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Banks as Monitors of Other Banks: Evidence from the Overnight Federal Funds Market*

This study provides evidence that banks are effective monitors of their peers by showing that the interest rate paid on federal funds transactions reflects differences in credit risk across borrowers. In addition, the size and relative importance in the funds market of the trading institutions are shown to affect the rates charged for overnight borrowing, thereby providing insight into the nature of competition in the federal funds market. Transaction volume and size-of-transaction effects are uncovered, as is evidence of relationship banking between banks. These results are made possible by unique data identifying individual federal funds transactions.

I. Introduction

Banks have traditionally been both regulated and supervised in order to protect them from failure and to maintain the safety and viability of the financial system. Recently, however, rapid developments in technology and increased financial sophistication have challenged the ability of traditional regulation and supervision to foster a safe and sound banking system (see Jones 1998). As banks continue to become more adept at innovating beyond the borders of existing regulation, policy makers have begun to look to the marketplace as a potential additional monitor of the risk-taking of banks (see Flannery 1998).

Although many ways to incorporate the marketplace into prudential supervision of banks can be imagined, one currently popular proposal envisages using banks themselves as monitors of other banks (see Calomiris 1998). The attraction of such an idea is readily apparent; who better to identify a risky bank than another bank? Never-

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theless, the ability of banks to identify the risk of other banks has never been documented.

This research investigates whether banks could effectively be employed as monitors of their peers by providing the first empirical examination of the pricing of interbank lending agreements. Banks lend significant amounts of money to one another every day in the federal funds market, the market where reserves are both bought and sold. These loans are both large and uncollateralized, and thus expose lending institutions to significant credit risk. Lending banks therefore have an incentive to monitor their counterparties and to price these loans as a function of, among other things, the credit risk of the borrowing bank.

The main empirical finding of this article is that the interest rate charged on federal funds transactions reflects, in part, the credit risk of the borrowing institution. In particular, borrowing banks with higher profitability, higher capital ratios, and fewer problem loans pay lower interest rates on federal funds loans. Thus, the empirical evidence suggests that banks identify risk in their peers and effectively monitor other banks.

The remainder of the article is organized as follows. Section II reviews previous work that examines the effectiveness of market participants to monitor bank risk. Section III summarizes the limited information that has been previously documented regarding pricing in the federal funds market. Section IV describes the source, strengths, and weaknesses of the transaction-level data used in the analysis. Section V presents the empirical findings. Section VI concludes.

II. Market Monitoring of Banks

Preliminary research examining whether market information could be a useful part of bank regulation and supervision has found that in many circumstances, supervisors and markets are often complementary sources of information regarding bank health (Berger, Davies, and Flannery 1998; De Young et al. 1998; Peek, Rosengren, and Tootell 1999). These studies conclude, therefore, that market information could be a useful supplement to traditional regulation. Nevertheless, banks do appear to have some ability to thwart market-based monitoring by shifting their liabilities away from claim holders (uninsured depositors) with a great incentive to monitor to those (insured depositors) with little incentive to monitor (Billet, Garfinkel, and O'Neal 1998).

Although market information has been shown to be potentially useful, deciding how best to incorporate this information into traditional regulation is difficult in practice. In particular, policy makers must decide *which market participants* holding *what financial claims* would make the best monitors of bank risk-taking. The most obvious monitors

for a bank would be depositors. As is well known, however, deposit insurance has the consequence of eliminating the incentive for insured depositors to monitor their banks (White 1989). Uninsured depositors may be able to fill this role. Evidence provided by Baer and Brewer (1986), Hannan and Hanweck (1988), and Ellis and Flannery (1992) demonstrates that rates paid on wholesale (uninsured) CDs can be partially explained by proxies for bank risk.

Bank equity holders, too, impose discipline on bank management. Extensive evidence suggests that following the failure of a bank, the stock price of surviving institutions reacts negatively when the surviving institution shares common portfolio characteristics with the failing institution (Cornell and Shapiro 1986; Swary 1986; Musumeci and Sinkey, Jr. 1990; Wall and Peterson 1990; Karafiath, Mynatt, and Smith 1991; and Jayanti and Whyte 1996). This finding suggests that equity holders can act in a way that distinguishes banks according to their risk. The ability of stockholders to discipline banks, however, may not be a useful complement to regulation and supervision because of the different incentives that stockholders and supervisors face when a bank nears insolvency. Because stockholders have limited liability, they have the incentive to gamble for resurrection by increasing risk, whereas supervisors wish to minimize losses and therefore want to restrict risk-taking.

It has long been understood that holders of banks' subordinated debt, because other lenders have higher priority in case of insolvency, have incentives similar to supervisors and thus might be a useful complement to current supervisory practice (Keehn 1989; and Wall 1989). Although Avery, Belton, and Goldberg (1988) and Gorton and Santomero (1990) raise doubts about whether subordinated debt yields provide information on bank risk, Flannery and Sorescu (1996) do find that such yields provide evidence of market discipline during periods when holders of subordinated debt were not implicitly insured.

Recent thinking on the benefits of using market-based information to complement banking supervision has addressed the question of not only the type of financial instrument that would be the most appropriate indicator of bank risk but also the type of investors who would be the most effective monitors. In particular, it has been suggested that banks might be particularly effective monitors of other banks because similar institutions might be expected to identify a peer's risk best. In one example of using interbank monitoring as a supplement to current regulation, Calomiris (1998, p. 6) proposes that banks be required to issue subordinated debt that must be held by ''reputable foreign financial institutions.''[1] According to the plan, a bank would be required to issue

1. Calomiris (1998) argues that the requirement that the institutions holding subordinated debt be foreign ensures that they will not be bailed out in a crisis.

subordinated debt equal to a fraction of its assets. Further, the debenture interest rate would not be allowed to exceed some given ceiling. Thus, whenever the issuing bank's creditors perceived a bank to be sufficiently risky, the bank would find itself unable to issue subordinated debt at a rate below the ceiling. The bank would then be forced to contract in order to maintain the required subordinated-debt-to-asset ratio.

Rochet and Tirole (1996) provide theoretical support for the notion that banks would be particularly good monitors of other banks. They argue that interbank relationships established through federal funds transactions or similar interdependencies generate powerful incentives for banks to monitor each other. Unfortunately, Rochet and Tirole (1996) also point out that the effectiveness of banks as monitors of other banks is influenced by other existing policies, most notably the ''too big to fail'' policy. In particular, if the largest banks were viewed as immune from failure, then these banks' creditors, including other banks, would have little incentive to monitor their exposures.

