Abstract

The paper proposes a two-step approach to assessing the extent to which the fall in credit in crisis-stricken East Asian countries was a supply- or demand-induced phenomenon. The first step is based on the estimation of a demand function for excess liquid assets by commercial banks. Such a function is derived analytically in the first part of the paper. The second step consists in establishing dynamic projections for the periods following the crisis and assessing whether or not residuals are large enough to be viewed as indicators of “involuntary” accumulation of excess reserves. The results for Thailand indicate that the fall in bank lending seems to have been a reflection of a credit crunch only in the immediate aftermath of the crisis; in subsequent periods, the constraining factor appears to have been the demand for credit.

JEL Classification Numbers: E42, F31, F41
1 Introduction

The causes of the sharp decline in credit to the private sector in the crisis-stricken countries of East Asia (as documented, for instance, by Alba et al. (1999)) continues to generate much controversy among economists. Some observers have argued that the fall in bank credit resulted from a credit crunch (that is, increased incidence of credit rationing), which may have been compounded by the unwillingness of commercial banks to charge higher interest rates and thereby exacerbate adverse selection problems of the Sitglitz-Weiss variety. Others have suggested that the decline in bank loans may have resulted instead from the reduction in the demand for credit, itself a consequence of the contraction in aggregate demand and the fall in output that accompanied the crisis.

Whether a contraction in domestic credit is due to supply or demand factors has, of course, important implications for monetary and fiscal policies. If banks are unwilling to lend because, for instance, of a perceived increase in the risk of default that cannot be internalized by raising the cost of borrowing, attempts to increase liquidity and force interest rates down to stimulate aggregate demand and the demand for loans will prove largely ineffectve. By contrast, if banks are unable to lend (because firms are curtailing their demand for credit as a result, for instance, of a perceived weakening in future demand and thus lower profits), easing the fiscal stance may help expand aggregate demand and generate an expansion in credit.

Recent attempts at determining whether the fall in bank credit in Asia's crisis-stricken countries resulted from supply or demand factors have provided mixed results. Several papers have used survey evidence on changes in bank lending and firm borrowing during the crisis to assess the incidence of a credit crunch. Some of the better-known studies include those of Domac and Ferri (1999a), Dollar and Hallward-Driemeier (1998), Dwor-Frecaut, Hallward-Driemeier, and Colaco (1999), and Ito and Pereira da Silva (1999). The latter study, in particular, used survey data for commercial banks to argue in favor
of a credit crunch in Thailand during the period extending from mid-1997 (immediately after the inception of the crisis) to early 1998.\footnote{As noted by Ito and Pereira da Silva (1999), if the nominal credit stock is deflated by a composite index consisting of consumer prices and the nominal exchange rate (in order to account for the fact that a significant share of the loans provided by Thai commercial banks and finance companies just before the crisis were denominated in foreign currency and the book value of these loans was recorded at the current exchange rate), the deceleration in the rate of growth of real credit to the private sector was quite dramatic in that country: a year-on-year contraction of -2.4 percent in August 1997, -5.3 percent in October, -12.2 percent in November and -18 percent in December (Ito and Pereira da Silva (1999, p. 14)).} By contrast, Dollar and Hallward-Driemeier (1998) found little evidence of a credit crunch in Thailand— in the sense of firms with orders but unable to get credit to finance working capital needs. The evidence that they gathered suggests, on the contrary, that constraining factors on output expansion appeared to have been weak perceived demand and the sharp increase in the price of imported inputs resulting from the large nominal exchange rate depreciation that occurred in the months following the crisis.\footnote{It should also be noted that in Thailand, firms had contracted large amounts of unhedged short-term debt on world capital markets and were thus highly vulnerable to currency depreciation; see Alba et al. (1999).} Along the same lines, Dwor-Frecaut, Hallward-Driemeier, and Colaco (1999) analyzed the results of a survey conducted between November 1998 and February 1999 in Indonesia, Korea, Malaysia, the Philippines, and Thailand of 3,700 firms, covering major manufacturing and export sectors. They found that at prevailing interest rates, credit availability in the aggregate was not seen by the surveyed firms as a major constraint on production plans. They concluded therefore that the fall in credit was demand-driven.

Because survey evidence can be seriously biased— for instance, tight credit can reduce demand, and lack of demand may be perceived as the main problem by respondents— several other studies have relied on other methodologies. Domaç and Ferri (1999b), for instance, used a conceptual framework based on the “credit view” of monetary policy to analyze the existence of a credit crunch in Indonesia, Korea, Malaysia, the Philippines, and Thailand.\footnote{See Walsh (1998, Chapter 7) for a detailed discussion of the credit channel of monetary policy.}
Specifically, they argued that a widening of the spread between the lending rate and a representative rate on risk-free assets while at the same time real bank credit is falling represents prima facie evidence that the demand for loans could not have declined by more than the supply of credit. They found evidence (based on the spread between bank lending rates and corporate bonds) consistent with this view and thus concluded that the credit crunch was widespread, affecting particularly small-sized firms, for whom close substitutes for bank credit are unavailable.\(^4\)

By contrast, Ghosh and Ghosh (1999) used a switching regression framework for analyzing the behavior of real private credit in Korea and Indonesia. They estimated both supply and demand functions for credit and determined, for each period, whether supply or demand was the constraining factor. They found that, in Indonesia (where the crisis started in September 1997), there was evidence of a credit crunch in the third and fourth quarters of 1997. By the end of the first half of 1998, however, the decline in actual credit reflected mostly the fall in the demand for loans induced by the deepening recession. Similarly, in Korea (where the crisis started a month later) they found evidence of a credit crunch in the last quarter of 1997, but from the first quarter of 1998 onward, the constraining factor appears to have been the demand for credit. Thus, and in contrast to the survey-based evidence, the study by Ghosh and Ghosh provides evidence of both demand and supply factors at play: the fall in private sector lending in East Asia (at least in Korean and Indonesia) may have been the result of bank tightening of credit supply in the first stage, and a drop in borrower demand in the second stage.

