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Risk pricing of wholesale funds and the behavior of retail deposit rates☆

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ABSTRACT

We explore the relationship between bank risk and retail deposits. Predicted risk premiums on wholesale funds explain retail rate heterogeneity through two channels. First, increased bank risk premiums encourage the bank to substitute from wholesale funds to small certificates of deposits (CD) by increasing small CD rates. Second, increased rival risk premiums in a local market require the bank to increase small CD rates even more. Our results are consistent with risk encouraging the use of small CDs as a marginal source of funds and promoting local market competition for small CDs. As risk premiums rise, banks also reduce rates on other retail deposits. Our approach has implications for regulatory and monetary policies and financial stability.

1. Introduction

Understanding how bank-specific risk affects bank liability management has implications for antitrust policy, monetary transmission, and regulations focused on financial stability. This paper explores risk-induced substitution between wholesale and retail deposits and the implications it has for retail rate behavior. We argue that the bank's own risk and the risk of its rivals in a local market affect the pricing of the bank's retail deposit and determine the ability of the bank to use retail deposits as a marginal source of funds. We show that an increase in the bank's forecasted own-risk premium encourages substitution into interest-sensitive retail certificates of deposits (CDs) through raising retail CD rates, while an increase in local-market rival-risk premium inhibits substitution.

We first assume a bank's predicted risk-priced premium on wholesale funds incentivizes it to substitute between wholesale and retail deposits by altering retail rates. We argue that this risk-induced substitution creates two channels – own-bank and rival-bank effects. Through the first channel, an increase in the bank's predicted risk-priced premium induces the bank to substitute away from more expensive uninsured wholesale funds towards cheaper insured retail deposits, by raising retail rates. The larger this predicted risk premium the greater is the pressure for the bank to increase retail rates, all else equal. This pricing pressure is bank specific and is independent of the market in which the bank operates. Through the second channel, increased risk of the bank's local market rivals incentivizes those rivals to raise their retail rates. Consequently, the bank faces greater deposit rate pressure in a local market where its predicted rival-risk premiums are high. This rival-risk pricing pressure is bank-market specific. The increased rival-risk pricing pressure affects the bank's retail rate by decreasing its supply for retail deposits in that market, incentivizing the bank to raise retail

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rates. This risk pressure is a second component of the bank's retail deposit pricing decision. Thus, we model the bank's retail rate decision as dependent on its predicted own-risk premium associated with its wholesale funding and the deposit-weighted predicted risk premiums associated with the wholesale funding of its rivals in a local market. Both of these channels are driven by the single mechanism of risk pricing of bank-specific risk in the uninsured wholesale market and the substitution into insured retail deposits it implies.

Most studies on retail pricing emphasize two themes – substitution between wholesale and retail funds (due to changes in the costs of wholesale funds), and competition in local markets (measured by market-specific characteristics). In those studies employing substitution, it is often unclear whether rates change due to variation in bank-specific risk or changes in policy-induced rates or both. Studies that explicitly include risk do not isolate a market-discipline mechanism. Papers characterizing competition often use market-specific concentration ratios, which do not focus on the competitive mechanism. Those that include rival rates use contemporaneous competitor rates as regressors, inconsistent with microeconomic theory where own-bank and rival-bank rates are jointly determined. These studies also include a small percentage of total local-market rivals, limited by survey data. Thus, previous approaches to modeling competition raise theoretical and empirical concerns that could yield biased results.

We focus on these same themes of substitution and competition in our two-channel pricing model where the bank uses information in time *t-1* to forecast risk-pricing premiums for itself and for its local-market rivals in time *t*. These two predicted premiums proxy for wholesale pricing pressures used by the bank to set retail rates at the bank-market level in time *t* in response to its own risk and that of its rivals. This approach is consistent with the Bertrand-Nash equilibrium, where competitors assess all available information in period *t-1* on each other to set prices in period *t*. We emphasize bank-market competition, which differs among banks in a given market as well as across markets for a given bank. We circumvent the problem of limited data on competitor rates by including predicted risk-priced premiums on all rivals in each market (from the *Call Reports* and *Summary of Deposits*).

Our empirical results show that as the bank's predicted risk premium increases it raises rates on small CDs, and lowers rates on MMDAs, small Savings and interest-bearing Demand Deposits. Additionally, our deposit quantity results reveal that as the bank's predicted risk premium increases the quantity of small CDs rise and the quantities of MMDAs and small Saving and Checking Accounts fall. These rate and quantity results are consistent with our arguments that the bank treats small CDs as substitutes, and uses other retail deposits as complements to wholesale funds. The results also show that banks respond to predicted rival-risk pressure by raising rates on small CDs, consistent with risk promoting competition in local markets.

Our results have implications for competition, financial stability, and monetary policy. The inclusion of risk in a framework with rival banks defines a risk-induced local-market price competition. On the one hand, the effects of risk pricing on retail rates can produce competitive rate contagion across markets, encouraging local instability to spread nationally. On the other hand, a critical instability in a local market can be defused by spreading competitive rate pressures across markets. Understanding how this risk contagion operates is important for policies used to improve financial stability. The existence of a lending channel depends on the extent to which a bank can move from insured to uninsured funds as policy tightens. Kishan and Opiela (2012) show that policy rates intensify bank risk, producing a lending channel. Our bank-market results, in conjunction with that study, imply that a bank that manages its risk and operates in certain markets is able to bypass the lending channel.

Section 2 lays out an argument for how an increase in predicted risk premiums result in retail-pricing components for own-bank risk pressure and rival-bank risk pressure, in addition to an argument for both substitutability and complementarity of retail deposits with wholesale funds. Section 3 lists the hypotheses tested and presents the empirical models used to test those hypotheses. Section 4 presents the data and results. Section 5 outlines some policy implications.

2. The risk pricing of wholesale funds and the retail deposit rate behavior

2.1. The Risk-Pricing Mechanism, Substitution, Complementarity, and retail rate behavior

In this section, we explain how bank-specific risk working through predicted risk-priced premiums in the wholesale funds market sets up an own-risk and rival-risk retail rate decision. Our argument relies on the presence of a market for uninsured funds (wholesale deposit market) and a market for insured funds (retail deposit market). Wholesale deposits are purchased in a national (or large regional) market and are subject to risk-pricing/market-discipline. Retail deposits are purchased in a local market (e.g., an MSA) where the bank has some market power. Market power is embodied in the supply function of retail funds facing the bank, and is determined by bank-market conditions, including the competitive behavior of the bank's rivals in a local market. The bank uses these two markets to manage its liabilities.

We initially focus on a substitution argument, often referred to in the retail deposit rate literature, to illustrate two channels by which risk affects the bank's retail rate. Substitution not only explains the bank's rate reaction to its own risk, but when that substitution is applied to its rivals, it produces a competitive rate reaction by the bank that treats rival deposits as strategic complements. The literature shows evidence of both substitution and complementarity between wholesale and retail funds.

We start with a pricing argument where changes in predicted risk-priced premiums across banks are exogenous shocks driving pricing behavior in the current period.[1] For expositional purposes, we initially assume that each bank operates in a single retail deposit market. Assume that bank-specific default risk rises, as proxied by past financial statement variables available in period *t*.