The arguments of Rochet and Tirole (1996) suggest that the effectiveness of banks as monitors of their peers depends on whether lenders believe that an interbank transaction exposes them to potential losses. If so, then the pricing of such transactions should reflect differences in borrower risk. Whether, and to what extent, the credit risk of a borrowing institution is priced into interbank lending agreements is the important empirical question addressed in this article.

This article examines the pricing of individual federal funds transactions. The federal funds market is a particularly attractive place to examine the pricing of interbank lending because funds transactions are largely free of complicating factors present in other interbank contracts that would typically make gleaning the ''price'' of the loan difficult. In particular, federal funds transactions are uncollateralized, have an overnight maturity, have maturity equal to duration, and are free from unusual payment schedules or covenants. Thus, differential pricing should readily appear in a funds transaction's interest rate. By examining the determinants of the interest rate on federal funds transactions, one can directly test whether credit risk is priced into interbank lending agreements. Anticipating the results, the article concludes that differences in borrower credit risk are reflected in the interest rate charged.

III. Pricing in the Market for Federal Funds

To date, the literature has only provided anecdotal evidence regarding the pricing of individual federal funds transactions. Stigum (1990) discusses tiering in the funds market by which large institutions generally get better terms than smaller institutions. Allen and Saunders (1986) report in a footnote that, based on conversations with market partici-

pants, non-money-center banks generally pay between 1/8% and 1/4% above the rate of their money-center counterparts. In contrast, this article provides an in-depth empirical analysis of the pricing of individual federal funds transactions. In particular, the credit quality of the borrowing bank is shown to influence the price paid on a federal funds loan.

Before describing the data used in this article, it is worthwhile to dispel a common misperception that the Federal Reserve sets the rate at which financial institutions trade reserves. As part of its implementation of monetary policy, the Fed announces a ''target'' for ''the'' funds rate. For example, throughout the entire sample period studied in this article, the first quarter of 1998, the Fed had an announced ''target'' of 5.5%. The Fed, however, is not concerned about determining the rate for individual federal funds transactions. Rather, the Fed summarizes the cross-sectional variation in transaction interest rates by surveying five leading federal funds brokers about the total value of federal funds trades conducted at different interest rates. These totals are then aggregated across brokers for each interest rate, and a value-weighted average is then taken. This resulting daily average rate is published with the name ''effective federal funds rate.'' To implement monetary policy, the Fed conducts daily open market operations in an attempt to bring the effective federal funds rate to or near its stated target. Thus, although Fed action largely influences the effective federal funds rate, it is bank credit quality and other market factors that ultimately influence the cross-sectional differences in actual rates paid.

IV. Identification and Validation of Federal Funds Transactions

Both large and small institutions wish to trade in the federal funds market. This is because all institutions face some degree of unexpected inflows and outflows of reserves that they may wish to counteract through overnight borrowing or lending. In general, a bank looking to sell funds and an institution wishing to buy funds agree on a mutually acceptable quantity, term (typically overnight), and interest rate.[2] The lender (seller) of funds transfers the funds on the day of the sale to the borrower, and the borrower (buyer) of funds returns the borrowed amount plus interest to the lender the following business day. These two payments typically occur over Fedwire, the large-value transfer system operated by the Fed.[3]

These Fedwire payments allow the identification of federal funds

2. Brokers sometimes facilitate this process.

3. Small federal funds transactions between banks that have correspondent relationships may be arranged through book transfers (accounting entries) and may not require any Fedwire payments.

transactions analyzed in this study.[4] For business reasons, the Fed temporarily maintains a record of each payment transaction sent over Fedwire and, from this record, every Fedwire funds transfer made during the first quarter of 1998 was collected. Of the several hundred thousand transactions recorded each day, only a relatively small number are related to the federal funds market. Stigum (1990) argues that federal funds transactions are usually made in round lots of over $1 million. Based on this anecdotal evidence, the sample of transactions was searched, and payments whose amounts were greater than $1 million, ended in five zeros, and had a payment the following business day in the opposite direction in an amount that could reasonably be construed as the initial payment plus interest were identified as federal funds transactions. As interest rates charged vary across transactions, a range of values for valid rates of interest was allowed. For the results below, a window of interest rates was allowed, ranging from 50 basis points below the minimum to 50 basis points above the maximum of six publicly available measures of a day's federal funds rate: the 11:00 A.M. rate, the high, low, and closing rates reported by the surveyed brokers, the effective rate, and the Fed's target rate.[5]

Potentially the greatest weakness of this approach to identifying federal funds transactions is that the sending and receiving banks identified in the data need not be the actual parties to the transaction. These banks could be acting as dealers for the funds transactions of others, or the transactions may represent overnight lending arrangements between nonfinancial firms operating through different banks. It is also possible that there are transactions struck at a rate outside the selection window, and of course these will be missed.[6] Finally, this approach will fail to capture the small number of federal funds loans that do not have an overnight maturity.[7]

Before turning to the formal analysis, it is useful to consider whether the identification procedure correctly identifies federal funds transactions. The most reliable information available on true federal funds transactions is the effective federal funds rate, the weighted average interest rate of transactions conducted by five leading funds brokers. As a comparison, a weighted average interest rate for the sample of

4. A more detailed description of the transaction-identification process can be found in Furfine (1999).

5. The 11:00 A.M. rate is the weighted average interest rate derived from summaries of transactions that have already occurred that morning when the Fed conducts its daily (morning) survey of the five leading funds brokers. The high and low rates report the highest and lowest rates observed by any of the five brokers for the day. The closing rate is the rate on the last transaction conducted by the surveyed brokers.

6. Enlarging the window had a negligible effect on the number of payments identified as federal funds transactions.

7. According to a Federal Reserve Bank of New York (1987) survey, 96% of federal funds loans were for an overnight maturity.

