Deposit Market Competition, Costs of Funding and Bank Risk

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Abstract: Although a wide body of theoretical research finds that intense deposit market competition increases the incentives of banks to undertake excess risk, the empirical literature on the topic has not reached a consensus. In this paper we revisit the topic by estimating a system of equations describing the relation between bank risk and the deposit market competitive position. Our model incorporates both the simultaneity of a bank's risk and a bank's deposit market competitive position and the substitutability of wholesale and retail sources of funds. The analysis is based on a large dataset which matches information about the deposit market participation (prices and market shares) of 589 banks in 164 US local deposit markets with balance sheet data of the banks and the characteristics of the local markets. Our results support the notion of a risk-enhancing effect of deposit market competition.

Key words: bank competition, bank risk, deposit rates, market discipline

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1. *Introduction*

The profound changes in the structure of banking markets, which followed banking market liberalization in the United States and Europe and the repeated instances of financial system distress propelled research in the nexus of bank competition and risk.

In a seminal paper Keeley (1990) posits that intense banking competition results in a reduced bank charter value and riskier bank strategies. More recently, Allen and Gale (2000) present a theoretical model consistent with Keeley's results showing that the optimal risk of failure increases with the number of competitors in the deposit market[1]. In the same line of argument, Hellmann et al (2000) argue that the removal of deposit rate ceilings deteriorates franchise value and encourages moral hazard.

Koskela and Stenbacka (2000) and Boyd and de Nicolo (2005), on the other hand, argue that if loan market competition is also included in the analysis, results may be reversed. Koskela and Stenbacka (2000) focus on loan market competition alone and show that by reducing the loan rates loan market competition might reduce the risk of bank portfolio. Following a similar approach Boyd and de Nicolo (2005) jointly analyze deposit and loan market competition and find that while the number of deposit market competitors is positively correlated with bank risk, the number of loan market competitors can negatively affect the risk of failure of bank assets. Note that these models exclusively focus on the loan rate reducing impact of intense loan market competition. They ignore an alternative loan market channel which works through the increased probability of lemon projects to get financed when the number of banks operating in the market is increasing (Broecker, 1990). This channel, again, generates risk increasing effects of bank competition. In sum, while theoretical research so far agrees that deposit market competition itself has a risk intensifying

[1] Similarly, theoretical models by Hellmann et al (2000), Repullo (2004) and Hauswald and Marquez (2006) point to a positive relation between bank competition and risk.

effect, results with regard to loan market competition are so far inconclusive. Moreover, to the extent that high deposit market competition is correlated with high loan market competition the overall effect of bank market competition on risk is ambiguous.

Empirical research on the topic has so far only produced limited and 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].

One potential source for the seemingly contradictory results is the fact that the distinction between deposit and loan market competition suggested by recent theories has still not been sufficiently applied in empirical work[3]. Note that the distinction between deposit and loan market competition is not only theoretically relevant. Park and Pennacchi (2008) give an empirically interesting example of market liberalization (the liberalization of interstate branching) which affects deposit and loan market competition in different directions. These authors show that the creation of multimarket banks after the interstate branching liberalization dampens deposit market competition but intensifies the competition in the loan market. Moreover, a few examples of regulations primarily affecting deposit market competition, such as the abolishment of deposit rate ceilings and most recently the

[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.

[3] To our knowledge, Jimenez et al. (2007) represents the first empirical study of the competition and risk nexus that explicitly distinguishes deposit from loan market competition. The authors of this study examine the risk effects of deposit and loan competition, measured by the deposit and loan market Lerner indices[3] of individual banks, in separate sets of regressions. The authors show that loan market competition significantly increases risk, whereas the effect of deposit market competition is statistically insignificant. This is a surprising result because the theoretical literature agrees on just the opposite: there is a consensus on the risk-enhancing role of deposit market competition, whereas loan market competition can generate ambiguous effects.

transformation of traditional investment banks into deposit taking institutions, illustrate the importance of differentiating between deposit and loan market competition.

Given the lack of consensus in the empirical literature, the purpose of this paper is to present a novel, comprehensive empirical analysis of the relation between deposit market competition and bank risk. Convincing empirical evidence on the issue is needed to determine policy recommendations, since wrong policy can lead either to inefficient banking industries and thus endanger the efficiency of financial intermediation and capital allocation, or to a very fragile banking system, which could potentially jeopardize payment systems and liquidity provision[4].

The focus of this paper on deposit market, rather than loan market, competition is motivated by several issues. First, the most recent financial turmoil showed that banks with a weak deposit market position were more vulnerable. Here, we empirically analyse this anecdotal argument. Second, the theoretical research yields clear results for the deposit market, whereas the effect of loan market competition is ambiguous. Therefore, in this paper we confront a theoretically less controversial hypothesis with the data. Moreover, deposit markets are more local than loan markets, resulting in more precise market definitions and competition measures for deposits relative to loans. And finally, deposit products are characterized by a higher degree of homogeneity relative to loans[5], which again simplifies the characterization of the intensity of bank competition by reducing the number of required control variables. Having said this, we also present specifications of the empirical model including loan market competition proxies to avoid a potential bias in the estimations from omitting the intensity of loan market competition.

