Are demographics responsible for the declining interest rates? Evidence from U.S. metropolitan areas*

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Abstract

Interest rates have declined dramatically over the past 30 years. At the same time the birth rate has decreased, and life expectancy has increased. Demographic changes leading to an older population have been proposed as an explanation for the decline in rates. However, this conjecture is difficult to test because demographics change slowly over time, and are correlated with other country characteristics. We show that in a cross-section of U.S. MSAs, the relationship between interest rates and demographics is only partially consistent with the above conjecture, and with existing models, which predict a negative association between age and interest rates. This association is, indeed, negative for lending rates, but positive for deposit rates. We rationalize this pattern by extending an OLG model where the banking sector is not perfectly competitive.

JEL classification: E43, G21, J11.

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1 Introduction

Interest rates have declined dramatically over the past 30 years. At the same time the birth rate has declined, and life expectancy has increased. Figure 1 shows these trends. Demographic changes leading to an older population have been proposed as an explanation for the decline in rates. These issues are of first order importance for the global economy, for example **?** lists demographics as one of the major factors responsible for secular stagnation and the decline in world growth.

We show that in a cross-section of U.S. MSAs, the relationship between interest rates and demographics is not entirely consistent with existing models, and with the conjecture that an older population is driving the decline in interest rates. Specifically, lending rates are negatively associated with an older population, as existing models predict (for example **?**, **?** or **?**). However, deposit rates are positively associated with an older population, inconsistent with past theories. The deposit pattern is stronger in MSAs with a less competitive banking sector. This suggests that the relationship between interest rates and demographics is more complicated than previously thought.

To rationalize these empirical findings, we build a model similar to **?** but with imperfect competition in the banking sector. We solve this model under different assumptions about the birth rate and death rate. We show that if the population is aging due to a longer life expectancy instead of a lower birth rate, then it is possible for deposit and lending rates to either rise or fall with an older population. In response to a rising life expectancy, households borrow less in young age, and save more in middle age as they require more resources in retirement. Imperfectly competitive banks may respond to these shifts in the demand curves by rising or lowering rates, depending on the exact shape of the curves. However, for realistic parameters, we find that both the lending rate falls, and the deposit rate rises, as in the data.

This paper's contribution is twofold. First, we provide new empirical estimates of the relationship between demographics and interest rates. We discuss past empirical findings on this topic below, in the literature review section. To summarize, several studies have found some evidence of a negative relationship between the fraction of prime savers in the population (roughly the 45-64 group) and interest rates, using U.S. time series data. However, because both demographics and interest rates move at relatively low frequencies, the "spurious regression problem" described by **?** may put some of these results in doubt. Two recent papers have used international panels to study the relationship between demographics and interest rates, but have come to opposite conclusions, one finding a positive relationship between rates and the fraction of working age households in the economy, and the other a negative relationship between rates and the middle-aged to young (MY) ratio. Although the international cross-section alleviates some of the econometric concerns associated with low frequency data, demographics are correlated with a host of country characteristics that may also influence interest rates, for example **?** shows that fertility is cross-sectionally negatively related to both the level of GDP and the level of human capital. While some of these concerns are still present in U.S. MSA level data, U.S. MSAs may be more homogenous among some of these dimensions. Furthermore, U.S. MSAs provide a much larger cross-section than international studies, which allows us to directly control for various MSA characteristics.

Our second contribution is to extend a standard overlapping generations (OLG), general equilibrium model, such as **?** or **?**, to have imperfect Bertrand competition among banks, as in **?** and **?**. Table 1 summarizes the model's results. If demographic differences across cities are driven by birth rates or by expected population growth (first row), then imperfect competition introduces a spread between the lending and the borrowing rate, but it does not change the negative relationship between population age and interest rates. That is, the deposit and lending rates are both negatively associated with an older population. However, if demographic differences across cities are driven by differences in death rates or in life expectancy, then imperfect competition can flip the relationship between age and the deposit rate. Thus, the model can match the pattern we observe in the data, where older cities have lower lending rates but higher deposit rates.

1.1 Literature review

The idea connecting demographics to rates of return goes back to at least **?**. It is made clear in **?** and **?** where, if there is no productivity growth, the interest rate is exactly equal to the population growth rate. The intuition is that if the population growth rate is low, then the number of retirees relative to workers is large, and the resource constraint implies that the retirees must consume relatively little per capita. In equilibrium, this causes interest rates to be low, so that agents who save in their working years get a relatively small return on their wealth, and consume relatively little in retirement. This idea also appears in **?**, who argue that the middle-aged to young (MY) ratio should be positively related to asset valuations, and negatively to future rates of return. Similar or related ideas have also been modeled by **?**, **?**, **?**, **?**, **?**, **?**, **?**, **?**, **?**, **?**. For example, the last two papers on this list both build quantitative, calibrated dynamic models and argue that demographics account for a 1%-1.5% reduction in global interest rates.