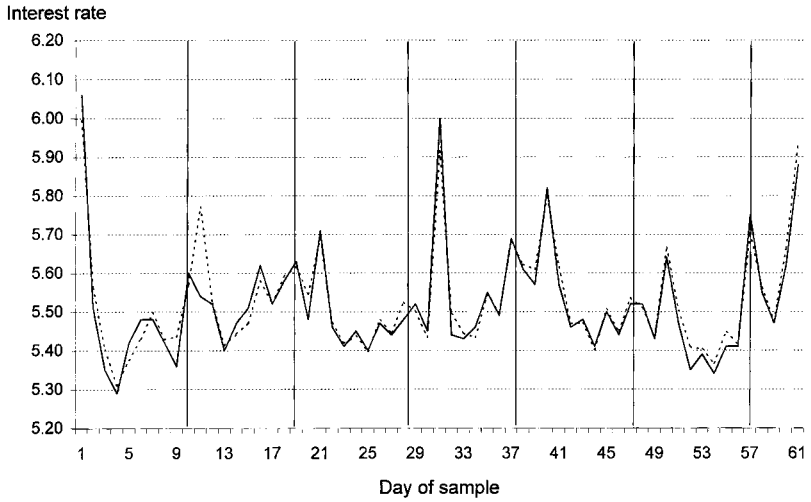

FIG. 1.—Sample and published effective funds rate. Solid line, published series; dashed line, sample. Vertical lines indicate reserve settlement days.

transactions identified in the data was calculated for each day and compared with the published effective federal funds rate. These two series are plotted in figure 1. As is evident from the figure, the interest rate series calculated from the sample of transactions replicates the published series quite well. The average daily interest rate in the sample is 5.529%, whereas the average effective federal funds rate during the first quarter of 1998 was 5.520%, a difference of less than 1 basis point. The standard deviation of the sample daily rate is 0.139, slightly below the published value of 0.147. Finally, the two series have a correlation of 0.95. Thus, the sample appears to reflect the federal funds market accurately.[8]

V. Empirical Results

The empirical analysis estimates the importance of various factors in determining the interest rate paid on a federal funds transaction. Because the focus of this study is on the effectiveness of banks as monitors of other banks, the sample of transactions was limited to those between U.S. commercial banks with call report data available for December 31, 1997. Because of the importance of government-sponsored agencies,

8. The underestimation of the variability of daily interest rates is partially explained by reserve settlement days. For the 55 days that were not reserve settlement days, the sample standard deviation (SD) is 0.142 versus 0.148 for the published series. On the 6 reserve settlement days, the sample SD is 0.101, as opposed to 0.142 for the published series.

TABLE 1 Interest Rates Paid by Size of Institution

	Average Interest Rate (SD)		Difference between Cols. 1 and 2
	Lender < $10 Billion in Assets (1)	Lender > $10 Billion in Assets (2)	(3)
Borrower < $10 billion in assets	5.50%	5.62%	.12%
	(.001%)	(.003%)	(.003%)
Borrower > $10 billion in assets	5.47%	5.55%	.08%
	(.001%)	(.002%)	(.002%)
Difference between rows A and B	−.03%	−.07%	
	(.002%)	(.003%)	

NOTE.—Standard errors given in parentheses.

foreign institutions, and federal home loan banks, this criterion reduced the sample of transactions from 190,439 to 117,756. An additional 729 (0.62%) observations were deleted because of extreme outliers in the borrowing bank's call report data, leaving a final sample of 117,027 transactions.

The dependent variable for the analysis is the interest rate on the given federal funds transaction, measured at an annual rate.[9]

Table 1 reports some simple statistics about the data that validate the anecdotal evidence about interest rate setting in the funds market presented in Allen and Saunders (1986) and Stigum (1990). Larger institutions tend to get more favorable rates, regardless of which side of the transaction they are on. For example, institutions with over $10 billion in assets, on average, receive 12 basis points more than a smaller institution when lending to a small institution and 8 basis points more when lending to another large institution. When borrowing, institutions with over $10 billion in assets save 3 basis points when borrowing from a small institution and 7 basis points when borrowing from a large institution. Differences of means tests are all highly significant. These simple statistics suggest that, at a minimum, one would need to control for the size of the participating institutions when trying to explain the cross-sectional variation in interest rates. The next subsection systematically reviews the different determinants of pricing that are examined.

Determinants of Transaction Interest Rates

Borrower credit risk. As federal funds transactions are a type of bank loan, one would expect that the borrower's credit risk would be an important determinant of a transaction's interest rate. Although the

9. Transactions that extend over holidays or weekends require more than 1 day of interest. Thus, the calculated interest rates account for the number of calendar days that pass between delivery and repayment of the loan.

short-term nature of the loan suggests limited scope for credit risk, these loans are large and also uncollateralized.[10] Several proxies for the borrower's credit risk were considered. First, a bank's profitability, measured by its return on assets, is included. A bank's profitability should be positively correlated with its ability to repay its federal funds transactions and so this measure is expected to be negatively related to the transaction interest rate. A bank's loan quality may also partially capture a bank's ability to service its debts. A bank's loans past due more than 90 days and its nonaccruing loans as a proportion of total loans were included to account for this possibility. If these variables were proxies for credit risk, one would expect them to be positively related to the transaction interest rate. Ultimately, a bank's capitalization reflects its ability to repay, and therefore the regressions include the ratio of a bank's total capital to risk-weighted assets. Banks with higher capital ratios might be expected to pay lower interest rates. In addition, the ratio of the transaction size to the borrower's capital was included to account for the possibility that relative capitalization may be a more relevant proxy for borrower credit risk than the previous absolute measure.[11]

As a check on the robustness of the findings, the above measures of borrower risk were also constructed at the holding-company level. Measuring risk at the holding-company level might be justified in light of the Fed's source-of-strength doctrine as modified by the Federal Deposit Insurance Corporation Improvement Act (FDICIA) of 1991. The FDICIA requires capital infusions on the part of the bank holding company as part of a voluntary capital restoration plan to aid a troubled bank subsidiary (Schinski and Mullineaux 1995). Thus, the financial strength of a bank's holding company might be the relevant measure of counterparty risk.

Borrower and lender characteristics. To measure the importance of borrower credit risk accurately, one must adequately control for other factors that influence the observed interest rate. The first set of controls represents other characteristics of the borrowing bank. The estimation includes a variable that measures the market share of the particular borrowing bank. That is, for institution X, this variable would be the amount borrowed by institution X on day Y divided by aggregate borrowing on day Y.

A small number of banks may actually be borrowing in the funds market on behalf of others. To account for the possibility that these

10. Even for loans of an overnight maturity, the interest rate charged must be a markup over a risk-free rate to compensate the lender for the possibility of losing the entire principal (Merton 1974). For example, if a federal funds loan had a 0.1% (1 in 1000) chance of default, a risk-neutral investor would require a markup of approximately 10 basis points.