[4] Allen and Gale (2004) show that financial system instability might be efficient and is therefore not necessarily undesirable. Policymakers, however, are often reluctant to face the short-term political cost of dealing with financial instability (as the experience from most recent financial crises clearly illustrates).

[5] A precise analysis of loan market competition would require information on key borrowers' characteristics which is publicly not available.

In our research framework we depart from the existing literature in several dimensions. First, we explicitly include the market for wholesale funds in the analysis of competition and risk. We do this for two reasons: first, when including the cost of wholesale liabilities we extend the scope of the analysis to the impact of bank funding costs in general (rather than retail deposits alone) on bank risk behaviour. This extension substantially broadens the validity of our findings given the growing relevance of bank wholesale liabilities[6]. Second, the availability and price of wholesale funding, such as federal funds, subordinated debt, or bank corporate bonds[7], affects the deposit market behaviour of individual banks. Although the link between deposit and wholesale funding has been studied in recent literature on the industrial organization of banking (Kiser, 2003; Park and Pennacchi, 2008), its implication for the competition and risk relationship has so far been ignored. Next, as argued by the market discipline literature wholesale funds are particularly relevant for the determination of a bank's risk preference, because they are not insured. A number of empirical studies (Furfine, 2001; Maechler and McDill, 2006, King, 2007; Ashcraft, 2008; Dinger and von Hagen, 2008) have shown that the availability and costs of wholesale funding are strongly related to bank risk. Moreover, Billet et al (1998) argue that risky banks tend to shift their liabilities from uninsured to insured funds. That is, a bank's liability structure (wholesale versus retail deposits) depends on the risk of the bank. By including both the retail deposit rate and the cost of wholesale funding in our model, we study the effect of the costs of insured and uninsured bank liabilities on bank risk behaviour within a uniform framework[8]. This approach allows us to integrate the arguments of the market discipline literature in the analysis of the competition-risk relationship.

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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%.

[7] Park and Pennacchi (2008) define wholesale liabilities as large liabilities that have account balances above $100,000 and that are not fully insured by the FDIC.

[8] Note that most of the market discipline literature has so far concentrated on uninsured bank liabilities because of their stronger risk sensitivity (see Maechler and McDill, 2006 for a comprehensive review).

Another innovation of our study is that we concentrate on the intensity of deposit market competition faced by each individual bank, whereas most of the existing empirical studies have employed market-level competition proxies such as concentration ratios, Herfindahl indices, or Panzar-Rose H-statistics[9]. Such average competition proxies are not only unable to disentangle deposit from loan market competition; they also assume that all banks operating in the same local market face the same intensity of competition. This assumption is, however, too stark, since depending on various features banks might exert different degrees of market power. In a simplified framework a bank's market power can be proxied by the local market share of the bank. However, as noted by Kiser (2003) market power will be only noisily measured by the market share since even small banks with a negligible market share can exert some market power if depositors' switching costs are high. To this end, we choose to measure the intensity of deposit market competition faced by a bank by the deposit rate offered by the bank in each of the local deposit markets[10,11]. The choice of deposit rates as competition measure reflects our focus on deposit rather than loan market competition.

From an industrial organization perspective, prices and price mark-ups are straightforward competition measures. However, when deposit rates or deposit mark-downs relative to wholesale funding costs are used to determine whether competition increases risk, the problem of simultaneity arises: riskier banks might be forced to offer higher deposit rates[12].

[9] 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, resp. the loan market Lerner index of the bank. 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.

[10] To our knowledge, Hutchison and Pennacchi (1996) are the first to use deposit rates offered by a bank relative to a wholesale rate (the T-bill rate) as a proxy for the monopoly rent extracted by the bank in the deposit market. Similarly, the approach of Jimenez et al. (2007) of measuring deposit market competition by the deposit market Lerner index is based on the relation between deposit rates and a wholesale (the money market) rate.

[11] In the robustness checks section we present results based on an alternative bank-level measure of the intensity of deposit market competition suggested by Goyal (2005), namely the ratio of demand to total deposits.

[12] More generally, most measures of the competitive position on the individual bank level can be argued to be endogenous with respect to bank risk. Keeley (1990), for example, recognizes the endogeneity of the Tobin's q-

Note that this is true even when deposits are insured, because depositors may still require a risk premium to compensate them for the potential switching costs should the bank fail. We deal with the simultaneity by explicitly identifying a system of simultaneous equations. This approach represents a substantial contribution of our model over the reduced-form approaches that have widely been applied in the analysis of the competition–risk relationship[13].

The results of our empirical analysis point to a robust, positive, and statistically and economically significant relation between the deposit rates offered by a bank and its asset portfolio and default risk. That is, banks with less deposit market power pursue riskier strategies. These results support the implications of the charter value paradigm. Moreover, we show that they are robust to including the wholesale market in the analysis. These results are consistent with the results of a range of earlier theoretical and empirical studies on market discipline and show a positive relation between the cost of funding and bank risk.

The rest of the paper is organized as follows. Section 2 presents a short overview of the underlying theoretical and empirical arguments of the relation between retail and wholesale deposits and bank risk and states the main hypotheses. Section 3 presents the data. Section 4 illustrates the econometrical model and our identification strategy. Section 5 reveals the results of the empirical estimation, and Section 6 concludes.

