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Résumé

Les banques américaines obtiennent la majeure partie de leur financement à partir d'une combinaison de dépôts à taux zéro et dépôts portant intérêt. En utilisant les variations démographiques locales comme instruments pour la composition du passif des banques, je montre que lorsque la politique monétaire se resserre, les banques avec une plus grande proportion des dépôts à taux zéro dans leur bilan observent des augmentations supérieures dans le taux payé sur les dépôts portant intérêt. Cela se produit parce que la politique monétaire restrictive réduit la quantité de dépôts à taux zéro disponibles aux banques. Les banques réagissent en émettant plus de dépôts portant intérêt, mais paient un taux d'intérêt qui augmente avec la quantité emprunté. Cette nouvelle preuve étaie l'existence du canal du crédit bancaire de la politique monétaire.

Mots-clés : Banques, Dépôts, Canal du Crédit Bancaire, Politique Monétaire.

Codes JEL : E44, E50, G21, L16.

Abstract

U.S. banks obtain most of their funding from a combination of zero-interest deposits and interest-bearing deposits. Using local demographic variations as instruments for banks' liability composition, I show that when monetary policy tightens, banks with a larger proportion of zero-interest deposits on their balance sheet experience larger increases in their interest-bearing deposit rate. This happens because tight monetary policy reduces the quantity of zero-interest deposits available to banks. Banks react issuing more interest-bearing deposits, but pay an interest rate that increases with the quantity being borrowed. This new evidence supports the existence of the bank lending channel of monetary policy.

Keywords: Banks, Deposits, Lending Channel, Monetary Policy.

JEL Classification: E44, E50, G21, L16.

Non-Technical Summary

Deposits are the main source of funding for U.S. banks. From 1994 to 2008, on average 80% of a U.S. bank's total assets were funded through deposits. Among deposits, checking deposits usually pay very little interest, and until 2011, did not pay any interest at all by regulation. For households and firms, the opportunity cost of holding such zero-interest deposits depends on the profitability of other liquid investments, such as deposits that pay interest and Treasury Bills. Consider the case in which the Federal Reserve engages in a monetary policy tightening. Market interest rates increase, and depositors may decide to withdraw their zero-interest deposits to invest in more appealing investments. Confronted with the outflow of zero-interest deposits, banks may want to issue more interest-bearing deposits so to keep their loan supply unaltered. However, if the interest rate that banks are asked is too high, they may not want to substitute every dollar lost. They may prefer to decrease their loan supply. The link between monetary policy and bank loan supply is extensively studied.[1] Conversely, how monetary policy affects banks' liability structure and funding cost has received far less attention. Characterizing these effects, however, is important to understand why bank loan supply is ultimately affected.

In this paper, I analyze yearly data of every U.S. commercial and savings bank from June 30, 1994 to June 30, 2008. I study if banks with a larger part of their balance sheet funded through zero-interest deposits experience larger increases in their interest-bearing deposit rate after a monetary policy tightening. My hypothesis is that if zero-interest deposits are sensitive to monetary policy changes, and the interest-bearing deposit rate increases with the quantity being borrowed, this should be the case. In fact, when those conditions hold true, tight monetary policy reduces the quantity of zero-interest deposits available to banks, and forces banks to substitute the outflow of zero-interest deposits by issuing interest-bearing deposits at increasing interest rates.

The empirical challenge is that banks' liability composition is endogenous. Banks, in fact, have the ability to choose the quantity of zero-interest deposits on their balance sheet, even if these deposits cannot be directly remunerated. For example, they can attract zero-interest deposits investing in advertising or better liquidity services. Such expenses are typically unobservable. This implies that once one runs an econometric model where the proportion of zero-interest deposits to total assets is an explanatory variable, he cannot be sure that the effects come from this variable or from the unobservable advertising expenses which are correlated with it and fall in the error term.

I overcome this issue making use of instrumental variables techniques. The idea is to quantify the mechanism using the part of banks' proportion of zero-interest deposits that is due to exogenous elements. To this extent, I first need to find exogenous variables that influence the quantity of zero-interest deposits available to each bank. Using household-level data, I provide evidence that demographics influence the supply of zero-interest deposits by households and firms. For example, the older the household, the larger are the amounts in his checking accounts. In aggregate, therefore, when population age increases, local banks may obtain a relatively higher proportion of zero-interest deposits. I obtain a broad set of county-year level demographic and economic characteristics, and I aggregate them to the bank-year level depending on where each bank has its branches. I show that

[1] See, for example, Kashyap and Stein (2000), Kishan and Opiela (2000), Campello (2002), Gambacorta (2005), Ashcraft (2006), and Jiménez, Ongena, Peydro, and Saurina (2012)).

demographic and economic changes alter the quantity of zero-interest deposits available to banks, and the effects are consistent with the household-level analysis.

Armed with these exogenous shifters, I assess the effects of interest. My main finding is that the more banks obtain funding through zero-interest deposits before a monetary policy tightening, the larger is the increase in the interest-bearing deposit rate when the monetary policy change realizes. This is because in periods of tight monetary policy, the quantity of zero-interest deposits available to banks decreases, and banks substitute such outflow by issuing interest-bearing deposits at increasing interest rates. Using the estimated parameters, I measure the effect on banks' interest-bearing deposit rate of the increase of 119 bps in the Federal funds rate that happened between June 30, 2004 to June 30, 2005. I am interested only in the change in banks' interest-bearing deposit rate that is due to the substitution of outflowed zero-interest deposits with interest-bearing deposits, and not in the change in that rate due to the generalized increase in market interest rates. I find that a bank with an additional standard deviation of zero-interest deposits as on June 30, 2004 would have paid interest bearing deposits 1.6 bps more in the following period.

I corroborate my findings by directly studying the bank-level dynamics of zero-interest deposits and interest-bearing deposits. I find that for every 100 bps increase in the Federal funds rate, the quantity of zero-interest deposits available to banks decreases by 1.37%. When confronted with such outflow, banks increase their borrowings of interest-bearing deposits by .64%. Thus, I find confirmation of the overall mechanism.

This paper provides new insights on how monetary policy is transmitted to banks. In particular, it details and tests a mechanism that supports the bank lending channel of monetary policy transmission. According to that channel, tight monetary policy eventually reduces bank loan supply (Bernanke and Blinder (1988) and Bernanke and Gertler (1995)). As suggested by Kashyap and Stein (1994), the link between monetary policy and bank loan supply arises when monetary policy forces banks to substitute funding sources, and this substitution is not costless. One reason banks are unable to costlessly replace a funding outflow with alternative liabilities is that the supply of such alternatives is imperfectly elastic. To my knowledge, mine is the first paper to characterize how monetary policy impacts banks' liability composition and funding cost. Thus, it adds to the literature by providing evidence that monetary policy alters the quantity of zero-interest deposits available to banks, forcing them to substitute zero-interest deposits with interest-bearing deposits. Additionally, by finding that such substitution is increasingly costly, it points to an imperfect elasticity of the interest-bearing deposit supply, and thus corroborates the existing rich empirical literature on the bank lending channel. The main caveat of this paper, however, is that it does not explicitly explore the asset side of banks, and so does not link monetary policy with bank loan supply.

Finally, this paper adds to the literature on money demand. Meltzer (1963) studies the relationship between the quantity of money, which includes cash and zero-interest deposits, the nominal interest rate, and a measure of economic activity. The quantity of money decreases the higher the nominal interest rate, as this is its opportunity cost. In this paper, I look at the bank-level dynamics of zero-interest deposits and I find an interest rate semi-elasticity equal to -0.0137. So, while zero-interest deposits are only part of the money circulating in the economy, I obtain an interest rate semi-elasticity similar to the one found by Ireland (2009) for the entire money aggregate.

1 Introduction

On average, 80% of a U.S. commercial bank's total assets are funded through deposits. Among deposits, checking deposits usually pay very little interest, and until 2011, did not pay any interest at all.[2] The opportunity cost of such zero-interest deposits is likely to depend on the profitability of other liquid investments, such as deposits that pay interest and Treasury Bills. Consider the case in which the Federal Reserve engages in a tight monetary policy. When market interest rates increase, depositors may decide to withdraw their zero-interest deposits to invest in more appealing investments. The outflow of zero-interest deposits leads banks to issue more interest-bearing deposits. However, if the interest rate that banks are asked increases with the quantity being borrowed, banks may not substitute every dollar lost. Instead, they may decrease their loan supply. The link between monetary policy and bank loan supply is extensively studied.[3] Conversely, how monetary policy affects banks' liability structures and funding costs has received far less attention. Characterizing these effects, however, is important to understand why bank loan supply is ultimately affected.

In this paper, I analyze yearly data of every FDIC-insured U.S. commercial and savings bank from June 30, 1994 to June 30, 2008. I study if banks with a larger part of their balance sheet funded through zero-interest deposits experience larger increases in their interest-bearing deposit rate after a monetary policy tightening. My hypothesis is that if zero-interest deposits are sensitive to monetary policy changes, and the interest-bearing deposit rate increases with the quantity to borrow, this should be the case. In fact, when those conditions hold true, tight monetary policy has the effect of reducing the quantity of zero-interest deposits available to banks, and leads banks to substitute the outflow of zero-interest deposits by issuing interest-bearing deposits at increasing interest rates. My identification strategy exploits exogenous variation in each bank's amount of zero-interest deposits, and quantifies how the reaction of zero-interest deposits to monetary policy changes transmits to the bank's interest-bearing deposit rate. I also extend my baseline model to study how the mechanism alters with bank size and local banking market concentration. Larger banks have greater access to alternative funding possibilities, such as the wholesale market, and thus a smaller effect of substitution may display on their interest-bearing deposit rate. Similarly, as

[2] Regulation Q explicitly prohibited interest payments on demand deposits, which account for the majority of checking deposits.

[3] See, for example, Kashyap and Stein (2000), Kishan and Opiela (2000), Campello (2002), Gambacorta (2005), Ashcraft (2006), and Jiménez, Ongena, Peydro, and Saurina (2012)).

analyzed by Drechsler, Savov and Schnabl (2015), banks located in more concentrated markets have greater market power, and may want to upward revise their deposit rates to a lower extent. So, even if confronted with the same outflow of funding, such banks may substitute a smaller quantity of zero-interest deposits.

The baseline empirical model relates the interest-bearing deposit rate that a bank pays in a year to three components: the initial proportion of zero-interest deposits to total assets; its interaction with the monetary policy change, as proxied by the year change in the Federal funds rate; and the initial proportion of loans. The main parameter of interest is the one of the interaction term. This captures the change in the interest-bearing deposit rate due to the shift in the quantity of zero-interest deposits, as caused by the monetary policy change, and its substitution with interest-bearing deposits.[4] Additionally, the parameters attached to the initial proportions of zero-interest deposits and loans provide guidance on the relationship between the quantity of interest-bearing deposits borrowed and the interest rate paid. Other things being equal, a bank that starts a period with a smaller proportion of zero-interest deposits, and a larger proportion of loans, has greater need to issue interest-bearing deposits during the period. Thus, the coefficients of such variables being significantly different from zero would imply that the interest-bearing deposit rate depends on the quantity borrowed, and so that the interest-bearing deposit supply is not perfectly elastic.

The identification challenge is that the initial proportions of zero-interest deposits and loans are endogenous. Both zero-interest deposits supply and loan demand depend on elements such as advertising, managerial ability, and effort, which are decided by each bank and are mostly unobservable. These elements also affect the quantity of zero-interest deposits and loans after the monetary policy change is realized. Thus, they affect the interest-bearing deposit rate paid and enter into the unobservable term. This makes the initial proportions of zero-interest deposits and loans correlated with the error term, and an OLS estimation inconsistent and biased. I make use of instrumental variables techniques. I exploit a novel set of exogenous shifters derived from the demographic and economic variations that hit the location of each bank. Using data from the Survey of Consumer Finances and the Consumer Expenditure Survey, I first provide household-level evidence that demographics influence the supply of zero-interest deposits and the demand for

[4] Using this specification, I hypothesize that monetary policy changes affect the quantity of zero-interest deposits available to each bank proportionally to the amount initially borrowed.

loans by households and firms. For example, the older the household, the larger the amounts in his checking accounts, and the larger are his expenditures. In aggregate, therefore, when population age increases, local firms face higher demand for their products and services, and may also increase the demand for bank loans. I obtain a broad set of county-year level demographic and economic characteristics, and I aggregate them to the bank-year level depending on where each bank has its branches. I show that these shifters change banks' amounts of zero-interest deposits and loans, and the effects are consistent with the household-level analysis. In fact, banks that are located in areas where the mean age of the population increases display upward shifts in the proportions of zero-interest deposits and loans to total assets.

Armed with these exogenous shifters, I assess the effects of the three explanatory variables on the interest-bearing deposit rate.[5] The main finding is that the the interest-bearing deposit rate relates positively to the interaction term of the initial proportion of zero-interest deposits with the monetary policy change, and the effect is strongly significant. This indicates that in periods of tight monetary policy, the amount of zero-interest deposits decreases, and banks substitute such outflow by issuing interest-bearing deposits at increasing interest rates. This last point is confirmed by the other estimated parameters. The interest-bearing deposit rate decreases the larger the initial proportion of zero-interest deposits, and increases the larger the initial proportion of loans. In other words, the interest-bearing deposit rate increases with the quantity being borrowed, and the supply is not perfectly elastic. All these findings are robust to the inclusion of variables that control for each bank's ability and/or necessity to collect interest-bearing deposits, for example the bank capitalization (e.g. Kishan and Opiela (2000), Gambacorta and Mistrulli (2004), Gambacorta (2005), and Jiménez et al. (2012)), the participation to a bank holding company (Campello (2002), Gambacorta (2005), and Ashcraft (2006)), and the international scale of activity (Cetorelli and Goldberg (2012)).

