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Discussion paper

DEPOSIT MARKET COMPETITION, WHOLESALE FUNDING, AND BANK RISK

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Deposit Market Competition, Wholesale Funding, and Bank Risk

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Abstract: In this paper we revisit the long debate on the risk effects of bank competition and propose a new approach to the empirical estimation of the relation between deposit market competition and bank risk. Our approach accounts for the opportunity of banks to shift to wholesale funding when deposit market competition is intense. The analysis is based on a unique comprehensive dataset which combines retail deposit rates data with data on bank characteristics and with data on local deposit market features for a sample of 589 U.S. banks. Our results support the notion of a risk-enhancing effect of deposit market competition.

Key words: bank competition, wholesale funding, bank risk, deposit rates

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1. *Introduction*

Profound changes in the structure of U.S. and European banking markets and repeated instances of financial system distress have propelled interest in the relationship between bank competition and bank risk. However, after more than two decades of extensive research on the issue, the literature is still missing a definite answer on whether intense deposit or loan market competition is positively related to bank risk.

In this paper we examine the impact of deposit market competition on bank risk empirically. For this purpose we propose a new analytical framework that accounts for the substitutability of retail deposits and wholesale funds and uses the costs of wholesale funding as an identifying tool in the analysis of the nexus between deposit market competition and risk. The intuition behind our approach is the following: when the deposit market competition faced by a bank intensifies, the cost of retail funding relative to wholesale liabilities rises, and the bank's demand for wholesale funding (federal funds, subordinated debt, etc.) shifts upwards[1]. As a result, the cost and the volume of wholesale funding are correlated with the intensity of retail deposit market competition faced by the bank.

Moreover, the cost and volume of wholesale funding are also related to bank risk. This is the case because, as the literature on market discipline shows, the supply of wholesale funding available to a bank depends on the risk of the bank, since uninsured wholesale lenders are likely to either ration funds to high-risk banks or charge riskier banks higher interest on wholesale funding (Flannery and Sorescu, 1996; DeYoung et al., 1998; Morgan and Stiroh, 2001; Furfine, 2001; King, 2007; Ashcraft, 2008; Dinger and von Hagen, 2009). The volume and the cost of the wholesale liabilities observed on a bank's balance sheet, therefore, depend

[1] Pennacchi (1988) models the effect of retail deposit market competition on banks' retail funding costs and banks' incentives to sell/buy loans. Here we extend the argument to the choice of optimal (retail versus wholesale) liability structure.

on both the risk of the bank and the intensity of retail deposit market competition it faces. We account for these interrelations between bank risk and the costs of retail and wholesale funding by estimating a joint empirical model of the impact of those costs on bank risk.

Understanding how bank competition—and retail deposit market competition, in particular interacts with bank risk is essential for the formulation of appropriate regulatory policies. Given the applicability to policy, it is not surprising that a wide body of research has focused on examining, theoretically and empirically, the potential trade-off between competition and stability. However, both theoretical and empirical results are still mixed. The indefinite state of the debate motivates us to revisit the question.

Earlier theoretical contributions (e.g., Dermine, 1986) show that market power increases banks' incentives to invest in safer projects. In a seminal paper, Keeley (1990) shows that deregulation of the U.S. banking market led to more intense competition between banks, which then caused banks to pursue riskier strategies. Following another line of argument, Broecker (1990) also shows that the average quality of banks' asset portfolios is negatively correlated with the number of loan market competitors, because a rise in the number of banks increases the probability of "lemon" borrowers to be granted a loan. In a related argument, Dell Ariccia and Marquez (2005) show that the share of "unknown" borrowers determines the incentives of the banks to invest in screening costs and thus increases the probability of lending booms and banking crises.

Focusing on deposit market competition, Allen and Gale (2000) show that if banks choose a parameter that determines the default risk of their assets, the optimal risk of failure is increasing with the number of deposit market competitors. Based on a similar line of argument, Hellmann et al. (2000) and Repullo (2004) also theoretically show a positive relation between bank risk and competition. Shy and Stenbacka (2004), however, argue that this result only holds because deposit insurance makes depositors insensitive to bank risk. If in the absence of deposit insurance, banks compete in both the risk and the deposit rate dimensions, in the presence of deposit insurance they only compete in the deposit rate dimension. Boyd and de Nicolo (2005) also challenge Allen and Gale's (2000) approach. These authors argue that if Allen and Gale's assumption that asset portfolios and return distributions are given is dropped, banks would face an optimal contracting problem in which the actions of borrowers are unobservable. In this case, the number of competitors may reduce the risk of bank failure. The intuition behind this result is that if loan market competition is less intense, banks will set high loan rates, which will drive borrowers to choose riskier projects.

Empirical research on the topic has so far also produced mixed results. Demsetz et al. (1996), Brewer and Seidenberg (1996), Saunders and Wilson (1996), Salas and Saurina (2003) and Jimenez et al. (2007) document a positive link between the intensity of bank competition and bank risk, whereas Boyd et al. (2006), de Nicolo and Loukianova (2007), Schaeck et al. (2008) and Schaeck and Cihak (2008), show the existence of a negative relationship[2].

The empirical research on the relation between bank competition and risk faces numerous challenges such as disentangling deposit from loan market competition (which theory suggests can generate opposite risk effects), finding appropriate proxies for competition, and handling the endogeneity of a bank's deposit market competitive position with respect to its risk.

Our approach addresses these challenges directly. First, whereas most of the existing literature measures competition by broad concentration ratios, which cannot disentangle deposit and loan market competition, we explicitly focus on deposit market competition. Second, we concentrate on the intensity of the deposit market competition faced by each individual bank

[2] Berger et al. (2008) focus on the robustness of alternative models of bank competition and risk. They find that results are sensitive to changes in the risk measure (loan portfolio versus overall risk) and to the choice of the competition measure.

and use the deposit rates paid by a bank in a given local market as a proxy for the intensity of the deposit market competition faced by the bank in that particular local market[3]. By using retail deposit rates offered by the bank as a proxy for the intensity of the deposit market competition it faces, we allow banks operating in the same local market to face different intensities of competition, for example, because of comparative advantages in serving some depositor groups. Third, we recognize that a bank's competitive position in the deposit market is not exogenous with respect to bank risk,[4] and we employ the substitutability between retail and wholesale funding as an identification tool. Our identification strategy was motivated by experiences from the recent financial crisis, when the failure of major investment and money center banks with little or no access to retail funding shed new light on the relation between the access to retail deposits and bank risk. Consequently, we can now relate the question of the risk effects of deposit market competition to the extensive use of wholesale funding (Tirole, 2009; Brunnermeier and Pedersen, 2009).

Our main contribution consists in identifying a joint system of the costs of retail and wholesale bank funding and bank risk. This approach extends the scope of bank competition and risk analysis by including wholesale funding[5]. There are two direct advantages associated with this approach. First, we are not exclusively focused on retail deposits, which by the end

[3] We are aware of only three other empirical studies which employ bank-level competition measures. Schaeck and Cihak (2008) use the Boone indicator (Boone, 2008) as a competition measure. This indicator does not distinguish between deposit and loan market power of the bank. Jimenez et al. (2007) measure deposit and loan market competition separately by the deposit and the loan market Lerner index of the bank, respectively. They, however, have only aggregate retail rate data for each of the sample banks and no information about the rates in the different local markets. Berger et al. (2008) employ a bank-level overall Lerner index reflecting output and input prices in both the deposit and loan market.