2. Deposit market competition, markets for wholesale funds, and bank risk

Following the theoretical model by Allen and Gale's (2000) the main hypothesis of this study is that deposit market competition is positively related to bank risk. In the framework of this

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ratios. Schaeck and Cihak (2008) are also concerned about the endogeneity of the Boone indicator with respect to bank risk. With regard to deposit market competition endogeneity is present because the risk of the bank offering a deposit product affects the whole range of measures of a bank's deposit market conduct (e.g., prices and market shares).

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

theoretical model intense bank competition results in high deposit rates which in turn shift upwards the optimal risk level chosen by a bank. Following this argument we focus on the impact of retail deposit rates (as proxy for deposit market competition) on bank risk.

Modern banks, however, have alternative sources of funding other than retail deposits. As already mentioned, retail funds now represent only around 50% of bank liabilities. Therefore, if we focus on the costs of retail deposits alone in a study of bank risk we will ignore a significant share of alternative liabilities. That might give rise to a substantial omitted variable bias, especially if the risk shifting mechanism works through the interest rate banks pay on their liabilities (as suggested by Allen and Gale's, 2000 model). To this end we include the cost of alternative wholesale funds as an additional explanatory variable.

A simple reduced-form model of risk as a function of deposit and wholesale rates could, however, produce biased results since both retail deposit rates and the rates banks pay on wholesale liabilities might be endogenous with respect to risk. In our identification scheme we not only focus on the endogeneity of wholesale and retail rates but also account for the relationship between retail and wholesale funding suggested by Kiser (2003) and Park and Pennacchi (2008). To control for these interactions we employ a zero restriction identification strategy based on estimating separate equations for bank risk, retail deposit rates and wholesale rates using a set of instrumental variables for each of the three endogenous variables.

Finding, as we do below, that high retail deposit rates correspond to higher risk preferences can, on the one hand, be interpreted as support for the charter-value hypothesis (if banks expect high returns from their deposit market participation, they will not risk losing their charter by undertaking excessively risky projects). On the other hand, consistent with Allen and Gale's model, the results can imply that when banks have to pay a high rate on their liabilities, their risk preferences are shifted upwards[14]. Note that this is true both for retail and for wholesale liabilities.

3. *The econometric model*

The idea of our empirical model is to estimate the relationship between bank risk and deposit market competition taking into account the substitutability between retail and wholesale funds. Reflecting the arguments presented in Section 2, the model starts with a main equation describing the impact of deposit and wholesale rates on bank risk:

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

where *r* denotes the risk of the bank, *d* the retail deposit rates and *w* the wholesale rate. The subscripts *i*, *j*, and *t* refer to the bank, the local market (MSA), and the time period, respectively. Accounting for the simultaneity of risk and retail and wholesale rates we identify the model using a zero restriction identification strategy[15]. We explicitly model the reverse causality by the following equations:

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

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

Equation (2) models the dependence of deposit rates on bank risk and the costs of wholesale funding. Its formulation is based on models presented by Kiser (2003) and Park and Pennacchi (2008). In these models, loans are seen 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 wholesale

[14] This result is also consistent with the implications of a more general model of the risk effects of the costs of funding for firms with limited liability (see Freixas and Rochet, 1997).
[15] 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 will imply that we might observe the same retail rate in two consequent quarters.

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[16]. 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 are important determinants of retail deposit rates[17]. In the formulation of the empirical model we use the interest rate on wholesale liabilities as a proxy for the availability and the costs of wholesale funds[18].

Equation (3) describes the risk sensitivity of the wholesale funding rate[19]. 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 borrowing. Moreover, Flannery and Sorescu (1996), DeYoung et al. (1998), and Morgan and Stiroh (2001) find that riskier banks pay higher interest on subordinated debt[20].

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[16] In order to relate our results to Park and Pennacchi's (2008) model we explicitly study the impact of multimarket mergers on bank wholesale and retail rates and risk in a subsection of Section 4.

[17] 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.

[18] In the subsection on the estimation technique (3.5) we discuss the effects and treatment of the sample selection issue related to the rates on wholesale liabilities.

[19] 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.

[20] 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 rate, and wholesale rates

Existing empirical studies have so far employed different risk measures in their analysis. Boyd et al. (2006) and Schaeck and Cihak (2008), for example, concentrate on the risk of the bank measured by the z-score. These authors choose this risk measure because it is closely related to the probability of default. They show 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 when measured by this proxy. 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.

In order to deliver results comparable to those earlier studies, we present alternative regression specifications using the z-score and the nonperforming loans ratio. Following Boyd et al. (2006), we compute the z-score as the ratio between the sum of a bank's average return on assets (ROA) and capitalization (E/A = equity/total assets) and the standard deviation of the return on assets[21]:

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

The z-score, therefore, presents information on how many standard deviations of the return on assets are needed to drive the bank into default. Banks with a low z-score are more likely to default. That is, the z-score is decreasing with bank risk. To alleviate 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.

[21] Computed by using rolling windows of 8 quarters.

We followed Ashcraft in constructing our ratio of a nonperforming loans risk measure and use the ratio with a four-quarter lead[22]. This differs from Jimenez et al. (2007), who use the current ratio of nonperforming loans. 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[23].