I assess the economic importance of the mechanism using the estimated parameters. I measure the effect on banks' interest-bearing deposit rate of the increase of 119 bps in the Federal funds rate that happened between June 30, 2004 to June 30, 2005. I am interested only in the change in banks'

[5]In my specification, I absorb any aggregate component by time fixed effects. Equally, I control for every time-invariant bank-specific element with bank fixed effects. Finally, I control for the contemporaneous demographic changes, as these shift the contemporaneous supply of zero-interest deposits and demand for loans. In fact, the more customers supply zero-interest deposits and the less they demand for loans, the less a bank needs to borrow interest-bearing deposits.

interest-bearing deposit rate that is due to the substitution of outflowed zero-interest deposits with interest-bearing deposits, and not in the part due to the generalized increase in market interest rates. I take two banks that differ for one standard deviation in the proportion of zero-interest deposits as at June 30, 2004, and measure how expensive is to substitute the outflow coming from such extra standard deviation. My estimates suggest that the bank that has one extra standard deviation on June 30, 2004 needs to pay interest-bearing deposits 1.6 bps more in the following period. To put this number in perspective, the standard deviation of the interest-bearing deposit rate paid by banks in the period is 55 bps. This means that the substitution of one extra standard of zero-interest deposits explains around 3% of the standard deviation of the interest-bearing deposit rate. This effect is non-negligible, particularly if one thinks that it is net of the effects of zero-interest deposit supply and loan demand shocks, and bank fixed effects, which are likely to be important determinants of the interest-bearing deposit rate's cross-sectional variation.

My baseline model does not directly investigate how monetary policy affects the quantity of zero-interest deposits available to banks, and the substitution of funding sources. It derives those patterns from the analysis of the observed interest-bearing deposit rates. I then corroborate my findings by directly studying the dynamics of the bank-level log dollar quantities of zero-interest deposits and interest-bearing deposits. These quantities are functions of their past levels, the level of the Federal funds rate, GDP growth, inflation, the demographic and economic shifters, and bank fixed effects. The regressions confirm the findings obtained in the analysis of the interest-bearing deposit rate. For every 100 bps increase in the Federal funds rate, the quantity of zero-interest deposits available to banks decreases by 1.37%. When confronted with such outflow, banks increase their borrowings of interest-bearing deposits by .64%. Thus, they do substitute zero-interest deposits with interest-bearing deposits.

In a recent contribution, Drechsler et al. (2015) propose and test a mechanism of monetary policy transmission that depends on the banking market structure. They first conjecture that when monetary policy tightens, households decrease their holdings of cash and zero-interest deposits, and look for more profitable investments. Since banks have the monopoly in creating liquid assets that pay interest, i.e. the interest-bearing deposits, tight monetary policy raises their market power, especially in more concentrated banking markets. They confirm their theoretical predictions using data on U.S. banks. They show that in case of tight monetary policy, the greater the banking market concentration, the less banks revise their deposit rates upward, and the lower are the increases in the quantity of interest-bearing deposits flowing to them. Overall, their analysis concentrates on how banks optimally price interest-bearing deposits depending on the monetary policy stance and the banking market structure. For comparison, my analysis shows instead that monetary policy does alter the quantity of zero-interest deposits available to banks, and forces them to substitute zero-interest deposits with interest-bearing deposits at increasing interest rates. Nevertheless, my baseline model can be extended to understand how the substitution mechanism changes with bank size and banking market concentration, so to also incorporate the insights of Drechsler et al. (2015). I find that when monetary policy tightens, the quantity of zero-interest deposits available to banks decreases irrespectively of bank size and banking market concentration. However, banks located in more concentrated markets observe a smaller increase in their interest-bearing deposit rates, and substitute the outflow of zero-interest deposits to a lower extent. This is consistent with such banks being less willing to increase their deposit rates as found by Drechsler et al. (2015). Conversely, mixed evidence appears for bank size. In case of monetary policy tightening, larger banks issue interest-bearing deposits to a lower extent. This confirms that they can substitute the outflow of zero-interest deposits in markets alternative to the one of interest-bearing deposits, for example the wholesale market. However, I do not find that this is associated to a lower increase in the interest-bearing deposit rate, which is what may be expected from the smaller issue of interest-bearing deposits.

Finally, I conduct several robustness checks that challenge the validity of the instrumental variables used. First, I use as IVs further lags of the demographic changes. This relaxes the initial assumption that demographic changes only affect the contemporaneous quantities of zero-interest deposits and loans. Second, I provide reduced-form estimates, which further relax the initial identifying assumption. The exclusion restriction is now that past demographic changes do not have different effects on contemporaneous zero-interest deposit supply and loan demand depending on the contemporaneous monetary policy change. Third, I address the possible critique that demographic variables are aggregated to the bank level using banks' endogenous branch network, and are thus themselves endogenous. I re-construct bank level demographic variables fixing banks' branch networks to 1994. 1994 is the last year before the Riegle-Neal Act was effective, and therefore represents a moment at which cross-state branching operations were restricted (Johnson and Rice

(2008)). Banks' branch network as at 1994 can then be considered exogenous. All the robustness checks confirm my findings.

This paper is mainly related to the literature on the bank lending channel of monetary policy transmission (Bernanke and Blinder (1988) and Bernanke and Gertler (1995)). Kashyap and Stein (1994) suggest that the lending channel arises when monetary policy forces banks to substitute funding sources, and this substitution is not costless. One reason banks are unable to costlessly replace a funding outflow with alternative liabilities is that the supply of such alternatives is imperfectly elastic.[6] To my knowledge, I am the first to characterize how monetary policy impacts banks' liability structures and funding costs. Therefore, this paper adds to the literature by providing evidence that monetary policy alters the quantity of zero-interest deposits available to banks, forcing them to substitute zero-interest deposits with interest-bearing deposits. It finds that such substitution is increasingly costly, thus pointing to an imperfect elasticity of the interest-bearing deposit supply. As a result, this paper corroborates the existing rich empirical literature on the bank lending channel.[7]

This paper also connects to the literature on money demand. Meltzer (1963) studies the relationship between the quantity of money, which includes cash and zero-interest deposits, the nominal interest rate, and a measure of economic activity. The quantity of money decreases the higher the nominal interest rate, as this is its opportunity cost. Lucas (1988) finds an interest rate semi-elasticity equal to -0.1, for a sample period ending in 1985. Other analyses, which focus on more recent periods, find a lower interest rate semi-elasticity. For example, Ball (2001) and Teles and Zhou (2005) find -.05, while Ireland (2009) -.018. In my paper, I find an interest rate semi-elasticity equal

[6] Stein (1998), Kashyap and Stein (2000) and Jayaratne and Morgan (2000) argue that the imperfect elasticity is due to adverse selection. Monetary policy changes shift the supply of insured deposits, and banks have the ability to adjust their funding needs only by raising uninsured funds. In presence of adverse selection, banks cannot raise any amount of uninsured funds, and are credit rationed at equilibrium. So, a monetary policy tightening, which reduces the amount of insured deposits, decreases the overall amount of bank liabilities, and thus bank loan supply. Maechler and McDill (2006) provide empirical evidence that financially sound banks can raise uninsured deposits by raising the associated interest rate, while weak banks cannot. Maechler and McDill (2006) do not investigate, however, if monetary policy changes actually shift the supply of insured deposits to banks.

[7] The lending channel is found to be heterogeneous in the cross-section of banks. Monetary policy tightenings are followed by smaller loan supply decreases in larger banks (e.g. Kashyap and Stein (1995, 2000) and Kishan and Opiela (2000)), in banks with a larger buffer of liquid securities (Kashyap and Stein (2000) and Jiménez et al. (2012)), in more capitalized banks (Kishan and Opiela (2000), Gambacorta and Mistrulli (2004), Gambacorta (2005), and Jiménez et al. (2012)), in banks that are part of a multi-bank holding company (Campello (2002), Gambacorta (2005) and Ashcraft (2006)), in banks with international scope (Cetorelli and Goldberg (2012)), and in banks with a higher exposure to interest rate risk (Landier, Sraer, and Thesmar (2013)).

to -0.0137. Thus, I find a magnitude similar to the one of Ireland (2009).[8] Closely related to the money demand literature, Nagel (2015) analyzes the substitution between money and near-money assets and the implied liquidity premia.

Finally, this paper is also connected to a growing body of literature that looks at how liquidity shocks that hit banks are eventually transmitted to their loan supply (Khwaja and Mian (2008), Paravisini (2008), Iyer and Peydro (2011), and Gilje, Loutskina, and Strahan (2013)).[9] My findings indicate that substituting funding sources is not costless. Any outflow of zero-interest deposits, originated by a monetary tightening or any other cause, forces banks to borrow at increasing costs. As a consequence, potential loans that would bring a marginal revenue that is lower than the increased marginal cost are unserved, which is why loan supply decreases.

The remainder of the paper is organized as follows. Section 2 describes the mechanism and the identification strategy that enables me to test it. Section 3 presents the instrumental variables I use and the conditions under which they are valid. Section 4 displays the results, and Section 5 presents the robustness checks. Finally, Section 6 concludes.

2 The mechanism and the identification strategy

2.1 U.S. bank deposit types and the associated interest rates

Figure 1 shows that U.S. small- and medium-sized banks have, on average, 85% of their total assets backed by domestically raised deposits. The percentage is slightly lower for large banks, at around 75%.[10] U.S. bank deposits are not, however, homogenous.

Demand deposits are "*deposits that are payable on demand*", and are used by depositors as a liquid store of value.[11] Until July 21, 2011, Regulation Q explicitly prohibited interest payments

[8]Note, however, that my analysis displays two main differences relative to the cited studies. First, I focus on zero-interest deposits only, and not on a money aggregate. Second, I use a panel of bank-level zero-interest deposit amounts, while other analyses use aggregate data.

[9]Similarly, Peek and Rosengren (1997), Chava and Purnanandam (2011), Schnabl (2012), and Cetorelli and Goldberg (2012), analyze how liquidity shocks from abroad propagate into the domestic credit market through cross-border ownership of banks.

[10]I define small banks as those below the 50th percentile for total assets nationally in a given period. Medium banks are those between the 50th percentile and the 95th percentile. Large banks are those above the 95th percentile.

[11]FRB Regulations, Part 204, Sec. 2. Definitions.

on these deposits.[12] There were no such restrictions on savings deposits, money market deposit accounts, and time deposits, raised both in small denomination (< \$100,000) and in large denomination (> \$100,000) accounts. Those deposits were allowed to pay a positive interest rate, while being less liquid than demand deposits and similar to securities such as Treasury Bills.

The Federal Reserve Board's Regulation D requires banks to hold a certain fraction of their reservable liabilities in reserves.[13] Reservable liabilities consist of net transaction accounts, non-personal time deposits, and eurocurrency liabilities. Net transaction accounts, in turn, are composed essentially of demand deposits.[14] Since December 27, 1990, however, non-personal time deposits and eurocurrency liabilities have had a reserve ratio of zero. As a consequence, demand deposits must almost exclusively be backed by reserves.

In the period from June 30, 1994 to June 30, 2008, which is the focus of this analysis, demand deposits pay no interest and are reservable. On the opposite, other deposits are allowed to pay interest, and are not reservable. In the following, I will distinguish between those two deposit types referring to the first as zero-interest deposits and to the second as interest-bearing deposits. Note that zero-interest deposits and interest-bearing deposits do not differ with respect to deposit insurance. The coverage limit for both was \$100,000 until October 3, 2008, at which point it was raised to \$250,000.[15] In practice, therefore, both zero-interest deposits and interest-bearing deposits may be only partly insured.

Interest-bearing deposits are the major source of funding that is alternative to zero-interest deposits.[16] Thus, the interest-bearing deposit rate may be taken as the main interest rate that a

[12]FRB Regulations, Part 217, Sec. 3. Interest on demand deposits. The Board of Governors of the Federal Reserve System repealed the prohibition, implementing Section 627 of the Dodd-Frank Wall Street Reform and Consumer Protection Act, with effective date July 21, 2011.

[13]These take the form of vault cash and, if vault cash is insufficient, of a deposit maintained with a Federal Reserve Bank.

[14]Total transaction accounts include demand deposits and automatic transfer service (ATS) accounts, NOW accounts, share draft accounts, telephone or preauthorized transfer accounts, ineligible bankers acceptances, and obligations issued by affiliates maturing in seven days or less. To get the net, one has to subtract from total transaction accounts the amounts due from other depository institutions and cash items in the process of collection.

[15]Preliminarly, the Congress approved a temporary increase which was effective through December 31, 2010. On July 21, 2010, President Barack Obama signed the Dodd-Frank Wall Street Reform and Consumer Protection Act into law, which permanently raised the current standard maximum deposit insurance amount to \$250,000. Also, before and after the crisis, particular sub-categories of deposits were given extra coverage.

[16]This is particularly true for small- and medium-sized banks. These banks finance mainly with retail – i.e. fully insured – deposits, and have limited access to alternative funding sources, such as wholesale markets (Bassett and Brady (2002) and Park and Pennacchi (2009)). On the contrary, large banks have the ability to finance on wholesale markets. Note, however, that interest-bearing deposits include large denomination time deposits, which are often considered as wholesale financing (e.g. Song and Thakor (2007) and Huang and Ratnovski (2011)).

bank needs to pay if it needs to substitute zero-interest deposits. Moreover, unless the supply of interest-bearing deposits is perfectly elastic, banks are not able to finance an arbitrary amount of interest-bearing deposits at a constant interest rate. The interest rate required by investors may be increasing with respect to the quantity to finance: the larger the amount to borrow, the higher the interest rate to pay. As I detail in the following, the interest rate elasticity of the supply of interest-bearing deposits will mediate the effect of monetary policy changes on the interest-bearing deposit rate.

2.2 The mechanism

The Federal funds rate is the price at which banks trade their reserves. When the Federal Reserve changes its monetary policy stance, it targets a new Federal funds rate, and may conduct open market operations to reach it.[17] In open market operations the central bank trades with commercial banks and exchanges securities, such as Treasury Bills, against money (reserves). For example, when the Federal Reserve aims for a tight monetary policy, it announces a higher target for the Federal funds rate. Unless the effective Federal funds rate automatically adjusts, the Federal Reserve sells securities and withdraws money held in banks' reserves until the target is reached. In the process, the price of securities decreases, and their implied return increases.