[1] Other papers assume the cost-of-funds, mix-of-liabilities or competition determine risk-taking behavior (Boyd et al. see Craig & Dinger, 2010). Because quarter-to-quarter measures of risk are quite volatile, we assume that fluctuations in risk are exogenous. Consequently, we use risk to explain retail rate heterogeneity.

Consequently, in the wholesale market, uninsured depositors decrease the supply of funds to the bank in time period t, driving the wholesale rate up. That is, depositors discipline the bank by pricing perceived bank-specific risk. Because financial information on its risk in time period *t-1* is publicly available in time *t*, the bank predicts the risk premium depositors will force it to pay in time period t. The bank responds to its predicted risk premium, and consequent loss of wholesale funds, by appropriately setting the retail deposit rate in period *t* so as to substitute into cheaper retail deposits.[2] Thus, an increase in bank-specific risk and the resulting predicted increase in the cost of wholesale funds incentivize the bank to move into cheaper inputs by raising retail rates.[3] We call this effect on retail rates due to a change in predicted own-bank risk pressure the *Own-Risk Effect*.

Most retail rate studies also assume that either policy-induced rates or differences in bank-specific risk drive a substitution between wholesale and retail funds. That substitution is usually argued to follow from fluctuations in interbank rates, although it is often unclear whether rates change due to variation in bank-specific risk or due to changes in monetary policy-induced rates (e.g., Kiser, 2003). Recent papers that refer to risk assume implicitly or explicitly that a higher risk premium can induce a substitution from wholesale to retail funds (e.g., Gambacorta, 2008; Craig & Dinger, 2010; Acharya & Mora, 2012). However, none of these studies include a measure of a risk-priced-premium nor explicitly incorporate the effect of market discipline on retail rates. For those studies that include balance-sheet measures of risk, some show coefficients that have counter-intuitive or insignificant signs, raising the possibility that their results could be due to risk-related constraints other than risk-priced premiums.[4]

Next, we apply to the bank's rivals in a local market the same risk-pricing argument we applied to the bank. When rival-risk rises, rivals will subsequently raise their retail rates. The predicted risk-pricing premium pressure from the bank's rivals proxies for a type of price competition facing the bank that should affect how the bank sets its retail deposit rate. We assume that the bank is faced with a group of competitors for retail deposits in a particular local market, and that these competitors receive shocks in the way of an increase in their own predicted risk-priced premiums, based on financial statement variables in period *t-1*. The bank's rivals will react similarly to how the bank reacted to its own-risk effect. Due to risk pricing in the wholesale market, predicted to occur in period *t*, rivals will have incentive to substitute into retail funds by raising their retail rates in the local market. The bank uses this information on its local market rivals to predict the extent to which rival risk premiums will translate into higher rival retail rates. The bank uses this information to gauge the extent to which that pressure will adversely impact the bank's supply of retail funds in period t.[5] This competitive pricing pressure will incentivize the bank to initially substitute away from retail deposits and into wholesale funds, increasing the bank's demand for wholesale funds. Because the cost of wholesale funds is increasing in the quantity of funds, the bank will react by paying a higher wholesale rate and, therefore, will be motivated to raise retail rates further in period *t*.[6] Thus, increases in the predicted risk premiums of its rivals will put competitive pressure on the bank's retail deposit rates. We call this effect on retail rates of the bank due to a change in predicted rival-bank risk pressure the *Rival-Risk Effect*.[7]

The argument that risk is a driver of competition is at the heart of the risk-contagion literature.[8] Use of a predicted risk-priced premium associated with the bank's rivals to characterize local market competition is a type of price contagion. Recent studies emphasize price contagion in retail markets (Acharya & Mora, 2012; Craig & Dinger, 2010), but they include rival rates contemporaneously. They also either include survey data on a limited number of rivals in each market or use an imputed rival rate at the bank level. Also, Acharya and Mora (2015) primarily emphasizes contagion during the financial crisis. Thus, the approaches to modeling competition in other studies raise issues about consistency with microeconomic theory and concerns about possible biasedness of their results.

Our characterization of rival-risk price pressure is consistent with market power through its impact on deposit funds supply facing the bank. This market power can be characterized as arising from oligopolistic pricing behavior that is driven by risk-pricing pressure from the bank's rivals in a particular market. This rival-risk effect and the price competition it implies is consistent with a Bertrand-Nash equilibrium in which each firm sets its price in period *t* based on *t-1* information about how other firms will react.[9]

Our substitution argument is applicable to the relation between wholesale funds and small CDs. Evidence shows that small CDs are the most interest sensitive of retail deposits and appear to be the best substitutes for wholesale deposits (Acharya & Mora, 2012, 2015; Jordan, 2000; Craig & Dinger, 2010; Berlin & Mester, 1999).

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[2] The upward-sloped supply of retail funds assumes that the bank has some market power, possibly due to product differentiation (see e.g., spatial and representative consumer models in Carlton and Perloff (2005) chapter 7).

[3] Even though there is not risk pricing of insured deposits, the probability of bank default indirectly affects the pricing of retail rates, and in a way that is consistent with the risk-pricing of insured deposits.

[4] E.g., regulatory or bank-imposed constraints associated with risk (see, e.g., Berger, Klapper, & Turk-Ariss, 2009)

[5] The effect of rival price changes on the supply of retail deposits facing the bank can be viewed as a change in the bank's elasticity of supply (see, e.g., Carlton & Perloff, 2005 or Egan, Hortaçsu, & Matvos, 2014).

[6] Kashyap and Stein (2000) and Kishan and Opiela (2000) provide indirect evidence that the cost of wholesale funds increases in the quantity of funds. Jordan (2000) assumes a constant cost of funds. Park and Peristiani (1998) provides a rationale for both types of supply functions. Empirical evidence of positive-slopped and inelastic supply functions are shown in Berlin and Mester (1999) and Egan et al. (2014).

[7] When depositors decrease deposits at risky rival banks they move to relatively safer banks. We assume that this shifting of funds is too small to offset the *Rival-Risk Effect*.

[8] Kaufman (1994) presents a general definition of contagion. Cooperman, Winson, and Wolfe (1992) examine CD rate contagion, but omit rival bank rates. Jordan (2000) and Billett, Garfinkel, and O'Neal (1998) emphasize deposit-quantity contagion, which is consistent with risk promoting price contagion.

[9] Cosimano, Fullencamp, and Sheehan (1999), VanHoose (2010), Kopecky and VanHoose (2012) present retail rate models consistent with the Bertrand competition.

2.2. Advantages of a risk-pricing framework

Unlike other studies, the use of a bank-market rate variable decomposed into bank and bank-market risk-pricing effects has several advantages for structuring the effect of risk on retail pricing behavior. First, using predicted risk premiums as an instrument for rival pricing pressure mitigates endogeneity problems associated with using contemporaneous rival rates (Acharya & Mora, 2012).[10] Second, risk-pricing/market-discipline is the general approach in the literature for measuring risk-related costs (risk premia) on uninsured funds (Flannery, 1998; Flannery & Nikolova, 2004). There is a body of evidence documenting that changes in risk can exact substitution between wholesale and retail deposits (Billett et al., 1998; Jordan, 2000; Kiser, 2003; Craig & Dinger, 2010; Acharya & Mora, 2015). However, no paper that we are aware of uses predicted risk-priced premiums as an instrument for the relevant prices that initiate substitution or complementarity between wholesale and retail funds. Our approach thus contributes to a better understanding of the relationship between bank risk, bank competition, and bank deposits management.