This paper attempts to shed additional light on the current controversy policy, particularly the role of informational asymmetries.

\(^4\)It should be noted, however, that spreads can increase for a variety of reasons. For instance, in the model of Agénor and Aizenman (1998), an increase in spreads may result from an expected rise in monitoring costs associated with lending operations. An expected tightening in prudential regulations requiring banks to hold more liquid assets may also lead to higher spreads, to the extent that these assets yield lower returns (and thus lower income) than other assets that the banks would have chosen otherwise.
by proposing a two-step econometric approach. The first step is based on the estimation of a demand function for excess reserves (or liquid assets) by commercial banks that captures, in particular, the precautionary motive for holding nonremunerated assets. The second step consists in establishing dynamic projections for the periods following the crisis and assessing whether actual values of excess reserves are “close enough” (in a statistical sense that is made more precise below) to those predicted by a stable regression model. If that is the case, the increase in actual holdings of excess reserves can be construed as consistent with a supply-induced reduction in credit; if that is not the case, the accumulation of excess liquid assets can be seen as “involuntary”—in which case the slowdown in credit is more likely to reflect a reduction in demand. Underlying our approach is the view that increased incidence of rationing—particularly of the more risky categories of borrowers—may take the form of increases in excess reserve holdings motivated, in the context of a crisis, by higher perceived uncertainty or risk of default. Greater volatility of deposits (relative to currency holdings) and increased riskiness of lending, in particular, may also prompt banks to hold higher levels of precautionary excess reserves.

The remainder of the paper is structured as follows. Section II presents a theoretical model of the demand for excess liquid reserves by commercial banks in the presence of both liquidity risk and real sector volatility. The impact of various variables (including required reserves and funding costs) on the demand for excess reserves is also analyzed. Section III presents estimates of the resulting demand equation for Thailand, using pre-crisis data; it also discusses the in-sample properties of the model. Section IV examines the out-of-sample performance of the model (July 1997 onward for Thailand) and analyzes whether the regression forecasts are consistent with the hypothesis of a credit crunch. The last section summarizes the results and offers some concluding remarks.
2 A Model of Excess Liquid Assets

At the heart of our analysis of the factors underlying the fall in credit in East Asia is a model of excess liquid reserves. As is well known from the early literature surveyed by Baltensperger (1980), Santomero (1984) and Swank (1996), reserve management models deal with a bank’s funding or liquidity risk. To manage this type of risk, and in deciding how much cash and other liquid assets they should hold, banks internalize the fact that they can draw funds from either the interbank market or the central bank in case of unexpected contingencies.

To begin with, consider the following simple model of reserve management (Baltensperger (1980)). Assume that there is only one representative bank whose deposits $D$ are given exogenously. The bank must decide upon the level of liquid, non-interest bearing reserve assets, $R$, and non-reserve assets, which take the form of illiquid loans, $L$. Its balance sheet is given by

$$ R + L = D: \tag{1} $$

Reserves are necessary because the bank is exposed to liquidity risk. Deposits $u$ occur randomly according to a density function $\bar{A} = \mathcal{E}^0$. When the net outflow of cash exceeds the reserves, $u < R$, the bank must face illiquidity costs that are taken to be proportional to the reserve deficiency $\max(0, u - R)$. Put differently, in case of illiquidity the bank must borrow the missing reserves at a penalty rate $q$, with $q > r_L$, where $r_L$ is the interest rate on loans. Let $r_D$ denote the deposit rate; the bank’s profit is thus

$$ \Pi = r_L L + r_D D - q \max(0, u - R); $$

which implies that the bank’s expected profit is

$$ E(\Pi) = r_L L i r_D D i q \max(0, u - R) \bar{A}(u) du; \tag{2} $$

that is, using (1):

$$ E(\Pi) = (r_L i r_D) D i r_L R i q \max(0, u - R) \bar{A}(u) du; \tag{3} $$

6
Assuming risk neutrality, the optimal level of reserves is determined so as to maximize expected profits. The necessary condition is thus:

$$\frac{\partial \mathbb{E}(\xi)}{\partial R} = \beta r_L + \alpha \mathbb{1}_i \mathbb{E}(R) = 0;$$

that is

$$R^* = \alpha i (\frac{q}{r_L});$$  \hspace{1cm} (4)

Equation (4) implies that the marginal opportunity cost of holding an extra unit of reserves, $r_L$, is equated to the marginal reduction in liquidity costs. Optimal reserves decrease with the lending rate $r_L$ and increase with the penalty rate $q$.  

For our purpose here, we extend this simple model in several directions, following in part Prisman and Slovin (1986). Specifically, we account for required reserves, the link between the demand for cash and deposits, and output shocks. Suppose that the demand for loans, $L$, is negatively related to the lending rate and proportional to expected output, $Y_e$:

$$L = f(r_L)Y_e; \hspace{0.5cm} f^0 < 0:$$  \hspace{1cm} (5)

Similarly, the supply of deposits by the public, $D$, is taken to be positively related to the deposit rate and proportional to expected output:

$$D = g(r_D)Y_e; \hspace{0.5cm} g^0 > 0:$$  \hspace{1cm} (6)

Suppose that agents determine $L$ and $D$ at the beginning of each period, before the realization of shocks to output. In addition, there is a demand for cash determined at the end of the period, following the realization of output and liquidity shocks. The bank is required to maintain liquid reserves in

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5 Because $\mathbb{E}(\xi)$ is concave in $R$, the necessary condition is also sufficient.