[4] See Shy and Stenbacka (2004) for a model of the endogeneity of deposit market competition and risk. Obviously, as these authors note, deposit insurance schemes reduce the impact of bank risk on the competitive position of the bank relative to deposit markets. Nevertheless, as numerous examples from the recent crisis showed, depositors care about the risk of the bank.

[5] To our knowledge the only study that relates wholesale funding, competition, and risk is Goyal (2005). In his empirical framework Goyal (2005) assumes that high bank competition is reflected in low bank charter value and high bank risk, and he examines the effect of the charter value on the yield and the inclusion of covenants on bank subordinated debt. He finds that low charter values correspond to more covenants in the subordinated debt contract and higher subordinated debt yields.

of our sample period represent only about 50% of total bank liabilities[6]. We are rather including a wider set of liabilities in the analysis. Second, since wholesale funding is related to both retail deposit market competition and risk, its explicit inclusion in the analysis strengthens identification and avoids a potential omitted variable bias.

Our empirical analysis is based on a rich dataset of deposit rates offered by 581 U.S. banks in 164 metropolitan statistical areas (MSAs), combined with balance sheet data of the banks as well as market structure characteristics of the MSAs. The time period encompasses 1997 to 2006. The richness of the data allows us to employ variation across local deposit markets, across banks, and across time in the analysis.

The results of our empirical analysis point to a robust, positive, and statistically and economically significant relation between the retail deposit rates offered by a bank and its asset portfolio and default risk. These results are consistent with the economic insight that banks with cheap retail sources of funding pursue more conservative risk strategies (Allen and Gale, 2000; Hellmann et al., 2000, etc). They should not, however, be interpreted as a direct support for limiting bank market competition. The reason being that we compare levels of bank assets' portfolio risk but do not empirically determine the threshold whereupon the risk of individual banks should be considered excessive, which would establish a direct link to financial system stability. Also, since we do not present any welfare analysis, we are unable to address the trade-off between the lack of efficiency resulting from imperfect bank competition and the potential fragility of competitive banks. Our results can, however, be used by regulators to focus regulatory and supervisory attention on banks with a limited access to retail deposits.

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[6] Data from the "Flow of Funds Accounts" by the Federal Reserve Board suggest that retail deposits represent less than 58% of total bank liabilities in 2002; by 2007 the share of retail deposits has fallen below 52%.

The rest of the paper is organized as follows. Section 2 introduces the data. Section 3 presents the empirical methodology. Section 4 discusses the results of our empirical study. Section 5 discusses some robustness checks, and Section 6 concludes.

2. ***Data***

This empirical study is based on a comprehensive dataset combining three main data sources. First, we employ the financial statements (balance sheets and income statements) reported by 589 U.S. banks in the *Quarterly Reports of Conditions and Income* (Call Reports). We then match the Call Report data with *BankRate Monitor* data on the retail deposit rates offered by each of these banks in each of 164 metropolitan statistical areas covered by *BankRate Monitor*[7](if the respective bank has a branch in the MSA). *BankRate Monitor* deposit rate data have weekly frequency. To match the quarterly frequency of the Call Reports, we use only the deposit rates reported on the last week of each quarter. Third, we match our bank-market observations with characteristics of the local bank market (the MSA) drawn from the *Summary of Deposits*[8]. The data encompass a period starting on September 19, 1997, and ending on July 21, 2006.

After merging our data, we have a multidimensional (unbalanced) panel dataset consisting of bank-level data (risk variables, bank size, capitalization), market-level data (HHI, market size, average income of the MSA's population, income growth, etc.), and bank-market-level data (retail deposit rates, share of the MSA's branches, branches per deposit volume in the market, etc.). It is often assumed in the banking literature that multimarket banks charge uniform rates across local markets (e.g. Radecki, 1998; Park and Pennacchi, 2008). A closer look at our sample, however, uncovers a high degree of cross-market variation in multimarket banks' pricing. The data presented in Table 1 illustrate that the variation in the deposit rates set by a

[7]The coverage of *BankRate Monitor* limits our sample to 589 banks.
[8] *Summary of Deposits* data have annual frequency (as of end of June). We attach the same values of the local market variables to all four corresponding quarters.

multimarket bank in the different MSAs is equal to about one-third of the variation of all deposit rates offered by all banks in a MSA. We explore this cross-market variation in the pricing of multimarket banks as a proxy for local market competitive conditions.

Table 1: Cross-market and cross-bank variation in checking account rates

	variation within the market		variation within the bank	
Year*	standard deviation	mean absolute deviation from the mean	standard deviation	mean absolute deviation from the mean
1998	0.25	0.18	0.07	0.03
1999	0.33	0.24	0.15	0.07
2000	0.33	0.24	0.13	0.08
2001	0.49	0.37	0.21	0.14
2002	0.60	0.43	0.17	0.14
2003	0.56	0.40	0.16	0.12
2004	0.80	0.53	0.27	0.13
2005	0.71	0.50	0.29	0.14
2005	1.05	0.70	0.20	0.15
2006	0.96	0.65	0.17	0.13

Note: Variation within the market is computed by first computing by local market the variation (standard deviation or mean absolute deviation from the mean) of the checking account rates offered by all banks. Then the variation is averaged across local markets. Variation within the bank is computed by first computing by multimarket bank the variation (standard deviation or mean absolute deviation from the mean) of the checking account rates offered in the various local markets. Then the variation is averaged across all multimarket banks.

3. *Methodology*

In this section we present an empirical model of the impact of bank retail deposit market competition on bank risk, which integrates the simultaneity of a bank's competitive position with respect to deposit markets, the cost [?] of wholesale funding, and bank risk. We measure a bank's deposit market competitive position in a given local market by the retail deposit rates offered by the bank in this market. Our empirical model then translates into a model on the relation between retail and wholesale rates and bank risk. It starts with a main equation describing the impact of deposit and wholesale rates on bank risk. This equation models our main hypothesis that the risk of the bank depends on the costs of its retail and wholesale liabilities (Allen and Gale, 2000, Hellmann et al., 2000, Repullo, 2004):

$$r_{i,t} = f(d_{i,j,t}, w_{i,t}, controls) \quad , \qquad (1)$$

where r denotes the risk of the bank, d the retail deposit rates, and w the interest rate on wholesale liabilities[9]. The subscripts i, j, and t refer to the bank, the local market (MSA), and the time period, respectively.

Accounting for the simultaneity of bank risk and banks' retail and wholesale rates, we explicitly model the reverse causality by the following equations and identify the model using a zero restriction identification strategy[10]:

$$d_{i,j,t} = f(r_{i,t}, w_{i,t}, controls) \quad (2)$$

$$w_{i,t} = f(r_{i,t}, controls) \quad (3)$$

Equation (2) models the dependence of retail deposit rates on bank risk and the costs of wholesale funding[11]. The dependence of deposit rates on bank risk is based on the assumption of some risk sensitivity of insured deposits, or in other words, that bank risk is a determinant of its deposit market competitive position. The risk of the bank can also affect its retail deposit rates through a "wholesale" channel: as shown by Billet et al. (1998), riskier banks shift from uninsured wholesale funds to insured retail liabilities. Such a shift requires higher retail rates to attract sufficient retail deposits.

The dependence of deposit rates on wholesale rates has already been shown in theoretical work. Kiser (2003) and Park and Pennacchi (2008) model loans as the output in a production function that uses retail and wholesale funds as inputs. The assumption is then made that, whereas banks can have market power in the retail deposit market, they are price takers in the

[9] Equation (1) explicitly accounts only for the variable costs of retail and wholesale funds. We include a number of control and instrument variables to account for the variation in the fixed costs of deposits and wholesale funds.