3. Hypotheses and empirical model

3.1. Hypotheses tested

The implications of our model of own-risk and rival-risk can be expressed in terms of the following hypotheses.

Hypothesis 1. A positive relation between own-bank risk and retail rates implies retail funds are substitutes with wholesale funds, and a negative relation between own-bank risk and retail rates implies retail funds are complements with wholesale funds.

Hypothesis 2. A positive relation between rival-bank risk and the bank's retail rates implies the bank's retail funds are strategic complements, and a negative relation between rival-bank risk and the bank's retail rates implies the bank's retail funds are strategic substitutes.

3.2. Empirical analysis

We now operationalize our approach in an empirical model to test the above hypotheses. In Section 2, the two-channel pricing model assumes pricing decision is made at the centralized level, which takes into consideration the bank's aggregate risk condition and the aggregate risk condition of the group of rival banks it meets in a particular local market. Thus, it uses these two predicted risk premiums to set rates at the bank-market level. Therefore, we model the risk-priced premium of the bank and its rivals at the bank level and use the predictions from that model in regressions at the bank-market level. More formally, we model the retail rate decision, denoted by $r_{\bar{i}\bar{j}}$, facing a particular bank $\bar{i}$ (we define the bank and bank variables as aggregated to the high holder) in a particular market $\bar{j}$ in which it operates, at time *t*. The setting of this rate depends on the bank's own predicted risk-priced premium $(\widehat{ownbnkprem})$, and on the deposit share-weighted predicted risk-priced premium $(\widehat{rivalbnkprem})$ of its rivals in its market $\bar{j}$. These two regressors act as instruments for own-bank and rival-bank wholesale price pressure on retail rates.

$$r_{\bar{i}\bar{j}\text{t},} = \beta_1(\widehat{ownbnkprem})_{\bar{i},\text{t}} + \beta_2(\widehat{rivalbnkprem})_{\bar{i}\bar{j},\text{t}} + \sum_{l=1}^{m}\theta_l(ownbnkcontrol_{l,\bar{i},\text{t}-1}) + \sum_{l=1}^{h}\varnothing_l(mktcontrol_{l,\bar{j},\text{t}-1}) + u_t + v_{\bar{i}\bar{j}} + \varepsilon_{\bar{i}\bar{j},\text{t}} \tag{1}$$

Eq. (1) includes time fixed effects u_t, bank-market fixed effects $v_{\bar{i}\bar{j}}$ and an error term $\varepsilon_{\bar{i}\bar{j},t}$. $\widehat{ownbnkprem}$ and $\widehat{rivalbnkprem}$ are predicted, using information in time *t-1*, to impact a bank's cost of wholesale funds in time t, and are estimated from risk associated with the bank. $\widehat{rivalbnkprem}$ is a bank-market variable. We use Eq. (1) to test Hypothesis 1–2 on own-risk premiums and on rival-risk premiums.

The predicted risk-priced premium $\widehat{ownbnkprem}$in Eq. (1) is estimated from the following risk-pricing equation for each bank *i*,

$$ownbnkprem_{i,t} = \sum_{l=1}^{3}\psi_l(risk_{l,i,t-1}) + \sum_{l=1}^{3}\varpi_l(liquidity_{l,i,t-1}) + \sum_{l=1}^{m}\phi_l(control_{l,i,t-1}) + w_i + z_t + e_{it} \tag{2}$$

where the dependent variable is the imputed interest rate on large time deposits for the *ith* bank at time *t,* computed as interest expense on large time deposits divided by the average dollar amount of large time deposits. *Risk* is proxied by bank-specific risk measures that include three ratios: non-performing loans-to-total loans, commercial and industrial (C & I) loans-to-total loans, and the leverage ratio (capital-to-asset ratio). *Liquidity* is proxied by three ratios: liquid assets-to-total assets, and unused commitments-to-the sum of total loans and unused commitments, and the ratio of wholesale funds to total liabilities. We also include the log of real total assets as a control variable (see the Appendix for the definition for all of these variables).[11] Aggregate bank fixed effects (*w*), time fixed effects (*z*) and financial crisis dummy are also included. The coefficients associated with *risk* and *liquidity* take on the usual signs that are given in the risk-pricing/market-discipline literature (see, e.g., Kishan & Opiela, 2012 and the references therein for a recent

[10] We view this endogeneity issue as an omitted variable problem. The omitted variable is the predicted risk-pricing premium, or retail pricing pressure faced by the bank's rivals. It is obtainable using last-period risk data.

[11] These measures of default risk, leverage and liquidity are commonly used in the market-discipline/risk-pricing literature (e.g., see Ellis & Flannery, 1992; Hannan & Hanweck, 1988; Flannery & Sorescu, 1995; Maeckler & McDill, 2006. See further references in Kishan and Opiela (2012)).

application of estimated risk pricing).[12] The predicted risk premium, $\widehat{ownbnkprem}$, is computed using the bank-specific measures of risk and liquidity.[13]

For the effect of rival rates on the bank's retail pricing decision we turn to the second term in Eq. (1). $\widehat{rivalbnkprem}$ is the deposit share-weighted risk premium of competitor banks that bank $\bar{i}$ faces in its market. This measure is given by,

$$(\widehat{rivalbnkprem})_{\bar{i}\bar{j}} = \frac{\sum_{i=1}^{n_{\bar{i}\bar{j}}} [(dep_{i\neq\bar{i},\bar{j}}) \times \widehat{ownbnkprem}_{i\neq\bar{i},\bar{j}}]}{\sum_{i=1}^{n_{\bar{i}\bar{j}}} [(dep_{i\neq\bar{i},\bar{j}})]} \quad (3)$$

In this expression, we include the weighted $\widehat{ownbnkprem}$of each bank $i \neq \bar{i}$, and where each $\widehat{rivalbnkprem}$is weighted by the lagged share of each rival's deposits in market $\bar{j}$, where the sum of deposits in market excludes the deposits of bank $\bar{i}$. This measure focuses solely on rival risk premiums facing bank $\bar{i}$ in market $\bar{j}$. It excludes bank's deposits in market $\bar{j}$ in both the numerator and denominator. That is, the total deposit share of bank $\bar{i}$'s rivals sums to one.

Eq. (1) also includes bank-level control variables and market control variables. Bank variables include: the ratio of unused commitments-to-total commitments plus loans and real loan growth (as a proxies for funds demand), notional derivatives usage to total assets, and the logarithm of real total assets (to control for size effects). Bank-market variables include: rival-bank risk premium, deposit share of the bank in a particular market, ratio of total number of branches of the bank in a market to its total deposits in that market (as a proxy for service), and total number of banks in a market. For market variables we include the unemployment rate (proxy for local-market conditions that impact rates of all banks in that market) and the Herfindahl_Hirschman index (HHI) of deposit concentration for the $\bar{j}$th market.[14] All bank balance sheet variables, bank-market, and market level variables are lagged one period to reduce endogeneity issues.