6 Moreover, if the distribution function of deposit flows can be approximated by a normal distribution, reserves can be shown to be proportional to the variance of deposit flows (see Baltensperger (1980)).
proportion to its deposit base, at the interest rate \( r \). Let \( \mu \) denote the reserve requirement rate and \( R \) total reserves; excess reserves, \( Z \), are thus given by

\[
Z = R \cdot \mu D;
\]

that is, using (1) to eliminate \( R \),

\[
Z = (1 - \mu)D - L; \quad (7)
\]

With \( C \) denoting currency holdings, the equilibrium condition of the money market is given by

\[
C + D = kY; \quad k > 0; \quad (8)
\]

where \( k \) is the reciprocal of velocity (assumed constant in what follows) and \( Y \) realized output.

Suppose that the demand for cash is also proportional to realized output; specifically, let us assume that

\[
C = cY; \quad (9)
\]

where \( c = C/D \). We will assume in what follows that both output and \( ck = (1 + c) \) are random and given by

\[
Y = Y^e(1 + \cdot); \quad \frac{ck}{1 + c} = \pi(1 + \cdot); \quad (10)
\]

where \( \cdot \) and \( \cdot \) are random shocks. Using (9) and (10), the demand for cash can be rewritten as

\[
C = \pi kY^e(1 + \cdot)(1 + \cdot); \quad (11)
\]

For simplicity of exposition, suppose that the composite term \((1 + \cdot)(1 + \cdot)\), denoted \( x \), is normally distributed with constant mean \( 1 \) and constant variance \( 3/4 \):

\[
x = (1 + \cdot)(1 + \cdot) \sim N(1; 3/4); \quad (12)
\]
To meet unexpected withdrawals (unanticipated demand for cash), the bank now can not only borrow at a penalty rate of $q$, as in the simple model presented above, but it may also use its excess reserves, $Z$. Using (7), the expected reserve deficiency is thus now given by

$$E \max[0; C_i \cdot ((1 - \mu)D_i + L)]$$

Using this result, together with (5), (6), (8), and (11), the bank’s expected profits can be written as

$$\pi = [r_L f(r_L) + r_D g(r_D)]Y^e + rR - \pi \max[0; C_i \cdot ((1 - \mu)D_i + L)]$$

(13)

Assuming that the functions $f(\phi)$ and $g(\phi)$ are quasi-concave functions, the following propositions can be established:

**Proposition 1** An increase in the penalty rate increases deposits and lending rates, as well as excess reserves held by commercial banks.

**Proposition 2** An increase in the volatility of output and liquidity shocks has ambiguous effects on the deposit rate, the lending rate, and excess reserves. If the initial level of the penalty rate is sufficiently high, an increase in volatility has a positive effect on all three variables.

**Proposition 3** An increase in the reserve requirement rate unambiguously raises the lending rate and lowers excess reserves. If the degree of volatility is not too high, it also raises the deposit rate.

Proof of the results summarized in these propositions are provided in Appendix A. Proposition 1 implies that, for a high enough level of the penalty rate, excess reserves will exceed expected withdrawals, that is, $Z_i \cdot 1 > 0$. Under such conditions, Propositions 1, 2 and 3 can be combined to lead to the following demand function for excess reserves:

$$Z = Z(\hat{\phi}; \mu; \hat{\phi})$$

(14)

Equation (14) forms the basis of our empirical investigation.
3 Estimation Results: Thailand, 1992-97

As noted in the introduction, the first step of our approach to assessing the extent to which the credit crunch that East Asian countries experienced in the immediate aftermath of their financial crisis was a supply or demand-induced phenomenon consists in estimating a demand function for excess liquid reserves by commercial banks. Equation (14) can be viewed as providing a benchmark specification for desired, as opposed to actual, excess reserves. We therefore generalize it to a dynamic setting. Specifically, we use a regression model in which the logarithm of the ratio of excess liquid assets held by commercial banks, $EL$, over total bank deposits, $D$, is a function of the following variables:\footnote{Appendix B provides a more detailed description of these variables and identifies our data sources.}

2. the lagged value of the ratio of excess reserves to deposits, $\ln(EL/D)_{-1}$, to account for partial adjustment to the desired ratio;

2. the ratio of required liquid assets, $RR$, to total bank deposits, $D$, which captures the impact of reserve requirements, as derived in equation (14);

2. the coefficient of variation of the cash-to-deposit ratio and the deviation of output from trend, to account for the impact of volatility and liquidity risk, and thus the precautionary effect on the demand for reserves, as emphasized in (14);

2. the discount rate, $r$, which corresponds to the penalty rate identified in (14). As noted by Van't Dack (1999), the discount window has been the last resort facility for banks and finance companies in Thailand.

In addition to these variables, which are all consistent with the theoretical model derived in the previous section, we also include the logarithm of
deviations of output from trend, \( \ln(Y - Y_T) \). This variable can be viewed as a proxy for unexpected changes in the demand for cash. A cyclical upturn, for instance, would lead banks to anticipate higher, transactions-related, demand for currency by the public and would therefore lead them to increase their holdings of excess reserves. To account for the possibility of a gradual impact of funding costs and cyclical movements in output on the demand for excess reserves, we use Almon polynomial lags on both variables (see Greene (1997)).

Figure 1 displays the evolution of some of the variables included in our model during the period 1992-98. The first panel shows the evolution of the ratio of excess liquid assets (obtained as the difference between actual and required liquid assets) to bank deposits.\(^8\) The figure shows that excess liquid assets started to increase significantly well before the crisis (as early as late 1996), rising quite dramatically in the immediate aftermath of the currency and financial turmoil that began with the devaluation of the baht in July 1997. At the same time, the cyclical component of output turned sharply negative. The figure also shows that the money market rate fluctuated considerably during the period 1992-98—exceeding at times the discount rate and falling well below it at other times. Finally, both the ratio of credit to the private sector to deposits, and the ratio of currency in circulation to deposits, increased at first and subsequently fell in the aftermath of the crisis.