[10] One of the reasons we prefer a static to a dynamic identification scheme (e.g., one based on lags of the dependent variable) is the rigidity of bank retail deposit rates, which implies that we might observe the same retail rate in two consecutive quarters.

[11] Jimenez et al. (2007) is the only other study we are aware of that uses prices as a measure of the intensity of competition. The authors explore the relation between competition and risk in the Spanish banking sector. They fail to recognize, however, the simultaneity of prices and proceed with a reduced-form model.

wholesale market. In this framework, Kiser finds that an exogenous rise in the wholesale rate is related to an increase in the optimum retail deposit rate offered by the bank. Following the same line of argument, Park and Pennacchi (2008) assume that only large multimarket banks can borrow wholesale funds at an exogenously given wholesale rate. This access to wholesale funding makes large banks less aggressive when competing for retail funds. In both models the availability and the cost of wholesale liabilities determine retail deposit rates[12]. In our approach we approximate the availability and the costs of wholesale funds by the interest rate on wholesale liabilities paid by the bank[13].

Equation (3) describes the risk sensitivity of the wholesale funding rate[14]. Wholesale rates are assumed to be risk-sensitive because wholesale creditors adjust the interest rate to the probability of the borrower's failure since wholesale liabilities are not covered by deposit insurance. Furfine (2001), for example, proves that riskier banks pay higher rates on federal funds. Moreover, Flannery and Sorescu (1996), DeYoung et al. (1998), and Morgan and Stiroh (2001) find that riskier banks pay higher interest on subordinated debt[15]. Following Pennacchi (1988), we also allow wholesale rates to depend on retail rates, assuming that banks facing intense deposit market competition show a higher demand for wholesale funds. In this equation we also control for the impact of retail deposit rates on a bank's demand for wholesale funds.

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[12] An alternative approach of modeling the relationship between retail and wholesale deposits is taken by Jimenez et al (2007). These authors concentrate solely on the difference between wholesale and retail rates (deposit market Lerner index) as a measure of deposit market power and do not explicitly model the interaction between wholesale and retail rates.

[13] In the subsection on the estimation technique (3.4) we discuss the effects and treatment of the sample selection issue related to the rates on wholesale liabilities.

[14] Here we deviate from the simple Lerner indices approach presented by Jimenez et al (2007) which implicitly assumes that all banks, independent of their risk levels, face the same country-wide money market rates.

[15] To our knowledge the only study that relates wholesale funding, competition, and risk is Goyal (2005). In his empirical framework Goyal assumes that high bank competition is reflected in low bank charter value and high bank risk, and examines the effect of the charter value on the yield and the inclusion of covenants on bank subordinated debt. He finds that low charter values correspond to more covenants in the subordinated debt contract and higher subordinated debt yields.

3.1. Measures of bank risk, deposit rates, and wholesale rates

We employ two alternative measures of bank risk in the estimations: the z-score and the non-performing loans ratio[16]. Following Boyd et al. (2006), we compute the z-score as the ratio of the sum of a bank's average return on assets (ROA) and capitalization (E/A = equity/total assets) to the standard deviation of the return on assets[17]:

$$z - score = \frac{\overline{ROA} + \overline{E/A}}{\sigma(ROA)}. \quad (4)$$

The z-score, therefore, presents information on how many standard deviations of the return on assets are needed to drive the bank into default and is a broader measure of risk than the nonperforming loans ratio, which is exclusively focused on loan risk. Banks with a low z-score are more likely to default. That is, the z-score is decreasing with bank risk. To facilitate the interpretation of the results and the comparison with the alternative risk measures, we use the negative z-score as a risk proxy in the regressions.

Our alternative risk measure, the nonperforming loans ratio, is computed as the ratio of impaired loans to total outstanding loans. In the baseline specifications of the regressions we use the log of the ratio with a four-quarter lead[18]. The intuition is that the risk of the current projects will only be reflected with a delay in the nonperforming loan ratios of the bank[19].

[16] Boyd et al. (2006) and Schaeck and Cihak (2008) measure bank risk by the z-score. They find that bank competition (measured by the Herfindahl index or the concentration of the banking industry in Boyd et al, 2006 and the Boone indicator in Schaeck and Cihak, 2008) has a negative impact on risk. On the other hand, Jimenez et al. (2007) concentrate on the risk of the loan portfolio measured by the ratio of nonperforming loans to total loans. They find that deposit market competition has no significant impact on asset risk, but loan market competition is positively related to the risk of a bank's asset portfolio.

[17] The means and the standard deviation are computed by using rolling windows of 8 quarters.

[18] Regression specifications using the current (as in Jimenez et al., 2007) and the two-quarter-lead of the nonperforming loan ratios result in qualitatively the same results.

[19] As a robustness check we have rerun the model using the ratio of nonperforming loans to equity as a risk measure (again with a four-quarter lead). According to Ashcraft (2007), this is a better measure of bank risk since the capitalization of the bank affects the amount of nonperforming loans a bank can absorb before harming

Turning to bank retail deposit rates as a proxy for deposit market competitive position, we choose checking account rates as the most suitable for our exercise[20]. This choice is motivated by the fact that previous research has documented that checking account rates are more sensitive to changes in the local bank market structure than money market deposit account rates[21] and certificates of deposit (Hannan and Prager, 1998, Craig and Dinger, 2009). Since we observe bank retail rates in different local markets (MSAs) we control for the intensity of local deposit market competition and identify the deposit rate equation using the variation of local market characteristics across the MSAs.

And finally, in our baseline specification, we use the interest rate on federal funds purchased as a proxy for the costs of wholesale funding. Purchased federal funds are liabilities with a very short maturity and thus are not perfect substitutes for retail deposits. The rate a bank pays on federal funds is, however, shown to be closely correlated with alternative bank wholesale liabilities (such as subordinated debt, advances from Federal Home Loan Banks, and others), which are potentially better substitutes for retail deposits from a bank's point of view. The advantage of federal funds over these alternative wholesale liabilities for our framework is that we have fed funds observations for most banks in our sample[22]. Moreover, comparison across banks is further facilitated by the fact that the fed funds market has a standardized "product"[23]. We follow King (2008) and approximate the interest rate on fed funds purchased

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its creditors. The results of the estimation are very similar to those using nonperforming loans to total loans as a dependent variable.

[20] *Bankrate Monitor* reports the rates on a variety of retail deposit products, such as checking accounts, money market deposit accounts, and certificates of deposits, with a maturity of three months to up to five years.

[21] We have rerun all regression specifications using the money market deposit account rates as a retail deposit rate measure. The results are qualitatively the same as when the checking account rate is employed, although statistical significance is sometimes lower. Results are available from the authors upon request.

[22] In order to account for the noise introduced in the fed funds rate data when the volume of fed funds liabilities is negligibly small, we introduce a screen based on the share of fed funds liabilities in total assets in the estimation of equation (3) and account for the potential selection bias by using a Heckman correction (Heckman, 1976).

[23] Alternative wholesale funding products bear a substantial nonprice component such as covenants (see Goyal, 2005), which should be accounted for, for a precise comparison. Data about these are, however, unavailable for the broad range of banks included in our study.

by the ratio of "expense of federal funds purchased and securities sold under agreements to repurchase" (line riad4180 in the Call Report) to "federal funds purchased and securities sold under agreements to repurchase" (line rcfd3353 in the Call Report)[24]. In the robustness section we alternatively estimate the model using the subordinated debt rate as a wholesale rate proxy.

