R$, more cash will be held in vault when it is an eligible asset than when it is not, i.e., $V^c > V^b$; this relationship is illustrated in Figure 3. The offsetting differences in D and L needed to preserve the balance sheet identity depend on the function $D(\cdot)$.

It may seem then that bank profitability in the two cases cannot be compared directly without further parametricizing the model. However, the bank can always act as if it were in case (b) and hold V^b , so it is better off by at least $(i_L - i_R)V^b$ when cash and reserve deposits are both eligible assets; insofar as the bank adjusts its portfolio from case (b) to case (c), it is made still better off. Altogether, when reserves are remunerated at below the lending rate, including vault cash among eligible assets reduces the effect of the requirement on banks' portfolios and profitability. There is a presumption that this effect will be greater, for a given deposit base, the more cash is held, but contrary examples can be constructed.

It is possible that in case (c) banks may hold more cash than when unconstrained. From (7), one can derive

$$\frac{dV^c}{di_R} = \frac{1 - \rho D'}{[i_L(1-\rho) + i_R\rho - i_D]D'' - C''} \quad (8)$$

Higher remuneration of deposits with the central bank induces substitution of reserve deposits for cash, but it also encourages the bank to expand generally, which is achieved by holding more cash. The expression (8) is negative for ρ and D' small enough, that is, when the substitution effect predominates. If so, then starting from $i_R = i_L$ where the bank's portfolio is unaffected by the reserve requirement, a small fall in i_R can lead to the bank holding more vault cash than it would if unregulated.

d. Remunerating vault cash

Suppose now that, in addition to the conditions defining case (c), vault cash may also be remunerated at a rate i_V . The maximization problem becomes

$$\max_V i_L[(1 - \rho)D + K] + i_R(\rho D - V) + i_V V - i_D D - C, \quad (9)$$

which is solved by

$$[i_L - i_D - \rho(i_L - i_R)]D' - C' = (i_R - i_V). \quad (10)$$

Again by the second order condition, the remuneration of vault cash induces the bank to hold still more cash than when only deposits with the central bank are remunerated (case (c)). So, for instance, when $i_R = i_L$, remunerating vault cash certainly raises the bank's cash holdings above its nonregulated level. When expression (8) is negative, reducing the remuneration of reserve deposits raises cash holdings still further because the substitution effect is more pronounced.

2. Incorporating transactions balances

A bank that can obtain transaction services by holding some reserves faces a similar problem, but now has two instruments at its disposal, vault cash and reserve deposits. The optimal policy setting needs to be refined to allow for the more complex behavior of banks.