4. Data and results

4.1. Data

To examine the relationship between the bank's retail rate and bank's own-risk and rivals-risk at the bank-market level, we employ data from several sources. Quarterly bank balance sheet variables are taken from the *Report of Condition and Income* (Call Report). The data are from 1998q1 to 2010q4. When total loans or assets have non-positive values we drop that bank in that quarter. To adjust for outliers, we winsorize observations that lie above the 99 th percentile or below the 1 st percentile for each balance sheet variable. For this bank-level data, we aggregate to the high holder.[15] We obtained weekly branch-level interest rate data for several types of accounts associated with about 4000 banks and about 350 MSAs. These rate data are from *RateWatch*. Tables 1A and 1B show within banks and within MSAs, the variation of rates for 6-month small CDs and interest-bearing checking accounts, respectively. Note that there is considerable cross-market variation, consistent with Craig and Dinger (2010) and counter to assumptions in Park and Pennacchi (2009) and Hannan and Prager (2004a, 2004b, 2004c). To match the weekly frequency of the interest rate with the quarterly data from the Call Reports, we chose to use the interest rate reported by a bank in a market on the last full week of each quarter. For the retail interest rate, we used the interest rate reported on six-month CDs, money market deposit accounts, savings accounts, and interest-bearing checking accounts averaged over all branches of the bank in each local market. Bank-market-level observations were then matched with local market characteristics from the FDIC *Summary of Deposits (SOD)* data. The Data Appendix contains the source and definition of each of the variables used in our regressions. After merging the above three datasets, we obtain an unbalanced panel with interest rates offered by 4076 banks in 350 MSAs over the period 1998q1-2010q4. Summary statistics of the variables are reported in Table 1C. Bank balance sheet variables show substantial variation across banks and over-time.

4.2. Empirical results

4.2.1. Empirical results for small CDs

We start by estimating Eq. (1) for 6-month Certificates of Deposit (CD) with a minimum deposit of 10 thousand dollars. The results for 6-month CD rates appear in Table 2 column (1). Results for tests of hypotheses 1 and 2 on the coefficients for predicted own-risk and rival-risk premiums appear in column (1). If these small retail CDs are substitutes for wholesale funds, we expect each of these two coefficients to be positive. The results show the own-risk and rival-risk coefficients are both positive and significant at 1% and 5% levels, respectively.[16] These estimates imply that a 1% point rise in the predicted own-risk premium is associated with a 19 basis point rise in the bank 6-month CD rate, whereas a similar rise in the rival-risk premium leads to a 24 basis point rise in the bank 6-month CD rate. These two

[12] Our results for Eq. (2) are available on request.

[13] Kishan and Opiela (2012) compute a forecasted risk-priced premium and examine the effect of monetary policy on that premium. $\bar{j}$.

[14] We also tried 3 firm HHI of deposit concentration; results were unchanged.

[15] Acharya and Mora (2015) also aggregate to the bank's high holder.

[16] Since own-risk and rival-risk variables are generated regressors, Pagan (1984) has shown that errors in two step procedure are non-spherical. Mishkin (1982) argues that in this case the OLS estimates of the covariance matrix of the parameters tend to understate the true covariance matrix, yielding invalid inferences based on t and F test. We bootstrap the standard errors by resampling observations from the data, with replacement, 500 times.

Table 1A
Six month CD rates.

Year	Within Bank Coefficient of Variation	Within Market Coefficient of Variation
1999:4	5.18	7.78
2000:4	5.17	9.33
2001:4	7.18	17.19
2002:4	8.96	20.74
2003:4	9.62	19.05
2004:4	11.11	20.26
2005:4	10.14	17.54
2006:4	9.97	16.40
2007:4	8.81	16.10
2008:4	12.08	25.37
2009:4	13.33	37.50
2010:4	14.89	45.83

Table 1B
Checking Account rates.

Year	Within Bank Coefficient of Variation	Within Market Coefficient of Variation
1999:4	17.69	37.21
2000:4	22.58	42.31
2001:4	22.22	55.17
2002:4	26.32	57.89
2003:4	28.57	63.33
2004:4	29.03	62.50
2005:4	32.50	63.41
2006:4	36.73	71.43
2007:4	39.53	75.00
2008:4	42.86	82.14
2009:4	41.18	83.33
2010:4	33.33	76.92

Note: Variation within the market is computed by first computing the variation of the checking account rates offered by all banks in a particular local market. Then the variation is averaged across local markets. Variation within the bank is computed by first computing the variation of the checking count rates offered in the various local markets by a multimarket bank.
Then the variation is averaged across all multimarket banks.

Table 1C
Summary Statistics.

Variable	Mean	Median	25per	75per	Std. dev.
Unused_commt ratio (%)	12.02	11.05	6.92	16.06	6.82
Liquidity ratio (%)	25.92	23.95	15.96	33.77	13.21
Wholesalefund ratio (%)	21.1	19.73	13.12	27.48	10.68
Non-performing loan ratio (%)	1.45	0.83	0.34	1.78	1.96
Capita-asset ratio (%)	10.12	9.56	8.28	11.41	2.63
CI loan ratio(%)	15.70	13.79	8.96	20.17	9.55
Interest derivative ratio (%)	0.43	0	0	0	2.34
Real total asset (in2005$,000)	1,566,448	129,711.2	64,030.7	$1.77e^{+09}$	$2.83e^{07}$
Branch share per-mkt(%)	4.92	2.53	0.72	7.35	5.79
Deposit share per-mkt(%)	5.22	1.85	0.42	6.74	7.87
Num of mkts_banks	18.39	2	1	11	38.74
Num of banks_mkt	63.78	35	20	74	66.68
HHI (0–1 scale)	0.13	0.12	0.09	0.15	0.07
Imputed Large CD rate (%, annualized)	4.01	4.0	2.80	5.19	1.46
Ratewatch Int rate (%):					
6 mcd	2.32	1.99	1.15	3.44	1.42
3 mcd	1.90	1.59	0.9	2.78	1.28
12 mcd	2.58	2.25	1.45	3.70	1.41
MMdeposit10k	1.18	0.90	0.50	1.50	0.98
Savings deposit	0.69	0.50	0.25	1.0	0.60
Checking account	0.45	0.25	0.15	0.53	0.48

Table 2
Response of the Bank Interest rate to Own-Risk and Rival-Risk Pressure.