11. The distribution of this variable was highly skewed, and therefore the log of this ratio was used.

institutions may generally pay a different interest rate, the regressions include a dummy variable indicating whether or not the borrowing bank is a dealer in the funds market, defined as an indicator for one of the five institutions in the sample that both bought and sold at least $1 billion in funds on each day of the sample. The analysis also includes a variable indicating whether the borrowing bank was a net seller of funds, on average, during the quarter ending December 31, 1997. This variable controls for the possibility that a bank transacting differently from its typical requirements might pay a different interest rate.[12]

As documented by the simple statistics in table 1, the size of the borrower likely influences the interest rate paid. Dummy variables denoting five different size categories of borrowers attempted to account for this. Size is defined as the borrower's total assets as of December 31, 1997.

The second set of control variables accounts for characteristics of the lending institution. An identical set of variables measuring the lending institution's lending share, dealer status, typical net position, and size was included in the regressions.

Transaction characteristics. The third set of control variables measures the characteristics of the transaction. The first such variable proxies for the funds market's liquidity at the time of the transaction. The relationship between liquidity and pricing in the funds market may be like that found in stock- and foreign-exchange markets.[13] However, the data here do not allow for a traditional volume-liquidity-pricing study because the information available on timing relates to the time that the payments were transferred over Fedwire and not to the time that the original trade was made. Anywhere from a few minutes to several hours may elapse between the execution of a federal funds trade and the flow of money over Fedwire. Nevertheless, one should expect payment times to be positively correlated with trading times simply because the payments necessarily follow the underlying trade. Thus, one might use the timing of payment flows to proxy for market liquidity. To explore this possibility, the analysis includes a variable measuring the share of federal funds value that was delivered over Fedwire during the half-hour period of the given transaction.

Liquidity may also be affected by the size of the transaction. For example, very large loans may have both a limited supply and a limited demand. Dummy variables denoting transactions less than or equal to

12. The call report does not distinguish between federal funds and repo transactions, and so the indicator for ''net selling'' behavior is not strictly comparable to the transactions used in this study. Quarterly average values were used to construct this measure to account for the possibility of bank window dressing as documented by Allen and Saunders (1992).

13. Bollerslev, Domowitz, and Wang (1997), Peiers (1997), and Huang and Masulis (1999) study this relationship in foreign exchange markets. Stephan and Whaley (1990) and French and Roll (1986) examine the same in equity markets.

$10 million, between $10 million and $100 million, and over $100 million were included in the estimation. These categories identify 38.7%, 55.1%, and 6.2% of the transactions, respectively.

The final transaction characteristic examined is the duration of the federal funds loan. The duration of a loan may affect pricing because it affects the intraday balances of the participating institutions. These balances are important to a bank because the Fed charges banks that have a negative balance, a ''daylight overdraft,'' interest at an annualized rate of 27 basis points (Richards 1995).[14] Because overdraft charges are applied to a bank's *average* overdraft during the 18 hours that Fedwire operates, an earlier delivery or a delayed repayment of a federal funds loan will affect a bank's interest charges in the same proportion that it affects the magnitude of a bank's average overdraft. For example, extending the duration of a federal funds loan for 1 hour would save a borrowing bank running a daylight overdraft one-eighteenth of 27 basis points, or 1.5 basis points.

For many reasons, however, one would expect that extending the duration of a federal funds loan by 1 hour would correlate with an increase in the interest rate observed of less than 1.5 basis points. First, since both the borrower and the lender are aware that the timing of payments influences the fees charged by the Fed, the two counterparties may agree to share the 1.5 basis point benefit. Second, the borrowing bank may not necessarily be running an overdraft at the time of repayment and so would be unwilling to pay for an extended duration. Third, the Fed's treatment of intraday reserve balances is asymmetric. Although the Fed charges 27 basis points for overdrafts, it does not pay anything to a bank that holds a positive intraday balance. Overall, therefore, the value of extending a federal funds loan by 1 hour is an empirical question. For this reason, a variable measuring the number of operating hours that the loan was outstanding has been included in the analysis.

Borrower and lender relationships. The fourth set of controls proxies for the relationship that may exist between the borrower and seller of funds. The relationship-banking literature finds empirical evidence that small borrowers (presumed to be nonfinancial firms) benefit by maintaining a relationship with a single bank or a small number of banks (see, e.g., Petersen and Rajan 1994; and Berger and Udell 1995). In the case of the federal funds market, both the borrower and the lender are financial institutions. Borrowing institutions may build relationships with particular institutions to establish that they are a good credit risk. By so doing, they may get a more attractive interest rate.

Relationships were measured in two ways: by the number of transactions between the given pair of banks and by the number of days on

14. This discussion abstracts from a bank's allowable deductible.

which the given pair of banks transacted.[15] These measures of relationships implicitly assume that the patterns observed during this quarter are indicative of the relationship between the counterparties in the past. As the theories of relationship banking focus on small borrowers, the above measures were also interacted with a dummy variable indicating whether the borrowing institution has less than $250 million in assets.[16] Such small financial institutions may have a particularly difficult time conveying to potential lenders that they are a good credit risk, and thus they may especially benefit from establishing a relationship.

Day of the sample. Finally, dummy variables for each of the 61 business days in the sample were included. As documented in Hamilton (1996), Spindt and Hoffmeister (1988), and Furfine (2000), the effective federal funds rate follows patterns during the 2-week reserve maintenance period as well as around holidays and ends of quarters. To isolate the cross-sectional variation in loan pricing, a complete set of dummy variables was used rather than attempting to measure each calendar-related effect separately. To save space, the results for these variables are not reported but are available separately. These dummy variables capture the daily variation in interest rates found in the effective funds rate, differing only slightly because of the weighting that occurs in the published series.

Before turning to the empirical results, table 2 reviews the definitions of the various variables, and table 3 presents some summary statistics. As mentioned, the interest rate data replicate the effective funds rate quite well, and it is therefore no surprise that the transaction-level average interest rate of 5.504% is so close to the target funds rate of 5.5%. The summary statistics also indicate a fair degree of skewness in the distribution of many variables. In banking, a small number of institutions typically have characteristics quite different from most other institutions, and this sample is no different. Whereas the median observation on the borrowing share variable is 1.4%, its mean is 3.9%. This is reflective of a small number of institutions with significant market share. For example, one institution bought 21.4% of a day's total funds exchanged. A similar skewness is apparent in the size of the institutions. The participating institutions have a size ranging from a low of only $10 million in assets to a high of $297 billion. Transaction size and measures of relationships are also skewed. For instance, the mean transaction size is just under $38 million, but the median is only $18 million. With regard to proxies for relationships, some banks sell funds to a given institution only once during the entire quarter. The median number of transactions for a given pair of institutions is 51, although as many as 2,007 transactions occurred between a given buyer and seller.