Empirical work has been mostly supportive of these theories for interest rates, though less so for other asset classes. Starting with evidence on U.S. interest rates, **?**, **?**, **?**, and **?** all show that measures of the fraction of the population in prime saving years, for example the fraction of those aged 40-65 relative to the working age population, are negatively related to the short rate. However, as mentioned earlier, demographics and interest rates tend to be slow moving, thus, even a 100 year time series provides relatively few independent observations. To the best of our knowledge, there are only three studies that use an international cross-section to measure the impact of demographics on interest rates. Consistent with the theory, **?** (7 OECD countries, 1960-1999) and **?** (35 countries, 1964-2011) find a negative relationship between the MY ratio, and short term rates. On the other hand, **?** (21 OECD countries, 1970-2014) find a positive relationship between the working age fraction, and interest rates.

The evidence on the link between demographics and asset prices is even more mixed when one considers equity returns. On the one hand, **?** find a positive relationship between the increase in the average age of the U.S. working age population (1945-1994), and the contemporaneous stock valuations, but also with future excess returns. On the other hand, **?** finds no relationship when considering a wider range of time periods and demographic measures. **?** finds a negative relationship between the 45-64 population fraction, and future excess returns for the U.S. **?** find no relationship between world age and future stock return, but a positive relationship in a cross-section of 18 countries (1970-1995). **?** and **?** both find a positive relationship between middle aged fraction and contemporaneous stock valuations for the U.S., and **?** find similar results for an international panel. **?** finds a positive (negative) relationship between the retired (working age) fraction and net equity market outflows, i.e. dividends plus repurchases, and a negative relationship between the retired fraction and the equity premium. **?** find that an increase in the retired population fraction negatively predicts stock returns in an international panel, however this relationship is positive but insignificant for the U.S. and positive and significant for the U.K. **?** and **?** find that the MY ratio is positively related to the price-to-dividend ratio. To summarize, there is some evidence that a higher fraction of workers is positively related to current valuations, but there is no consensus on its relationship to future equity returns.

Demographics may matter for changes in house prices as well. **?** argue that the entry of the baby-boom generation into house-buying years caused the 1970s housing boom, and predict slower future house price growth due to the baby-bust generation. **?** argues against this conclusion, pointing out that the rental price was falling in the 1970s, inconsistent with **?**. **?** find a negative relation between the increase in the average age of the working age population, and house price changes. **?** finds a positive relationship between demand for housing estimated from the age distribution, and housing prices. ? finds a positive relationship between the working-age to retired ratio, and house prices.

Other asset returns have also been considered. For example ? and ? find a negative relationship between the working age or net saver population, and inflation. ? find a relationship between demographics, and future industry demand, profit, and equity returns.

This paper is also related to the literature on imperfect competition among commercial banks, and its effect on deposits and loans rates. In our model, banks are oligopolists and face demand curves for loans and deposits, as in ? and ?. More recently, there has been a renewed interest in the importance of imperfect competition in banking. ? show that when banks aren't perfectly competitive, they increase spreads when the Fed funds rate rises. Relative to a perfectly competitive market, this leads to higher outflows of deposits and lower lending when the Fed funds rate rises, especially in more concentrated markets. ? shows that this channel is somewhat offset by competition from the shadow banking sector, which faces more yield sensitive clientele, does not increase spreads by as much, and attracts more deposits when the Fed Funds rate rises. Both papers have implications for monetary policy; ? estimate a dynamic model of imperfectly competitive banks to study monetary policy pass-through. ? study the sensitivity of mortgage lending and mortgage rates to changes in MBS yields. Like these papers, our paper shows that when banks aren't perfectly competitive, spreads need not be constant, and intuition from competitive models may not carry over.

2 Empirical results

2.1 Data

We collect the data from several sources. Our dependent variable is the bank rate (either loan or deposit) in an MSA in a particular year. Our key independent variable is the fraction of population in an MSA of a particular age in a particular year.

Specifically, deposit rates are calculated as banks' interest expenses divided by total deposits, and loan rates are calculated as banks' interest income divided by total loans, both from Call Report. We define the spread as the difference between loan and deposit rates. The bank rate at the MSA level is defined as the simple average of bank level rates within each MSA. In the robustness section, we also use value-weight average deposit and loan rates as dependent variables.