rhs variables	(1) 6 month CDs	(2) 3 month CDs	(3) 12 month CD	(4) Check. dep.	(5) Savings. dep	(6) MMDA
own-risk$_t$	0.191***	0.294***	0.123*	−0.363***	−0.394***	−0.115
	(0.072)	(0.084)	(0.071)	(0.053)	(0.054)	(0.089)
rival-risk$_t$	0.245**	0.208	0.153	−0.195*	−0.114	−0.557***
	(0.124)	(0.139)	(0.117)	(0.110)	(0.101)	(0.164)
bank-market variables						
deposit share MSA ratio $_{t-1}$	0.006***	0.004**	0.002	−0.004***	−0.003***	0.005**
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
branch-deposit msa ratio $_{t-1}$	−0.065	−0.025	−0.187***	−0.105	0.370***	0.072
	(0.073)	(0.105)	(0.074)	(0.367)	(0.105)	(0.287)
number banks MSA $_{t-1}$	0.002**	0.0003	0.002***	0.003***	0.003***	0.001
	(0.0007)	(0.001)	(0.0006)	(0.001)	(0.0006)	(0.001)
aggregate-bank variables						
derivatives usage ratio $_{t-1}$	−0.0001***	−0.0001***	−0.0001***	0.0001***	0.00004*	−0.00001
	(0.00002)	(0.00003)	(0.00001)	(0.00002)	(0.00002)	(0.00002)
log(assets) $_{t-1}$	−0.009	−0.018	−0.024	0.054***	0.026	0.061**
	(0.019)	(0.022)	(0.020)	(0.017)	(0.016)	(0.025)
unused-commit-loan ratio $_{t-1}$	0.005***	0.006***	0.004***	−0.001	0.001*	0.006***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.00007)	(0.001)
total-loan growth $_{t-1}$	0.002***	0.003***	0.002***	0.001***	0.001***	0.002***
	(0.0004)	(0.0004)	(0.0004)	(0.0003)	(0.000)	(0.0005)
market-variables						
HHI $_{t-1}$	−0.099	−0.185**	−0.130	0.100	0.042	−0.180*
	(0.086)	(0.081)	(0.086)	(0.067)	(0.071)	(0.095)
MSA unemployment rate $_{t-1}$	−0.018***	−0.011***	−0.016***	0.002	0.004*	0.007
	(0.003)	(0.004)	(0.003)	(0.002)	(0.002)	(0.004)
Ho: Own-risk = rival-risk	F = 0.14	F = 0.26	F = 0.05	F = 1.79	F = 5.35	F = 5.12
	P = 0.71	P = 0.61	P = 0.83	P = 0.18	P = 0.02	P = 0.02
R^2	0.91	0.87	0.91	0.54	0.69	0.66
number of observations	102,644	95,831	99,768	98,435	98,856	99,481

Note: All specifications use panel regression with bank-market fixed effects and time fixed effects. The coefficients are estimated using bootstrapped robust standard errors, which appear in parentheses below these coefficients. The reported R^2 is within R^2. Significant at 1% ***; 5% **; and 10% *.

coefficients are, however, not statistically significantly different from each other, as shown by the F-test at the bottom of Table 2. These results are consistent with our hypotheses that there are substitutive effects between wholesale and retail CDs, and that rival-bank risk impacts the bank's retail rate decision. The latter result is consistent with the bank treating rival 6-month CDs as strategic complements. That is, the bank responds to rising rival CD rates by raising the rate on its CDs. Most of the bank-market, bank level, and market level variables in column (1) are of the anticipated sign and significant at better than the 10% level.

We also include the results for 3-month and 12-month small CDs, which appear in Table 2, columns (2) and (3), respectively. The results from these tables are similar in quality to those for 6-month CDs. These results provide evidence of robustness of our 6-month CD results.

4.2.2. *Empirical results for MMDAs, small savings Accounts, and Interest-bearing demand deposits*

Table 2 columns (4), (5) and (6) contain the results for the rate-setting behavior of Money Market Deposit Accounts (MMDAs), small saving accounts, and checking accounts, respectively. We lump the discussion on these deposits together because their results are almost identical, suggesting banks treat them similarly.

For MMDAs, small savings deposits, and checkable deposits, both own-risk and rival-risk effects shown in columns 4–6 are negative. Own-risk effects are statistically significant for checkable and small savings deposits at 1% level – a strong result. The negative signs for the own-risk effects indicate that as the predicted cost of wholesale funds grow due to increased risk, the bank reduces rates on MMDAs, small saving and checkable deposits. This should cause the dollar quantity of these deposits to fall (shown in the next section). It might be a reasonable behavior for the cost-minimizing bank that is faced with high interest elasticity for small certificates of deposits and a low interest elasticity for other retail deposits. If the bank is substituting out of wholesale deposits and into small CDs (as is consistent with the results in Table 2 columns (1)–(3)), the bank might reduce rates on deposits that have low interest sensitivity in order to allow these funds to drain off. That is, a bank raising rates on small CDs faces a higher funding cost and might be tempted to reduce its costs by reducing rates on less interest sensitive deposits.[17] Thus, these results imply that MMDAs,

[17] Low interest elasticity might be due to the services associated with these transactions accounts. This result is consistent with Sharpe (1997) who finds evidence that switching costs are high at MMDAs relative to small CDs. The result that rates on MMDAs and interest-rate checking are less sensitive to risk-pricing pressures than are small CDs is also consistent with studies that show low substitutability by depositors between the various components of monetary aggregates (see, e.g., Kishan & Opiela, 1993).

Table 3
Response of the Quantities to bank own risk.

	Small CDs/asset$_{t-1}$ (1)	(Check. + sav. + mmda)/asset $_{t-1}$ (2)
Own risk	0.182***	−0.373***
	(0.041)	(0.033)
Liquidity ratio$_{t-1}$	−0.032***	−0.021***
	(0.002)	(0.002)
Unused commit ratio $_{t-1}$	−0.003	0.009***
	(0.002)	(0.002)
NPL ratio $_{t-1}$	0.003***	−0.0005
	(0.0005)	(0.0004)
Capast ratio $_{t-1}$	0.036***	0.029***
	(0.006)	(0.005)
Totln ratio $_{t-1}$	0.052***	0.054***
	(0.008)	(0.007)
totast $_{t-1}$	−0.052***	−0.107***
	(0.006)	(0.005)
# braches $_{t-1}$	0.019***	0.057***
	(0.004)	(0.004)
R^2(within)	0.799	0.692
Number of obs.	62,848	62,848

Note: All variables are in logs. All regressions also include one lag of the dependent variable, three seasonal dummies, time fixed effects, and bank fixed effects. Bootstrapped robust standard errors are in parentheses below the coefficients. The reported R^2 is within R^2. Significant at 1% ***; 5% **; and 10% *.

small savings, and checkable deposits are complements with wholesale funds. The rival-risk effects are statistically significant for MMDAs and checkable deposits rates at 1% and 10% levels, respectively. This strong result for the negative relationship between predicted rival-risk premium and the bank MMDA rate indicates that the bank treats rival MMDAs as strategic complements to its own MMDAs (i.e., the bank responds in kind to a rival change in rates). That is, the bank responds to this rival rate cut by also cutting rates on its MMDAs.[18] The control variables in columns (4)–(6) are comparable to the coefficients in columns (1)–(3) for the small CDs. The coefficient on HHI is negative and statistically significant at 10% level for MMDAs, suggesting that the banks in more concentrated markets tend to offer lower interest rates on MMDAs.

4.2.3. Deposit quantity results

Our rate results seem to indicate that small CDs are substitutes for wholesale funds and that other retail deposits are complements to wholesale deposits. However, to effectively argue that our rate results are consistent with retail deposits being either substitutes or complements to wholesale funds, we need to provide some evidence on how the quantities of retail deposits move as predicted premiums change. Unfortunately, quantity data for these deposits are not available at the market level. Therefore, we use bank level quantity data along with predicted own-risk premiums to test for substitutability/complementarity. The lack of market level quantity data also prevents us from testing the effect of rival risk on strategic substitutability/complementarity.

Table 3, column (1) contains the results for small CD quantities scaled by lagged total asset. The own-risk premium coefficient is positive and significant at better than the 1% level. This result, along with the positive coefficients on the relation between own-risk and retail CD rates shown in columns 1–3 in Table 2, point to a bank that is raising rates to attract more funds as its predicted risk premium increases. This implies substitution between wholesale funds and retail CDs.