15. These variables were entered in log form to account for the highly skewed nature of their distribution.

16. A smaller cutoff of $100 million delivered similar results.

TABLE 2 Definitions of Variables Used in This Study

Variable	Definition
Borrower's credit risk (from December 31, 1997, call report):	
Return on assets	Net income divided by total assets
Loans 90 or more days past due	Total loans 90 or more days past due as a fraction of total loans
Nonaccruing loans	Nonaccruing loans as a fraction of total loans
Risk-based capital ratio	Total (tier 1 and tier 2) capital as a fraction of risk-weighted assets
Log (transaction-size-to-capital ratio)	Log of transaction size as a fraction of total (tier 1 and tier 2) capital
Other institution characteristics (for both borrowing and lending bank):	
Daily borrower (lender) share	Share of the day's total borrowing (lending) of the given institution
Assets $<$ \$250 million	Indicator variables reflecting the borrower's or lender's total assets
Assets between \$250 million and \$1 billion	
Assets between \$1 billion and \$10 billion	
Assets between \$10 billion and \$100 billion	
Assets $>$ \$100 billion	
Dealer bank	Indicator variable representing a bank that bought and sold at least \$1 billion of federal funds during each of the 61 days of the sample period
Quarter-end net seller	Indicator variable representing a bank that reported more ''federal funds sold and securities purchased with intent to resell'' than ''federal funds purchased and securities sold with intent to repurchase,'' reported as quarterly averages on the December 31, 1997, call report
Transaction characteristics:	
Transaction $\leq$ \$10 million	Indicator variables reflecting the size of the federal funds transaction
Transaction between \$10 million and \$100 million	
Transaction over \$100 million	
Business hours duration	Number of Fedwire operating hours between delivery of the federal funds sold and return of the funds with interest
Liquidity	Share of the day's total federal funds value that was delivered during the given transaction's half-hour interval
Relationship characteristics:	
Log (no. of transaction pair)	Log of the number of transactions involving the sale of funds by the given lender to the given borrower during the entire sample period
Log (no. of days pair)	Log of the number of days on which funds were sold by the given lender to the given borrower during the entire sample period

TABLE 3 Summary of Transaction Data

	Mean	SD	Median	Minimum	Maximum
Interest rate	5.504	.349	5.469	.585	19.950
Borrower's credit risk:					
Return on assets	.011	.004	.011	−.001	.030
Loans 90 or more days past due	.002	.003	.002	0	.047
Nonaccruing loans	.005	.003	.005	0	.015
Risk-based capital ratio	.113	.014	.109	.091	.231
Transaction-size-to-capital ratio	.018	.053	.005	.000	3.534
Other borrower characteristics:					
Daily borrower share	.039	.057	.014	.000	.214
Asset size (millions of $)	89,900	104,000	38,800	40	297,000
Dealer bank	.300	.458	0	0	1
Quarter-end net seller	.142	.349	0	0	1
Lender characteristics:					
Daily lender share	.027	0.045	.003	.000	.214
Asset size (millions of $)	52,400	93,300	3,880	10	297,000
Dealer bank	.219	.413	0	0	1
Quarter-end net seller	.783	.412	1	0	1
Transaction characteristics:					
Transaction size (millions of $)	37.7	68.9	18.0	1	990
Business hours duration	15.31	2.79	15.73	1.17	34.66
Liquidity	.107	.065	.103	.000	0.274
Relationship characteristics:					
No. of transaction pair	215.58	457.32	51	1	2,007
No. of days pair	40.98	19.23	47	1	61

NOTE.—Summary statistics in the federal funds transaction data containing 117,027 observations over 61 business days between January 2, 1998, and March 31, 1998.

Regression Results for the Full Sample

Table 4 presents the output from three regression specifications for the complete sample of 117,027 observations. The first three columns report the results when borrower risk is measured at the bank level and the last three columns report the results when borrower risk is measured at the holding-company level. The different specifications utilized two different proxies for the quality of the borrower's loan portfolio and two ways of measuring bank relationships. Overall, the variables included in the regression explain 20% of the variation in interest rates charged, although time dummies alone explain 16%. Looking across columns, it is clear that the different specifications are not particularly influential.[17] For ease of exposition, therefore, the description of the results will focus on the coefficients reported in column 2.

17. With the exception of loans past due in specification 1, all of the variables that proxy for the credit risk of the borrowing institution enter significantly and with the correct sign. The only other significant difference across specifications is that relationship proxies only enter significantly when they are measured by days rather than by the number of transactions.

A 1 SD increase in the borrower's return on assets correlates with a reduction in the loan rate of approximately 0.75 basis points. A similar increase in nonaccruing loans tends to relate to a rise in interest rates of around 0.2 basis points. A 1 SD increase in a borrowing bank's capital ratio correlates with nearly a full basis-point reduction in interest rates. The most economically significant variable regarding borrower credit risk appears to be the transaction-size-to-capital ratio. A 1 SD increase in this variable correlates with a 1.5 basis point increase in the transaction interest rate.

Turning to the variables representing other characteristics of the borrower, estimates suggest an increase in the share of overall borrowing tends to increase the transaction interest rate. This is consistent with movement along a supply curve. A 1 SD increase in the market share of the borrowing bank correlates with a 0.5 basis point increase in the transaction interest rate.

Asset size is an extremely important determinant of transaction interest rates. As the size of the borrowing bank increases, transaction interest rates generally fall. The smallest institutions pay nearly a quarter of a percentage point more for overnight funds than institutions with over $1 billion in assets. Dealing in funds does not affect the rate at which one can borrow, nor does the typical net funds position.

For the lending institution, higher lending shares correlate with lower interest rates, consistent with movement along a demand curve. A 1 SD increase in a bank's lending share correlates with a transaction interest rate 1 basis point lower. As was the case for the borrowing bank, greater size improves the terms of the loan, although to a lesser extent than was true for borrowers. The smallest institutions receive around 10 basis points less than the largest institutions receive when lending. Being a dealer seems to improve the terms of lending, with such institutions receiving about 2 basis points more for funds sold. The coefficient on the net selling indicator suggests that institutions that on balance sell funds actually receive less for their money when they sell. Since net selling institutions are generally small, this may reflect the fact that the size dummies are underestimating the pricing advantage of large institutions.