Estimation results based on monthly data for the period January 1992 to June 1997 are shown in the first column of Table 1. Our estimation technique is ordinary least squares; the small size of our sample precludes, in our view, a more sophisticated approach aimed at estimating a “long-run” demand for

\(^8\)As noted by Sirivedhin (1998), prudential regulations in Thailand around the time of the crisis required commercial banks to hold liquid assets (averaged over a fortnight) of not less than 7 percent of their deposit base; eligible assets included at least 2 percent non-interest-bearing deposits at the Bank of Thailand, a maximum of 2.5 percent cash in vault, and (making up the remainder) bonds issued by the government, approved state enterprises, specialized financial institutions or the Bank of Thailand.
excess reserves based on cointegration analysis. The results are consistent with our general priors and the equation performs fairly well; the adjusted R-squared is 0.85, and there is no evidence of serial correlation, as indicated by Durbin’s h statistic. The lagged ratio of excess reserves to deposits is highly significant. The cyclical component of output has also a significant positive impact on excess liquid assets, particularly when looking at the cumulative impact measured by the sum of the coefficients on the current and lagged values. The required reserves ratio is borderline significant and negative, as predicted by the model. The discount rate and our measures of volatility are not significant, but have the correct sign. Regressions (2) and (3) show that dropping the volatility measures has no significant impact on the parameter estimates.

Figure 2 shows the behavior of actual and predicted values of the logarithm of the ratio of excess liquid assets to deposits (based on regression (1) of Table 1, our preferred specification) for the period January 1994 to June 1997. Although the model does not capture very well the increase in that ratio during the early part of 1996, it does a reasonably good tracking job, given that the simulation is dynamic and uses therefore the predicted value of the dependent variable itself to calculate its lagged value.

Columns (4) to (6) in Table 1 show the estimation results for the complete sample for which the data are available, January 1992 to September 1998. The results are similar to those discussed above, except that now the volatility of output shocks (as measured by the coefficient of variation of the cyclical component of output) becomes borderline significant, and the degree of significance of the required reserve ratio (as measured by its t-statistic) increases somewhat. Moreover, a standard Chow test for stability indicates that there is no statistically significant evidence of a change in the parameters of the model estimated over the pre-crisis period only (equation (1) of Table

\footnote{For an approach to the simultaneous estimation of the demand for reserves and credit based on cointegration analysis, see for instance Civcir and Parikh (1995).}
1) and the model that encompasses post-crisis observations as well (equation (3) of Table 1). This stability result is important because it implies that the difference between the pre- and post-crisis behavior of excess liquid assets, as predicted by the model, can only reflect changes in the behavior of the determinants of the demand for these assets (as captured in the regression model), as opposed to changes in the parameters characterizing the behavior of commercial banks.

4 Out-of-Sample Simulations

The second step of our approach to assessing the existence of a credit crunch in Thailand in the aftermath of its economic and financial crisis consists in establishing dynamic projections for the period July 1997 onward and assessing whether the residuals derived from the predictions of the regression model of excess liquid assets estimated in the previous section (that is, the difference between actual and projected values) are small enough to be consistent with the predicted path of reserves, or on the contrary large enough to be viewed as indicators of “involuntary” accumulation of excess reserves—which would be more consistent with a demand-induced slowdown in credit.

Figure 3 shows the behavior of actual and predicted values of the logarithm of the ratio of excess liquid assets to deposits for the period July 1997 to October 1998, together with a one-standard error band (upper panel of the figure) and a two-standard error band (lower panel). These results are again based on dynamic simulations of regression (1) of Table 1, our preferred specification. What comes out very clearly from the figure is that in the immediate aftermath of the crisis, actual values are within the error bands associated with the predictions of the model; if one uses a one-standard error band, this occurs between July 1997 to May 1998, whereas with a two-standard error band this occurs until August 1998. After that, however, actual values grow increasingly outside the error bands.
The interpretation of these results, within the framework of our general hypothesis, is as follows. To the extent that our regression model captures well the higher perceived degree of uncertainty or risk of default in the aftermath of the crisis, there is an initial stage in which increases in excess reserve holdings reflect a supply-side phenomenon—that is, higher excess liquid assets consistent with bank behavior. To the extent that higher unremunerated reserves are equivalent (everything else equal) to voluntary reductions in lending, the immediate aftermath of the crisis seems to have been accompanied by a credit crunch. However, over time, to the extent that the accumulation of excess liquid assets appears to have been “involuntary”, in the sense of being inconsistent with the demand behavior of banks, it is consistent with a demand-induced reduction in credit.

To test the robustness of our results, we rerun the regressions with two changes in specification. First, we estimated the model with unrestricted lags (of up to four quarters) of deviations of output from trend and the discount rate, instead of using Almon polynomial lags. The discount was never significant whereas the fourth-quarter lagged value of output was significant. We performed the same exercises as we did above, and found similar results. Second, we used the money market rate, instead of the discount rate, as a measure of the cost of funds for domestic banks. Estimation results, using the one-period lagged value of the money market rate, are reported in Table 2. They show that although the money market rate has the correct sign, it is not significant in any of the regressions—possibly as a result of the high degree of volatility displayed by that variable (see Figure 1). Although in the terms of the standard error of the regression and the adjusted R-squared the regressions in Table 2 compare favorably with those shown in Table 1, the cost of funds appears to be better measured by the discount rate.\(^\text{10}\) In principle, if access to the discount window of the central bank and the interbank market are subject to the same requirements—regarding, notably, eligible securities—the expected cost of funds for banks should be the lowest of the two values shown in the figure.