Table 3, column (2) shows the coefficient results for the combination quantity of MMDAs, small savings, and transactions accounts. This coefficient is negative and significant at better than the 1% level. This result, along with the coefficients on rates for these three accounts in Table 2, is consistent with a bank that is reducing rates on these less interest deposits to reduce its total cost of funds and allowing these deposits to drain off.

We can combine the results in Table 3, column (1), with the results shown in column (1) of Table 2 to garner a rough estimate of the impact of a rise in predicted risk premium on the cost of raising funds through small CDs. For example, average quantity of small CDs in the period 2005:4 (mid-point of our sample) was $269,402,300. Hence, for an average bank, a 1% point rise in the own-risk premium would have resulted in $490,312.19 increase in the quantity of small CDs. According to the RateWatch data, the average 6-month CD rate in 2005:4 was 2.91%. Results shown in Table 2, column (1) imply that a 1% point rise in own risk would have increased the 6-month CD rate to 3.1%. Other things constant, an increase of $490,312.19 in small CDs at the higher interest rate of 3.1% would have increased the bank's interest expense by approximately $15,200, an increase of 0.6% from the average interest expense of $2,350,470.00 in 2005:4. This conceptual exercise, however, must be viewed cautiously. Nonetheless, the example suggests that the rise in the interest expense caused by the higher demand for small CDs by the bank is economically meaningful. To reduce the interest expense, the bank, therefore, reduces the rates on less interest sensitive transaction accounts and treats them as

[18] Carlton and Perloff (2005), p. 378.

complements to large time deposits.

The results of complementarity between transactions accounts (MMDAs, Saving Accounts and Demand Deposits) and wholesale deposits are consistent with studies that look at the relation between bank-specific risk and changes in the quantity of deposits. For example, Jordan (2000) combines MMDAs with other transactions deposits and finds that at eight quarters before it fails, a bank moves out of large CDs (uninsured funds) and into small CDs. He also shows that failing banks decrease core deposits (including MMDAs and small savings.)

4.2.4. Substitutability/complementarity between wholesale and retail deposits

Our result of substitutability and complementarity between wholesale funds and various types of retail deposits are consistent with the results of other studies (e.g., Jordan, 2000). This result can be motivated with at least two models of bank asset and liability management.

First, Song and Thakor (2007) argue that the composition of a bank's loan portfolio dictates what type of deposits it uses to finance its portfolio. They divide loans into relationship and transaction loans. Relationship loans are of high value to a bank but opaque to depositors, posing the greatest risk of deposit withdrawal. Transaction loans are of lesser value to the bank but are transparent and pose little withdrawal risk. Consequently, a bank finances relationship loans with demand deposits, which are stable due to the provision of services to depositors. Transactions loans are financed with wholesale funds and small time deposits, which are more volatile because they pay only interest.[19]

If we assume that banks have a fixed (proportional) preference that dictates a certain relationship/transaction composition of their loans, then this preference dictates the composition of funds between non-interest and interest sensitive deposits. Given a forecasted adverse shock to the risk premium on wholesale funds (as in our econometric model), the increased cost of funding will induce a bank to decrease total loans, but maintain preferences for a proportional loan composition. They will substitute the relatively more expensive wholesale funds with small time deposits by raising the rate on the latter. Because relationship loans fall with total loans, a bank decreases its demand deposit funding. If deposit rates are the quickest way to achieve changes in deposits then demand deposit rates will fall and demand deposit quantities will fall. The result is an apparent complementarity between wholesale funds and interest-bearing demand deposits.

Second, we can assume a two-stage substitution and cost minimization argument. In the first stage an increase in the cost of wholesale funds due to an increase in risk induces a substitution into the only other alternative – retail funds (Kiser, 2003). Assume the retail fund market is a multi-product market where interest rates on deposits are the control variable for the bank and where the supply functions of the different deposits differ in their interest sensitivities. Those deposits with high interest sensitivities have no transactions services (e.g., small certificates of deposit). Those deposits with high transactions services have low interest sensitivities (e.g., interest-bearing demand deposits). In using interest rates to move into retail deposits, a bank would adjust multiple rates simultaneously to minimize the cost of raising retail deposits. This would entail reducing the rate on interest insensitive demand deposits and increasing the rate on small certificates of deposit.

It should also be noted that small CDs and demand deposits are priced differently. When small CD rates are raised, only the newly issued CDs bear the higher rate. However, when the rates on transactions accounts are lowered, both existing and newly created deposits are priced at the lower rate. Therefore, in minimizing costs, this pricing difference further encourages the bank to use interest rates to decrease demand deposits.

4.2.5. System of equations model

Although we offer a motivation for our results of substitutability and complementarity, we have not yet allowed for possible cross-equation correlations for different types of deposits. We now allow for estimation of own-risk and rival-risk effects in a multiple-equation fixed effect panel-data procedure described in Blackwell (2005). This procedure allows for panel heteroskedasticity, panel autocorrelation, and contemporaneous correlation. Since small CDs and transaction deposits provide different types of services to consumers and entail different costs for banks, we estimate two separate sets of multiple-equation panel-data models – one for non-transactions deposits and one for transactions deposits. First, we specify a multiple-equation model consisting of Eq. (1) estimated simultaneously for all three maturities of small certificates. Second, we run a system of equations, as in Eq. (1), for all other core deposits simultaneously (i.e., for MMDAs, small savings and interest-bearing demand deposits). The results for these two separate systems of equations are reported in Table 4. The coefficient size results for own-risk and rival-risk effects are almost identical to the separate deposit equation results in Table 2. However, the significance on the system of equation coefficients is greater than that in Table 2. These results also illustrate that there are dependencies across deposit types for those deposits that have similar characteristics. These results offer evidence that transactions deposits and pure interest deposits are priced differently and used in different ways to compete with other banks.

One advantage of multiple-equation model is that it allows us to test different hypotheses across equations. Several hypotheses tests are listed in the lower part of Table 4. A few results are noteworthy. We fail to reject the null hypothesis that the coefficients on own-risk for different maturities of small CDs are equal. We also fail to reject this same hypothesis for the coefficients of small savings and interest-bearing checking deposit rates. Almost all of the other null hypotheses are rejected at 95% or better significance level -

[19] Note that we are categorizing small time deposits as a marginal source of funds that are highly substitutable with wholesale deposits. Song and Thakor (2007) lump small time deposits with demand deposits (under core deposits). However, Acharya and Mora (2015) provide evidence that banks treated small time deposits as a marginal source of funds, in place of wholesale funds, during the recent financial crisis.