With regard to transaction-specific variables, the results suggest that the largest transactions generally trade around 5 basis points below smaller transactions. As transactions over $100 million are generally between very large institutions, this coefficient may partly be capturing the pricing of transactions between money-center banks described by Allen and Saunders (1986). The coefficient on the duration of the federal funds loan provides evidence of an intraday market for funds. Each hour of additional duration is correlated with a 0.9-basis-point increase in the transaction interest rate. This estimate is consistent with the prior expectation of getting a positive coefficient of less than 1.5 basis points.

TABLE 4 Parameter Estimates—All Transactions

	Bank Level			Holding-Company Level		
	(1)	(2)	(3)	(4)	(5)	(6)
Borrower's credit risk:						
Return on assets	−1.2004	−1.9145	−1.9282	−1.0314	−.6579	−.6683
	(.2843)**	(.2782)**	(.2793)**	(.2722)**	(.2800)*	(.2798)*
Loans 90 or more days past due	−2.6482			.6684		
	(.2510)**			(.1547)**		
Nonaccruing loans		.7087	.7053		.0942	.1027
		(.3551)*	(.3556)*		(.0385)*	(.0386)**
Risk-based capital ratio	−.6339	−.6793	−.6703	−.7644	−.7513	−.7516
	(.0496)**	(.0501)**	(.0503)**	(.0585)**	(.0597)**	(.0599)**
Log(Transaction-size-to-capital ratio)	.0082	.0085	.0088	.0086	.0085	.0090
	(.0015)**	(.0016)**	(.0016)**	(.0006)**	(.0006)**	(.0006)**
Other borrower characteristics:						
Daily borrower share	.0646	.0884	.0727	.1254	.1298	.1145
	(.0362)	(.0358)*	(.0371)*	(.0384)**	(.0384)**	(.0391)**
Assets < $250 million	.2206	.2288	.2515	.1815	.1820	.1980
	(.0675)**	(.0673)**	(.0673)**	(.0671)**	(.0671)**	(.0672)**
Assets between $250 million and $1 billion	.1004	.1048	.1051	.0705	.0706	.0681
	(.0079)**	(.0079)**	(.0079)**	(.0060)**	(.0060)**	(.0061)**
Assets between $1 billion and $10 billion	−.0030	−.0004	−.0007	−.0146	−.0150	−.0162
	(.0052)	(.0052)	(.0052)	(.0034)**	(.0035)**	(.0035)**
Assets between $10 billion and $100 billion	−.0243	−.0227	−.0230	−.0298	−.0308	−.0314
	(.0039)**	(.0039)**	(.0039)**	(.0032)**	(.0033)**	(.0033)**
Assets over $100 billion			Baseline			
Dealer bank	−.0012	−.0019	−.0041	.0058	.0050	.0027
	(.0036)	(.0037)	(.0036)	(.0039)	(.0039)	(.0038)
Net seller on average	.0054	.0046	.0045	.0047	.0050	.0050
	(.0033)	(.0033)	(.0033)	(.0034)	(.0034)	(.0034)
Lender characteristics:						
Daily lender share	−.2393	−.2442	−.2848	−.2420	−.2415	−.2898
	(.0414)**	(.0413)**	(.0427)**	(.0412)**	(.0412)**	(.0425)**
Assets < $250 million	−.0943	−.0950	−.0990	−.0972	−.0968	−.1000
	(.0080)**	(.0080)**	(.0079)**	(.0079)**	(.0079)**	(.0078)**

Assets between $250 million and $1 billion	−.1069	−.1080	−.1116	−.1085	−.1080	−.1108
	(.0079)**	(.0079)**	(.0078)**	(.0079)**	(.0079)**	(.0078)**
Assets between $1 billion and $10 billion	−.0827	−.0831	−.0843	−.0848	−.0844	−.0851
	(.0078)**	(.0078)**	(.0078)**	(.0078)**	(.0078)**	(.0078)**
Assets between $10 billion and $100 billion	−.0155	−.0165	−.0167	−.0167	−.0165	−.0166
	(.0070)*	(.0070)*	(.0070)*	(.0070)*	(.0070)*	(.0070)*
Assets over $100 billion			Baseline			
Dealer bank	.0236	.0233	.0199	.0215	.0215	.0179
	(.0066)**	(.0067)**	(.0066)**	(.0067)**	(.0067)**	(.0066)**
Net seller on average	−.0185	−.0185	−.0186	−.0170	−.0170	−.0169
	(.0022)**	(.0022)**	(.0021)**	(.0022)**	(.0022)**	(.0021)**
Transaction characteristics:						
Transaction ≤ $10 million			Baseline			
Transaction between $10 million and $100 million	−.0031	−.0036	−.0040	−.0059	−.0054	−.0062
	(.0027)	(.0027)	(.0027)	(.0028)*	(.0028)	(.0029)*
Transaction over $100 million	−.0506	−.0523	−.0541	−.0535	−.0527	−.0552
	(.0056)**	(.0056)**	(.0056)**	(.0052)**	(.0052)**	(.0053)**
Business hours duration	.0090	.0090	.0089	.0090	.0090	.0089
	(.0006)**	(.0006)**	(.0006)**	(.0006)**	(.0006)**	(.0006)**
Liquidity	−.0085	−.0072	−.0040	−.0045	−.0046	−.0020
	(.0154)	(.0154)	(.0154)	(.0153)	(.0153)	(.0153)
Relationship characteristics:						
Log (no. of transaction pair)			.0014			.0026
			(.0012)			(.0012)*
Log (no. of transaction pair) (small borrower)			−.0442			−.0362
			(.0227)			(.0229)
Log (no. of days pair)	−.0064	−.0062		−.0041	−.0041	
	(.0015)**	(.0015)**		(.0015)**	(.0015)**	
Log (no. of days pair) (small borrower)	−.0342	−.0367		−.0308	−.0298	
	(.0229)	(.0227)		(.0229)	(.0229)	
Observations	117,027	117,027	117,027	117,027	117,027	117,027
R^2	.20	.20	.20	.20	.20	.20
R^2 with only time dummies	.16					

NOTE.—Mean of dependent variable = 5.50432. SD of dependent variable = .3493963. Robust standard errors given in parentheses.
* Significant at 5% level.
** Significant at 1% level.