Monetary policy may thus alter the quantity of zero-interest deposits that is available to banks. This happens for at least two reasons. First, in the conduct of monetary policy, the Federal Reserve directly manipulates the amount of reserves (Bernanke and Blinder (1988) and Kashyap and Stein (1995)). Since reservable liabilities – i.e. zero-interest deposits – are a fixed multiple of reserves, setting the amount of reserves corresponds then to setting the amount of zero-interest deposits. Second, as argued by Disyatat (2008, 2011), monetary policy affects zero-interest deposits by changing their opportunity cost. Because zero-interest deposits may not pay interest, their opportunity cost depends on the profitability of alternative investments (e.g. interest-bearing deposits, Treasury Bills). When monetary policy alters such profitability, it thus affects the quantity of zero-interest deposits available to banks.

[17] Guthrie and Wright (2000) suggest that "open mouth" operations are actually enough for the coordination on the new target rate. The central bank has the ability to move rates simply by announcing its intentions. The threat to adjust liquidity as needed to achieve the target rate makes, in fact, the market coordinate on the new rate.

To summarize, to the extent that tight monetary policy implies both a reduction in reserves and an increase in market interest rates, the quantity of zero-interest deposits available to banks may decrease. The opposite may hold for a loose policy. At the same time, monetary policy also affects the supply of interest-bearing deposits to banks. In fact, to the extent that market interest rates adjust for monetary policy changes, the opportunity cost of interest-bearing deposits alters, and this shifts investors' supply. For example, an increase in market rates shifts the opportunity cost of interest-bearing deposits upward, and pushes interest-bearing depositors to require a higher interest rate.

This discussion suggests that monetary policy may change banks' liability structure. A tight monetary policy may decrease the quantity of zero-interest deposits available to banks, forcing them to raise interest-bearing deposits. In turn, the interest-bearing deposit rate required by investors may also increase because of the direct effect of monetary policy on market rates. The key question that I address, however, is whether substituting outflowed zero-interest deposits with interest-bearing deposits is increasingly expensive. This is particularly important because, if that was the case, a bank that observed a larger outflow of zero-interest deposits would need to pay a higher interest-bearing deposit rate, and may decide to reduce its loan supply more. In the online appendix I build a stylized theoretical model that provides a theoretical background to this discussion. Here I report its main outputs.

A monopolistic bank operates over two periods. In both periods, the bank invests in loans and has access to zero-interest deposits and interest-bearing deposits. In the first period, the bank can choose both the amount of loans and the liability structure. Even though zero-interest deposits cannot be directly remunerated, the bank can attract them providing greater "service quality". Service quality can be an extensive branch and/or ATM network, but also any other non-interest feature that zero-interest depositors may value, such as advertising and marketing.[18] In the second period, a stochastic monetary policy shock hits the economy, and the supplies of zero-interest deposits and interest-bearing deposits are modified in response. The bank can only optimize over the quantity of loans. In fact, the service quality that the bank installed in period 1 may still attract

[18]Empirical studies, reviewed by VanHoose (2010), find that service quality affects depositors' choices. In these analyses, service quality takes the form of weekly office hours/24h ATM service (Heggestad and Mingo (1976)), branch density (Kim and Vale (2001) and Cerasi et al. (2002)), and IT/advertising outlays (Martín-Oliver and Salas-Fumás (2008)).

new zero-interest deposits, but cannot be adjusted in period 2. Such would be the case, for example, of an advertising campaign that took place in period 1, and still triggers effects in period 2.

Consider now two scenarios. Relative to the first, in the second scenario, the bank has a larger amount of zero-interest deposits at the end of period 1. In both cases, the supply of interest-bearing deposits is not perfectly elastic, and the interest-bearing deposit rate is increasing with the quantity to finance. In period 2, monetary policy tightens. As a consequence, zero-interest deposits decrease proportionally to the amount initially held. In both scenarios the bank substitutes the outflowed zero-interest deposits issuing more interest-bearing deposits. However, because the interest-bearing deposit rate increases with the amount being borrowed, the interest-bearing deposit rate paid by the bank in the second scenario is higher than the one paid in the first scenario. In fact, the larger the amount of zero-interest deposits with which the bank starts period 2, the larger the amount to substitute, and the more the interest-bearing deposit rate increases. This, in turn, affects period 2 loan supply. When it is more expensive to obtain funding, for the bank it is optimal to reduce its loan supply further. So loan supply decreases more in the second scenario. This mechanism is in accordance with Kashyap and Stein (1994), who suggest that if the bank is not able to borrow any amount of interest-bearing deposits at a constant interest rate, any outflow of zero-interest deposits decreases bank loan supply.

The mechanism and its magnitude rest on two elements. First, the sensitivity of zero-interest deposits to monetary policy changes. Second, the imperfect elasticity of the supply of interest-bearing deposits. If zero-interest deposits are very sensitive to monetary policy changes, a mild monetary policy tightening may cause a massive outflow of zero-interest deposits, leading banks to obtain a large amount of interest-bearing deposits, thus facing a large increase in the interest-bearing deposit rate. Similarly, when when the supply of interest-bearing deposits is almost inelastic, a minimal increase in the quantity of interest-bearing deposits requires a large increase in the interest rate.

The main output of the model is the equation that links the interest-bearing deposit rate to the initial amount of zero-interest deposits and the monetary policy change. It can be directly brought to the data, and allows me to test the mechanism by measuring the change in the interest-bearing deposit rate that is due to the substitution of zero-interest deposits with interest-bearing deposits.

2.3 Banking data

I obtain data on U.S. commercial and savings banks from the Federal Deposit Insurance Corporation (FDIC), the U.S. agency responsible for providing deposit insurance to account holders. All FDIC-insured banks, filers of either the Reports of Condition and Income (Call Reports), or Thrift Financial Reports, are accounted for. I employ two datasets: the Statistics on Depository Institutions (SDI); and the Summary of Deposits (SOD). The first includes balance sheets and income statements on a quarterly basis. The second displays every branch location for each bank, and the amounts of deposits collected therein, as at June 30 of every year. The period under consideration is from June 30, 1994 to June 30, 2008.

Unfortunately, the demographic and economic information that I merge with the bank level data is released only as at July 1 of every year. In this study, therefore, periods are one-year long and run from July 1 to the following June 30. Stock banking data – i.e. balance sheet variables – are taken as at June 30. Instead, quarterly flow banking data – i.e. income statement variables – need to be manipulated in order to obtain yearly figures.

The interest-bearing deposit rate is the main variable to be constructed from the flow banking data. It is defined as follows. First, I obtain quarterly interest rates dividing the domestic deposit interest payments realized during a quarter by the amount of interest-bearing deposits outstanding at the end of the previous quarter. I compound the gross quarterly interest rates realized in the four quarters that compose the period of interest. Then, I subtract one. So, for example, the 1996 interest-bearing deposit interest rate paid by a given bank is the product of the gross quarterly interest rates realized during the third and fourth quarters of 1995, and first and second quarters of 1996, minus one.

As argued, for example, by Adams (2012), the consolidation process experienced by the U.S. banking industry in the last twenty years includes many mergers and acquisitions. It is not clear what the effects on my analysis would be of including observations from banks involved in such activities. Thus, I isolate mergers and acquisitions in two ways. First, I obtain the list of mergers from the website of the Chicago Federal Reserve Bank. I exclude observations of banks engaging in such activities in that particular year. Second, I compute the year-specific distribution of banks' total assets growth, and I exclude observations below the first percentile or above the 99th.

2.4 Identification strategy

I observe an unbalanced panel of J banks operating over T periods. At any period t, the interest-bearing deposit rate paid by bank j is r_{jt}, and it is expressed in hundreds of basis points (bps). Consistent with the theoretical model in the online appendix, I define d_{jt-1} as the amount of zero-interest deposits that j has at $t-1$ normalized by j's total assets at $t-2$. Similarly, l_{jt-1} is the amount of total loans and leases that j has at $t-1$ normalized by j's total assets at $t-2$. Also, d_{jt-2} (l_{jt-2}) is the amount of zero-interest deposits (loans and leases) that j has at $t-2$ normalized by $t-2$ total assets.[19]

The change in monetary policy stance that happens in period t is proxied by the change in the Federal funds rate, ΔFF_t.[20] This is in line with Bernanke and Blinder (1992) and Kashyap and Stein (2000). Both ΔFF_t and r_{jt} are expressed in hundreds of bps.

I model r_{jt} as:

$$r_{jt} = \gamma d_{jt-1} + \gamma^{\Delta FF} \left(d_{jt-1} \times \Delta FF_t\right) + \delta l_{jt-1} + \beta shifters_{jt} + \eta_t + \eta_j + \eta_{jt} \qquad (1)$$

where $shifters_{jt}$ are bank-period specific shifters of zero-interest deposit supply and loan demand. η_t and η_j are time and bank fixed effects, while η_{jt} is the idiosyncratic error.

The key parameter of interest is $\gamma^{\Delta FF}$. Suppose that when the bank borrows more interest-bearing deposits it needs to pay a higher interest rate. The supply of interest-bearing deposits is therefore not perfectly elastic. If period t monetary policy change ΔFF_t decreases the quantity of zero-interest deposits available to banks proportionally to the amount initially borrowed, and bank j responds by borrowing more interest-bearing deposits, r_{jt} increases. $\gamma^{\Delta FF}$ measures the change in r_{jt} due to the substitution of zero-interest deposits with interest-bearing deposits. Specifically, $\gamma^{\triangle FF}$ traces the impact on r_{jt} of a 100 bps change in the Federal funds rate per unit of zero-interest

[19]The normalizing factor of period $t-1$ and period $t-2$ zero-interest deposits and loans is arbitrary. One alternative could have been to normalize by the total assets of each period. The reason I use this specification, however, is that it allows me to isolate the effects of different shifters on zero-interest deposits and loans. For example, when I regress d_{jt-1} over d_{jt-2} and such shifters, the shifters explain the normalized change in zero-interest deposits, and the specification allows me to measure their effect. If I used, instead, the normalization by each period's total assets, and regressed the normalized amount of zero-interest deposits over the shifters, I would not be able to say if those impact zero-interest deposits, or total assets, or both.

[20]I obtain historical data on the Federal funds rate from the website of the Federal Reserve Bank of New York. I take the geometric average of the effective daily Federal funds rate over period t, and over period $t-1$. I take the difference between the two, and obtain ΔFF_t.

deposits held at $t-1$. It is important to note that $\gamma^{\triangle FF}$ is different from zero when both the supply of interest-bearing deposits is not perfectly elastic, and zero-interest deposits are sensitive to monetary policy changes.

A direct test on the elasticity of the interest-bearing deposit supply can be performed studing the estimates of the parameters γ and δ. Since zero-interest deposits are alternative to interest-bearing deposits, γ is significantly different from zero only when the interest-bearing deposit rate depends on the quantity borrowed. In that case, in fact, the more a bank borrows zero-interest deposits, the less it needs to borrow interest-bearing deposits, and the lower is the impact on the interest-bearing deposit rate. Testing if γ' estimate is significantly different from zero is thus equivalent to testing if the supply of interest-bearing deposits is perfectly elastic. Moreover, suppose that γ's estimate appears to be negative. This would suggest that, for a bank, obtaining funding through zero-interest deposits prevents the interest-bearing deposit rate from rising, which also means that the interest-bearing deposit rate increases with the quantity being borrowed. The sign of γ therefore provides indication on whether the interest-bearing deposit rate increases or decreases with the quantity being borrowed.

A similar reasoning holds for δ's estimate. Other things equal, a bank that starts a period with a larger amount of loans on its balance sheet has to obtain a larger quantity of interest-bearing deposits over the period. In fact, bank loans cannot be liquidated quickly, and tend to stay on the balance sheet from one period to the other, also irrespective of the monetary policy change.[21] This implies that δ captures the extent to which the interest-bearing deposit rate changes or not with the quantity being borrowed.

The model controls for the exogenous shifts in loan demand and zero-interest deposit supply. The reason is that if r_{jt} is a function of the quantity of interest-bearing deposits that j borrows, changes in loan demand and zero-interest deposit supply affect the quantity of interest-bearing deposits demanded by the bank, and in turn the interest rate paid. Aggregate components, such as GDP growth, are captured by the time fixed effect η_t, while bank-specific components are captured

[21] The argument about the liquidity of the bank balance sheet is linked to prior evidence on the bank lending channel. Among others, Kashyap and Stein (2000) and Jiménez et al. (2012) note that when monetary policy tightens, banks with larger buffers of liquid securities on their balance sheet are able to decrease their loan supply to a lower extent. The reason is that they have a greater ability to respond to the withdrawal of zero-interest deposits by liquidating the securities they have, without the need to decrease their loan supply. Here the reasoning is regarding the necessity to keep the amount of liabilities unaltered. Controlling for the initial proportion of loans and leases is, essentially, controlling for the need to borrow interest-bearing deposits over the period.

by the vector $shifters_{jt}$. In the following section I detail what variables are included in this vector. Finally, note that the time fixed effect η_t also controls for the direct effect that monetary policy has on market interest rates. This means that, for example, an increase in the general level of market interest rates is captured by η_t, and $\gamma^{\Delta FF}$ purely captures the change in the interest rate paid due to the substitution of zero-interest deposits with interest-bearing deposits.

2.5 Endogeneity of d_{jt-1} and l_{jt-1}

As discussed, banks can attract zero-interest deposits providing greater service quality. Examples of service quality include a large branch network, advertising, and managerial effort and ability. The amount of zero-interest deposits that a bank displays at $t-1$, d_{jt-1}, depends on the service quality provided at $t-1$. Similarly, while not specifically modelled, it is likely that period $t-1$ loan demand, and thereby l_{jt-1}, are also a function of period $t-1$ service quality. Investments in service quality are typically not measurable and may have effects for more than one period. In that case, the amount of loans and zero-interest deposits at t are also a function of period $t-1$ service quality. So, if the interest-bearing deposit rate depends on the quantity borrowed, r_{jt} is also a function of period $t-1$ service quality. Because service quality cannot be measured, it enters in (1) in the unobservable η_{jt}. However, as d_{jt-1} and l_{jt-1} are a function of period $t-1$ service quality, they correlate with η_{jt}, and are endogenous in (1).