Table 2 illustrates descriptive statistics of the variables included in our estimations. It shows substantial variation of the checking account rate, between 0 and 3.8%. Some of that variation is due to the time series dimension of our data, which span a period from 1997 to 2006 and cover a full interest rate cycle. Our risk measures also exhibit substantial variation: the z-score varies between 2 and 492, and the nonperforming loan ratios vary between zero and more than 12%.

Table 2: Descriptive statistics

Variable	Number of observations	Mean	Standard deviation	Minimum	Maximum
checking account rate (in %)	18715	0.538	0.539	0.000	3.800
T-Bill three month (in %)	18715	3.361	1.769	0.880	6.210
effective fed funds rate (in %)	18715	3.535	1.949	0.938	7.125
rate on subordinated debt (in %)	13279	0.025	0.181	0.000	7.793
rate on federal funds purchased (in %)	17439	0.026	-0.823	0.002	100.335
Z-score	9679	78.820	94.260	2.575	492.196
NPL (in %)	12098	0.004	0.004	0.000	0.122
number of branches per 1000000 USD deposits	16039	0.022	0.022	0.000	1.050
herfindahl index	17879	0.159	0.066	0.051	0.770
BHCdummy	18715	0.947	0.225	0.000	1.000
average income in the MSAs (in thous. USD)	15581	32.257	16.367	5.672	375.689
average income growth in the MSAs	15581	0.050	0.024	-0.054	0.158

Note: The "raw" rates on wholesale liabilities before applying the screen of federal funds purchase > 1% of total assets and outstanding subordinated debt >1% of total assets are reposted in the table.

3.2.Identification and Instruments

Our identification follows a "zero restriction" strategy. Each of the endogenous variables is instrumented by a suitable set of instrumental variables, which are uncorrelated with the error term but strongly correlated with the instrumented endogenous variable.

[24] As King (2008) notes, this approximation includes the cost of securities sold under agreements to repurchase, which are a collateralized liability of the bank and might be less sensitive to bank risk. The fact that a substantial risk sensitivity is shown even when repos are included, further strengthens our argument.

In the case of retail deposit rates, we base our identification strategy on the assumption that banks control for local deposit market competition when setting their deposit rates[25]. Here we borrow from the literature, which has found that the ratio of *branches to deposits,* the *Herfindahl* index of the local deposit market, and the *market size* are significant determinants of a bank's retail deposit rates (see Prager and Hannan, 2004). We argue that these variables are only right-hand variables for the deposit rate equation, not the wholesale rate or risk equations, and thus employ these variables as instruments for the retail deposit rate. The *branches-to-deposits* ratio is computed at the bank-market level as the ratio of the number of bank *i*'s branches in local market *j* to bank *i*'s total deposits (in millions of USD) in this market. The underlying assumptions when using these variables as deposit rate instruments is that banks with more branches can attract deposits at lower rates (because they have better geographical proximity to retail customers). The *Herfindahl* index is the sum of squares of the deposit market shares of all banks operating in the MSA (this variable is drawn from the FDIC *Summary of Deposits*). This variable controls for the concentration of market power. The *market size* variable is the log of the population of the respective market.

The instrumentation of the wholesale rate in the deposit and risk equations focuses on variables which affect the rate a bank pays on wholesale liabilities but which do not have an impact on deposit rates and bank risk. Our major instrument for the rate on wholesale fund is the average effective level of the federal funds rate (as announced by the Federal Reserve Bank of New York, based on its survey of four major brokers). The inclusion of this instrument follows the argument that the rate banks pay on wholesale liabilities reflects changes in the average rate on fed funds[26]. We also use a dummy variable, which takes the

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[25] Note that we observe substantial cross-market variation in retail rates within the multimarket banks (which we will discuss in our data section) in our sample, which can be employed in the identification.

[26] Note that by including this instrument in the regressions we also control for the general interest rate level, so that variation in the checking account rate is then only related to cross-market and cross-bank variation and not to the general interest rate cycle. A change in the effective fed funds rate is probably also related to the amount

value of one if the bank belongs to a bank holding company and zero otherwise (*BHC dummy*), as an additional instrument for the wholesale rate. The intuition behind this instrument is that wholesale funding is cheaper for banks that are members of large bank holding companies (BHCs), but risk choice and the deposit rate do not necessarily depend on BHC membership. Both the average fed funds rate and the BHC dummy are weak instruments. The average fed funds rate shows no variation across banks, while the BHC dummy shows almost no variation across time. To strengthen identification, we also include a dummy variable taking the value of one if the bank is a member of the Federal Home Loan Bank, and zero otherwise (*FHLB dummy*), as an additional instrument for the wholesale rate. The inclusion of this instrument follows King (2008) and Ashcraft, Bech and Frame (2008). These authors argue that advances from the Federal Home Loan Bank system are empirically relevant substitutes for other forms of wholesale borrowing. Their availability can, therefore, shift a bank's demand for federal funds.

The risk of a bank can be instrumented by the average economic conditions in the local markets where a bank operates. Cross-country evidence suggests that bank default risk (Boyd and de Nicolo, 2006) and nonperforming loans (Dinger and von Hagen, 2009) are negatively related to average income and economic growth. For the United States, Mian and Sufi (2008) demonstrate for the case of mortgage lending a negative relation between default rates and MSA average income. Moreover, theoretical and empirical research shows that lending standards depend on local economic growth (see Ruckle, 2004, for a discussion). General economic conditions are effective instruments because, although they significantly affect the risk of the banks operating in the local market, they do not have a direct impact on wholesale and deposit rates. Following this line of argument, we instrument the risk of a bank by the

of risk taken on by the bank (see Jimenez et al., 2008), as well as the deposit rate it can charge, but we assume that this impact goes through the costs of wholesale funding faced by the bank. Since our system is overidentified, we also have tried including this variable in the deposit rate and the risk equation with little change in the results.

average household income in the markets where a bank operates (*income*) and the annual household income growth averaged across the markets where a bank operates (*income growth*)[27].

In the case of all instruments, the Stock-and-Watson-rule-of-thumb measure[28] confirms the strength of the instrument, and, in the case of multiple instruments, a Hansen test does not reject exogeneity of the instruments.

3.3.Control variables

As suggested by earlier research, a few variables such as capitalization and bank size can affect all three dependent variables (Hannan and Hanwick, 1998, Furfine, 2001, Boyd et al., 2006). That is why, we include as control variables in all three equations the ratio of bank equity to total assets as a measure of *capitalization,* and the log of the bank's total assets as a proxy for *bank size,* as well as the squared *bank size* variable (to control for nonlinearities in the relation between bank size and bank risk and retail and wholesale rates).

A bank's competitive position in the loan market can also affect its risk and the costs of retail and wholesale funding. To this end, we include the ratio of loans in the balance sheet plus the volume of securitized loans to the total assets of the bank (*loans to total assets*) as a control for the bank's market power in the loan market[29]. The idea is that if a bank has substantial market power in the loan market, it will have a higher share of loans (which on average

[27] Average FICO scores can alternatively be used as a risk instrument. We do not have the FICO score data for the full sample period at our disposal. Previous research (see Cohen-Cole, 2008), however, suggests a very strong correlation between average FICO scores and average household income.

[28] The so-called Stock and Watson rule of thumb (Stock and Watson, 2003) is often used as a proxy for the strength of an instrument. According to this rule, the first-stage F-statistic testing the hypothesis that the coefficients on the instruments are jointly zero should be at least 10. In the case of the deposit rate instruments, the F-statistic is 14.5, for the wholesale rate instruments the F-statistic is 13.2, and for the risk instruments the F-statistic is 12.4.