Such pricing is quite significant economically given that banks have an 18-hour window in which to return funds that are borrowed. The coefficient on the proxy for market liquidity is not statistically different from zero. However, as mentioned, the timing of federal funds payments is not equivalent to the timing of federal funds trades. It may be the case that this error in measurement is sufficient to mask a true liquidity effect, or it may be that there is not a relationship between price and volume in the funds market as has been found elsewhere.

Results for the relationship proxies are consistent with the notion that banking relationships are important in the funds market when relationships are measured in days. A 1 SD increase in the number of days that the two banks have transacted correlates with a 0.5 basis point reduction in the transaction interest rate. For the smallest borrowers, the effects are much larger, although these estimates are not significant at traditional levels.

Regression Results for Subsamples

Table 5 reports the output from the same specification as in the second column of table 4, except that the sample of transactions has been limited.[18] For ease of comparison, the first column of table 5 replicates the second column of table 4. The second column of table 5 includes only transactions less than or equal to $10 million in the regression. For such transactions, borrower credit risk appears far more important than for the sample as a whole. Although nonaccruing loans no longer enter significantly, the other coefficients on proxies for credit risk enter with noticeably higher absolute values. For instance, a 1 SD increase in the borrower's return on assets now correlates with a decline in the interest rate of around 1.1 basis points. The coefficient on relative transaction size is nearly double that estimated from the entire sample. With regard to other variables, the size of the lending institution is correlated with about twice the change in interest rates as was true for the entire sample, but the size of the borrowing institution is correlated with a noticeably smaller change. Relationships also appear more significant in the sample of smaller transactions. A 1 SD increase in the length of an interbank relationship correlates with a 1.2 basis point decline in transaction interest rates, over twice that found in the full sample.

The third column of table 5 presents the results for the subsample of transactions involving at least one dealer bank. Because a dealer is involved with these transactions, it is more likely that they do not represent transactions undertaken for the account of the sending and receiving bank. Thus, one might expect it would be more difficult to explain

18. As reported at the bottom of table 5, *F*-tests reject the hypothesis that (*a*) the four borrower risk coefficients and (*b*) all the coefficients from each subsample are the same as those reported for the full sample.

pricing for this subset of transactions. Consistent with this prior belief, the results show that proxies for credit risk generally fail to correlate with pricing in a manner consistent with theory. The coefficient on return on assets is insignificant, and the coefficients on nonaccruing loans and relative transaction size are significant but of the wrong sign. The only credit risk variable entering with the proper sign is the borrower's capital level, but this enters with a smaller magnitude than it did for the whole sample. Overall, the regression explains 0.16 of the variation in transaction interest rates, but 0.14 of this is due to the time dummies.

The last column of table 5 explores whether pricing in the federal funds market is noticeably different on the 6 reserve settlement days covered by the sample. As described in Hamilton (1996), Spindt and Hoffmeister (1988), and Furfine (2000), such days typically witness a higher than average effective funds rate. The results suggest that there are many noteworthy differences in the way transactions are priced on these days. First, the relative transaction size variable enters with a coefficient nearly three times the magnitude of that found in the complete sample. Second, the largest borrowers actually tend to pay significantly *higher* interest rates than banks of a moderate size. According to the estimates, banks with over $100 billion in assets pay around 5 basis points more than banks with between $1 and $100 billion in assets on settlement days. Third, the size of the lending institution, while still generally positively correlated with interest rates, reveals only a difference of around 5 basis points between the biggest and smallest institutions, around half that of the full sample. Fourth, the liquidity variable is significant for the first time. This likely captures the fact that most federal funds value is delivered in the afternoon and that the funds rate on settlement days tends to increase more noticeably in the afternoon. Finally, relationships do not appear to influence pricing on settlement days.

Because the behavior of the funds rate on settlement days has attracted so much attention, it is perhaps worthwhile to question to what extent the different behavior of the effective rate can be attributed to the differences uncovered in the cross-sectional pricing of transactions on those days. During the first quarter of 1998, the weighted average funds rate calculated from my sample was 7 basis points above target, averaged across the 6 settlement days. To try to explain this fact, fitted values were calculated from the full-sample coefficients and the settlement-day coefficients. The predicted weighted average rate was then calculated for the settlement days and compared across the two estimates. The estimates for the settlement day coefficients were, on average, about 1 basis point higher. Thus, changes in the pricing behavior of institutions can only explain 1 point of the 7-basis-point increase in the funds rate occurring on the settlement days in my sample. The time

TABLE 5 Parameter Estimates—Various Samples

	All Transactions (from Table 4, Col. 2)	Transactions ≤ $10 Million	Transactions Involving a Dealer Bank	Transactions on Settlement Days
Borrower's credit risk:				
Return on assets	−1.9145	−2.8684	−.2856	−1.1643
	(.2782)**	(.4856)**	(1.0553)	(.5901)*
Nonaccruing loans	.7087	−.0282	−4.1361	.2647
	(.3551)*	(.7429)	(.9462)**	(.8246)
Risk-based capital ratio	−.6793	−.9925	−.5144	−.5579
	(.0501)**	(.1008)**	(.1517)**	(.1309)**
Log (transaction-size-to-capital ratio)	.0085	.0155	−.0124	.0233
	(.0016)**	(.0027)**	(.0036)**	(.0029)**
Other borrower characteristics:				
Daily borrower share	.0884	.2262	−.2423	.0747
	(.0358)*	(.0723)**	(.0594)**	(.0638)
Assets < $250 million	.2288	.1481	.8391	.0894
	(.0673)**	(.0680)*	(.5934)	(.0526)
Assets between $250 million and $1 billion	.1048	.0382	.0936	.0750
	(.0079)**	(.0137)**	(.0236)**	(.0183)**
Assets between $1 billion and $10 billion	−.0004	−.0157	.0171	−.0398
	(.0052)	(.0093)	(.0158)	(.0113)**
Assets between $10 billion and $100 billion	−.0227	−.0283	−.0315	−.0546
	(.0039)**	(.0077)**	(.0106)**	(.0082)**
Assets over $100 billion			Baseline	
Dealer bank	−.0019	−.0017	.0496	−.0189
	(.0037)	(.0067)	(.0095)**	(.0068)**
Net seller on average	.0046	.0074	−.0137	.0050
	(.0033)	(.0067)	(.0062)*	(.0060)
Lender characteristics:				
Daily lender share	−.2442	−.5192	−.1944	−.0987
	(.0413)**	(.1944)**	(.0548)**	(.0666)
Assets < $250 million	−.0950	−.1930	−.1321	−.0333
	(.0080)**	(.0245)**	(.0125)**	(.0150)*
Assets between $250 million and $1 billion	−.1080	−.2095	−.1358	−.0563
	(.0079)**	(.0244)**	(.0115)**	(.0149)**
Assets between $1 billion and $10 billion	−.0831	−.1890	−.0838	−.0402
	(.0078)**	(.0241)**	(.0109)**	(.0151)**