When banks have the ability to provide service quality, so as to affect zero-interest deposit supply and loan demand, estimating (1) by OLS leads to inconsistent and biased estimates. IV techniques, however, can apply. The (excluded) IVs need to correlate with the endogenous variables d_{jt-1} and l_{jt-1}, but need to have zero correlation with η_{jt}. In other words, such variables need to affect the amount of zero-interest deposits and loans that a bank has, but do not have to depend on the service quality that the bank provides. Moreover, they need not to display effects in period t, otherwise they should be included as regressors in (1).

My strategy is to think to current amounts of zero-interest deposits and loans as functions of their past levels and past shifters, $shifters_{jt-1}$. Those lagged endogenous values and shifters can thus be used as IVs in (1) under few conditions. In the following section, I discuss a set of zero-interest deposits supply and loan demand shifters derived from demographic and economic variations. I detail the vector of IVs and the conditions under which such variables are valid IVs.

3 The instrumental variables

3.1 Demographics as shifters of zero-interest deposits and loans

The Flow of Funds of the U.S. indicates that in 1994 households held 51% and nonfinancial businesses held 25% of the $1240.2bn aggregate amount of checkable deposits and currency. In 2010, of the total amount of $2359.8bn, households held 18% and non-financial businesses held 32%. That suggests that zero-interest deposits supply essentially depends on these two players and shocks hitting them or their preferences should be ultimately experienced by banks. The effect of households' demographic characteristics on deposit supply is not new. Becker (2007) looks at U.S. metropolitan statistical areas (MSAs) and draws a causal relationship between each MSA's fraction of seniors (people aged 65 or more), the amount of deposits (not distinguishing by type of deposits) collected by banks, and the number of firms operating in the MSA. In addition, demographics may also have a direct effect on firms' loan demand to the extent that they affect households' spending and consumption.

To understand the effects of households' demographic characteristics on the zero-interest deposit supply and loan demand in a given geographical region, two margins need to be considered. The first is how households' demographics affect households' direct holdings of zero-interest deposits. The second is how households' demographics affect consumption and spending and, as a consequence, firms' holdings of zero-interest deposits and loan demand. The second margin, which relates to the macroeconomic effects of demographics, merits an example. At the aggregate level, if household spending is larger, so do firms' money holdings. Firms, in fact, exchange with households, and receive cash against goods and services. To meet the greater demand, firms may place larger orders for their inputs, and may do so upstream firms as well. So, the increase in households' spending may stimulate firms' willingness to invest, and firms' loan demand may also increase.

I first analyze households' holdings of zero-interest deposits as a function of their demographic characteristics. The Survey of Consumer Finances collects household-level information on checking account holdings together with demographic characteristics, such as age, race, level of education, income, and number of people in the household. I obtain data for the years 1995, 1998, 2001, 2004, 2007, and 2010. Then, I explain the probability that a household has a checking account by its demographic characteristics using the Probit model:

$$\Pr\left[Own\,check\,acct_{ht} = 1 | X_{ht}\right] = \Phi\left(X_{ht}\alpha\right)$$

where subscripts h and t denote, respectively, households and time. $Own\,check\,acct_{ht}$ takes the value of one when h has a checking account at t, and $\Phi(.)$ is the cumulative normal distribution function. X is a matrix of households' demographic characteristics. It includes the age of the head (Age), the log of the number of people in the household ($\log(HHsize)$), controls for race and education, the household (log) total income ($\log(inc)$), and year dummies. The controls for race are $Black$, $Hispanic$, and $Other$, and take the value of one if the head is, respectively, black/African-American, hispanic, or either Asian, American Indian/Alaska Native or Native Hawaiian/Pacific Islander. The controls for education are $College$ and PhD, which equal to one if the head has taken any college-level, respectively PhD-level, classes.

Next, conditionally on the household having at least one checking account, I explain the (log) dollar amount that it detains ($Check\,acct_{ht}$) by the usual demographic characteristics (X_{ht}) using the model:

$$\log\left(1 + Check\,acct_{ht}\right) = X_{ht}\beta + u_{ht}$$

where u_{ht} denotes the error term.

Table 1 displays the results.[22] Demographics do affect both the probability of having a checking account and the amounts stored therein, and in the same direction. The relationship is positive with income, education level and age. It is negative with the household being non-white, with a particularly strong magnitude in the case of black/African-American. The result on age is consistent with that of Becker (2007). Similarly, the effect of belonging to a minority is coherent with the analysis conducted by the Federal Deposit Insurance Corporation in January 2009 (FDIC (2009)).

[22] The Survey of Consumer Finances uses multiple imputation to correct for missing and sensitive data. Every respondent is accounted five times in the public dataset (Kinneckell (2000)). Because not all observations are independent, neglecting multiple imputation in a regression analysis would result in artificially high t-values. I follow the approach described in Puri and Robinson (2007) and use for my estimations the package *rii* developed for Stata by Dan Blanchette and David Robinson. Standard errors are adjusted averaging the standard errors from each imputation, plus adding on a term that accounts for the variation across implicates. This technique is derived from Montalto and Sung (1996) and Little and Rubin (1987).

Using data from a special supplement to the U.S. Census Bureau's Current Population Survey, that study finds that a large fraction of U.S. households do not have a bank account, and that participation is particularly low amongst minorities. Table 1 also reveals that the more numerous is the household – i.e. the larger is $\log(HHsize)$ – the lower is the amount held in the checking account(s). Arguably, the reason is that larger households spend more and this depletes the holdings of cash and zero-interest deposits.

I then analyze households' expenditures as a function of their demographic characteristics. I obtain micro data on households' quarterly expenditures from the 2003 Quarterly Interview Survey, included in the Consumer Expenditure Survey (CEX). I explain the (log) dollar amount of a household's expenditures (Exp) by its demographic characteristics X following the model:

$$\log(1 + Exp_h) = X_h\beta + u_h$$

where h indicates the household, and u_h the error term. I consider different types of expenditures Exp: total expenditures ($Total$), total food expenditures ($Food$), total expenditures for food consumed at home ($Home\,food$), total expenditures for shelter, utilities, fuels, public services, household operations, housefurnishings and equipment ($House$), total expenditures for housefurnishings and equipment ($Furnish$), and total apparel expenditures ($Apparel$). Similarly to the analysis of households' holdings of zero-interest deposits, X includes the age of the head (Age), the log of the number of people in the household ($\log(HHsize)$), the same controls for race and education, the household (log) total income ($\log(inc)$), but also a control for whether h resides in a urban area ($Urban$), and region dummies.

Results appear in Table 2, and show that expenditures increase with income, education level, and age of the head. Conversely, they decrease when the household belongs to a minority. Consistent with the hypothesis advanced, more numerous households appear to have larger expenditures. Importantly, all demographic characteristics influence all types of expenditures in the same direction.[23]

The analysis of households' holdings of zero-interest deposits and households' expenditures can be combined. Household income and age of the head are positively related to the probability of

[23] The only exception is the age of the head. This is positively related to most types of expenditures (including total expenditure) but negatively to expenditures for housefurnishings and equipment, and for total apparel.

having a checking account, the amount of money stored therein, and the level of expenditures. An increase in per capita income and average age in a given region should then be associated with an increase in the supply of zero-interest deposits, and firms' demand for loans. Minorities have, all other things equal, a lower probability of having a checking account, lower amounts in their checking accounts, and lower expenditures. As a consequence, the higher their presence, the lower the zero-interest deposits supply and firms' loan demand are expected to be. Finally, household size relates negatively to the amounts deposited in the checking accounts, but positively to expenditures. Therefore, its effect on the zero-interest deposit supply in a region depends on which effect is actually dominating. Nevertheless, the effect of household size on firms' loan demand is clear and expected to be positive.

3.2 Bank-level demographic and economic data

The Population Estimates Program (PEP) of the U.S. Census Bureau utilizes current data on births, deaths, and migration, in order to calculate on July 1 every year, the county-level estimates of population, demographic components of change, and housing units.[24] These estimates are often termed "postcensal estimates", and are used for Federal funding allocations and in setting the levels of national surveys. When two consecutive decennial censuses take place, both the beginning and ending populations are known. "Intercensal estimates" are then produced adjusting the existing time series of postcensal estimates for the entire decade to smooth the transition from one decennial census count to the next.[25]

I retrieve intercensal estimates for every county in the U.S. from 1994 to 2008. The variables include the number of people disaggregated by gender, five-year age group, race and ethnicity.[26] I manipulate the data to obtain for each county-year the mean age of the population ($Mean\,age$), the proportion of young ($\leq$ 19 years old, $Prop\,Young$) and elderly people ($\geq$65 years old, $Prop\,Old$),

[24] The data sources considered and confronted are many, and include the Internal Revenue Service (IRS), the Social Security Administration (SSA), the National Center for Health Statistics, and other state and federal agencies.

[25] More specifically, intercensal estimates differ from the postcensal estimates because they rely on a mathematical formula that redistributes the difference between the April 1 postcensal estimate and the April 1 census count at the end of the decade.

[26] The categories of race used by the U.S. Census Bureau come from the Office of Management and Budget Directive No. 15. Race categories are white, black/African-American, American Indian/Alaska Native, Asian/Pacific Islander. The hispanic origin is captured by ethnicity and is not considered as an additional category of race. Therefore, there can be overlappings between any race and the hispanic origin.

the proportion of blacks/African-Americans ($Prop\,Black$), hispanics ($Prop\,Hisp$) and American Indians/Alaska Native, together with Asian/Pacific Islander ($Prop\,Other$). Data on household size are not available at the county-year level. However, as larger households are normally those where the number of children is higher, the proportion of children in the population will be used as a proxy for the average household size in the area.[27]

I also collect county-year per-capita income (after taking the log, $\log(Inc\,pc)$), and number of jobs per-capita ($Jobs\,pc$) from the Bureau of Economic Analysis (BEA), Regional Economic Accounts. Finally, I obtain counties' land area in square miles from the U.S. Census of 2010 and compute the population density dividing the total resident population by that area and taking the log ($Pop\,density$).

As stressed, both demographic and economic data are obtained at the county-year level. Because, in general, banks are located in more than one county, it is necessary to find a way to aggregate this information to the bank-year level. The SOD data displays the precise location of each bank branch. I obtain the total number of branches that a given bank j has at time t, and compute the proportion of branches that j has in county c. This ratio is then used to compute a weighted average of the demographic and economic conditions that the bank faces. In formula, x_{ct} being the county-year demographic or economic variable, and NBR_{jct} the number of branches that bank j has in c at time t, the bank-year demographic variable x_{jt} is

$$x_{jt} = \sum_{c} \frac{NBR_{jct}}{NBR_{jt}} x_{ct}$$

The figures obtained are the demographic levels $demogr_{jt}$. Demographic innovations, $\triangle demogr_{jt}$, are obtained taking the year changes. I present the summary statistics of the demographic levels and innovations in Table 3. The table presents means and standard deviations comparing the years 1996 and 2008. Note that, over this period, banks have been exposed, on average, to a decrease in the proportion of children and increases in the mean age, proportion of minorities (especially his-

[27] I test this relationship using the data from the Survey of Consumer Finances and the Consumer Expenditure Survey. I explain the (log) household size ($HHsize$) by the usual demographic characteristics, plus the proportion of people in the household aged less than 18 ($Prop\,young$), and the proportion of people aged over 64 ($Prop\,old$). Results reveal that household size is strongly and positively related to the proportion of people in the household aged less than 18. The correlation is negative with the proportion of people aged over 64, suggesting that when the number of elderly people increases, the household shrinks in size. All parameter estimates are consistent across the two datasets.

panics), and population density. The other significant point is that demographic changes are very heterogeneous in the cross-section of banks. Their standard deviations are, in fact, much larger than their mean values. Such cross-sectional heterogeneity potentially implies that different banks are exposed to different shocks on their amounts of zero-interest deposits and loans.

3.3 Conditions for the validity of the IVs

I return to model (1) and to the endogeneity of d_{jt-1} and l_{jt-1}. I take bank-year specific demographic changes $\triangle demogr_{jt}$ as shifters for zero-interest deposit supply and loan demand. Thus, $\triangle demogr_{jt}$ enter as regressors in model (1) replacing $shifters_{jt}$. Additionally, I think to d_{jt-1} and l_{jt-1} as functions of their past values, d_{jt-2} and l_{jt-2}, and period $t-1$ demographic changes $\triangle demogr_{jt-1}$. In other words, I think to d_{jt-2}, l_{jt-2}, and $\triangle demogr_{jt-1}$, as IVs for d_{jt-1} and l_{jt-1}. These would be valid instruments under two conditions. First, any unobservable service quality set by banks in period $t-2$ does not trigger any direct effect in period t and so does not fall in η_{jt}. If that was not the case, d_{jt-2} and l_{jt-2}, which depend on period $t-2$ service quality, would be correlated with η_{jt}, and would not be valid instruments. Second, zero-interest deposit supply and loan demand fully adjust for the contemporaneous demographic changes. If, instead, $\triangle demogr_{jt-1}$ had direct effects on period t zero-interest deposit supply and loan demand, they should enter as independent variables in equation (1), and could not be used as IVs.

The baseline estimations that follow assume that d_{jt-2}, l_{jt-2}, and $\triangle demogr_{jt-1}$ are valid instruments. Since d_{jt-1} is endogenous in (1), so is the interaction term $d_{jt-1} \times \Delta FF_t$. Let $\hat{d}_{jt-1}$ be the fitted value resulting from the "preliminary" regression of d_{jt-1} on d_{jt-2}, l_{jt-2}, $\triangle demogr_{jt-1}$, $\triangle demogr_{jt}$, time and bank fixed effects. I follow Wooldridge (2001), and define as (excluded) IVs for $\{d_{jt-1};\ l_{jt-1};\ d_{jt-1} \times \Delta FF_t\}$ the set $\left\{d_{jt-2};\ l_{jt-2}; \triangle demogr_{jt-1};\ \hat{d}_{jt-1} \times \Delta FF_t\right\}$.