[29] The inclusion of more comprehensive loan market competition measures and the analysis of their interactions with deposit market competition is a planned extension of this research project.

generate higher returns than alternative assets) in its portfolio[30]. Since the bank can securitize and sell the loans after origination, we add the amount of securitized loans to on-balance sheet loans. Moreover, as suggested by King (2008), the rate of loan growth might be an important determinant of the wholesale rate. Since the loan growth rate can also significantly affect the retail deposit rates offered by the banks and the risk of their asset portfolio, we also include *loan growth* as a control variable in all three equations.

3.4.Estimation technique

In the estimation of equations (1) and (3), bank-level dependent variables (the risk proxy and the rate on wholesale liabilities) are regressed on bank-market-level explanatory variables (e.g., deposit rates). In this case, the assumption of uncorrelated error terms across the observations may be violated (it is likely that observations of the same bank in different markets will show correlated error terms), resulting in potentially inconsistent estimates. We adopt three alternative approaches to deal with our multidimensional panel.

First, we use the full sample of bank-market observations and cluster the standard errors by bank. Second, we alternatively estimate the model on the bank level by computing the average values of the bank-market-level variables (deposit rate, average income, branches-to-deposits ratio, etc.). For each bank and time period, we compute the average value of each of these variables across all the local markets in which the bank operates. Through the aggregation, we achieve consistency of the estimated coefficients but lose information on the intensity of the local deposit market and dramatically reduce the number of observations, which in turn reduces the efficiency of the estimation. Obviously, this estimation approach can only account for the variation across banks. It has, however, the advantage that it accounts for the possibility that banks reshuffle deposits across local markets. In this case, the average

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[30] The intuition behind this proxy of loan market competitiveness follows the intuition suggested by Goyal (2005) for using the ratio of demand deposits to total deposits as a proxy of the deposit market power of a bank.

intensity of deposit market competition might be the one that matters for bank risk. And third, we estimate the model using the subsample of single-market banks (143 out of our sample of 589 banks operate in only one MSA). Single-market banks (SMBs) face deposit market competition in one market only, and their bank-level risk is related to the competitive conditions in only this deposit market. The drawback of this approach is that we again dramatically reduce our sample size.

In the estimation of the wholesale rate equation we control the potential selection bias, which arises from the fact that if banks perceive that they have to pay a disadvantageous rate on their wholesale liabilities, they may refrain from borrowing wholesale funds[31]. Consequently, for such banks we will observe no (or only negligible volumes) of wholesale funding. For these reasons we use the censored regression specification suggested by Heckman (1976) when estimating the wholesale rate equation. Unless the share of wholesale liabilities is large enough, the purchased funds are likely to represent unusual purchases made under extreme time pressure and are thus unlikely to represent the price of wholesale funds as deposit substitutes. Because of this, we did not include an observation in the estimated wholesale funds equation unless the volume of federal funds purchased represented at least 1% of the bank's assets. [32] The Heckman specification creates an auxiliary variable in the first stage, the "inverse Mills' ratio," which represents the bias caused by the censoring process. As noted by Heckman, instrumental variable estimators are still consistent, once the predicted inverse Mills' ratio is included in the system[33].

[31] These selection issues have been explicitly studied by King (2008).

[32] As robustness check we have re-estimated the model using both a fix volume of the federal funds purchased as a trigger point (1 million USD, as in King, 2008) and alternative trigger values of the fed funds purchased share in total assets (0.05% and 2%). Results do not change qualitatively.

[33] Note that the Mill's ratio is significant in the estimation of all specifications of the wholesale equation.

4. *Estimation results*

In this section we present the results of the baseline model, with the rate on federal funds purchased as a wholesale funding rate proxy and the checking account rate as a proxy of the intensity of deposit market competition. The results illustrated in Table 3, which contains a column for each of the risk measures (negative z-score and the nonperforming loans ratio (NPL)), reflect the estimation based on the full sample of bank-market level observations with a quarterly frequency. These results show a statistically significant positive link between deposit rates and bank risk, which is robust to the choice of the risk measure. The estimated coefficients suggest a relatively large economic significance of the results. So, a one-standard-deviation increase of the checking account rate corresponds to a drop in the z-score of slightly more than 100 basis points and an increase in the nonperforming loans ratio of 0.003 (equal to roughly the average of the nonperforming loans ratio). The rate on federal funds purchased enters the regression using the z-score as a risk measure with a statistically insignificant coefficient. Its effect on the nonperforming loans ratio is, however, positive and statistically significant: banks paying higher rates on federal fund have on average riskier loan portfolios. The magnitude of the estimated coefficient, however, suggests that the economic significance of the wholesale rate's impact is lower than the one of retail deposit rates[34].

[34] The lower economic and statistical significance of the wholesale rate relative to the retail rate coefficients might be due to the fact that our measure of retail rates is less noisy than our wholesale rate measure (imputed from the Call Report) and that our retail rate instruments are stronger than the wholesale rate instruments.

Table 3: All banks; bank-market level observations; the wholesale rate is measured by the rate on fed funds purchased

Risk measure	negative Z-score		NPL	
	Coefficient	Standard error	Coefficient	Standard error
Dependant variable: bank risk				
checking account rate	1.590 ***	0.482	0.006 ***	0.003
rate on federal funds purchased	-0.057	0.067	0.001 ***	0.001
bank size	-3.901 ***	0.783	0.011 ***	0.003
bank size^2	0.129 ***	0.022	0.000 ***	0.000
capitalization	-43.593 ***	1.421	-0.021 **	0.009
loan growth	-0.557 ***	0.104	0.000	0.001
loans_ta	0.940 **	0.380	0.012 ***	0.002
income	-0.003 ***	0.001	0.000	0.000
income growth	-10.299 ***	2.499	-0.017 ***	0.008
constant	15.676 **	7.200	-0.101 ***	0.027
Observations	4715		7216	
R-squared	0.32		0.09	
Dependant variable: checking account rate				
bank risk	0.189 ***	0.023	72.405 ***	14.150
rate on federal funds purchased	0.058 ***	0.009	0.081 ***	0.027
bank size	-0.360 ***	0.120	-0.426 ***	0.093
bank size^2	0.007 **	0.003	0.010 ***	0.003
capitalization	8.775 ***	1.281	-3.232 ***	0.623
loan growth	0.152 ***	0.046	0.007	0.064
loans_ta	-0.849 ***	0.063	-0.689 ***	0.109
market size	0.000 ***	0.000	0.000	0.000
branch_deposit	4.153 ***	1.028	2.258 ***	0.654
HHI	-1.085 ***	0.221	-0.637 ***	0.165
constant	7.134 ***	1.210	4.896 ***	0.829
Observations	4715		7216	
R-squared	0.19		0.18	
Dependant variable: rate on federal funds purchased				
checking account rate	0.997 ***	0.178	1.139 ***	0.185
bank risk	0.019	0.019	25.461	14.993
bank size	0.818 ***	0.109	1.027 ***	0.138
bank size^2	-0.021 ***	0.003	-0.026 ***	0.004
capitalization	-3.025 ***	1.243	-3.365 ***	0.687
loan growth	-0.314 ***	0.085	-0.356 ***	0.081
loans_ta	0.353 ***	0.133	0.654 ***	0.162
effective fed funds rate	0.431 ***	0.019	0.448 ***	0.021
FHLB dummy	-0.275 *	0.162	-0.341 *	0.180
BHC dummy	0.047	0.293	0.349	0.294
constant	-7.223 ***	1.366	-9.793 ***	1.468
Observations	4715		7612	
Censored observations	634		634	
R-squared	-		-	

Note: Two-stage least squares IV estimations. Endogenous variables are: bank risk (measured by z-score, NPL, checking account rate and the rate on fed funds purchased. The fed funds rate equation is estimated using a Heckman procedure to control for potential selection bias. *, **, *** indicate significance at the 10%, 5% and 1% level, respectively.