When we turn to measuring deposit market competition, we adopt the bank's retail deposit rates as a proxy for its deposit market competitive position for our baseline specification. Note that the fact that we observe bank retail rates in different local markets (Metropolitan Statistical Areas – MSAs) allows us to account for the intensity of local deposit market competition and identify the deposit rate equation using the variation of local market characteristics across the MSAs. We also look at the share of demand deposits in the total deposits volume as a deposit market competition proxy (Goyal, 2005) as a robustness check. From the variety of deposit rates reported by *Bankrate Monitor* (checking accounts, money market deposit accounts, and certificates of deposits with a maturity of three months to up to five years), we choose the checking account rates as the most suitable for our exercise[24]. 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 rates (Hannan and Prager, 1998, Craig and Dinger, 2008), whereas rates on certificates of deposits do not significantly react to such changes.

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[22] 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.

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

[24] 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 in the case when the checking account rate is employed as retail deposit rate measure, although statistical significance is sometimes lower. Results are available from the authors upon request.

And finally, in our baseline specification, we use the interest rate on federal funds purchased as a proxy for the costs of the wholesale funding. Purchased federal funds are liabilities with very short maturity and thus not perfect substitutes for retail deposits. The rate a bank pays on purchased 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 purchased federal funds over these alternative wholesale liabilities for our framework is that we have fed funds observations for most banks in our sample[25]. Moreover, comparison across banks is further alleviated by the fact that the fed funds market has a standardized "product"[26]. We follow King (2008) and approximate the interest rate on fed funds purchased 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)[27]. In the robustness section we alternatively estimate the model using the subordinated debt rate as a wholesale rate proxy.

3.2. Identification and Instruments

Our identification follows a "zero restriction" strategy. Each of the endogenous variables are instrumented by a suitable set of instruments. Econometric theory suggests that a valid instrument should be uncorrelated with the error term but strongly correlated with the

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[25] 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).

[26] 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.

[27] As King (2008) notes, this approximation includes the cost of securities sold under agreements to repurchase, which is 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.

instrumented endogenous variable. Following, we instrument the endogenous variables in our model (retail deposit rate, rate on wholesale funding, and bank risk) by variables which have been shown by earlier research to be strongly correlated with the respective endogenous variable, but for which we can argue exogeneity with respect to the error terms, especially for those necessary equations in the system where they are not included as a right-hand variable.

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[28]. Here we borrow from the literature which has found that ratio of *branches to deposits*, the *share of the branches* of the bank, 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 this market. The *share of the branches* is computed as the proportion of the branches of the bank to the total number of bank branches in the local market. The market size is the log of the population of the respective market. The underlying assumptions when using these variables as deposit rate instruments is that banks with more branches (better geographical proximity to retail customers) can attract deposits at lower rates. On the other hand, neither the wholesale rate nor the risk preference of the bank directly depends on the number of branches.

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 do not have an impact on deposit rates and bank risk. Our major instrument for the wholesale fund is the average

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

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 fed funds target rate set by the Fed. We also use a dummy variable, which takes the 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 BHCs, but risk choice and deposit rate do not necessarily depend on BHC membership. Note that both the average fed funds rate and the BHC dummy are weak instruments because in each time period there's no (or little as in the BHC dummy case) variation across banks. 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.

A change in the effective fed funds rate is probably also related to the amount of risk taken on by the bank (see Jimenez et al, 2008), as well as the deposit rate it can charge[29]. 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.

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, 2008) are negatively

[29] 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.

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 the wholesale and deposit rates. Following this line of argument, we instrument the risk of a bank by the 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*).

In the case of all instruments, the Stock-and-Watson-rule-of-thumb measure[30] 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 dependant variables (Hannan and Hanwick, 1998, Furfine, 2001, Boyd et al, 2006). To this end, 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*. 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.

[30] 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.

3.4. Data and samples

The analysis is based on a large dataset combining three main data sources. Deposit rates are drawn from BankRate Monitor, Inc. The data encompass deposit rates offered by 589 U.S. banks in 164 local markets (metropolitan statistical areas) for the period starting on September 19, 1997, and ending on July 21, 2006.

We match the deposit rate data with a broad range of bank characteristics reported in the *Quarterly Reports of Conditions and Income* (*Call Reports*). *BankRate Monitor* deposit rate data have weekly frequency. To match the quarterly frequency of the *Call Reports,* we only use the deposit rates reported on the last week of each quarter. We also include control variables for the local markets. The source of the local-market controls is the *Summary of Deposits,* and these data are available only at an annual frequency.

After merging our data we have a multidimensional 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.).

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. In this step we deviate from a large body of the literature (e.g. Radecki, 1998; Park and Pennacchi, 2008) which assumes that multimarket banks charge uniform rates across local markets. We deviate from this assumption because our sample exhibits a high degree of cross-market variation of multimarket banks' pricing. The data presented in Table 1 illustrates that the variation in the deposit rates set by a multimarket bank in the different MSAs is equal to about one third of the variation of all deposits rates offered by all banks in a MSA. It is our assumption that the cross-market variation in the pricing of multimarket banks is suggestive 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.

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 local deposit market intensity and dramatically reduce the number of observations, which in turn reduces the efficiency of the estimation. 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 intensity of deposit market competition might be the one that matters for bank risk.

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	0.001	0.003	0.000	0.122
branch_deposit	16039	0.022	0.022	0.000	1.050
share of branches in the MSA	16039	0.116	0.066	0.001	0.390
BHCdummy	18715	0.947	0.225	0.000	1.000
average income in the MSAs	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 > 0.05% of total assets and outstanding subordinated debt >0.05% of total assets are reposted in the table.