In order to challenge the validity of the chosen instruments, Section 5 provides different robustness checks. First, I derive the IVs from further lags of the two endogenous variables and of the demographic changes. The identifying assumption behind this set of IVs is milder than that of the baseline estimations because (1) older amounts of the endogenous variables incorporate levels of service quality that are even more likely to not have any further effects in period t, and (2) demographic changes that are further in time should have even more negliglible effects in period

t. Second, I conduct a reduced-form estimation, in which d_{jt-2}, l_{jt-2}, and $\triangle demogr_{jt-1}$ enter (1) directly as independent variables. The only endogenous variable is $d_{jt-1} \times \Delta FF_t$, and its IV is $\hat{d}_{jt-1} \times \Delta FF_t$. The identifying assumption is milder than the one of the baseline estimations. In fact, it only requires that either period $t-2$ service quality and period $t-1$ demographic changes do not have differential effects on period t zero-interest deposit supply and loan demand depending on the monetary policy change. For example, the increase in population density needs to always have the same effects on zero-interest deposit supply and loan demand irrespective of whether the Federal funds rate has increased or not.

4 Results

4.1 Preliminary regressions

Section 3 presented household-level evidence on the relationship between demographics and zero-interest deposits and loans. Here, I present the bank-level evidence. Banks are located in different areas, and are exposed to different demographic variations. If the household-level analysis is confirmed, the consequence is that banks display different amounts of zero-interest deposits and loans.

In the following "preliminary" regressions, the two endogenous variables d_{jt-1} and l_{jt-1} are function of their past amounts d_{jt-2}, and l_{j-2}, period $t-1$ and period t demographic changes, and time and bank fixed effects. If demographic dynamics actually shapes banks' amounts of zero-interest deposits and loans, the parameters' estimates of period $t-1$ changes should be significantly different from zero. Table 4 presents the results. Following the results of Petersen (2009), I cluster standard errors by bank and year using the formulas contained in Thompson (2011).

In the first column, the dependent variable is the normalized amount of zero-interest deposits, d_{jt-1}, while in the second column the dependent variable is the normalized amount of loans, l_{jt-1}. Overall, demographic changes shape the amounts of zero-interest deposits and loans in the same direction. However, the same change alters the amounts of zero-interest deposits and loans with different magnitudes and significance.

Household size, as proxied by the proportions of children and elderly people, increases both the quantity of zero-interest deposits and loans. The household-level analysis highlights that larger households tend to have smaller amounts of funds in their checking accounts, but have larger expenditures. The results of Table 4 seem to suggest that the effect on expenditures dominates in the aggregate. The more households spend, the more they exchange with firms. The result is that larger amounts of cash and zero-interest deposits circulate in the system and loan demand also increases.

Increases in mean age positively affects both d_{jt-1} and l_{jt-1}. However, statistical significance is mild and appears only when the dependent variable is zero-interest deposits. This is consistent with older households detaining larger amounts of zero-interest deposits, and spending more for consumption. The changes in the proportions of minorities have the expected negative sign, but most display low statistical significance. Only the effect of $\triangle PropHisp_{jt-1}$ on l_{jt-1} is significant at standard levels.

The change in income per capita positively affects the amount of zero-interest deposits and loans, but its effect is not statistically significant. Contrary to the expectations, a positive change in the number of jobs per capita negatively affects zero-interest deposits and especially loans. Finally, population density positively affects both zero-interest deposits and loans, and its effects are strongly significant. The more numerous a community, the more it holds zero-interest deposits, and the more it demands loans.

Finally, the series of zero-interest deposits and loans are very persistent, and the past amounts, d_{jt-2} and l_{jt-2}, appear strongly significant.

4.2 Baseline model

Table 5 presents parameters' estimates of the baseline model (1). The table displays different settings showing the effects of different degrees of saturation and of not correcting for endogeneity. The first column includes aggregate variables, such as GDP growth, as controls, while all other columns include instead time fixed effects. The first three columns display OLS estimates, while the last two display IV estimates. Finally, the third and last column include as regressors the controls for bank capitalization, participation to a bank holding company, and international reach. In all cases, standard errors are clustered by bank and year.

I start with the IV estimates in the fourth column, which should be taken as reference. The main finding is that the interest-bearing deposit rate relates positively to the interaction term of the lagged normalized amount of zero-interest deposits and the Federal funds rate change. Thus, when monetary policy tightens, and $\triangle FF_t > 0$, the more a bank initially finances through zero-interest deposits, the more the interest-bearing deposit rate increases. This suggests that tight monetary policy reduces the quantity of zero-interest deposits available to banks, and forces them to substitute the outflowed zero-interest deposits with interest-bearing deposits. Crucially, for the substitution to be possible, the interest rate needs to increase with the quantity of funding being replaced.

This main result relies on two elements. First, zero-interest deposits are sensitive to monetary policy changes. Second, the supply of interest-bearing deposits is not perfectly elastic and the interest-bearing deposit rate increases with the quantity being borrowed. This latter element can be directly tested within the estimation results. Table 5 shows that the interest-bearing deposit rate is negatively related to the lagged normalized amount of zero-interest deposits. As zero-interest deposits are alternative to interest-bearing deposits, this indicates that the interest-bearing deposit rate increases with the quantity of interest-bearing deposits being borrowed. The more a bank holds zero-interest deposits, the less it needs to borrow on the interest-bearing deposit market, and the lower is the interest rate that the bank pays. As the interest rate depends on the quantity being borrowed, the supply of interest-bearing deposits is not perfectly elastic.

In line with this, Table 5 also shows that the interest-bearing deposit rate is positively related to the initial normalized amount of loans. Holding constant the amount of zero-interest deposits, a larger stock of loans pairs with a larger amount of interest-bearing deposits that the bank needs to borrow. This is because loans cannot be liquidated quickly, and still appear on the bank balance sheet in the following period. The positive effect of the stock of loans on the interest-bearing deposit rate, therefore, provides additional evidence that the interest-bearing deposit rate increases with the quantity of interest-bearing deposits to borrow.

The IVs include period $t-2$ normalized amounts of zero-interest deposits and loans and period $t-1$ demographic changes. Because the number of IVs is greater than the number of endogenous variables, it is possible to perform the Sargan test. This is a test of over-identifying restrictions. The joint null hypothesis is that the instruments used are valid, i.e. uncorrelated with the error term, and that they are correctly excluded from the estimated equation. The p-value is reported at the bottom of the table. It is above usual confidence levels, suggesting that the instruments used are valid.

The presented results are stable across the different settings proposed. However, two important remarks appear comparing the different columns of Table 5. First, the magnitude and the significance of the parameters' estimates increase moving from OLS to IV regression. Indeed, as long as the unobservable term includes any factor that influences the supply of zero-interest deposits and loan demand both at t and $t-1$, OLS parameters are both biased and inconsistent. Second, increasing the degree of saturation of the model does not affect neither the magnitude nor the significance of the parameters' estimates.

On that second element, it is important to note that the results hold when I control for variables that either soften the necessity to raise interest-bearing deposits and/or to ease its collection. Following the literature on the lending channel of monetary policy, I include the Tier1 ratio as a measure of capitalization.[28] The more a bank is capitalized, the less it needs to finance with interest-bearing deposits and, at the same time, the better it signals to interest-bearing depositors about the quality of its assets (Holmstrom and Tirole (1997), Kishan and Opiela (2000), Gambacorta and Mistrulli (2004), Gambacorta (2005), and Jiménez et al. (2012)). In this sense, $Tier\,1\,ratio_{jt-1}$ also captures bank j's risk. Accordingly, I find that banks with a higher Tier1 ratio pay less their interest-bearing deposits, and the effect is strongly significant. I also include two dummy variables, BHC_{jt-1} and $International_{jt-1}$, which capture whether bank j belongs to a bank holding company (BHC) at $t-1$, or, respectively, operates in other countries at $t-1$. They are proxies for the ability to finance through internal capital markets, so to avoid financing on the domestic interest-bearing deposit market. In one case, such a possibility comes from getting funds from other banks in the BHC (Campello (2002), Gambacorta (2005), and Ashcraft (2006)). In the other case, the possibility comes from foreign branches of the bank (Cetorelli and Goldberg (2012)). However, those two dummies do not appear to have a significant effect.

4.3 Economic significance

When monetary policy tightens, the more a bank obtains funding from zero-interest deposits, the larger the outflow of funding that it observes, and the more it needs to pay to substitute that

[28] $Tier\,1\,ratio_{jt-1}$ is defined as the ratio of period $t-1$ amount of Tier 1 (core) capital to period $t-2$ total assets.

outflow. In this subsection, I discuss the quantitative implications of this finding. In particular, I measure to what extent the cross-sectional variation in the interest-bearing deposit rate can be explained by differences in the need to substitute zero-interest deposits.

I consider the following example. On June 30, 2004, the target level of the Federal funds rate was 125 bps. One year later, after eight upward revisions, it became 325 bps. In annualized terms, this monetary policy change corresponds to an increase of 119 bps. Before this change, banks displayed heterogeneous liability compositions. On June 30, 2004, the mean normalized amount of zero-interest deposits is .12 and the standard deviation is .07. At the first percentile, zero-interest deposits are zero, and at the 99st, zero-interest deposits are .36.

I first look at two banks differing for one standard deviation in the amount of zero-interest deposits as at June 30, 2004. Because of the policy change, an extra standard deviation of zero-interest deposits needs to be partly substituted with interest-bearing deposits. I measure the increase in the 2005 interest-bearing deposit rate due to the substitution of such extra standard deviation using the IV estimates of Table 5, fourth column. This increase amounts to 1.6 bps. Similarly, I compare a bank that is at the first percentile for the initial amount of zero-interest deposits with one that is at the 99th percentile. This second bank pays interest-bearing deposits 8.5 bps more purely to substitute the larger outflow of zero-interest deposits that it faces. All these figures are net of the effects of zero-interest deposit supply shifters, loan demand shifters, and bank fixed effects.

To put these numbers in perspective, note that the standard deviation of the interest-bearing deposit rate paid by banks in 2005 is 55 bps. The substitution of one standard deviation difference in the quantity of zero-interest deposits, as implied by the 2005 monetary policy tightening, explains around 3% of that observed standard deviation. This effect is relatively small but non-negligible. As I detail in the following section, the reason the effect is relatively small is that zero-interest deposits are mildly sensitive to monetary policy changes. However, note that this effect is already net of the effects of zero-interest deposit supply shifters, loan demand shifters, and bank fixed effects, which are likely to be important determinants of the interest-bearing deposit rate's cross-sectional variation. That is why it is non-negligible.

4.4 Extended models

Model (1) can be extended to study how the mechanism changes with bank size and banking market concentration. I capture bank size by two dummy variables, $Top\,50_{jt}$, and $Top\,5_{jt}$. They indicate if bank j is in period t in the top 50th, respectively fifth, percentile for total assets at the national level. As for market concentration, I compute the Herfindahl–Hirschman Index in terms of amount of deposits of the markets in which bank j operates. This measure, $HHI\,Deps_{-jt}$, is computed without considering bank j's market shares, which is why the subscript is $-j$.[29] I modify model (1) by interacting d_{jt-1} and $d_{jt-1} \times \Delta FF_t$ with the measures created. However, as d_{jt} is endogenous in the model, so are its interaction terms. Let the interacted characteristic of bank j at t be $char_{jt}$. The set of endogenous variables is $\{d_{jt-1};\ l_{jt-1};\ d_{jt-1} \times char_{jt};\ d_{jt-1} \times \Delta FF_t;\ d_{jt-1} \times \Delta FF_t \times char_{jt}\}$. I consider as set of (excluded) IVs $\{d_{jt-2};\ l_{jt-2};\ \triangle demogr_{jt-1};\ \hat{d}_{jt-1} \times char_{jt};\ \hat{d}_{jt-1} \times \Delta FF_t;$ $\hat{d}_{jt-1} \times \Delta FF_t \times char_{jt}\Big\}$.

Table 6 presents the IV results associated to these extended models. While not reported, all regressions include period t demographic changes, period $t-1$ Tier1 ratio, and the dummy variables capturing the participation to a BHC, and the international reach, as at $t-1$. Standard errors are clustered by bank and year. The first column shows the effect of bank size only, the second of market concentration only, while the third integrates the two.

The first result is that the change in the interest-bearing deposit rate due to the substitution of zero-interest deposits with interest-bearing deposits is the same across banks of different size. This appears from the fact that the parameter attached to $d_{jt-1} \times \triangle FF_t$ is not statistically different across banks of different size.

The second finding is that the change in the interest-bearing deposit rate, as cause by the substitution of funding sources, becomes smaller the higher the banking market concentration. There are two possible alternative explanations to this result. First, banks that are set in more concentrated markets face a zero-interest deposit supply that is less sensitive to monetary policy

[29]The SOD data display the precise location of each bank branch and the amount of deposits collected therein. I use these data to compute the Herfindahl–Hirschman Index associated to each bank and year. I first obtain the total outstanding amount of deposits present in a county-year. I compute each bank's market share. I take the square, and sum over all banks. I remove the squared market share of the bank to which the measure refers. In this way, I obtain a measure of concentration of the market to which each bank is exposed, independently of the bank's actions. Finally, I aggregate these bank-county-year measures to the bank-year level using the strategy adopted for demographics, and obtain $HHI\,Deps_{-jt}$.

changes. This, in fact, would imply a lower need to substitute zero-interest deposits with interest-bearing deposits. Second, as described by Hannan and Berger (1991), Neumark and Sharpe (1992), and Drechsler et al. (2015), banks that are set in more concentrated markets are less willing to adjust their interest-bearing deposit rate to monetary policy changes. However, precisely because the interest rate does not change much, such banks would be able to substitute zero-interest deposits with interest-bearing deposits only to a limited extent. In the following subsection, I provide evidence that the latter explanation is the one that better describes what happens in reality.

The third column includes the interactions with both bank size and market concentration. The two previous results are confirmed. All columns report the p-value of the Sargan test, and in all cases, it is above usual confidence levels. This suggests that the instruments used are valid.