\(^{10}\)In principle, if access to the discount window of the central bank and the interbank market are subject to the same requirements—regarding, notably, eligible securities—the expected cost of funds for banks should be the lowest of the two values shown in the figure.
5 Summary and Concluding Remarks

The purpose of this paper has been to propose an alternative approach to examining the extent to which the fall in credit that characterized most crisis-stricken countries in East Asia reflected a credit crunch, that is, increased incidence of credit rationing by banks. We began by developing a demand function for excess reserves (or liquid assets) by commercial banks that captured, in particular, the impact of reserve requirements, funding costs, and precautionary motives related to liquidity risk and output volatility. We then estimated a dynamic version of the model for both the pre-crisis period for Thailand (January 1992 to June 1997) and a larger period with post-crisis observations (January 1992 to September 1998) and showed that the stability of the model cannot be rejected using standard tests. We then used the model to establish dynamic projections for the post-crisis period (July 1997 to October 1998). Our general assumption is that if actual values of excess reserves are within one- or two-standard error bands, the observed reduction in credit is consistent with a supply-side phenomenon. On the contrary, if actual values are outside the errors bands, this can be construed as evidence of “involuntary” accumulation of excess reserves; the slowdown in credit may thus more likely reflect a reduction in the demand for loans—possibly reflecting firms’ perceived weaknesses in future demand for their products.

Our results suggest that the fall in bank lending in Thailand seems to have been a reflection of a supply phenomenon (as argued by those who believe in the credit crunch hypothesis) only in the immediate aftermath of the crisis; in subsequent stages, the constraining factor appears to have
been the demand for credit. That is, the fall in the demand for credit may have forced banks to hold more excess liquid reserves than desired. Overall, therefore, our results are consistent with those obtained by Ghosh and Ghosh (1999) for Korea and Indonesia, using a very different methodology. It is also important to note that the absence of evidence on credit rationing at the aggregate level is not inconsistent with binding credit constraints at the microeconomic level. Thus, our results are not necessarily inconsistent with those obtained for instance by Domaç and Ferri (1999a), which indicate that small and medium-sized firms faced binding constraints in accessing credit markets in the aftermath of the crisis.

\footnote{It would be useful to apply the methodology developed here to other crisis-stricken countries in East Asia; whether this would prove fruitful or not remains to be seen. As noted by Domaç and Ferri (1999b) in Indonesia, the ratio of excess reserves to deposits did not display the same sharp increase observed in Thailand.}
Appendix A
Derivation of Propositions 1 to 3

Assuming that the functions \( f(q) \) and \( g(q) \) are quasi-concave, the results summarized in Propositions 1 and 2 can be written as

\[
\frac{dr_L}{dq} > 0; \quad \frac{dr_D}{dq} > 0; \quad \frac{dZ}{dq} > 0;
\]

and

\[
\text{sg} \left( \frac{dr_L}{d\sigma^4} \right) = \text{sg} \left( \frac{dr_D}{d\sigma^4} \right) = \text{sg} \left( \frac{dZ}{d\sigma^4} \right) = \text{sg} (Z - 1);
\]

To establish these results, we begin by rewriting (13), with \( Y_e \) normalized to unity, and using (1) to eliminate \( R \), as

\[
\frac{d\theta}{dq} = r_L f(r_L) + r_D g(r_D) + \text{sg} \left( \frac{dr_L}{d\theta} \right) = \text{sg} \left( \frac{dr_D}{d\theta} \right) = \text{sg} \left( \frac{dZ}{d\theta} \right) = \text{sg} (Z - 1);
\]

Assuming, as indicated in the text, that \( x \) is normally distributed with constant mean \( \mu \) and constant variance \( \sigma^2 \), this expression can be rewritten as

\[
\frac{d\theta}{dq} = r_L f(r_L) + r_D g(r_D) + \text{sg} \left( \frac{dr_L}{d\theta} \right) = \text{sg} \left( \frac{dr_D}{d\theta} \right) = \text{sg} \left( \frac{dZ}{d\theta} \right) = \text{sg} (Z - 1);
\]

where \( \sigma \) is the density function of \( x \) (assumed normal). Maximizing this expression with respect to the deposit and lending rates yields the first-order conditions

\[
\frac{d\theta}{dq} = (r_L + r_D) f(0) + \text{sg} \left( \frac{dr_L}{d\theta} \right) = \text{sg} \left( \frac{dr_D}{d\theta} \right) = \text{sg} \left( \frac{dZ}{d\theta} \right) = \text{sg} (Z - 1);
\]

where \( \sigma \) is the cumulative distribution function of \( x \).
Let \( D = r_D g^0 \) and \( L = r_L f^0 \) denote, respectively, the elasticities of the supply of deposits by the public and the demand for loans. The above expressions can be rewritten as

\[
\begin{aligned}
 r_L \cdot L (r_L, r) + q'_{L} (1 i \% 0) & = 0; \\
 D (r L, r D) + r D + q'_{D} (1 i \% 0) & = 0;
\end{aligned}
\]

which imply that

\[
\begin{aligned}
 r_L = \frac{r + q(1 i \% 0)}{1 i \% L}; \\
 r_D = \frac{r + q(1 i \% 0)}{1 + "D"};
\end{aligned}
\]

These expressions indicate, in particular, that an increase in the penalty rate \( q \) raises both the deposit and lending rates to an extent that is inversely related to the elasticity of supply of deposits and demand for loans.

Let us assume that the quantity \( r_L f(r_L) \) is \( r_D g(r_D) + r g(r_D) \) \( f(r_L) \) is quasi-concave in \( r_L \) and \( r_D \), so that\(^{12}\)

\[
\begin{aligned}
 f^\Phi & > 2(f^0)^2 < 0; \\
 g^\Phi & > 2(g^0)^2 < 0: 
\end{aligned}
\]

Under these assumptions, it can indeed be established that both \( dr_L = dq \) and \( dr_D = dq \) are positive. To do so, note that

\[
\begin{aligned}
 l \cdot r_L r_L = (r_L i r) f^\Phi + 2f^0 i q^\Phi (1 i \% 0) + q^\Phi \frac{f^0}{\% 0} = 0;
\end{aligned}
\]

\(^{12}\) Let \( h(r_L, r_D) \) be defined as

\[
h(r_L, r_D) = r_L f(r_L) i r_D g(r_D) + r g(r_D) i f(r_L);
\]