a. The unconstrained case

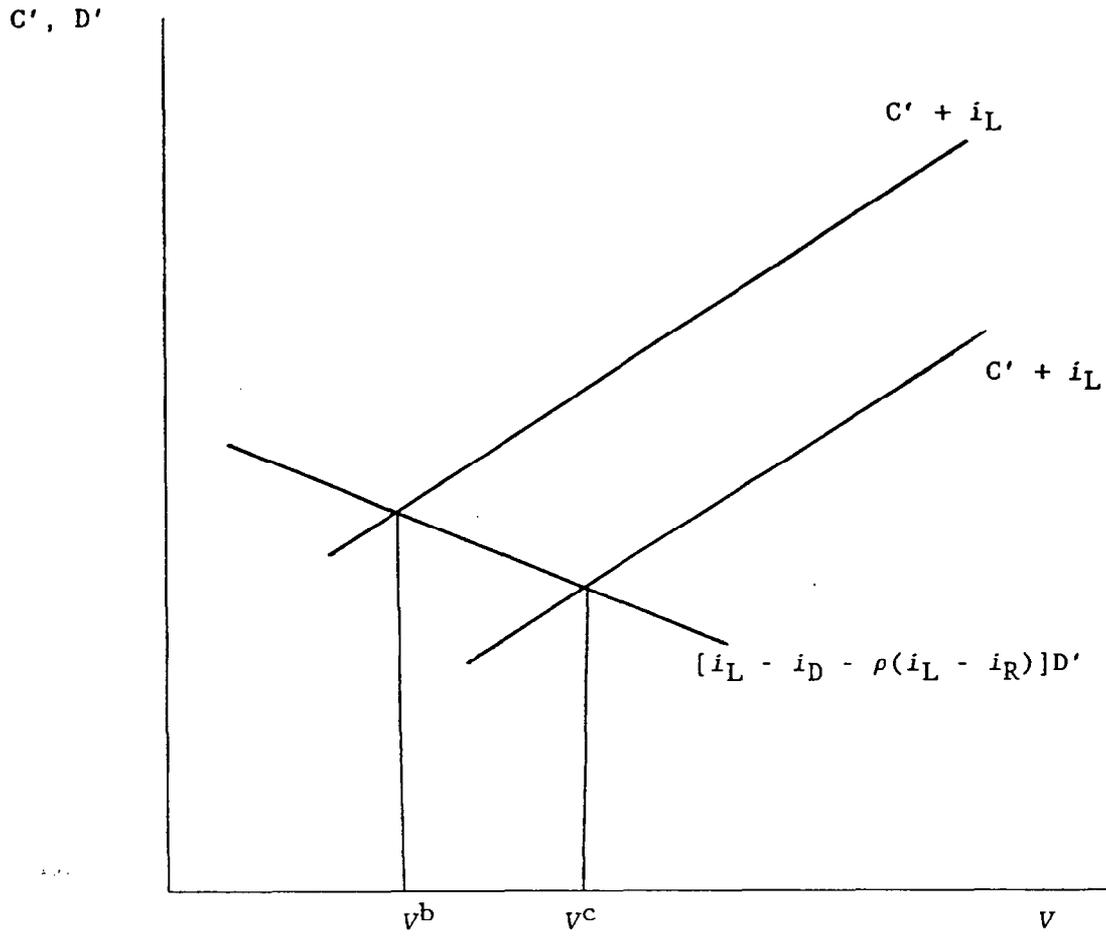
In the absence of regulation, the bank adjusts V and R to maximize

$$\Pi = i_L L - i_D D(V) - C(V) + T(R/D)$$

subject to the budget constraint. Equivalently, it solves

$$\max_{V,R} i_L [D(V) + K - V - R] - i_D D(V) - C(V) + T(R/D). \quad (11)$$

Figure 3. Vault cash as an eligible asset



The first order conditions are

$$[i_L - i_D]D' - C' + T'RD'/D^2 - i_L = 0 \quad (12a)$$

$$T'/D - i_L = 0 \quad (12b)$$

which combined yield

$$[i_L(1 - R^u/D^u) - i_D]D'(V^u) - C'(V^u) = i_L \quad (12c)$$

where a superscript 'u' again denotes an optimum value when the bank is unconstrained. Equation (12b) shows that, due to the additive separability between the costs of vault cash and the transaction services of reserve deposits, the ratio R^u/D^u depends only on the levels of i_L and D and on the function $T(\cdot)$; for a given deposit base, a bank that finds it relatively cheap to hold much cash and attract retail customers has no more or less incentive to hold reserves than a corporate or wholesale bank.

b. Reserve requirements

The authorities decide to impose a reserve requirement, so that $R = \rho D$, but required reserves are to be remunerated at a rate i_R . The required reserve ratio is set at a level so high, that the bank never voluntarily holds excess reserves. The bank can adjust only its holdings of vault cash to maximize

$$\Pi = i_L[D(V)(1-\rho) + K - V] - i_D D(V) - C(V) + i_R \rho D(V) + T(\rho). \quad (13)$$

The first order condition is now

$$[i_L(1-\rho) - i_D + i_R \rho]D' - C' = i_L \quad (14)$$

Note that, evaluated at the optimum,

$$d\Pi/d\rho = [i_R - i_L]D + T',$$

which does not depend on the bank's specialization but only on the size of its balance sheet.