Assets between $10 billion and $100 billion	−.0165	−.0412	−.0023	−.0064
	(.0070)*	(.0220)	(.0075)	(.0124)
Assets over $100 billion			Baseline	
Dealer bank	.0233	.0254	.0426	.0095
	(.0067)**	(.0207)	(.0100)**	(.0110)
Net seller on average	−.0185	−.0192	−.0146	−.0109
	(.0022)**	(.0046)**	(.0051)**	(.0039)**
Transaction characteristics:				
Transaction < $10 million			Baseline	
Transaction between $10 million and $100 million	−.0036		−.0079	.0063
	(.0027)		(.0072)	(.0054)
Transaction over $100 million	−.0523		−.0136	−.0407
	(.0056)**		(.0120)	(.0119)**
Business hours duration	.0090	.0107	.0088	.0090
	(.0006)**	(.0013)**	(.0011)**	(.0012)**
Liquidity	−.0072	.0192	.0375	.0575
	(.0154)	(.0338)	(.0368)	(.0239)*
Relationship characteristics:				
Log (no. of days pair)	−.0062	−.0134	−.0085	.0022
	(.0015)**	(.0035)**	(.0039)*	(.0040)
Log (no. of days pair) (small borrower)	−.0367	−.0130	−.3397	−.0151
	(.0227)	(.0231)	(.2862)	(.0159)
Observations	117,027	45,278	48,483	11,617
R^2	.20	.18	.16	.24
R^2 with only time dummies	.16	.12	.14	.16
Mean of dependent variable	5.50432	5.475114	5.531565	5.545332
SD of dependent variable	.349	.442	.473	.228
Joint test of significance of 4 borrower risk measures	$F(4, 116{,}942) = 77.16$ Prob > F = .0000	$F(4, 45{,}195) = 55.38$ Prob > F = .0000	$F(4, 48{,}398) = 11.72$ Prob > F = .0000	$F(4, 11{,}587) = 23.45$ Prob > F = .0000
Joint test of significant difference from col. 1 coefficients of 4 borrower risk measures		$F(4, 116{,}921) = 18.72$ Prob > F = .0000	$F(4, 116{,}920) = 26.85$ Prob > F = .0000	$F(4, 116{,}918) = 7.35$ Prob > F = .0000
Joint test of significant difference from col. 1 coefficients of all variables		$F(21, 116{,}921) = 36.09$ Prob > F = .0000	$F(22, 116{,}920) = 13.31$ Prob > F = .0000	$F(24, 116{,}918) = 6.17$ Prob > F = .0000

NOTE.—Robust standard errors given in parentheses. Prob = probability.
* Significant at 5% level.
** Significant at 1% level.

dummies captured the remainder of the effect. Thus, factors outside of those examined here explain most of the unusual settlement-day behavior of interest rates.

VI. Implications and Conclusions

The price of a federal funds loan reflects, in part, the credit risk of the borrowing institution. In particular, banks with higher profitability, fewer problem loans, and higher capital ratios pay lower interest rates when they borrow overnight. This suggests that banks can distinguish credit risk among their peers and price loan contracts accordingly.

Being able to distinguish credit risk, however, does not imply that interest rates on federal funds transactions would be able to price credit risk adequately when counterparty default became likely. For instance, a risk premium of 300 basis points would only compensate a risk-neutral lender for a 3% probability of default *within the next year*. Put another way, a 300 basis point additional spread on a $1 million overnight loan generates an additional $83.33 in revenue each day for the lending institution, a negligible amount when the bank could conceivably lose its entire principal. Thus, access to federal funds borrowing dries up for a bank with a significant perceived possibility of default.[19] Further, this decline in borrowing is generally not accompanied by exceptionally high risk premiums because, as argued by Benston et al. (1986), a bank wishes to avoid giving the market a signal that it is having difficulty attracting funds.[20]

For good reason, therefore, discipline of very risky institutions in the federal funds market takes the form of quantity rationing rather than higher interest rates on transactions. That is, a bank with a high perceived probability of failure generally cannot attract overnight unsecured funds, regardless of price. Nevertheless, the finding that banks do charge interest rates that distinguish the risk of their generally healthy peers does have at least three implications. First, banks can and do monitor the risk present in their interbank transactions. Thus,

19. When such drying up of liquidity occurs depends largely on when financial markets realize a bank is in trouble. The uninsured depositor run on Continental Illinois first began on May 8, 1984, a relatively short time before the FDIC's resolution plan was approved by Congress on September 26 of that same year (Wall and Peterson 1990). In contrast, Peek and Rosengren (1998) report that the closure of the Bank of New England Corporation (BNEC) on January 7, 1991, followed almost 2 years of declines in overnight depositors. By the end of 1989, the BNEC had lost over half its overnight funding (both secured and unsecured) and by June of 1990, BNEC's overnight borrowing stood at roughly 3% of its early 1989 levels.

20. Consistent with this proposition, Ellis and Flannery (1992) note that Continental Illinois failed to report offering rates for its uninsured CDs between May 16 and October 3, 1984. Between May 9 and May 15, 1984, Continental's offer rates on 3-month CDs were only 30–40 basis points above the rates offered by First Chicago and Chase Manhattan.

proposals to incorporate some sort of interbank monitoring into traditional regulation and supervision have been given some empirical credibility. Second, the magnitude of the differential pricing found in the overnight funds market is economically significant. Consider two hypothetical banks, one of which has values for the four risk variables equal to the tenth percentile in the sample while the other has values equal to the ninetieth percentile. That is, one bank is constructed to be ''risky'' and the other to be ''safe.'' Holding all other variables constant, the coefficient estimates from the first column of table 5 predict an interest rate differential between these two banks of 18.4 basis points. Considering only banks with assets greater than $10 billion, the interest rate differential between the two similarly defined hypothetical banks is still over 11 basis points. Third, this pricing of credit risk found at an overnight maturity suggests that if something like the Calomiris (1998) plan were implemented using 10-year subordinated debt, a fairly wide range of allowable debenture interest rates might be required if risk and maturity have a significantly positive correlation.

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