4.5 Sensitivity of zero-interest deposits and interest-bearing deposits to monetary policy

The baseline model does not directly study how monetary policy affects the quantity of zero-interest deposits available to banks, and the substitution of funding sources. It derives the findings from the analysis of the observed interest-bearing deposit rates. This subsection provides direct evidence on those patterns.

I structure a simple dynamic panel data model of the form:

$$\begin{aligned}\log(x_{jt}) &= \rho_1 \log(x_{jt-1}) + \rho_2 \log(x_{jt-2}) + \xi_1 inflation_t \\ &+ \xi_2 GDP\, growth_t + \alpha Fed\, funds\, rate_t \\ &+ \beta \triangle demogr_{jt} + \eta_j + \eta_{jt}\end{aligned}$$

where x_{jt} denotes the dollar quantity of either zero-interest deposits or interest-bearing deposits of bank j at year t . The log of such quantity is a function of its two lagged values, period t inflation, GDP growth, and Federal funds rate, period t demographic changes, and bank fixed effects η_j. The unobservable term is η_{jt}. Parameter α captures the sensitivity of the dependent variable to the Federal funds rate, and is the key parameter of interest. In order to capture cross-sectional differences in such sensitivity, I also interact $Fed\,funds\,rate_t$ with the measures of bank size and banking market concentration.

I estimate the model using Blundell and Bond's (1998) GMM two-step estimator.[30] Parameters' estimates, together with Windmeijer's (2005) robust standard errors, appear in Table 7. The first two columns present the estimates of the effect of $Fed\,funds\,rate_t$ without interactions. A 100 bps increase in the Fed funds rate causes a decrease in the quantity of zero-interest deposits of 1.37 %. On the contrary, it causes an increase in the quantity of interest bearing deposits of .64%. Both effects are strongly statistically significant. This confirms that monetary policy does affect the quantity of zero-interest deposits available to banks, and that it causes a substitution with interest-bearing deposits. Importantly, the numbers clarify that the sensitivity of zero-interest deposits to monetary policy changes is low.

The other columns differentiate the effects of monetary policy by bank size and market concentration. It appears that the sensitivity of zero-interest deposits to monetary policy does not alter with bank size and banking market concentration. However, there appear differences in the reaction of interest-bearing deposits to monetary policy. Larger banks, i.e. those above the fifth percentile for total assets, and banks located in more concentrated markets react to monetary policy tightenings by raising interest-bearing deposits to a lower extent.

These findings can be combined with those presented in the previous subsection. Monetary policy affects the quantity of zero-interest deposits available to banks irrespectively of bank size and banking market concentration. However, banks react to the same monetary policy change differently depending on these elements.

Larger banks have sources of funding alternative to deposits, for example the wholesale market. Thus, they can operate on those alternative funding markets, and do not need to necessarily substitute zero-interest deposits with interest-bearing deposits. Indeed, I find that larger banks react to a monetary policy tightening by issuing interest-bearing deposits to a lower extent. However, I do not find that this is associated to a lower increase in the interest-bearing deposit rate. That is what one would expect because issuing a smaller quantity of interest-bearing deposits puts less pressure on the interest-bearing deposit rate to increase. Therefore, the evidence on the effects of monetary

[30] Flannery and Hankins (2013) suggest that Blundell and Bond's (1998) system GMM is among the most accurate methodologies to estimate dynamic panel data models in the context of corporate finance datasets.

policy depending on bank size appears mixed.

A clear pattern arises, instead, for banking market concentration. I find that following a monetary policy tightening, banks located in more concentrated markets issue interest-bearing deposits to a lower extent, and they observe lower increases in their interest-bearing deposit rate. The reason is the following. The more banks have market power, the more they do not upward revise the interest-bearing deposit rate in case of tight monetary policy. By doing this, in fact, they increase the wedge between current market interest rates and deposit rates, and maximize their profit (Drechsler et al. (2015)). However, the effect is also that they are not able to find interest-bearing depositors willing to lend to them. Thus, they substitute the outflowed zero-interest deposits to a lower extent.

5 Robustness checks

5.1 Demographic changes taken further in the past

As stressed in the identification strategy, in order to be valid instruments, the demographic innovations $\triangle demogr_{jt-1}$ need to affect zero-interest deposits and loans only at the moment in which they realize and not in subsequent periods. Otherwise, if they directly affected period t zero-interest deposits and loans, they should be included in the main equation and could not be used as IVs. The Sargan test seems to exclude that their effect actually propagates to subsequent periods. Nevertheless, I consider here two robustness checks that minimize even more the concern that the instruments used may not be valid.

Instead of considering as IVs the demographic changes that happen in $t-1$, I use those that happen in earlier periods. For example, those that happen in period $t-2$. I re-normalize period $t-1$ amount of zero-interest deposits and loans with respect to period $t-3$ total assets. I obtain d_{jt-1} and l_{jt-1}. Similarly, I define d_{jt-3} (l_{jt-3}) as the amount of zero-interest deposits (loans and leases) held by bank j at $t-3$ normalized by period $t-3$ total assets.[31] The change of normalization enables me to measure the effect of period $t-2$ demographic changes on period $t-1$ zero-interest deposits and loans. Indeed, I first regress d_{jt-1} on d_{jt-3}, l_{jt-3}, $\triangle demogr_{jt-2}$, $\triangle demogr_{jt}$, time

[31] I also re-define the Tier1 ratio, $Tier1\,ratio_{jt-1}$, as period $t-1$ Tier1 (core) capital normalized by period $t-3$ total assets.

and bank fixed effects. Similar to what previously defined, $\hat{d}_{jt-1}$ is the vector of fitted values, and the set of (excluded) IVs for $\{d_{jt-1};\ l_{jt-1};\ d_{jt-1} \times \Delta FF_t\}$ is now $\{d_{jt-3};\ l_{jt-3}; \triangle demogr_{jt-2}; \hat{d}_{jt-1} \times \Delta FF_t\Big\}$.

The idea of this new identification strategy is that the further in the past demographic shocks happen, the more negligible, if any, is their direct effect on period t zero-interest deposits and loans. On the contrary, their effect still rebounds on the endogenous variables. The reason is that period $t-2$ demographic changes may now affect d_{jt-1} and l_{jt-1} both directly and indirectly. The former is the effect that was not allowed in the baseline identification strategy and means that period $t-2$ demographic changes reverberate in the period after their realization. The latter, instead, is the effect that they have on period $t-2$ zero-interest deposit and loan amounts, which then transfers to period $t-1$ zero-interest deposit and loan amounts via those variables.

The third and fourth columns of Table 8 present parameters' estimates of model (1) with this new set of IVs. The qualitative effects of d_{jt-1}, l_{jt-1}, and in particular $d_{jt-1} \times \Delta FF_t$, on r_{jt} are corroborated. Relative to the estimates of Table 5, the magnitude of the effects changes, possibly due to the new normalization. Also, the significance of the parameter of d_{jt-1} decreases.

I then consider demographic shocks that realize in period $t-3$. I repeat the procedure detailed above, and present the results in the fifth and sixth columns of Table 8. The significance and sign of Table 5 parameters' estimates is confirmed. Also in this case, the magnitude changes. As final remark, it should be noted that taking demographic changes that happen further in the past necessarily comes at the cost of reducing the length of the panel.

5.2 Reduced-form model

I allow for the period $t-2$ normalized amounts of zero-interest deposits and loans and period $t-1$ demographic changes to have a direct effect on r_{jt}. I re-write the original model (1) as:

$$\begin{aligned} r^b_{jt} &= \sigma_1 d_{jt-2} + \gamma^{\Delta FF}\left(d_{jt-1} \times \Delta FF_t\right) + \sigma_2 l_{jt-2} \\ &+ \sigma_3 \triangle demogr_{jt-1} + \beta \triangle demogr_{jt} + \eta_t + \eta_j + \eta_{jt} \end{aligned}$$

where regressors now directly include d_{jt-2}, l_{jt-2} and $\triangle demogr_{jt-1}$. The only endogenous covariate is $d_{jt-1} \times \Delta FF_t$, and is instrumented by $\hat{d}_{jt-1} \times \Delta FF_t$. As in the main specification, $\hat{d}_{jt-1}$ is the fitted value resulting from the regression of d_{jt-1} on d_{jt-2}, l_{jt-2}, $\triangle demogr_{jt-1}$, $\triangle demogr_{jt}$, time and bank fixed effects.

The advantage of this specification is that the identifying assumption is milder than the one of the baseline model. The exclusion restriction is that lagged endogenous variables and period $t-1$ demographic changes do not have direct effects *joint* with the monetary policy change ΔFF_t. In other words, a period $t-1$ increase in the mean age of the population does not trigger differential effects on r_{jt} depending on the monetary policy change that is realized in t.

Results appear in the first two columns of Table 8. The estimate and statistical significance of $\gamma^{\Delta FF}$ are very close to the ones presented in Table 5.

5.3 Demographic variables weighted using 1994 branch networks

An important concern is that banks could set their branch network forecasting demographic dynamics. If a bank forecasts that a particular area will boom, it may set new branches there, so to benefit from the boom when it realizes. In that case, the observed branch networks and the weighting used to aggregate county demographics to the bank level are endogenous. As a consequence, the constructed bank level demographics are also endogenous, and their year changes are no longer valid instruments.

I address this issue noting that, until 1994, regulation significantly limited the ability of banks to open new branches. As detailed by Kane (1996) and Johnson and Rice (2008), until at least the 1980's, regulation on commercial banks' geographic expansion was heavy and pointed to both *intra*-state and *inter*-state *banking* and *branching*.[32] The picture changed with the Riegle-Neal Interstate Banking and Branching Efficiency Act (IBBEA) of 1994. The act permitted the consolidation of existing out-of-state subsidiaries, which would have become branches of the lead bank (of an existing multi-bank holding company), and also allowed banks to set up new out-of-state branches (the so-

[32] Intra-state operations are those happening within the bank's home state borders, while inter-state ones those across. With banking it is meant the establishment or acquisition of a separate charter. With branching, the establishment or acquisition of a branch office which is not separately chartered or capitalized.

called "*de novo* branching").[33] Indeed, between 1994 and 2005, states gradually moved towards a relaxation of the constraints, and the number of entries of out-of-state banks largely increased (Johnson and Rice (2008)).

This brief discussion suggests that banks' ability to adjust their branch network forecasting demographic dynamics is a legitimate concern, especially for the latter years of my sample period. Instead, 1994 is the last year in which there exist important limitations for banks to change their branch network. I exploit this and construct bank level demographics fixing banks' branch networks to 1994. The resulting bank-level variables capture the demographic dynamics to which each bank is exposed, but exclude from it the part due to the (endogenous) creation of new branches. I compute the year changes, and repeat the usual procedure to construct a set of IVs. The last two columns of Table 8 report the results for the baseline model using this new set of IVs. Again, parameters' estimates confirm the earlier results of Table 5. Relative to those, however, the parameter of d_{jt-1} loses statistical significance.

6 Conclusions

This paper studies a mechanism through which monetary policy affects the composition of banks' liabilities and, through that channel, banks' funding cost. When the stance of monetary policy changes, the quantity of zero-interest deposits available to banks may modify. Banks may respond by changing the quantity of interest-bearing deposits issued. However, if the interest rate to pay on these deposits depends on the quantity borrowed, the interest-bearing deposit rate paid by a bank will change depending on the quantity of zero-interest deposits being substituted.

I analyze the universe of FDIC-insured U.S. commercial and savings banks from 1994 to 2008. Exploiting exogenous variation in each bank's amount of zero-interest deposits, I trace how the reaction of zero-interest deposits to monetary policy changes is transmitted to the bank's interest-bearing deposit rate. My findings indicate that the more banks obtain funding through zero-interest deposits, the larger the funding outflow that they observe when monetary policy tightens, and the higher is the increase in their interest-bearing deposit rate. This main result rests on two elements.

[33] In fact, the act left to each state the possibility to "opt out" or put restrictions on inter-state branching operations (see Johnson and Rice (2008) and Rice and Strahan (2010)).

First, monetary policy significantly affects the quantity of zero-interest deposits available to banks. Second, the interest-bearing deposit rate increases with the quantity to borrow.

My findings provide support for the bank lending channel of monetary policy. Because substituting zero-interest deposits is increasingly expensive, banks may not substitute every dollar of outflowed zero-interest deposits. Tight monetary policy may therefore lead to a decrease in loan supply.

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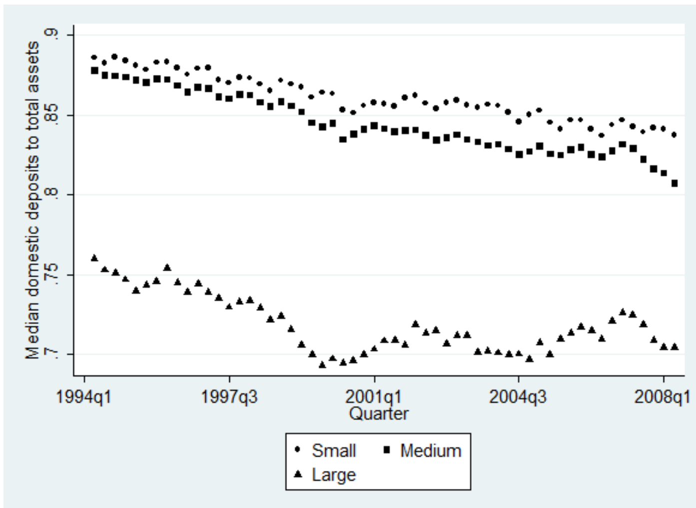
Figures

Figure 1: Domestic deposits to total assets. Median by class of bank size

This figure plots the quarterly evolution of the median ratio of domestic deposits to total assets, computed within class of bank size. I compute the ratio of domestic deposits to total assets for each bank-quarter, from 1994q2 to 2008q2. I define small banks as those below the 50th percentile for total assets nationally in a given quarter. Medium banks are those between the 50th percentile and the 95th percentile. Large banks are those above the 95th percentile. I then take the median of banks' ratios within each group-quarter. The data are from the FDIC, Statistics on Depository Institutions.