For a given required reserve ratio, the bank will hold the same amount of vault cash and take the same value of deposits as in the unconstrained case when

$$i_R = i_L \left[1 - \frac{R^u/D^u}{\rho} \right],$$

that is, when reserves are remunerated to the extent they are raised above their unconstrained level. Because the ratio R^u/D^u depends only on the shape of $T(\cdot)$ and the level of D , the same level of remuneration is

appropriate for all banks of given deposit base independent of their specialization. Again, higher reserve requirements will affect banks' capital and the supply of loans, and could thus influence equilibrium interest rates.

Remuneration at the lending rate would result in the bank holding too much cash because extra cash attracts deposits, which in turn permits the bank to earn interest and transaction services on more reserves. Low or zero remuneration would induce banks to hold less vault cash than in the unconstrained case.

c. Vault cash as an eligible asset

The inclusion of vault cash among eligible assets complicates the story still further, principally because each extra dollar of vault cash reduces reserve deposits by one dollar (assuming that there is no motive to hold excess reserves), and thus the corresponding transaction services are reduced.

The profit function can be written

$$\Pi = i_L[D(1-\rho) + K] - i_D D - C(V) + T\left[\frac{\rho D - V}{D}\right] + i_R[\rho D - V], \quad (16)$$

so the first order condition becomes

$$[i_L(1-\rho) - i_D + i_R\rho]D' - C' - T'(\cdot)\left[\frac{D - VD'}{D^2}\right] - i_R = 0. \quad (17)$$

There is in general some value of i_R such that equation (17) reduces to equation (12), that is, such that the bank's holding of vault cash and the supply of deposits is unaffected by the reserve requirement. 1/ However, the nondistortionary rate of remuneration does in general depend on the shapes of the functions $C(\cdot)$ and $D(\cdot)$, so a uniform rate must affect banks with different "production technologies" unequally.

1/ So for instance when the reserve requirement is so high that $T'(\cdot) = 0$, vault cash holdings and deposits will be unaffected by the reserve requirement when

$$i_R = i_L \left[1 + \frac{D'R^u/D^u}{1 - \rho D'} \right].$$

Since by assumption marginal reserve deposits do not now yield transaction services, they need to be remunerated at a rate above that on loans in order to reduce holdings of vault cash to their unconstrained level.

A comparison of equations (14) and (17) reveals that, if the term $T'[D-VD']/D^2$ is small or negative, including vault cash among eligible assets increases the incentive to hold it. The possibility, mentioned in section I(c), that a bank may hold more cash than when unconstrained, is less likely here because extra cash reduces the transaction services provided by reserve deposits.

3. Conclusion

It is assumed in this appendix that the central bank wishes to impose a reserve requirement, but in such a way as not to discriminate between banks on the basis of their specialization in retail or commercial business. The baseline is a situation where banks voluntarily hold vault cash, and perhaps unremunerated reserve deposits, for their transaction services.

According to the illustrative models presented here, if banks would hold no reserves voluntarily, remuneration at the lending rate eliminates distortions to banks' profitability, vault cash and deposits, whether or not vault cash is an eligible asset. However, loans must be lower according to the balance sheet constraint. Reserve requirements will have no effect on banks' cash in vault and deposit liabilities if reserve deposits alone are eligible assets, and required reserves are remunerated in proportion to their excess over voluntarily-held reserve deposits; the appropriate rate of remuneration is independent of banks' holdings of vault cash. If for some reason adequate remuneration cannot be provided, the "conventional wisdom" that including cash among eligible assets reduces the effect of the requirement on banks' behavior is largely confirmed. However, it is an empirical matter whether a bank that starts with a high cash to deposit ratio will be more affected by the imposition of a reserve requirement than one that specializes in wholesale activity; any discriminatory effect of reserve requirements depends on the various underlying differences between banks that manifest themselves in diverse specializations.

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