We have

\[
\begin{aligned}
h_{r_L} = f + (r_L i r) f^0; \\
2f^0 + r_L f^\Phi & = 2f^0 + (r_L i r) f^\Phi,
\end{aligned}
\]

so that \( h_{r_L, r_L} < 0 \) at \( h_{r_L} = 0 \). The latter condition, which is equivalent to \( f + (r_L i r) f^0 = 0 \), implies that \( r_L > i f \neq 0 \). Substituting this result in the definition of \( h_{r_L, r_L} \) gives, at \( h_{r_L} = 0 \),

\[
2f^0 \neq 0 \neq 0 < 0;
\]

or equivalently \( f^\Phi \neq 2(f^0)^2 < 0 \). Similar derivations yield the second result in (A1).
\[ r_{D_0} = (r_i \ r_D)g^{0_i} 2g^{0} + q(1_i \ \mu(1_i \ \circ)g^{0_i} \ q^{A(1_i \ \mu)g^{\theta^2}}_{\pi^0}; \]

\[ r_{L_0} = \frac{qA(1_i \ \mu)g^{\theta}}{\pi^0} < 0; \]

The effect of \( q \) on \( r_L \) can be assessed from

\[ \begin{align*}
  \frac{dr_L}{dq} &= \frac{1}{j} \ f^{(1_i \ \circ)} \ i \ f^{q_i} i \ qA\frac{[(1_i \ \mu)g^{\theta^2}}{\pi^0}] \ i \ q^{Af}(1_i \ \mu)g^{\theta^2}; \\
  \frac{dr_D}{dq} &= \frac{1}{j} \ f^{(1_i \ \circ)} \ i \ (1_i \ \mu)(1_i \ \circ)g^{0}; \quad (A2)
\end{align*} \]

Let \( f \) be

\[ f = \frac{1}{j} \ r_{L_0} \ r_{D_0}; \]

\( f \) is positive from the second-order conditions for profit maximization. We therefore have

\[ \frac{dr_L}{dq} = \frac{i \ (1_i \ \circ)}{j \ f^{(1_i \ \circ)} \ i \ f^{q_i} i \ qA\frac{[(1_i \ \mu)g^{\theta^2}}{\pi^0}] \ i \ q^{Af}(1_i \ \mu)g^{\theta^2}}; \]

where \( j \) is defined as

\[ j = (r_i \ r_D)g^{0_i} 2g^{0} + q(1_i \ \mu(1_i \ \circ)g^{0_i}. \quad (A3) \]

The above expression can be rewritten as

\[ \frac{dr_L}{dq} = \frac{f^{q(1_i \ \circ)}}{j \ f^{(1_i \ \circ)}i}; \]

which implies that, because \( f^{0} < 0 \), that

\[ \text{sg} \ \frac{dr_L}{dq} = i \ \text{sg}[i]; \quad (A4) \]

To show that \( dr_L = dq > 0 \) requires therefore showing that \( i < 0 \). To do so, note that quasi-concavity of \( g(\phi) \) implies that \( g^{0} < 2(g^{0})^2g \), so that

\[ i < (r_i \ r_D)g^{0_i} \ \frac{g^{0}}{g^{0}} + q(1_i \ \mu(1_i \ \circ)g^{0_i} \]
or equivalently
\[ i < \frac{g^0}{g^0} f(r_i, r_D) g^0_i \ g + \alpha g^0 \mu(1_i \ \circ) g: \]

From the first-order conditions for profit maximization, the quantity \((r_i, r_D) g^0_i \ g\) is equal to \(i \alpha(1_i \ \mu(1_i \ \circ)) g^0\). Substituting this result on the right-hand side of the above expression implies that the term in brackets is zero and therefore that \(i < 0\). Thus, from (A4), \(dr_L = dq > 0\).

The effect of \(q\) on \(r_D\) can be assessed in a similar manner. Specifically, it can be established that
\[
\frac{dr_D}{dq} = \frac{i (1_i \ \circ)}{j \in j} (1_i \ \mu) g^0((r_L i \ r)f^\alpha + 2f^0_i \ \alpha \ \beta(1_i \ \circ) i \ \frac{\alpha(f_\beta^2)^\frac{3}{4}}{3/4})
\]

or equivalently
\[
\frac{dr_D}{dq} = \frac{i (1_i \ \circ)(1_i \ \mu) g^0}{j \in j} f(r_L i \ r)f^\alpha + 2f^0_i \ \alpha \ \beta(1_i \ \circ) g:
\]

Thus,
\[
sg \frac{dr_D}{dq} = i \ sg[(r_L i \ r)f^\alpha + 2f^0_i \ \alpha \ \beta(1_i \ \circ)]: \quad (A5)
\]

Given the above definitions,
\[
(r_L i \ r)f^\alpha + 2f^0_i \ \alpha \ \beta(1_i \ \circ) = i \ \frac{f^\alpha}{f^0} i (r_L i \ r)f^0_i 2\left(\frac{f^\alpha^2}{f^0} + \alpha \ \beta(1_i \ \circ)\right):
\]

From the first-order conditions for profit maximization, the term in brackets on the right-hand side of this expression is also equal to
\[
i \ \frac{f^\alpha}{f^0} i (r_L i \ r)f^0_i 2\left(\frac{f^\alpha^2}{f^0} + (r_L i \ r)f^0 + L\right);
\]

which is equal to
\[
i \ \frac{f^\alpha}{f^0} L \ i 2\left(\frac{f^\alpha^2}{f^0} + \alpha \ \beta(1_i \ \circ)\right) = i \ \frac{1}{f^0} f \ \alpha \ \beta(1_i \ \circ) 2(f^\alpha^2 < 0): \]
Thus, from (A5), \( dr_D = dq > 0 \):

The effect of \( q \) on excess reserves is straightforward; it can be established that, given the above results,

\[
\frac{dZ}{dq} = (1 i \mu) g_0 \frac{dr_D}{dq} \cdot f_0 \frac{d\rho_L}{dq} > 0:
\]