Table 4
Response of the Retail Rates to Own-Risk and Rival-Risk in a System of Equations Model.

	system panel reg: Dep var:3,6,9 month CD rates			System panel reg, Dep. var.: chek, sav, mmda rates		
rhs variables	(1) 6 month CDs	(2) 3 month CDs	(3) 12 month CD	(4) Check. dep.	(5) Savings. dep	(6) MMDA
own-risk$_t$	0.544***	0.489***	0.462***	−0.782***	−0.772***	−0.185*
	(0.098)	(0.091)	(0.104)	(0.104)	(0.099)	(0.098)
rival-risk$_t$	0.387***	0.629***	0.022	−0.131	−0.223**	−0.756***
	(0.097)	(0.092)	(0.100)	(0.102)	(0.095)	(0.096)
bank-market variables						
deposit share MSA ratio$_{t-1}$	0.011***	0.008***	0.007**	−0.014***	−0.008***	0.004
	(0.003)	(0.002)	(0.003)	(0.003)	(0.002)	(0.003)
branch-deposit msa ratio$_{t-1}$	0.186	0.458***	0.128	−0.589*	0.054	−0.003
	(0.148)	(0.119)	(0.166)	(0.332)	(0.143)	(0.256)
number banks MSA$_{t-1}$	0.007***	0.004***	0.008***	−0.003***	−0.003***	−0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
aggregate-bank variables						
derivatives usage ratio$_{t-1}$	−0.0001***	−0.0002***	−0.0001***	0.0001***	0.00003	−0.00003
	(0.00003)	(0.00003)	(0.00002)	(0.00003)	(0.00003)	(0.00002)
log(assets)$_{t-1}$	−0.015	−0.075***	0.022	0.234***	−0.031	−0.022
	(0.027)	(0.023)	(0.029)	(0.028)	(0.026)	(0.025)
Unused_commit-loan ratio$_{t-1}$	0.021***	0.017***	0.024***	−0.015***	−0.018***	−0.009***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
total-loan growth$_{t-1}$	0.002	0.003**	0.003***	0.001*	0.001**	0.001
	(0.0006)	(0.0005)	(0.0006)	(0.0006)	(0.0006)	(0.0006)
market-variables						
HHI$_{t-1}$	−0.117	−0.192	−0.144	0.147	0.068	−0.129
	(0.167)	(0.136)	(0.168)	(0.165)	(0.152)	(0.137)
MSA unemployment rate$_{t-1}$	−0.264***	−0.206***	−0.278***	0.303***	0.274***	0.178***
	(0.004)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)
R^2	0.73			0.72		
# Obs.	595,071			595,075		

Hypothesis tests for System of Equations Model

Hypothesis:	F value	Prob > F
Ownrisk_3mrate = Ownrisk_6mrate = Ownrisk_12mrate	0.17	0.84
rivalrisk_3mrate = rivalrisk_6mrate = rivalrisk_12mrate	10.41	0.00
rivalrisk_3mrate = rivalrisk_6mrate	3.42	0.06
rivalrisk_3mrate = rivalrisk_12mrate	20.72	0.00
rivalrisk_6mrate = rivalrisk_12mrate	7.15	0.01
ownrisk_chk = ownrisk_sav = ownrisk_mm	11.83	0.00
ownrisk_chk = ownrisk_sav	0.01	0.94
ownrisk_chk = ownrisk_mm	17.45	0.00
ownrisk_sav = ownrisk_mm	17.63	0.00
rivalrisk_chk = rivalrisk_sav = rivalrisk_mm	12.71	0.00
rivalrisk_chk = rivalrisk_sav	0.47	0.49
rivalrisk_chk = rivalrisk_mm	21.12	0.00
rivalrisk_sav = rivalrisk_mm	16.50	0.00

Note: System of equations model with bank-market fixed effects and time fixed effects. The coefficients are estimated using bootstrapped robust standard errors, which appear in parentheses below these coefficients. The reported R^2 is within R^2. Significant at 1% ***; 5% **; and 10% *.

this includes rejection of hypotheses on the equality of coefficients associated differing deposit types for rival-rate effects.

4.2.6. Robustness of results during the financial crisis

Our own-risk and rival-risk results in Tables 2 and 3 are for the full period 1997:1–2010:4. However, several studies have tested for structural breaks in banking system behavior after the recent financial crisis. For example, Acharya and Mora (2015) show that banks lost demand deposits early on in the crisis and relied more on small certificates of deposit and other borrowed funds. During the financial crisis the Federal Reserve brought the federal funds rate down to almost zero from 2007:3 to 2008Q4 and held that rate near zero for several years afterwards. Although Acharya and Mora (2015) and others showed that banks competed for funds heavily until the end of 2008, some commentators claimed that banks continued competition for funds until after 2010.

For the sub-sample period 2007:3–2010:4, Table 5 shows the own-risk and rival-risk effects for retail deposit rates. Note that the

Table 5
Response of the Retail Deposit Rates to Own-Risk and Rival-Risk Pressure during the Financial Crisis (sub-sample 2007:4 – 2010:4).

rhs variables	(1) 6 month CDs	(2) 3 month CDs	(3) 12 month	(4) Check. dep.	(5) Savings. dep	(6) MMDA
own-risk$_t$	0.215***	0.347***	0.193***	−0.357***	−0.508***	−0.176**
	(0.073)	(0.078)	(0.073)	(0.042)	(0.051)	(0.079)
rival-risk$_t$	0.597***	0.508***	0.763***	−0.162*	−0.144	−0.122
	(0.149)	(0.163)	(0.149)	(0.089)	(0.098)	(0.154)
bank-market variables						
deposit share MSA ratio$_{t-1}$	0.002	0.002	−0.001	0.001*	0.002***	−0.0005
	(0.0016)	(0.001)	(0.002)	(0.0007)	(0.0007)	(0.001)
branch-deposit msa ratio$_{t-1}$	1.123	2.255	0.529	−0.105	−1.070	1.852*
	(1.473)	(1.651)	(1.309)	(0.367)	(0.659)	(1.002)
number banks MSA$_{t-1}$	0.003***	0.001	0.004***	0.002**	0.003***	0.003***
	(0.0009)	(0.001)	(0.001)	(0.0009)	(0.0006)	(0.001)
aggregate-bank variables						
derivatives usage ratio$_{t-1}$	−0.0001***	−0.0003***	−0.0008***	0.0001***	−0.00006***	−0.0002***
	(0.00002)	(0.00002)	(0.00002)	(0.00002)	(0.00001)	(0.00002)
log(assets) t-1	−0.017	−0.018	−0.001	0.054***	0.012	0.122***
	(0.035)	(0.036)	(0.036)	(0.017)	(0.028)	(0.039)
unused-commit-loan ratio t-1	0.005***	0.006***	0.002*	−0.001	−0.0006	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.0008)	(0.001)
total-loan growth t-1	0.003***	0.003***	0.003***	0.001*	0.0005	0.001**
	(0.0005)	(0.0005)	(0.0005)	(0.0002)	(0.0003)	(0.0005)
market-variables						
HHI t-1	−0.336***	−0.399***	−0.184	0.100	0.003	−0.010
	(0.125)	(0.141)	(0.128)	(0.067)	(0.087)	(0.137)
MSA unemployment rate t-1	−0.014***	−0.009**	−0.016***	0.002	0.003	0.010***
	(0.004)	(0.004)	(0.004)	(0.002)	(0.002)	(0.004)
Ho: Own-risk = rival-risk	F = 4.83	F = 0.0.75	F = 10.57	F = 1.79	F = 9.45	F = 0.09
	P = 0.03	P = 0.38	P = 0.001	P = 0.18	P = 0.00	P = 0.77
R^2	0.87	0.84	0.85	0.26	0.36	0.52
number of observations	35,037	33,011	34,993	34,566	34,682	34,048

Note: All specifications use panel regression with bank-market fixed effects and time fixed effects. The coefficients are estimated using bootstrapped robust standard errors, which appear in parentheses below these coefficients. The reported R^2 is within R^2. Significant at 1% ***; 5% **; and 10% *.

own-risk effects are almost identical as for the full sample period (see Table 2) for each type of deposit. However, the notable difference is in the rival-risk effects, which are much larger for all three of the small certificates of deposit. Consistent with the rate results, the deposit quantities in Table 6 show a positive and larger significant effect than that in Table 3. Together, Tables 5 and 6 are consistent with evidence and commentators observations that there was more intense competition during the financial crisis period.