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.

Table 2 illustrates descriptive statistics of the variables included in our estimations. It shows that the checking account rate varies between 0 and 3.8%. It is important to note that some of the variation is due to the time series dimension of our data. Our sample covers 1997 to 2006, which encompasses a period longer than a full interest rate cycle. The Z-score varies between 2 and 492. The nonperforming loan ratios vary between zero and almost 12%.

3.5. Estimation technique

We estimate each of the risk and deposit rate equations using a two-stage instrumental-variable estimating technique with standard errors clustered for each bank. The estimation of the wholesale rate equation is more challenging because of 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 restrain 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 0.5% 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].

4. Estimation results

We first 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 of this specification are illustrated in Table 3, which contains a column for each of the risk measures: negative z-score and the (four quarter lead of the) ratio of nonperforming loans to total loans (NPL). The results of this estimation show a statistically significant positive link between deposit rates and bank risk. In particular, a rise in deposit rates is associated with a raise in the negative z-score (which implies a lower distance to default and higher risk) and higher relative volumes of nonperforming loans. These results are consistent with the theoretical prediction of the risk-enhancing impact of

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

[32] As robustness check we have reestimated the model using both a fix volume of the federal funds purchased as a trigger point (1 Mio. USD, as in King, 2008) and alternative trigger values of the fed funds purchased share in total assets (0.01% and 1%). Results do not change qualitatively.

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

deposit market competition and are robust to the choice of the risk measure. Note that the estimated coefficients suggest a relatively large economic significance of the results. So, a 100 basis points relative difference in the checking account rate is associated with a 28 points drop in the Z-score and 9 basis points higher non-performing loans ratio.

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. It is interesting to note that in these regression specifications we find a positive relation between the checking account rate and the rate on federal funds purchased. This result is consistent with the substitutability between retail and wholesale funding and confirms the implications of Kiser's (2003) model.

And finally, the results of the estimation of the wholesale rate equation suggest again that the rate on federal funds purchased is positively related to the retail deposit rate. This relation is, however, statistically significant only when the z-score is used as a risk proxy. The results also confirm a positive relation between bank risk and the cost of wholesale funding. This result is robust to the choice of the risk measure and is consistent with Furfine (2001), who also uncovers a positive relation between a bank risk and the rate paid on wholesale liabilities.

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.

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	28.92	***	5.78	0.09	**	0.05
rate on federal funds purchased	833.97	***	185.65	6.51	*	3.52
bank size	-5.76	***	1.98	-0.03	*	0.02
capitalization	-419.83	***	54.73	-1.13	*	0.68
loan growth	2.98		2.61	0.09	*	0.05
income	0.02		0.05	0.00	**	0.00
income growth	-200.82		56.62	-0.78		0.75
constant	32.09		36.12	0.69	**	0.36
Observations	8162			13619		
R-squared	0.05			0.04		
Dependant variable: checking account rate						
bank risk	0.02	***	0.00	2.45	**	1.14
rate on federal funds purchased	15.63	***	6.86	38.34	***	13.92
bank size	0.08	***	0.03	-0.09		0.08
capitalization	3.25	***	1.32	-0.87	**	2.51
loan growth	-0.11	*	0.06	-0.48	***	0.20
branch_deposit	10.66	***	2.66	5.27		6.89
branches share	1.46	*	0.83	9.04	***	2.65
market size	0.00		0.00	0.00		0.00
constant	0.08		0.43	0.46		1.40
Observations	8162			10220		
R-squared	0.06			0.06		
Dependant variable: rate on federal funds purchased						
checking account rate	0.07	***	0.02	-0.05		0.20
bank risk	-0.001	**	0.00	1.35	**	0.55
bank size	0.01	***	0.00	-0.02		0.02
capitalization	0.04	*	0.02	-0.65	**	0.27
loan growth	0.00		0.00	0.00		0.01
effective fed funds rate	-0.01	***	0.00	-0.02		0.02
BHC dummy	0.05	***	0.01	0.05		0.10
FHLB dummy	-0.02	**	0.01	-0.02	**	-0.01
constant	-0.15	***	0.04	0.49		0.43
Observations	13619			13619		
Censored observations	795			795		
R-squared	0.030			0.03		

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	24.74	***	9.42	0.38	**	0.20
rate on federal funds purchased	81.04		93.37	-1.10		1.56
bank size	-0.20		3.31	-0.03		0.09
capitalization	-93.87		89.44	-0.33		2.25
loan growth	6.70	*	3.71	0.01		0.05
income	0.16		0.18	-0.00		0.00
income growth	-392.73	*	207.40	0.63		3.01
constant	-83.57		56.99	0.57		1.43
Observations	1558			2159		
R-squared	0.07			0.06		
Dependant variable: checking account rate						
bank risk	0.02		0.02	1.54	**	0.76
rate on federal funds purchased	4.65	**	2.14	2.16		3.28
bank size	-0.15		0.19	-0.06		0.13
capitalization	0.47		4.24	-0.12		4.01
loan growth	-0.06		0.15	0.00		0.09
branch_deposit	20.50		16.31	4.34		9.50
branches share	2.99		3.14	4.94	*	2.88
market size	0.00		0.00	0.00		0.00
constant	3.65		2.73	0.48		2.47
Observations	1558			2159		
R-squared	0.03			0.04		
Dependant variable: rate on federal funds purchased						
checking account rate	0.007		0.027	-0.013		0.014
bank risk	0.000		0.000	0.063		0.313
bank size	0.000	*	0.004	-0.003		0.002
capitalization	-0.025		0.011	-0.020		0.011
loan growth	0.002		0.002	0.002		0.002
effective fed funds rate	0.801	**	0.406	0.735	***	0.263
BHC dummy	-0.006		0.015	-0.015		0.012
FHLB dummy	-0.021	**	0.011	-0.019	**	-0.010
constant	0.013		0.076	0.066		0.038
Observations	3342			3342		
Censored observations	648			648		
R-squared	0.030			0.03		