Let us establish the effects of a change in \( \rho \). From a system similar to (A2), we can establish that

\[
\begin{align*}
\text{dr}_L &=q f_0 ^\rho \left( Z i \right) ^\rho \frac{\rho_2}{\rho_1} \cdot (1 i \mu) g_0 \frac{\rho_2}{\rho_1} \frac{d\rho_D}{dq} \cdot f_0 \frac{d\rho_L}{dq} > 0; \\
\frac{dZ}{d\rho} &= (1 i \mu) g_0 \frac{dr_D}{d\rho} \cdot f_0 \frac{d\rho_L}{d\rho} > 0;
\end{align*}
\]

which implies that

\[
\begin{align*}
\text{dr}_L &=q f_0 ^\rho \left( Z i \right) ^\rho \frac{\rho_2}{\rho_1} \cdot (1 i \mu) g_0 \frac{\rho_2}{\rho_1} \frac{d\rho_D}{d\rho} \cdot f_0 \frac{d\rho_L}{d\rho} > 0; \\
\frac{dZ}{d\rho} &= (1 i \mu) g_0 \frac{dr_D}{d\rho} \cdot f_0 \frac{d\rho_L}{d\rho} > 0;
\end{align*}
\]

Thus

\[
\frac{dr_L}{dq} = \frac{q(1 i \mu) g_0}{q(1 i \mu) g_0} \cdot f_0 \frac{d\rho_L}{dq} > 0;
\]

This result implies that, given the sign assumptions, and given that, as shown above, \( i < 0 \),

\[
\text{sg } \frac{dr_L}{d\rho} = \text{sg } (Z i) ^\rho;
\]

It can also be established that

\[
\text{sg } \frac{dr_D}{d\rho} = \text{sg } \frac{dZ}{d\rho} = \text{sg } (Z i) ^\rho;
\]

Finally, let us consider the effect of a change in the reserve requirement rate, \( \mu \), on interest rates and excess reserves, as summarized in Proposition 3. It can be shown that, in a manner analogous to (A2),

\[
\begin{align*}
\text{dr}_L &=q f_0 ^\rho \left( Z i \right) ^\rho \frac{\rho_2}{\rho_1} \cdot (1 i \mu) g_0 \frac{\rho_2}{\rho_1} \frac{d\rho_D}{d\rho} \cdot f_0 \frac{d\rho_L}{d\rho} > 0; \\
\frac{dZ}{d\rho} &= (1 i \mu) g_0 \frac{dr_D}{d\rho} \cdot f_0 \frac{d\rho_L}{d\rho} > 0;
\end{align*}
\]

This implies that, using the definition of \( i \), given above in (A3):

\[
\frac{dr_L}{d\mu} = \frac{q(1 i \mu) g_0}{q(1 i \mu) g_0} \cdot f_0 \frac{d\rho_L}{d\rho} > 0;
\]
from which it can be verified that, given that \( i < 0, \Delta r_L = \Delta \mu > 0 \).

We also have

\[
\frac{d\mu}{d\mu} = \frac{\partial f^0 g_i}{\partial \mu} + \frac{\partial f^0 (1_i \partial \mu)}{\partial \mu} \mid r_L r_L;
\]

that is

\[
\frac{d\mu}{d\mu} = i \frac{\partial g_i}{\partial \mu} \mid f^0 i \frac{g^0 41_i \partial \mu}{\partial \mu} \mid (r_L i r) f^0 + 2 f^0 i \partial f^0 \mid i \partial f^0 \mid i \frac{\partial A(f^0)}{\partial \mu};
\]

It can be established that the term in parentheses on the right-hand side is equivalent to

\[
i f^0 g_i 2(g_0)^2 \frac{g^0}{g} \frac{\partial g^0}{\partial \mu} \mid f^0(2 f^0) \frac{\partial f^0}{\partial \mu} \mid i \frac{\partial A(f^0)}{\partial \mu};
\]

Given the assumptions specified above, the first term is negative whereas the second is positive. If the degree of volatility is not too high (that is, if \( \frac{3}{4} \) is small) the first term will dominate and, given that \( i < 0 \), we will have \( \Delta r_L = \Delta \mu > 0 \).

Finally, to assess the impact of \( \mu \) on \( Z \), note that from the first-order conditions,

\[
(r_L i r) f^0 + f = f^0 i \frac{\partial (Z i 1)}{\partial \mu};
\]

which gives

\[
\frac{1}{f^0} \left( \frac{r_L i r + f}{f^0} \right) = i \frac{\partial (Z i 1)}{\partial \mu};
\]

This expression implies that

\[
sg \frac{dZ}{d\mu} = i sg \left( \frac{d\mu}{d\mu} + d(f \circ \mu) \right);
\]

The expression in brackets on the right-hand side can be rewritten as

\[
\frac{d\mu}{d\mu} + d(f \circ \mu) = \frac{d\mu}{d\mu} + f^0 \frac{d\mu}{d\mu} \mid f^0 \frac{d\mu}{d\mu} \mid f\frac{d\mu}{d\mu} \mid (f^0)^2 \frac{d\mu}{d\mu};
\]

so that

\[
\frac{d\mu}{d\mu} + d(f \circ \mu) = 2 i \left( f^0 \frac{d\mu}{d\mu} \right) \frac{d\mu}{d\mu} = \frac{(f^0)^2 i f \frac{d\mu}{d\mu}}{(f^0)^2} \frac{d\mu}{d\mu}.
\]

As shown earlier, \( \Delta r_L = \Delta \mu > 0 \); thus, \( dZ = d\mu < 0 \).
Appendix B
Data Sources and Definitions

The data used in this study are at a monthly frequency and cover the period January 1992 to October 1998. The variables are defined and measured as follows.