Table 6
Response of the Retail Deposit Quantities to Own-Risk and Rival-Risk Pressure during the Financial Crisis (sub-sample 2007:4 – 2010:4).

	Small CDs/asset$_{t-1}$ (1)	(Check. + sav. + mmda)/asset$_{t-1}$ (2)
Own risk	0.294***	−0.359***
	(0.075)	(0.049)
Liquidity ratio$_{t-1}$	−0.034***	−0.015***
	(0.006)	(0.004)
Unused commit ratio$_{t-1}$	0.011***	0.007** (0.003)
	(0.004)	
NPL ratio$_{t-1}$	−0.0003	0.003
	(0.001)	(0.002)
Capast ratio$_{t-1}$	0.020* (0.011)	0.049*** (0.008)
Totln ratio$_{t-1}$	0.139*** (0.024)	0.158*** (0.017)
totast$_{t-1}$	−0.217***	−0.212***
	(0.027)	(0.020)
# branches$_{t-1}$	0.022***	0.085***
	(0.015)	(0.013)
R^2(within)	0.61	0.53
Number of obs.	23,008	23,007

Note: All variables are in logs. All regressions also include one lag of the dependent variable, three seasonal dummies, time fixed effects, and bank fixed effects. Bootstrapped robust standard errors are in parentheses below the coefficients. The reported R^2 is within R^2. Significant at 1% ***, 5% **, and 10% *.

Our results show evidence that there was more intense price competition.

5. Conclusion and policy implications

In summary, we find evidence that bank-specific risk acting through risk-pricing in the wholesale market has a positive own-bank and positive local market rival-bank effect on the pricing of retail deposits. The coefficients on these two components have stable values for all models considered. These results imply that small CDs act as substitutes for wholesale deposits as predicted risk premiums on wholesale funds increase. These results imply that the deposit insurance guarantee on small CDs allow banks to attenuate their rate response risk pricing of wholesale funds by substituting into cheaper small CDs.

Our results have implications for competition, monetary policy, and financial stability. The inclusion of risk in a framework with rival banks defines a risk-induced local-market price competition. The results showing the possibility that some retail deposits are complements to wholesale funds further complicates the effect of risk on rate competition.

The existence of a lending channel depends on the extent to which a bank can move between uninsured and insured funds as policy tightens (Bernanke & Gertler, 1995). Kishan and Opiela (2012) shows that changes in policy rates affect bank risk premiums, which produce a lending channel. Our bank-market results, in conjunction with that study, imply that a bank that manages its risk and operates in certain markets might be able to mitigate the effects of contractionary policy on its funding costs, thereby bypassing the lending channel.

On the one hand, our results imply that the effects of risk pricing on retail rates can produce competitive rate contagion that spreads from local markets to the macro-financial markets, promoting instability. On the other hand, our results imply that instability in a local market could be defused by spreading competitive rate pressures across markets. Understanding how this risk contagion operates is important for policies used to improve financial stability.

As part of prudential regulation, regulators are concerned when a bank's deposit rates deviate substantially from those of its peers. Bank rates that are out of line might indicate high risk. Our results for a bank's response to own and rival risk imply that a bank could spread its risk-induced rate hikes over non-competitive markets, thereby decreasing the information content of peer-rate comparisons.

Appendix A. Data Appendix

Banks are aggregated to the top holder level (rssd9348).

Ratewatch interest rate:	Proprietary weekly data on interest rates on several bank products provided by the ratewatch. The data are aggregated to top holder by taking the average rate of a high-holder within a market (MSA).
Implicit interest rate on large time deposits:	Interest expense on large time deposits (riada517), divided by quarterly average of large time deposits (rcona514)
Total Asset:	rcfd2170
Total Loan:	rcfd1400
Unused commitment ratio:	Definition used by Acharya and Mora (2012). Unused commitments are rcfd3814 + rcfd3816 + rcfd3817 + rcfd3818 + rcfd6550 + rcfd3411. Unused commitments ratio is computed as unused commitments divided by the sum unused commitment and total loans.
Liquidity ratio:	As in Acharya and Mora (2012) Liquid assets are cash, federal funds sold & reverse repos, and securities excluding MBS/ABS: Cash: rcfd0010; Federal funds sold: rcfd1350 (before 2002Q1) and rconB987 + rcfdB989 (from 2002Q1). Securities excl. MBS/ABS before 2009Q2: rcfd1754 + rcfd1773 − (rcfd8500 + rcfd8504 + rcfdC026 + rcfd8503 + rcfd8507 + rcfdC027). And from 2009Q2: rcfd1754 + rcfd1773 − (rcfdG300 + rcfdG304 + rcfdG308 + rcfdG312 + rcfdG316 + rcfdG320 + rcfdG324 + rcfdG328 + rcfdC026 + rcfdG336 + rcfdG340 + rcfdG344 + rcfdG303 + rcfdG307 + rcfdG311 + rcfdG315 + rcfdG319 + rcfdG323 + rcfdG327 + rcfdG331 + rcfdC027 + rcfdG339 + rcfdG343 + rcfdG347).
Wholesale fund to liability ratio:	Wholesale funds are the sum of: large-time deposits, deposits booked in foreign offices, subordinated debt and debentures, gross federal funds purchased, repos, and other borrowed money: rcon2604 + RCFN2200 + rcfd3200 + rcfd2800 (rconB993 + rcfdB995 from 2002q1) + rcfd3190 Non-Performing loans to total loan ratio: Loans past due 90 days or more and nonaccurals: (rcfd1403 + rcfd1407) Capital to asset ratio:Capital: (rcfd3210) C & I loan to total loan ratio:C & I loan: (rcon1600)

Interest Derivative to total asset ratio:	Interest Derivative: (rcfd8693 + rcfd8697 + rcfd8701 + rcfd8705 + rcfd8709 + rcfd8713 + rcfd3450 + rcfda126 + rcfd8725 + rcfd8729 + rcfd8733 + rcfd8737 + rcfd8741 + rcfd8745 + rcfd8749 + rcfd8753) up to year 2000q4 After 2000q4: (rcfd8693 + rcfd8697 + rcfd8701 + rcfd8705 + rcfd8709 + rcfd8713 + rcfd3450 + rcfda126 + rcfd8725 + rcfd8733 + rcfd8737 + rcfd8741 + rcfd8745)
Bank_market deposit share:	source: FDIC's Summary of Deposits
Branch_deposit share:	computed as the sum of the number of branches of a bank in a market (MSA) divided by the total deposits of the bank in the market. Source: FDIC's Summary of Deposits.
Number of high-holders in a market:	Source: FDIC's Summary of Deposits
Market concentration (HHI):	Source: FDIC's Summary of Deposits
MSA unemployment rate:	BLS.

Appendix B. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.najef.2017.10.004.

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