Table 4: All banks; bank level observations; the wholesale rate is measured by the rate on federal funds purchased

Risk measure	negative Z-score			NPL		
	Coefficient		Standard error	Coefficient		Standard error
Dependant variable: bank risk						
checking account rate	2.552	***	0.597	0.004		0.004
rate on federal funds purchased	0.300	*	0.159	0.000		0.001
bank size	10.729	***	2.732	0.006		0.004
bank size^2	-0.315	***	0.084	0.000		0.000
capitalization	-55.711	***	4.081	0.035		0.016
loan growth	-0.345	***	0.142	0.001		0.001
loans_ta	1.435	***	0.454	0.011	***	0.003
income	-0.002		0.002	0.000		0.000
income growth	-8.718	***	3.490	0.023		0.018
constant	-102.354	***	22.119	-0.055		0.037
Observations	1181			2243		
R-squared	0.23			0.06		
Dependant variable: checking account rate						
bank risk	0.257	*	0.141	-57.333	***	18.272
rate on federal funds purchased	0.090		0.068	0.371	***	0.045
bank size	-1.244	**	0.508	-0.569	***	0.180
bank size^2	0.034	**	0.015	0.017	***	0.006
capitalization	21.385	*	11.672	3.668	***	1.411
loan growth	0.150		0.149	-0.009		0.093
loans_ta	-1.282	**	0.616	0.348		0.263
market size	0.000		0.000	0.000		0.000
branch_deposit	3.807		3.335	-4.282	***	1.590
HHI	-3.299	*	1.874	0.759	*	0.413
constant	14.926	**	5.954	4.578	***	1.441
Observations	1181			2243		
R-squared	0.21			0.07		
Dependant variable: rate on federal funds purchased						
checking account rate	0.937	***	0.355	0.778	**	0.373
bank risk	0.021		0.024	-3.087		16.084
bank size	1.029	**	0.421	1.058	**	0.423
bank size^2	-0.029	**	0.012	-0.030	**	0.012
capitalization	-2.320		2.337	-4.011	***	1.218
loan growth	-0.172		0.130	-0.182		0.129
loans_ta	0.531	**	0.216	0.654	***	0.240
effective fed funds rate	0.403	***	0.062	0.442	***	0.071
FHLB dummy	-0.038		0.217	-0.023		0.233
BHC dummy	-0.190		0.437	-0.119		0.444
constant	-8.486	**	4.021	-9.105	**	4.008
Observations	4141			4141		
Censored observations	345			345		
R-squared						

Note: Two-stage least squares IV estimations. Endogenous variables are: bank risk (measured by z-score, NPL), checking account rate and the rate on fed funds purchased. Bank-market level variables are averaged at the bank level. The fed funds rate equation is estimated using a Heckman procedure to control for potential selection bias. *, **, *** indicate significance at the 10%, 5% and 1% level, respectively.

Table 5: Single-market banks only; the wholesale rate is measured by the rate on fed funds purchased

Risk measure	**negative Z-score**			**NPL**		
	Coefficient		Standard error	Coefficient		Standard error
Dependant variable: bank risk						
checking account rate	1.348	*	0.817	0.017	**	0.010
rate on federal funds purchased	-0.202		0.181	0.005	*	0.003
bank size	-4.533		8.095	0.025		0.032
bank size^2	0.188		0.283	-0.001		0.001
capitalization	-38.766	***	12.998	0.066		0.060
loan growth	-2.433	**	1.151	0.033	***	0.009
loans_ta	1.673	*	0.919	0.012		0.009
income	-0.001		0.002	0.000		0.000
income growth	-9.472		6.396	0.175	**	0.074
constant	10.681		57.911	-0.242		0.246
Observations	180			323		
R-squared	0.13			0.03		
Dependant variable: checking account rate						
bank risk	-0.542		0.661	-55.670	**	23.661
rate on federal funds purchased	0.004		0.225	0.248	***	0.047
bank size	-31.179		36.267	-4.620	***	1.399
bank size^2	1.098		1.287	0.160	***	0.050
capitalization	-28.938		39.232	6.945	**	3.649
loan growth	-1.406		2.618	2.162	**	0.948
loans_ta	-0.845		1.020	-1.027	***	0.261
market size	0.000		0.000	0.000	**	0.000
branch_deposit	-81.461		99.843	-12.373		8.139
HHI	2.004		4.427	4.414	***	1.916
constant	217.188		250.414	33.452	***	9.784
Observations	180			323		
R-squared	0.07			0.26		
Dependant variable: rate on federal funds purchased						
checking account rate	0.767		1.008	0.760		1.013
bank risk	0.136	*	0.075	65.472	*	38.445
bank size	0.609		1.019	0.972		1.000
bank size^2	-0.014		0.032	-0.027		0.031
capitalization	8.863		7.360	-7.391	**	3.225
loan growth	-0.048		0.641	-0.078		0.637
loans_ta	-0.170		0.563	-0.245		0.604
effective fed funds rate	0.361	**	0.175	0.345	*	0.184
FHLB dummy	-0.010		0.412	0.480		0.440
BHC dummy	-0.643		0.569	-0.592		0.565
constant	-3.365		8.814	-7.706		8.509
Observations	704			704		
Censored observations	99			99		
R-squared	-			-		

Note: Two-stage least squares IV estimations. Endogenous variables are: bank risk (measured by z-score, NPL), checking account rate and the rate on fed funds purchased. Only observations of single-market banks The fed funds rate equation is estimated using a Heckman procedure to control for potential selection bias. *, **, *** indicate significance at the 10%, 5% and 1% level, respectively.

Turning to the control variables, the coefficients of the bank size variables suggest humped shape of the relation between bank size and bank risk. Moreover, well capitalized banks are supposed to pursue less risky strategies. Banks holding more loans on their portfolios are significantly riskier, and last but not least, average household income growth corresponds with less risky bank portfolios.

The results of the estimation of the deposit rate equation in this baseline specification also confirm the positive link between bank risk and deposit rates. So, for example, banks with a high z-score are expected to pay lower deposit rates. Similarly, banks with high relative volumes of nonperforming loans offer higher deposit rates. We also find support for a positive relation between the checking account rate and the rate on federal funds purchased. This result is consistent with the substitutability of retail and wholesale funding, and it confirms the implications of Kiser's (2003) model.

And finally, the results of the estimation of the wholesale rate equation support the hypothesis that banks which pay high retail deposit rates also pay on average higher wholesale rates relative to their peers. That is, within a comprehensive empirical framework, we are able to confirm a positive relation between the cost of retail and wholesale funding. Bank risk enters these regressions with statistically insignificant coefficients, which suggests that the rates on federal funds are not significantly responding to bank risk. This result is consistent with the discussion on the shortcomings of market discipline mechanisms in the case of exposures with very short (overnight) maturity.

Next, we re-estimate the model using a sample of observations averaged at the bank level. That is, for each bank and quarter we now use only one observation and cannot account for the market-level variation. By doing so, we control for the possibility that banks reshuffle deposits across local markets. The results of these estimations are presented in Table 4.

Qualitatively, these results are very similar to the bank-market-level results presented in Table 3. However, the reduced number of observations is reflected in the lower efficiency of the estimations. Nevertheless, the key result concerning the positive relationship between retail deposit rates and bank risk is also confirmed (significantly) in this specification. The estimated coefficients suggest a higher magnitude of the effect of deposit rates on the z-score (relative to the bank-market-level estimation). The effect of the checking account rates on the *NPL* is estimated to be of no statistical significance.