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.

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 similar magnitude of the effect of deposit rates on the Z-score. The effect of the checking account rates on the *NPL* is estimated to be of a larger magnitude in this specification.

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 replicate the results for the full sample of banks. These results are important because they confirm the existence of a positive relationship between deposit rates and bank risk for a sample of banks for which we expect the strongest geographical link between deposit market characteristics and bank risk. Again, the small sample size results in relatively low efficiency of the estimations.

In sum, we find a statistically and economically significant, and 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 conclusion of a series of theoretical papers (e.g., Allen and Gale, 2000, and Boyd and de Nicolo, 2005) that intense deposit market competition results in high bank risk. Moreover, within a more comprehensive framework, our empirical model is able to replicate the results of earlier studies showing that the costs of wholesale funding depend on bank risk (DeYoung et al, 1998, Morgan and Stiroh, 2001, and Furfine, 2001) and a positive relation between the cost of retail and wholesale funding (Kiser, 2003).

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	50.06		154.71	0.79	**	0.33
rate on federal funds purchased	44.74		12.25	9.69		13.20
bank size	-4.09		35.19	0.07		0.14
capitalization	-815.33		2308.43	1.99		3.36
loan growth	-6.22		21.82	-0.60		0.82
income	0.05		0.33	0.00		0.00
income growth	-192.06		422.99	-8.08		6.73
constant	31.73		603.26	-1.30		2.15
Observations	375			518		
R-squared	0.04			0.05		
Dependant variable: checking account rate						
bank risk	0.06	***	0.01	1.71	*	1.01
rate on federal funds purchased	77.74	***	29.62	5.47		15.56
bank size	-0.11		0.22	-0.25		0.35
capitalization	-14.30	**	6.63	-4.19		4.64
loan growth	-0.12		0.12	-0.28		1.02
branch_deposit	6.15		18.78	-72.00		61.11
branches share	-0.44		0.52	3.10		6.35
market size	0.00		0.00	0.00		0.00
constant	1.93		3.42	5.42		5.32
Observations	375			518		
R-squared	0.03			0.06		
Dependant variable: rate on federal funds purchased						
checking account rate	0.04		0.06	0.93		0.87
bank risk	0.00		0.00	3.30		5.84
bank size	0.00		0.01	0.10		0.07
capitalization	0.01		0.04	0.18		0.40
loan growth	0.00		0.00	-0.04	**	0.01
effective fed funds rate	0.52	*	0.29	0.54		0.30
BHC dummy	0.02		0.03	0.50		0.45
FHLB dummy	-0.01		0.01	-0.02	*	0.01
constant	-0.07		0.15	-2.03		1.91
Observations	823			823		
Censored observations	157			157		
R-squared	0.04			0.04		

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.

5. *Robustness checks*

In this section we describe a series of alternative estimations performed to confirm the robustness of the results.

To start with, we include a proxy for loan market competition to control for the impact of a bank's loan market competitive position on bank risk. We control for the intensity of loan market competition by including 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[34]. The idea is that if a bank has a substantial market power in the loan market it will have a higher share of loans (which on average generate higher returns than alternative assets) in its portfolio[35]. Since the bank can securitize and sell the loans after origination, we add the amount of securitized loans to on-balance sheet loans. Note that a bank's loan origination might also affect its deposit rates and the costs of wholesale funding. So, we include the *loans to total assets* as a control variable in all three equations of the model. The results of this model specification are illustrated in Table 6. The *loans to total assets* variable enters the regressions with statistically insignificant coefficients. The rest of the variables of interest enter the regressions with coefficient very similar to their coefficients in the baseline model. In particular, checking account rates are positively significantly related to bank risk as measured by both the negative Z-score and the *NPL*.

As another robustness check we introduce 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 borrowed. Nevertheless, subordinated debt has other drawbacks for our research framework,

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[34] 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.

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

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. When measuring the subordinated debt rate, we follow Kiser (2003) and approximate the interest rate on subordinated debt 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[36]. The results of the estimation of this model specification are illustrated in Table 7.

In this case, we are again able to document a positive relation between the retail rates offered by a bank and its risk. Furthermore, we confirm the positive relation between the subordinated debt rate and the risk of the bank (as already shown by DeYoung et al., 1998, and Morgan and Stiroh, 2001) and a positive link between a bank's subordinated debt rate and retail deposit rates (as shown by Kiser, 2003).