Tables

Table 1: Households' checking deposit holdings as a function of their demographic characteristics

This table presents the estimates of the effects of household demographics on the probability that the household has a checking account (left column), and, if the household has at least one, on the amount that it detains (right column). In the column on the left, I structure a Probit model, and $Own\, check\, acct_{ht}$ takes the value of one when household h has a checking account in year t. In the column on the right, the dependent variable is the log of one plus the amount detained by the household in its checking account(s) ($Check\, acct_{ht}$). The independent variables are household level demographics (X) and year dummies. X include the age of the head (Age), the log of the number of people in the household ($\log(HHsize)$), controls for race and education, and household (log) total income ($\log(inc)$). The controls for race are $Black$, $Hispanic$, and $Other$, and take the value of one if the head is, respectively, black/African-American, hispanic, or either Asian, American Indian/Alaska Native or Native Hawaiian/Pacific Islander. The controls for education are $College$ and PhD, which equal to one if the head has taken any college-level, respectively PhD-level, classes. In the column on the left, I report marginal effects. They are obtained setting independent continuous variables to median levels, and independent dummy variables to 0. The data are from the Survey of Consumer Finances (SCF), and the years considered are 1995, 1998, 2001, 2004, 2007 and 2010. Both estimations use population weights. Standard errors are in parenthesis. Significance levels: ***1%, **5%, *10%.

	$\Pr[Own\, check\, acct_{ht} = 1 \mid X_{ht}]$	$\log(1 + Check\, acct_{ht})$
Age_{ht}	.0016***	0.0217***
	(.0002)	(0.0008)
$\log(HHsize_{ht})$	.0084	-0.1750***
	(.0055)	(0.0288)
$Black_{ht}$	-.1647***	-0.4920***
	(.0111)	(0.0487)
$Other_{ht}$	-.0774***	0.0969
	(.0187)	(0.0694)
$Hispanic_{ht}$	-.1652***	-0.1850***
	(.0131)	(0.0598)
$College_{ht}$	.0954***	0.4450***
	(.0061)	(0.0345)
PhD_{ht}	.0868***	0.8770***
	(.0078)	(0.0463)
$\log(inc_{ht})$	.0443***	0.6010***
	(.0028)	(0.0283)
Time FE	Yes	Yes
N° Obs	141,590	117,448

Table 2: Household expenditures as a function of their demographic characteristics

This table presents the estimates of the effects of household demographics on the household expenditures. The dependent variables are the log of one plus one of the following household expenditures: total expenditures ($Total$), total food expenditures ($Food$), total expenditures for food consumed at home ($Home\,food$), total expenditures for shelter, utilities, fuels, public services, household operations, housefurnishings and equipment ($House$), total expenditures for housefurnishings and equipment ($Furnish$), and total apparel expenditures ($Apparel$). The independent variables are household demographics (X) and region dummies. X include the age of the head (Age), the log of the number of people in the household ($\log(HHsize)$), controls for race and education, the household (log) total income ($\log(inc)$), and a dummy that equals to one if the household resides in a urban area ($Urban$). The controls for race are $Black$, $Hispanic$, and $Other$, and take the value of one if the head is, respectively, black/African-American, hispanic, or either Asian, American Indian/Alaska Native or Native Hawaiian/Pacific Islander. The controls for education are $College$ and PhD, which equal to one if the head has taken any college-level, respectively PhD-level, classes. The data are from the 2003 Quarterly Interview Survey, included in the Consumer Expenditure Survey (CEX). Standard errors are in parenthesis. Significance levels: ***1%, **5%, *10%.

	$\log(1+\ldots)$					
	$Total_h$	$Food_h$	$Home\,food_h$	$House_h$	$Furnish_h$	$Apparel_h$
Age_h	0.0016***	0.0024***	0.0072***	0.0040***	-0.0044***	-0.0201***
	(0.0002)	(0.0002)	(0.0003)	(0.0003)	(0.0008)	(0.0007)
$\log(HHsize_h)$	0.5460***	0.6970***	0.8430***	0.5650***	0.6430***	0.8070***
	(0.0057)	(0.0066)	(0.0078)	(0.0079)	(0.0239)	(0.0201)
$Black_h$	-0.2640***	-0.2200***	-0.1110***	-0.0613***	-0.7530***	-0.1010***
	(0.0103)	(0.0121)	(0.0143)	(0.0144)	(0.0435)	(0.0367)
$Other_h$	-0.1530***	-0.1110***	-0.1140***	-0.0968***	-0.4500***	-0.2930***
	(0.0137)	(0.0161)	(0.0189)	(0.0191)	(0.0578)	(0.0488)
$Hispanic_h$	-0.2450***	-0.1110***	-0.0333**	-0.1010***	-0.5520***	-0.1210***
	(0.0120)	(0.0141)	(0.0166)	(0.0168)	(0.0507)	(0.0428)
$College_h$	0.3610***	0.1920***	0.1100***	0.3430***	0.8150***	0.7020***
	(0.0071)	(0.0084)	(0.0098)	(0.0099)	(0.0300)	(0.0254)
PhD_h	0.7350***	0.4380***	0.3070***	0.7360***	1.4480***	1.2900***
	(0.0105)	(0.0124)	(0.0146)	(0.0147)	(0.0445)	(0.0376)
$\log(inc_h)$	0.0498***	0.0205***	0.0127***	0.0339***	0.1310***	0.1160***
	(0.0009)	(0.0011)	(0.0013)	(0.0013)	(0.0039)	(0.0033)
$Urban_h$	0.1320***	0.1030***	0.0597***	0.2800***	0.1650***	0.3650***
	(0.0111)	(0.0130)	(0.0153)	(0.0155)	(0.0468)	(0.0395)
Region FE	Yes	Yes	Yes	Yes	Yes	Yes
N° Obs.	40,073	40,073	40,073	40,073	40,073	40,073

Table 3: Summary statistics of the bank level demographic variables

This table presents summary statistics of the (bank-level) demographic variables. Demographic variables are based on the conditions of the areas in which each bank operates. $Prop\,Young$ and $Prop\,Old$ are the proportions of young (≤ 19 years old) and elderly (≥ 65 years old) people. $Mean\,age$ is the mean age of the population. $Prop\,Black$, $Prop\,Hisp$, and $Prop\,Other$ are the proportions of blacks/African-Americans, hispanics, and American Indians/Alaska Native together with Asian/Pacific Islander. $\log(Inc\,pc)$ is the (log) per-capita income. $Jobs\,pc$ is the number of jobs per-capita. $Pop\,density$ is the log of the population density. Year changes in these demographic variables are indicated by a $\triangle$ in front. Bank-year level demographic variables are weighted averages of county-year level data. The weights depend on the proportion of branches that a bank has in a county-year. County-year level demographic data are from the intercensal estimates of the U.S. Census Bureau. County-year level economic data are from the Regional Economic Accounts, Bureau of Economic Analysis. Bank branches data is from the FDIC, Summary of Deposits.

	All sample			Year: 1996			Year: 2008		
Variable	*N° Obs.*	*Mean*	*St. Dev.*	*N° Obs.*	*Mean*	*St. Dev.*	*N° Obs.*	*Mean*	*St. Dev.*
$Prop\,Young_{jt}$	101,352	0.2796	0.0269	9,243	0.2883	0.0273	7,456	0.2687	0.0255
$Prop\,Old_{jt}$	101,352	0.1437	0.0382	9,243	0.1456	0.0403	7,456	0.1451	0.0356
$Mean\,age_{jt}$	101,352	37.3242	2.6701	9,243	36.5410	2.6468	7,456	38.1803	2.5678
$Prop\,Black_{jt}$	101,352	0.0864	0.1195	9,243	0.0847	0.1228	7,456	0.0931	0.1187
$Prop\,Hisp_{jt}$	101,352	0.0784	0.1206	9,243	0.0630	0.1151	7,456	0.0971	0.1259
$Prop\,Other_{jt}$	101,352	0.0398	0.0552	9,243	0.0265	0.0510	7,456	0.0541	0.0591
$\log(Inc\,pc_{jt})$	101,352	3.3070	0.2846	9,243	3.0566	0.2260	7,456	3.6056	0.2298
$Jobs\,pc_{jt}$	101,352	0.4323	0.1338	9,243	0.4202	0.1379	7,456	0.4405	0.1280
$Pop\,density_{jt}$	101,352	4.7711	1.8480	9,243	4.6368	1.8470	7,456	5.0133	1.8598
$\Delta Prop\,Young_{jt}$	101,352	-0.0015	0.0032	9,243	-0.0004	0.0033	7,456	-0.0012	0.0035
$\Delta Prop\,Old_{jt}$	101,352	0.0000	0.0039	9,243	-0.0006	0.0042	7,456	0.0017	0.0042
$\Delta Mean\,age_{jt}$	101,352	0.1373	0.2713	9,243	0.1029	0.2720	7,456	0.1392	0.3076
$\Delta Prop\,Black_{jt}$	101,352	0.0004	0.0088	9,243	0.0006	0.0094	7,456	0.0005	0.0088
$\Delta Prop\,Hisp_{jt}$	101,352	0.0027	0.0076	9,243	0.0024	0.0065	7,456	0.0026	0.0103
$\Delta Prop\,Other_{jt}$	101,352	0.0021	0.0046	9,243	0.0009	0.0026	7,456	0.0017	0.0049
$\Delta\log(Inc\,pc_{jt})$	101,352	0.0466	0.0441	9,243	0.0651	0.0490	7,456	0.0612	0.0526
$\Delta Jobs\,pc_{jt}$	101,352	0.0015	0.0206	9,243	0.0034	0.0207	7,456	-0.0031	0.0255
$\Delta Pop\,density_{jt}$	101,352	0.0202	0.1781	9,243	0.0217	0.1664	7,456	0.0211	0.2058

Table 4: Preliminary regressions

This table presents the estimates of the effects of the instrumental variables on the endogenous covariates in the main model. In the column on the left, the dependent variable d_{jt-1} is the normalized amount of zero-interest deposits that j has at $t-1$. In the column on the right, the dependent variable l_{jt-1} is the normalized amount of total loans and leases that j has at $t-1$. Normalizations are with respect to $t-2$ total assets. In both columns, the independent variables include period $t-2$ normalized amounts of zero-interest deposits d_{jt-2} and loans l_{jt-2}, period $t-1$ demographic changes $\triangle demogr_{jt-1}$, period t demographic changes $\triangle demogr_{jt}$, bank and time fixed effects. d_{jt-2} (l_{jt-2}) is defined as period $t-2$ amount of zero-interest deposits (total loans and leases) divided by the amount of total assets at $t-2$. Bank-year level demographic and economic variables are weighted averages of county-year level data. County-year level demographic data are from the intercensal estimates of the U.S. Census Bureau. County-year level economic data are from the Regional Economic Accounts, Bureau of Economic Analysis. The source of banking data is the FDIC, Statistics on Depository Institutions and Summary of Deposits. Parameters' estimates of period t demographic changes are not reported. The standard errors are in parenthesis and are clustered by bank and year following Thompson (2011). Significance levels: ***1%, **5%, *10%.

	d_{jt-1}	l_{jt-1}
d_{jt-2}	0.7125***	0.1185***
	(0.0376)	(0.0200)
l_{jt-2}	-0.0026	0.7332***
	(0.0047)	(0.0429)
$\Delta Prop\,Young_{jt-1}$	0.3775**	0.8573**
	(0.1567)	(0.4098)
$\Delta Prop\,Old_{jt-1}$	-0.3071*	-0.1402
	(0.1689)	(0.3761)
$\Delta Mean\,age_{jt-1}$	0.0060*	0.0074
	(0.0033)	(0.0077)
$\Delta Prop\,Black_{jt-1}$	-0.0094	-0.1074
	(0.0234)	(0.0738)
$\Delta Prop\,Hisp_{jt-1}$	-0.0272	-0.1958*
	(0.0318)	(0.1016)
$\Delta Prop\,Other_{jt-1}$	-0.0033	0.0156
	(0.0309)	(0.1694)
$\Delta \log(Inc\,pc_{jt-1})$	0.0220	0.0193
	(0.0134)	(0.0271)
$\Delta Jobs\,pc_{jt-1}$	-0.0146	-0.0985***
	(0.0099)	(0.0362)
$\Delta Pop\,density_{jt-1}$	0.0065***	0.0447***
	(0.0013)	(0.0033)
$\triangle demogr_{jt}$	Yes	Yes
Time FE	Yes	Yes
Bank FE	Yes	Yes
N° Obs.	101,352	101,352
R^2	0.3378	0.2694
Time period	1994 – 2008	

Table 5: Baseline model

This table presents the effects of period $t-1$ liability and asset structures on period t interest-bearing deposit rate under different specifications. In all columns, the dependent variable r_{jt} is the interest rate paid by bank j in period t on interest-bearing deposits. The independent variables always include period $t-1$ normalized amount of zero-interest deposits d_{jt-1}, its interaction with period t monetary policy change (ΔFF_t), period $t-1$ normalized amount of total loans and leases l_{jt-1}, period t demographic changes $\triangle demogr_{jt}$, and bank fixed effects. In the first column, the independent variables also include the level of the Federal funds rate FF_t, its change in t, the inflation rate $inflation_t$, and the GDP growth rate $GDP\,growth_t$. All other columns replace those controls by the year fixed effects. The third and fifth columns also add other control variables. $Tier\,1\,ratio_{jt-1}$ is the amount of period $t-1$ Tier 1 (core) capital to period $t-2$ total assets. BHC_{jt-1} and $International_{jt-1}$ are dummy variables that equal to one if the bank belongs to a bank holding company, or, respectively, operates in other countries, as at $t-1$. The first three columns display OLS estimates. The last two columns consider d_{jt-1}, $d_{jt-1} \times \Delta FF_t$, and l_{jt-1} endogenous. The set of excluded IVs is composed by d_{jt-2}, l_{jt-2}, period $t-1$ demographic changes, and $\hat{d}_{jt-1} \times \Delta FF_t$. $\hat{d}_{jt-1}$ is the fitted value of the normalized amount of zero-interest deposits computed from the preliminary regression of table 4. Bank-year level demographic and economic variables are weighted averages of county-year level data. The weights depend on the proportion of branches that a bank has in a county-year. County-year level demographic data are from the intercensal estimates of the U.S. Census Bureau. County-year level economic data are from the Regional Economic Accounts, Bureau of Economic Analysis. The source of banking data is the FDIC, Statistics on Depository Institutions and Summary of Deposits. Parameters' estimates of period t demographic changes are not reported. The standard errors are in parenthesis and are clustered by bank and year following Thompson (2011). Significance levels: ***1%, **5%, *10%.