And finally, we estimate the model on the sample of banks operating in only one local market (see Table 5). In this case, we are again able to qualitatively replicate the results from the bank-market-level estimation. The small sample size again results in relatively low efficiency of the estimations, but we still do find a positive statistically significant relation between retail deposit rates and bank risk. The economic significance of retail rate's effect on bank risk in this case is very high, especially when risk is measured by the nonperforming loans ratio.

In sum, we find a statistically and economically significant positive relation between the intensity of deposit market competition faced by a bank (measured by the retail deposit rate) and its risk level. Our empirical results, therefore, support the implications of a series of theoretical papers (e.g., Allen and Gale, 2000, Hellmann et al., 2000) that intense deposit market competition results in high bank risk.

5. Robustness checks

One potential concern with our sample is the length of the time period, which covers almost a decade. This decade was marked by substantial regulatory changes, as well as market innovations (such as the liberalization of the narrow banking concept, the liberalization of interstate branching, and the use of innovative loan securitization instruments), which might have changed the relation between retail and wholesale funding and bank risk. To address these concerns and test the robustness of the results, we split our sample period at the end of 2000, assuming that by that date the effect of most of these innovations was already present.

We then re-estimate the model for each of the two subperiods, 1997-2000 and 2001-2006. The results are presented in Table 6 and Table 7, respectively. The results for the earlier subperiod are mixed and statistically insignificant. The 2001-2006 subsample, however, shows with a very strong economic and statistical significance the positive relation between retail deposit rates and bank risk.

Another potential limitation of our approach is that we proxy the costs of wholesale funding by the rate on federal funds purchased. Federal funds are obviously at the shortest end of the maturity distribution of wholesale funds. To check the robustness, we re-estimate the model using the rate banks pay on subordinated debt as an alternative measure of the cost of wholesale liabilities. Because of its longer maturity, subordinated debt can be considered as a better substitute for retail deposits than federal funds. Nevertheless, subordinated debt has other drawbacks for our research framework, especially if we consider that subordinated debt issues might not be related to a shortage of retail funds but rather to the eligibility of subordinated debt as tier-2 capital. We impute the subordinated debt rate in analogy to the rate on fed funds purchased by the ratio of "interest on subordinated notes and debentures" (line riad4200) and the amount of outstanding "subordinated notes and debentures" (line rcfd3200) of the Call Report. Again, when estimating the wholesale rate equation, we account for the potential selection issue by estimating a Heckman model with instrumental variables[35]. The results of the estimation of this model specification are illustrated in Table 8. These results show that the positive link between retail rates, wholesale rates, and bank risk is robust to the choice of the wholesale rate measure.

[35] The results presented in Table 8 are based on the following censoring rule: the subordinated debt is accounted for if the share of subordinated debt in total assets is at least 1%. Alternative trigger points (0.5% and 2%) yield qualitatively the same results.

Table 6: Subperiod 1997-2000; all banks; bank-market level observations; the wholesale rate is measured by the rate on federal funds purchased

Risk measure	negative Z-score			NPL		
	Coefficient		Standard error	Coefficient		Standard error
Dependant variable: bank risk						
checking account rate	-10.357		8.344	0.006		0.005
rate on federal funds purchased	0.566		0.891	0.002	***	0.000
bank size	3.594		3.275	0.004		0.002
bank size^2	-0.123		0.099	0.000		0.000
capitalization	-86.108	***	16.240	0.035	***	0.008
loan growth	-0.222		0.464	0.000		0.001
loans_ta	4.651		6.713	0.005		0.006
income	0.004		0.006	0.000		0.000
income growth	-11.816		16.204	0.038	**	0.014
constant	-28.879		32.054	-0.056	**	0.024
Observations	529			2291		
R-squared	0.04			0.41		
Dependant variable: checking account rate						
bank risk	-0.063		0.070	-22.482		20.838
rate on federal funds purchased	0.059		0.118	0.019		0.060
bank size	0.224		0.450	-0.135		0.222
bank size^2	-0.009		0.014	0.001		0.007
capitalization	-4.218		3.956	-1.217		1.249
loan growth	-0.006		0.032	0.025		0.029
loans_ta	0.023		0.617	-1.885	***	0.535
market size	0.000		0.000	0.000	**	0.000
branch_deposit	-0.229		2.471	0.163		1.497
HHI	0.367		0.709	-0.164		0.303
constant	-1.379		4.808	3.885	**	1.775
Observations	529			2291		
R-squared	0.02			0.14		
Dependant variable: rate on federal funds purchased						
checking account rate	1.748	***	0.526	1.804	***	0.497
bank risk	-8.645		24.189	-31.123		44.782
bank size	1.734	***	0.401	1.889	***	0.476
bank size^2	-0.044	***	0.011	-0.048	***	0.013
capitalization	-5.027	**	1.656	-4.427	**	1.905
loan growth	-0.604	***	0.159	-0.605	***	0.154
loans_ta	2.999	***	0.571	3.248	***	0.706
effective fed funds rate	0.119	**	0.067	0.143	****	0.055
FHLB dummy	-0.246		0.190	-0.356	*	0.194
BHC dummy	0.879	*	0.486	1.007	*	0.524
constant	-16.851	***	4.067	-18.507	***	4.906
Observations	4620			4620		
Censored observations	179			179		
R-squared	-			-		

Note: Two-stage least squares IV estimations. Endogenous variables are: bank risk (measured by z-score, NPL), checking account rate and the rate on fed funds purchased. Only observations of single-market banks The fed funds rate equation is estimated using a Heckman procedure to control for potential selection bias. *, **, *** indicate significance at the 10%, 5% and 1% level, respectively.

Table 7: Subperiod 2001-2006; all banks; bank-market level observations; the wholesale rate is measured by the rate on federal funds purchased

Risk measure	negative Z-score			NPL		
	Coefficient		Standard error	Coefficient		Standard error
Dependant variable: bank risk						
checking account rate	1.951	***	0.515	0.011	**	0.005
rate on federal funds purchased	0.163	**	0.081	-0.003		0.002
bank size	-6.303	***	0.780	0.001		0.003
bank size^2	0.202	***	0.022	0.000		0.000
capitalization	-41.975	***	1.621	-0.041	***	0.011
loan growth	-1.463	***	0.192	0.000		0.001
loans_ta	2.111	***	0.536	0.018	***	0.004
income	-0.003	***	0.001	0.000	***	0.000
income growth	-13.413	***	2.010	-0.063	***	0.008
constant	34.298	***	6.920	-0.011		0.022
Observations	4186			4925		
R-squared	0.32			0.04		
Dependant variable: checking account rate						
bank risk	0.119	***	0.014	12.315	***	3.613
rate on federal funds purchased	0.107	***	0.008	0.324	***	0.016
bank size	0.415	***	0.124	0.066		0.094
bank size^2	-0.016	***	0.004	-0.004		0.003
capitalization	3.894	***	0.728	1.501	***	0.358
loan growth	0.232	***	0.045	0.121	***	0.046
loans_ta	-0.955	***	0.042	-0.876	***	0.056
market size	0.000	*	0.000	0.000		0.000
branch_deposit	5.379	***	0.920	0.801		0.705
HHI	-0.502	***	0.178	0.044		0.127
constant	-0.079		1.050	0.282		0.807
Observations	4186			4925		
R-squared	0.15			0.12		
Dependant variable: rate on federal funds purchased						
checking account rate	1.067	***	0.138	1.033	***	0.142
bank risk	0.034	**	0.015	24.093	**	11.258
bank size	0.118		0.083	0.042		0.104
bank size^2	-0.001		0.002	0.001		0.003
capitalization	-0.646		0.957	-3.375	***	0.529
loan growth	-0.242	***	0.083	-0.280	***	0.080
loans_ta	1.197	***	0.100	1.150	***	0.118
effective fed funds rate	0.261	***	0.016	0.253	***	0.018
FHLB dummy	-0.157		0.106	-0.024		0.119
BHC dummy	0.346		0.806	0.279		0.810
constant	-1.896		1.322	-1.676		1.400
Observations	9222			9222		
Censored observations	455			455		
R-squared	-			-		

Note: Two-stage least squares IV estimations. Endogenous variables are: bank risk (measured by z-score, NPL), checking account rate and the rate on fed funds purchased. Only observations of single-market banks The fed funds rate equation is estimated using a Heckman procedure to control for potential selection bias. *, **, *** indicate significance at the 10%, 5% and 1% level, respectively.