Next we re-estimate our model using the share of demand deposits to total deposits as a proxy for a bank's competitive position in the deposit market. Here, we follow Goyal (2005), who argues that if banks have a monopoly power in the deposit market, this will be reflected in a high share of demand deposits. Goyal's argument is based on the intuition that the ability of a bank to issue deposits at below-market rates is an important component of a bank's charter value (Keeley, 1990). Since demand deposits bear low (or no interest), a high share of demand deposits will indicate high market power[37]. Again, the advantage of this charter-value measure over alternative market-power measures (such as Tobin's q, for example) is that it is especially focused on deposit market participation.

[36] The results presented in Table 7 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 0.5%. Alternative trigger points (0.01% and 1%) yield qualitatively the same results.

[37] This argument obviously omits the high non-interest costs a bank has to endure in the maintenance of transactional accounts.

Table 6: All banks; bank-market level observations; loans to total assets included as a loan market competition proxy

Risk measure	negative Z-score			NPL		
	Coefficient		Standard error	Coefficient		Standard error
Dependant variable: bank risk						
checking account rate	28.15	***	5.81	0.07	**	0.05
rate on federal funds purchased	827.81	***	184.44	6.37	*	3.53
bank size	-5.64	***	1.98	-0.03	*	0.02
capitalization	-417.83	***	54.62	-1.07	*	0.68
loan growth	-2.99		2.60	-0.09		0.05
loans/total assets	36.71		33.96	57.68	*	34.27
income	0.02		0.05	0.00	*	0.00
income growth	-201.70	***	56.52	-0.77		0.75
constant	29.43		36.13	0.65	*	0.36
Observations	8162			13619		
R-squared	0.06			0.04		
Dependant variable: checking account rate						
bank risk	0.02	***	0.00	2.14	**	1.12
rate on federal funds purchased	15.18	**	6.79	39.85	***	13.19
bank size	0.08	**	0.03	-0.16	**	0.08
capitalization	3.44	***	1.32	-1.39		2.46
loan growth	-0.10	*	0.06	-0.50	**	0.19
loans/total assets	0.65		0.52	-0.26		1.18
branch_deposit	10.81	***	2.68	5.63		73.15
branches share	1.55	*	0.85	10.76	***	3.05
market size	0.00		0.00	0.00		0.00
constant	0.00		0.44	1.51		1.40
Observations	8162			10220		
R-squared	0.07			0.06		
Dependant variable: rate on federal funds purchased						
checking account rate	0.06	**	0.03	-0.04		0.18
bank risk	-0.01	**	0.00	1.35	**	0.55
bank size	0.01	***	0.00	-0.04		0.03
capitalization	0.04	*	0.02	-0.45	*	0.24
loan growth	0.00		0.00	0.00		0.01
loans/total assets	0.00		0.00	0.00		0.00
effective fed funds rate	-0.01	***	0.00	-0.02		0.02
BHC dummy	0.04	***	0.01	0.05		0.10
FHLB dummy	-0.02	**	0.01	-0.02	**	-0.01
constant	-0.18	***	0.06	0.38		0.33
Observations	13619			13619		
Censored observations	795			795		
R-squared	0.03			0.03		

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 7: 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	64.03	***	6.19	0.17	***	0.01
rate on subordinated debt	18.81	*	10.45	-2.95		2.97
bank size	-7.51	***	1.92	0.03	***	0.01
capitalization	-498.17	***	53.87	1.11	***	0.11
loan growth	9.39		6.17	0.00		0.02
income	-0.03		0.05	0.00		0.00
income growth	-236.39	***	112.18	-0.27		0.23
constant	40.53		43.35	-0.68	***	0.08
Observations	5212			7139		
R-squared	0.11			0.05		
Dependant variable: checking account rate						
bank risk	0.02	***	0.00	5.20	***	0.36
rate on subordinated debt	6.64		6.52	33.29	***	4.61
bank size	0.14	***	0.03	-0.21	***	0.02
capitalization	6.37	***	1.03	-5.68	***	0.69
loan growth	-0.04		0.06	-0.11	***	0.04
branch_deposit	-56.95	**	27.98	55.60	***	17.97
branches share	0.88	*	0.53	-0.30		0.48
market size	0.00		0.00	-0.00	***	0.00
constant	-1.44	***	0.53	3.84	***	0.37
Observations	5212			7139		
R-squared	0.06			0.07		
Dependant variable: rate on subordinated debt						
checking account rate	0.03		0.03	0.02		0.02
bank risk	0.01	**	0.00	1.55	**	0.69
bank size	0.00		0.00	0.00		0.00
capitalization	0.00		0.04	-0.02		0.04
loan growth	0.00		0.00	0.00		0.00
effective fed funds rate	0.00		0.00	0.00		0.00
BHC dummy	-0.01		0.01	-0.01		0.01
FHLB dummy	0.01		0.01	0.02		0.01
constant	-0.05		0.08	-0.05		0.08
Observations	13619			13619		
Censored observations	1245			1245		
R-squared	0.04			0.05		

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 8: All banks; bank-market level observations; the wholesale rate is measured by the on federal funds purchased, deposit market competition is proxied by the share of demand deposits in total deposits