	r_{jt}				
	OLS	OLS	OLS	IV	IV
d_{jt-1}	-0.2955	-0.3767*	-0.3329	-0.6933**	-0.6722**
	(0.2034)	(0.2235)	(0.2194)	(0.3104)	(0.3105)
$d_{jt-1} \times \Delta FF_t$	0.1123**	0.1325***	0.1295***	0.1973***	0.1955***
	(0.0560)	(0.0440)	(0.0438)	(0.0561)	(0.0551)
l_{jt-1}	0.5577***	0.6943***	0.7238***	0.9437***	0.9090***
	(0.0466)	(0.0585)	(0.0630)	(0.1177)	(0.1097)
FF_t	0.6850***				
	(0.0309)				
ΔFF_t	-0.4146***				
	(0.0602)				
$inflation_t$	-4.8650				
	(4.5402)				
$GDP\,growth_t$	7.4131				
	(5.8891)				
$Tier\,1\,ratio_{jt-1}$			-0.5276***		-0.7222***
			(0.1823)		(0.2545)
BHC_{jt-1}			0.0093		0.0028
			(0.0149)		(0.0131)
$International_{jt-1}$			-0.0402		-0.0457
			(0.0755)		(0.0758)
$\triangle demogr_{jt}$	Yes	Yes	Yes	Yes	Yes
Time FE	No	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes
Sargan test (d.f.)	–	–	–	9	9
p-value				0.2857	0.2785
N° Obs.	101,352	101,352	101,352	101,352	101,352
R^2	0.8713	0.9175	0.9176	0.9169	0.9173
Time period			1994 – 2008		

Table 6: Extended model. Bank size and banking market concentration

This table presents the estimates of the effects of period $t-1$ liability and asset structures on period t interest-bearing deposit rate differentiating by bank size and banking market concentration. The dependent variable r_{jt} is the interest rate paid by bank j in period t on interest-bearing deposits. In every column, the independent variables include period $t-1$ normalized amount of zero-interest deposits d_{jt-1}, its interaction with period t monetary policy change (ΔFF_t), period $t-1$ normalized amount of total loans and leases l_{jt-1}, period t demographic changes $\triangle demogr_{jt}$, control variables $controls_{jt-1}$, bank and time fixed effects. $controls_{jt-1}$ include $Tier\,1\,ratio_{jt-1}$, BHC_{jt-1} and $International_{jt-1}$. In the different columns, I interact d_{jt-1} and $d_{jt-1} \times \Delta FF_t$ with measures of bank size and market concentration. I capture bank size by two dummy variables, $Top\,50_{jt}$, and $Top\,5_{jt}$. They indicate if bank j is in period t in the top 50, respectively five, percentile for total assets at the national level. As for market concentration, I compute the Herfindahl–Hirschman Index in terms of amount of deposits of the banking markets in which bank j operates (HHI_{-jt}). Such index is computed without considering bank j's market shares. In every column, d_{jt-1}, $d_{jt-1} \times \Delta FF_t$, their interactions with any characteristic $char_{jt}$, and l_{jt-1}, are considered endogenous. The set of excluded IVs is composed by d_{jt-2}, l_{jt-2} period $t-1$ demographic changes, $\hat{d}_{jt-1} \times char_{jt}$, $\hat{d}_{jt-1} \times \Delta FF_t$, and $\hat{d}_{jt-1} \times \Delta FF_t \times char_{jt}$. Bank-year level demographic and economic variables are weighted averages of county-year level data. The weights depend on the proportion of branches that a bank has in a county-year. County-year level demographic data are from the intercensal estimates of the U.S. Census Bureau. County-year level economic data are from the Regional Economic Accounts, Bureau of Economic Analysis. The source of banking data is the FDIC, Statistics on Depository Institutions and Summary of Deposits. Parameters' estimates of period t demographic changes, control variables $controls_{jt-1}$, and negligible interaction terms are not reported. The standard errors are in parenthesis and are clustered by bank and year following Thompson (2011). Significance levels: ***1%, **5%, *10%.

	r_{jt}		
d_{jt-1}	-1.4452***	-0.7888**	-1.6427***
	(0.3011)	(0.3453)	(0.3661)
$d_{jt-1} \times Top\,50_{jt}$	1.0881***		1.1053***
	(0.1631)		(0.1693)
$d_{jt-1} \times Top\,5_{jt}$	0.9345**		0.9295**
	(0.4759)		(0.4730)
$d_{jt-1} \times HHI\,Deps_{-jt}$		0.8564	1.2969
		(0.9099)	(0.8929)
$d_{jt-1} \times \Delta FF_t$	0.1982***	0.3622***	0.3887***
	(0.0422)	(0.0671)	(0.0827)
$d_{jt-1} \times Top\,50_{jt} \times \Delta FF_t$	0.0804		0.0495
	(0.0573)		(0.0662)
$d_{jt-1} \times Top\,5_{jt} \times \Delta FF_t$	0.0263		0.0072
	(0.1286)		(0.1294)
$d_{jt-1} \times HHI\,Deps_{-jt} \times \Delta FF_t$		-1.0075***	-1.0707**
		(0.3675)	(0.4185)
l_{jt-1}	0.8518***	0.9048***	0.8479***
	(0.1007)	(0.1093)	(0.1006)
$Top\,50_{jt}$	-0.0268		-0.0317
	(0.0262)		(0.0265)
$Top\,5_{jt}$	-0.1401		-0.1398
	(0.1065)		(0.1047)
$HHI\,Deps_{-jt}$		-0.4898***	-0.5132***
		(0.1643)	(0.1549)
$\triangle demogr_{jt}$	Yes	Yes	Yes
$controls_{jt-1}$	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes
Sargan test (d.f.)	9	9	9
p-value	0.2311	0.2791	0.2322
N° Obs.	101,352	101,352	101,352
R^2	0.9196	0.9176	0.9198
Time period		1994 – 2008	

Table 7: Dynamic panel data analysis. Effect of Federal funds rate on (log) zero-interest deposits and interest-bearing deposits

This table presents the dynamic panel data estimates of the effects of period t Federal funds rate on period t zero-interest deposits and interest-bearing deposits. It also differentiates the effects by bank size and market concentration. The dependent variables are the log of one plus the amount of either zero-interest deposits or interest-bearing deposits. In every column, the independent variables include two lags of the dependent variable, period t inflation rate $inflation_t$, the rate of GDP growth $GDP\,growth_t$, and the Federal funds rate $Fed\,funds\,rate_t$, period t demographic changes $\triangle demogr_{jt}$, and bank fixed effects. In the different columns, I interact period t Federal funds rate with measures of bank size and market concentration. Bank size is captured by $Top\,50_{jt}$ and $Top\,5_{jt}$, while market concentration by HHI_{-jt}. The estimates are obtained using Blundell and Bond's (1998) GMM two-step estimator. Bank-year level demographic and economic variables are weighted averages of county-year level data. The weights depend on the proportion of branches that a bank has in a county-year. County-year level demographic data are from the intercensal estimates of the U.S. Census Bureau. National and county level economic data are from the Regional Economic Accounts, Bureau of Economic Analysis. The source of banking data is the FDIC, Statistics on Depository Institutions and Summary of Deposits. Parameters' estimates of period t demographic changes are not reported. Windmeijer's (2005) robust standard errors are in parenthesis. Significance levels: ***1%, **5%, *10%.

	log (1 + ...)							
	zero int dep	*int bear dep*	*zero int dep*	*int bear dep*	*zero int dep*	*int bear dep*	*zero int dep*	*int bear dep*
$\log(1+\ldots)_{t-1}$	0.7775***	1.1084***	0.7731***	1.0839***	0.7783***	1.1044***	0.7739***	1.0809***
	(0.0118)	(0.0141)	(0.0118)	(0.0131)	(0.0117)	(0.0153)	(0.0118)	(0.0158)
$\log(1+\ldots)_{t-2}$	0.0431***	-0.1372***	0.0413***	-0.1311***	0.0430***	-0.1345***	0.0411***	-0.1290***
	(0.0077)	(0.0144)	(0.0078)	(0.0135)	(0.0077)	(0.0147)	(0.0078)	(0.0146)
$inflation_t$	-0.3987***	-0.2394***	-0.3934***	-0.2193***	-0.3986***	-0.2359***	-0.3941***	-0.2174***
	(0.1022)	(0.0542)	(0.1020)	(0.0550)	(0.1023)	(0.0538)	(0.1021)	(0.0540)
$GDP\,growth_t$	0.7349***	-0.0907*	0.7374***	-0.0997*	0.7364***	-0.0870*	0.7391***	-0.0954**
	(0.0743)	(0.0489)	(0.0741)	(0.0513)	(0.0743)	(0.0475)	(0.0741)	(0.0478)
$FF\,rate_t$	-0.0137***	0.0064***	-0.0130***	0.0060***	-0.0136***	0.0093***	-0.0123***	0.0088***
	(0.0008)	(0.0005)	(0.0011)	(0.0006)	(0.0028)	(0.0013)	(0.0033)	(0.0015)
$FF\,rate_t \times Top\,50_{jt}$			-0.0007	0.0013			-0.0008	0.0008
			(0.0019)	(0.0009)			(0.0020)	(0.0009)
$FF\,rate_t \times Top\,5_{jt}$			-0.0120	-0.0155***			-0.0112	-0.0155***
			(0.0093)	(0.0049)			(0.0093)	(0.0048)
$FF\,rate_t \times HHI\,Deps_{-jt}$					-0.0012	-0.0179**	-0.0043	-0.0155**
					(0.0163)	(0.0074)	(0.0169)	(0.0076)
$Top\,50_{jt}$			0.0564***	0.0873***			0.0567***	0.0887***
			(0.0119)	(0.0063)			(0.0121)	(0.0065)
$Top\,5_{jt}$			0.1117*	0.0949***			0.1101*	0.0955***
			(0.0618)	(0.0274)			(0.0621)	(0.0272)
$HHI\,Deps_{-jt}$					-0.1091	-0.1307**	-0.0931	-0.1335**
					(0.1123)	(0.0560)	(0.1143)	(0.0577)
$\triangle demogr_{jt}$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N° Obs.	101,352	101,352	101,352	101,352	101,352	101,352	101,352	101,352
Time period	1994 – 2008							

Table 8: Robustness checks

This table presents robustness checks associated to the baseline model. In all columns, the dependent variable is the interest rate paid by bank j in period t on interest-bearing deposits. The first two columns display reduced-form estimates. The independent variables are period $t-2$ normalized amounts of zero-interest deposits and loans, period $t-1$ demographic changes, and period $t-1$ normalized amount of zero-interest deposits interacted with period t monetary policy change ΔFF_t. This last interaction variable is the only endogenous variable and is instrumented by $\hat{d}_{jt-1} \times \Delta FF_t$. The second two columns display the estimates obtained using $t-2$ demographic changes as instruments. Balance sheet are normalized by $t-3$ total assets, and period $t-3$ normalized amounts of zero-interest deposits and loans are also used as IVs. The third two columns display the estimates obtained using $t-3$ demographic changes as instruments. In this case, balance sheet are normalized by $t-4$ total assets, and period $t-4$ normalized amounts of zero-interest deposits and loans are also used as IVs. Finally, the last two columns display the estimates of the baseline model using demographics weighted by the branch network that each bank had in 1994. All columns include period t demographic changes $\triangle demogr_{jt}$, bank and time fixed effects. The second, fourth, six, and eighth columns also include $controls_{jt-1}$. County-year level demographic data are from the intercensal estimates of the U.S. Census Bureau. County-year level economic data are from the Regional Economic Accounts, Bureau of Economic Analysis. The source of banking data is the FDIC, Statistics on Depository Institutions and Summary of Deposits. The standard errors are in parenthesis and are clustered by bank and year following Thompson (2011). Significance levels: ***1%, **5%, *10%.

	r_{jt}							
	reduced-form est.		two-year lagged demogr.		three-year lagged demogr.		1994 weighted demogr.	
d_{jt-1}	–	–	-0.9790**	-0.5933	-2.7187***	-1.6888**	-0.6263*	-0.6031*
			(0.4090)	(0.3937)	(1.0306)	(0.8073)	(0.3263)	(0.3268)
$d_{jt-1} \times \Delta FF_t$	0.1857***	0.1876***	0.2652***	0.2617***	0.2712***	0.2566***	0.1960***	0.1949***
	(0.0552)	(0.0566)	(0.0618)	(0.0589)	(0.0481)	(0.0545)	(0.0507)	(0.0504)
l_{jt-1}	–	–	1.2348***	1.1068***	1.3400***	1.7179***	0.9220***	0.9216***
			(0.1855)	(0.1627)	(0.3058)	(0.4271)	(0.0998)	(0.0993)
d_{jt-2}	Yes	Yes	No	No	No	No	No	No
l_{jt-2}	Yes	Yes	No	No	No	No	No	No
$\triangle demogr_{jt-1}$	Yes	Yes	No	No	No	No	No	No
$\triangle demogr_{jt}$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$controls_{jt-1}$	No	Yes	No	Yes	No	Yes	No	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sargan test (d.f.)	–	–	9	9	9	9	9	9
p-value	–	–	0.3568	0.3625	0.4659	0.4798	0.7533	0.7536
N° Obs.	101,352	101,352	89,898	89,898	78,324	78,324	91,734	91,734
R^2	0.9154	0.9156	0.9046	0.9130	0.8773	0.8796	0.9261	0.9262
Time period	1994 – 2008							

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