- Excess liquid assets, EL, are from Bank of Thailand.
- Required liquid assets, RR, are from Bank of Thailand.
- Total deposits, D, are the sum of demand, time, and savings deposits in deposit money banks. The data are from International Financial Statistics (IFS), sum of line 24 and 25.
- Currency, C, is defined as currency in circulation outside of deposit money banks. Data are from IFS (line 14a).
- Manufacturing output, Y, is a seasonally-adjusted index, with 1990 as a base period. The data are from the International Monetary Fund.
- The trend component of manufacturing output, YT, is the quadratic trend which is equal to the fitted value obtained by regressing Y on constant term, time and time squared variables.
- The discount rate, r, is from IFS (line 60).
- The coefficient of variation for the log of currency to deposit ratio, CV[ln(C/D)], and the log of manufacturing output to trend component ratio, CV[ln(Y/YT)], are equal to the standard deviation of the specified variable divided by the average of it for 3 leads and lags, centered on the current period.
References


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Note: The dependent variable is $\text{ln}(\text{EL}/D)$, the log of excess liquid assets to total deposits ratio. $\text{ln}(\text{EL}/D)(-1)$ is the lagged value of $\text{ln}(\text{EL}/D)$. $\text{ln}(\text{RR}/D)$ is the log of required reserves to total deposits ratio. $\text{CV}(\text{ln}(\text{C}/D))$ is the coefficient of variation of the log of currency in circulation to total deposits ratio. $\text{ln}(\text{Y}/\text{YT})$ is the log of the industrial output to its quadratic trend. $\text{CV}(\text{ln}(\text{Y}/\text{YT}))$ is the coefficient of variation of $\text{ln}(\text{Y}/\text{YT})$. The regression technique is ordinary least squares with Almon polynomial distributed lags on the discount rate and $\text{ln}(\text{Y}/\text{YT})$. $\text{sum}$ is the sum of lags. $\bar{R}^2$ is the adjusted R-squared. see is the estimated standard error of regression. $h$ is Durbin’s $h$ statistics for autocorrelation. t-statistics are in parentheses.
Table 2
Thailand: Determinants of Excess Liquid Assets, Regressions with Money Market Rate.

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<td>0.688 (7.902)</td>
<td>0.765 (10.622)</td>
<td>0.682 (7.902)</td>
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<td>1.021 (1.337)</td>
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<tr>
<td><strong>t-1</strong></td>
<td>1.032 (1.132)</td>
<td>0.513 (0.599)</td>
<td>1.058 (1.167)</td>
<td>1.301 (1.675)</td>
<td>1.089 (1.401)</td>
<td>0.777 (1.105)</td>
<td>1.021 (1.337)</td>
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<tr>
<td><strong>t-2</strong></td>
<td>0.937 (1.020)</td>
<td>0.412 (-0.199)</td>
<td>0.147 (-0.199)</td>
<td>-0.050 (-0.142)</td>
<td>-0.214 (-0.224)</td>
<td>-0.258 (-0.296)</td>
<td>-0.210 (-0.239)</td>
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<tr>
<td><strong>t-3</strong></td>
<td>0.335 (0.263)</td>
<td>0.273 (0.212)</td>
<td>0.478 (0.381)</td>
<td>-0.303 (-0.290)</td>
<td>-0.455 (-0.432)</td>
<td>-0.299 (-0.288)</td>
<td>-0.329 (-0.321)</td>
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<tr>
<td><strong>t-4</strong></td>
<td>3.471 (2.011)</td>
<td>3.445 (1.999)</td>
<td>3.346 (1.920)</td>
<td>3.703 (2.206)</td>
<td>2.367 (1.645)</td>
<td>2.086 (1.440)</td>
<td>2.115 (1.469)</td>
<td>2.374 (1.759)</td>
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<tr>
<td><strong>sum</strong></td>
<td>6.234 (3.146)</td>
<td>6.456 (3.287)</td>
<td>4.970 (2.874)</td>
<td>6.948 (3.791)</td>
<td>5.241 (3.425)</td>
<td>4.240 (2.957)</td>
<td>3.685 (2.839)</td>
<td>4.515 (3.370)</td>
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<tr>
<td><strong>R²</strong></td>
<td>0.856</td>
<td>0.856</td>
<td>0.853</td>
<td>0.858</td>
<td>0.928</td>
<td>0.926</td>
<td>0.930</td>
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<td><strong>h</strong></td>
<td>-0.817</td>
<td>-0.797</td>
<td>-0.937</td>
<td>-0.803</td>
<td>-0.961</td>
<td>-0.915</td>
<td>-1.010</td>
<td>-0.984</td>
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Note: The dependent variable is ln(EL/D) is the log of excess liquid assets to total deposits ratio. ln(EL/D)(-1) is the lagged value of ln(EL/D). ln(RR/D) is the log of required reserves to total deposits ratio. CV(ln(C/D)) is the coefficient of variation of log of currency in circulation to total deposits ratio. ln(Y/YT) is the log of the industrial output to its quadratic trend. CV(ln(Y/YT)) is the coefficient of variation of ln(Y/YT). MM Rate(-1) the lagged value of the money market rate. The regression technique is ordinary least squares with Almon polynomial distributed lags on ln(Y/YT). sum is the sum of lags. R² is the adjusted R-squared. see is the estimated standard error of regression. h is Durbin’s h statistics for autocorrelation. t-statistics are in parentheses.
Source: International Monetary Fund, *International Financial Statistics* and Bank of Thailand

1/ Calculated as the difference between actual output and a quadratic trend.
Figure 2
Thailand: Predicted and Actual Values of Excess Liquid Assets to Deposits Ratio,
January 1994 to June 1997
(Dynamic in-sample simulation)
Table 1, Equation 1
Figure 3
Thailand: Predicted and Actual Values of Excess Liquid Assets,
July 1997 - October 1998
(Dynamic out-of-sample simulation)
Table 1, Equation 1

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### Table 1, Equation 1

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<td>Predicted Data</td>
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<td>0.05</td>
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</tbody>
</table>

- Log of excess liquid assets to deposits ratio
  (+/- one standard errors)
- Log of excess liquid assets to deposits ratio
  (+/- two standard errors)
- Excess liquid assets to deposits ratio