Risk measure	negative Z-score			NPL		
	Coefficient		Standard error	Coefficient		Standard error
Dependant variable: bank risk						
demand deposits/total deposits	-19.21	*	11.41	-13.38	**	6.42
rate on federal funds purchased	316.51		332.63	2.79		3.07
bank size	-35.44		28.85	-0.30		0.22
capitalization	-725.51	**	318.02	-15.83	***	5.20
loan growth	-1.62		10.05	-0.08		0.11
income	0.49		0.80	0.00		0.00
income growth	-901.16	**	407.46	-0.06		4.16
constant	850.21		659.78	7.53		5.84
Observations	1558			2159		
R-squared	0.07			0.06		
Dependant variable: demand deposits/total deposits						
bank risk	0.00		0.00	0.07		0.09
rate on federal funds purchased	3.78		2.52	1.49		1.41
bank size	-0.04		0.03	0.00		0.03
capitalization	-1.36		0.43	-0.70		0.42
loan growth	-0.01		0.01	-0.10		0.09
branch_deposit	-0.29		2.11	-4.72		5.54
branches share	0.64		0.68	0.52		0.58
market size	0.00		0.00	0.00		0.00
constant	0.78		0.37	0.27		0.48
Observations	1558			2159		
R-squared	0.03			0.05		
Dependant variable: rate on federal funds purchased						
demand deposits/total deposits	-0.05		0.06	0.01		0.06
bank risk	0.00		0.00	0.05		0.55
bank size	0.00	*	0.00	0.00		0.00
capitalization	-0.03	*	0.02	-0.02		0.02
loan growth	0.00		0.00	0.00		0.00
effective fed funds rate	0.29	***	0.05	0.23	***	0.09
BHC dummy	-0.01		0.01	-0.01		0.01
FHLB dummy	-0.02	*	0.01	-0.02	*	-0.01
constant	0.04		0.02	0.04		0.02
Observations	3342			3342		
Censored observations	648			648		
R-squared	0.04			0.04		

Note: Two-stage least squares IV estimations. Endogenous variables are: bank risk (measured by z-score, NPL), demand deposits to total deposits 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 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	33.87	***	4.88	0.10	**	0.06
bank size	-4.71	***	1.28	-0.04	**	0.02
capitalization	-323.35	***	43.94	-0.81		0.61
loan growth	1.15		2.14	0.00		0.02
income	0.02		0.04	0.00	*	0.00
income growth	-92.05	**	43.34	-0.07		0.61
constant	8.03		23.94	0.77	**	0.32
Observations	6847			9552		
R-squared	0.05			0.04		
Dependant variable: checking account rate						
bank risk	0.02	***	0.00	2.88	***	0.92
bank size	0.08	***	0.02	-0.28	***	0.10
capitalization	3.01	***	0.82	1.96		2.19
loan growth	-0.06		0.05	0.04		0.06
branch_deposit	5.94	***	1.76	-5.06		8.60
branches share	-0.36		0.43	3.08		2.24
market size	-0.01		0.00	-0.01	**	0.00
constant	0.55		0.28	4.99	***	1.85
Observations	6847			9552		
R-squared	0.05			0.08		

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.

Note that the share of demand deposits to total deposits as a proxy of a bank's competitive position in the deposit market is also potentially endogenous with respect to risk. This is the case because demand deposits represent transactional accounts with relatively high switching costs.

Therefore, if depositors perceive that a bank's risk of default is high, they may choose not to open transaction accounts with the bank in order to avoid the risk that access to their transactional account could be suspended in case the bank default. Therefore, we again need an instrument for the ratio of demand deposits to total deposits. It turns out that the instruments we use for the retail deposit rates (the branches per deposit ratio and the share of branches) are also valid instruments for the demand-to-total-deposits ratio. The intuition is that banks with widespread branch network are more likely to attract transactional deposits. The results of these regression specifications are illustrated in Table 8. They again indicate that banks with strong market power in the deposit market (with a high share of demand deposits) will show lower risk levels.

And finally, 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 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.

In sum, all robustness specifications confirm our baseline results of a positive relation between the intensity of competition faced by individual banks and their risk levels.

6. Conclusion

Although a number theoretical studies point to a positive link between deposit market competition and bank risk, empirical studies have produced only mixed results. In this paper we revisit the debate by estimating a system of equations which describe the relation between deposit market competition and bank risk. Our study brings two major innovations to the empirical literature on the competition–risk nexus. First, we apply a (semi-)structural approach, which explicitly deals with the potential endogeneity of bank competition measures with respect to risk. Second, we include in the analysis the wholesale funds market. Although wholesale funding affects both the risk of a bank and its behaviour in the deposit market, the wholesale market for funds has so far been ignored in the competition and risk literature.

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 strong evidence for the risk-increasing effects of deposit market competition.

Moreover, the results of our study show that riskier banks pay higher interest rates on their uninsured wholesale liabilities. These results are consistent with the implications of the market-discipline literature (DeYoung et al., 1998, Morgan and Stiroh, 2001, and Furfine 2001).

In sum, our empirical results confirm the existence of a trade-off between deposit market competition and bank risk. Since banks offering higher deposit rates tend to undertake riskier strategies, bank regulators might be interested in deposit rates as a signal of bank risk and focus supervisory efforts on banks offering higher rates on retail deposits. In terms of policy, our results imply that supervising authorities should endogenize the risk effects of deposit market competition when considering regulations that aim to increase banking system efficiency through intensified bank market contestability.

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