Table 8: All banks; bank-market level observations; the wholesale rate is measured by the subordinated debt rate

Risk measure	negative Z-score			NPL		
	Coefficient		Standard error	Coefficient		Standard error
Dependant variable: bank risk						
checking account rate	0.126		1.021	0.005	***	0.002
rate on subordinated debt	0.180		0.138	0.002	***	0.001
bank size	-17.055	***	1.486	0.002		0.003
bank size^2	0.473	***	0.045	0.000		0.000
capitalization	-50.817	***	2.622	0.011		0.009
loan growth	-1.256	***	0.239	0.000		0.001
loans_ta	-0.328		1.090	0.011	***	0.001
income	-0.003	***	0.001	0.000		0.000
income growth	-16.917	***	5.379	-0.014	***	0.004
constant	142.024	***	12.220	-0.034		0.028
Observations	3733			5715		
R-squared	0.33			0.38		
Dependant variable: checking account rate						
bank risk	0.144	***	0.018	-3.730		16.393
rate on subordinated debt	0.051	***	0.009	0.515	***	0.119
bank size	0.836	***	0.153	-1.295	***	0.433
bank size^2	-0.025	***	0.004	0.038	***	0.013
capitalization	5.535	***	0.990	4.992	***	1.707
loan growth	0.276	***	0.059	-0.036		0.138
loans_ta	-0.847	***	0.042	-0.356		0.229
market size	0.000	**	0.000	0.000		0.000
branch_deposit	4.347	***	1.188	-6.372	**	2.927
HHI	-0.375	**	0.171	-0.166		0.375
constant	-4.542	***	1.354	9.850	***	3.453
Observations	3733			5715		
R-squared	0.16			0.2		
Dependant variable: rate on subordinated debt						
checking account rate	2.892	***	0.506	2.916	***	0.637
bank risk	0.092	**	0.045	126.876	***	48.241
bank size	4.872	***	0.932	5.529	***	1.184
bank size^2	-0.119	***	0.023	-0.133	***	0.029
capitalization	-6.763	**	2.892	-16.810	***	2.270
loan growth	-1.471	***	0.267	-1.767	***	0.339
loans_ta	0.881	**	0.355	0.483		0.495
effective fed funds rate	0.047		0.048	-0.016		0.066
FHLB dummy	-2.767	***	0.532	-2.105	***	0.724
BHC dummy	-0.392	***	0.103	-0.428	**	0.213
constant	-44.055	***	9.575	-53.235	***	12.282
Observations	13842			13842		
Censored observations	5153			5153		
R-squared	-			-		

Note: Two-stage least squares IV estimations. Endogenous variables are: bank risk (measured by z-score, NPL), checking account rate and the subordinated debt rate. The sub debt rate equation is estimated using a Heckman procedure to control for potential selection bias. *, **, *** indicate significance at the 10%, 5% and 1% level, respectively.

Table 9: All banks; bank-market level observations; two-equation model without the wholesale rate

Risk measure	negative Z-score			NPL		
	Coefficient		Standard error	Coefficient		Standard error
Dependant variable: bank risk						
checking account rate	1.085	***	0.201	0.008	***	0.001
bank size	-4.229	***	0.739	0.009	***	0.001
bank size^2	0.136	***	0.021	0.000	***	0.000
capitalization	-44.434	***	1.268	-0.004		0.006
loan growth	-0.557	***	0.103	0.000		0.001
loans_ta	0.561	**	0.248	0.012	***	0.001
income	-0.003	***	0.001	0.000		0.000
income growth	-12.262	***	1.117	-0.005		0.005
constant	19.685	***	6.512	-0.085	***	0.013
Observations	4715			7216		
R-squared	0.31			0.02		
Dependant variable: checking account rate						
bank risk	0.172	***	0.018	118.582	***	11.189
bank size	-0.052		0.194	-0.963	***	0.177
bank size^2	-0.004		0.006	0.026	***	0.005
capitalization	5.779	***	0.864	-0.682		0.719
loan growth	0.095	***	0.028	-0.038		0.082
loans_ta	-0.968	***	0.034	-1.341	***	0.081
market size	0.000		0.000	0.000		0.000
branch_deposit	6.751	***	1.096	2.336	*	1.274
HHI	-0.405	**	0.189	-0.088		0.256
constant	5.336	***	1.550	9.309	***	1.452
Observations	4715			7216		
R-squared	0.18			0.26		

Note: Two-stage least squares IV estimations. Endogenous variables are: bank risk (measured by z-score, NPL), and checking account rate. Bank-market level variables are averaged at the bank level. *, **, *** indicate significance at the 10%, 5% and 1% level, respectively.

The statistical and economic significance of the wholesale rate and risk relation is in the case of subordinated debt rate even stronger than in the federal funds purchased rate[36], showing that the maturity of wholesale exposures is an important determinant of the relation between bank risk and the costs of wholesale funding.

And finally, in order to present results directly comparable to those of earlier studies that ignore wholesale funding, we re-estimate the model ignoring the impact of the costs of wholesale funding. In this case, we estimate only equation (1) and equation (2). The idea of this robustness check is to address the potential critique that the limitations of our measures of

[36] This positive link has already been shown by DeYoung et al. (1998), and Morgan and Stiroh (2001).

the costs of wholesale funding bias our results. The results of this model specification are presented in Table 9. They again show a very strong positive, economically and statistically significant relation between the retail deposit rates offered by a bank and its risk. That is, banks that have less deposit market power and thus offer higher deposit rates are riskier.

6. Conclusion

Despite the intense political and academic interest into the issue of the potential risk effects of bank competition, the literature has not yet reached a consensus on whether bank competition indeed has a positive effect on bank risk. In this paper we revisit the debate by estimating a system of equations which describe the relation between deposit market competition, the costs of wholesale funding, and bank risk. Although wholesale funding affects both the risk of a bank and its behavior in the deposit market, the wholesale market for funds has so far been ignored in the competition and risk literature. The main contribution of this study is, therefore, the integration of the market for wholesale bank funding into the analysis of the competition and risk nexus.

The results of our empirical estimation show a robust positive link between the intensity of deposit market competition faced by a bank and the risk of the bank. We interpret these results as evidence for the risk-increasing effects of deposit market competition and suggest that banks with less deposit market power are more likely to choose riskier strategies. However, our results reflect only potential costs of bank competition. The examination of the trade-off between the efficiency gains of a competitive versus oligopolistic banking sector and the higher risk of banks operating in competitive environment go beyond the scope of this study. This trade-off, which is essential for the formulation of regulatory policies, is still underexplored in the empirical banking literature and should be subject to further research.

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