Demographics variables (Young, middle, and old group ratio) are collected from U.S. Census data, which is available online. Young, middle and old groups are defined as ages 20-42, 43-64, and 65 and above, respectively. For each group, the ratio of that group in the population is the number of people in that group divided by the total population (excluding people who are younger than 20 years old) in each MSA. Because the U.S. Census happens every 10 years, we have only three time-series observations: 1990, 2000, and 2010 that can be matched with our bank rates.[1]

We also include several control variables. From Call Report, we collect bank size and credit quality. Bank size is the logarithm of bank assets. Credit quality is the percent of nonperforming loans. We then take average of bank size and credit quality of banks within each MSA to get MSA level values. The number of banks is just the total number of banks in each MSA. We calculate the number of banks and the Herfindahl index (HHI) for each MSA based on data from Summary of Deposit. The HHI, a common measure of market concentration, is defined as the sum of squares of the share of deposits of each bank within the MSA. The unemployment rate is from the Bureau of Labor Statistics. Income growth is from the Bureau of Economic Analysis and is defined as the change of personal income per capital in each MSA. The housing price index (HPI) in each MSA is from The Federal

[1]The U.S. Census also provides population estimates in the inter-Census years. We ignore these for the following two reasons. First, these are not truly independent observations, but are estimated from actual Census years. Second, since demographics change very slowly, annual data would provide very little additional variation in the explanatory variable.

Housing Finance Agency.

Table 2 reports some summary statistics. Our main results are based on three cross sections of MSAs from three periods: 1990, 2000, and 2010. The average deposit rate over these periods is 2.14%, and the average lending rate is 7.77%. Figure 1 shows that interest rates have generally trended down over the past four decades, while the population has aged. However, in our regressions, we control for year fixed effects; therefore, the trend should not affect our results. Table 3 also shows summary statistics for key variables in each of the three periods.

2.2 Results

In this subsection, we test whether demographics are associated with bank interest rates at the MSA level. Specifically, we run the following regression where an observation is defined at the level of an MSA-year (i, t).

$$Rate_{i,t} = \alpha^j + \beta^j POP^j_{i,t} + \kappa X_{i,t} + FE_t + \epsilon^j_{i,t} \tag{1}$$

where our key variables of interest are $Rate_{i,t}$ and $POP^j_{i,t}$, while $X_{i,t}$ represents a set of controls and FE_t controls for year fixed effects. $Rate_{i,t}$ is the interest rate in MSA i, year t; it is either the deposit rate, the loan rate, or the spread. $POP^j_{i,t}$ is the ratio of group j population relative to total population in MSA i, year t; group j represents either the young, the middle-aged, or the old. We run this regression separately for each group j because population shares, by construction, are negatively correlated with each other.[2]

[2]It is possible to run regressions with two out of the three population shares. These results are consistent with our findings from regressions with one demographic variable at a time. However, because there are three different ways we can choose two out of three demographic variables, we do not report these results.

2.2.1 Main results

Tables 4, 5, and 6 report the results of this regression for deposit rates, lending rates, and the lending-deposit spread, respectively.

Deposit rates are higher in MSAs where the older and, to some extent, middle aged groups make up a larger fraction of the population; they are lower when the young group makes up a larger fraction of the population. These results are highly significant, with the absolute value of t-statistics above three for the young and old groups. These results are also unaffected by the inclusion of controls for local economic conditions (unemployment rate, income growth, house prices, credit quality) and local banking sector controls (number of banks, bank HHI, and average bank size).

This finding is exactly opposite of what is predicted by existing models. There are two separate explanations for why an older population is associated with lower deposit rates in existing models. First, suppose that the high number of older people may be due to a relatively low population growth rate. When the population growth rate is low, banks expect to receive few deposits in the future, thus they must offer low rates of return today, as they will have few resources with which to repay current deposits. Second, when the number of 'prime-savers' is high, their demand for saving puts downward pressure on interest rates. 'Prime-savers' are households at their peak income earning years, roughly 45-65.

The pattern for lending rates is exactly the opposite to that of deposit rates. Lending rates are lower in MSAs where the older and middle aged groups make up a larger fraction of the population; they are higher when the young group makes up a larger fraction of the population. These results are slightly weaker than the deposit results, with t-statistics above 2 for the young and old fraction. They are also robust to various controls.

The lending rate results are consistent with predictions from previous work. In MSAs with more young people, the lending rates are significantly higher. If the spread is constant (including zero in the competitive case), then the intuition given earlier for deposit rates carries over to lending rates. Additionally, even if the spread is not constant, the Permanent Income Hypothesis of **?** implies that a higher fraction of young people in the population is associated with a higher demand for borrowing. This is because they have relatively low income and would like to smooth consumption over time. This higher demand for borrowing can result in higher lending rates. The intuition will be formalized in the next section, where we build an OLG model with both borrowing and lending in the presence of imperfectly competitive banks.

Like the lending rate, the lending - deposit spread is negatively (positively) related to the fraction of old (young) in an MSA. This result is not surprising in light of the previous two results, since the lending rate, and the negative of deposit rate are both negatively (positively) related to the fraction of old (young).

One possible explanation for why the behavior of deposit rates is so different from that of lending rates may be different amounts of risk across MSAs. We control for several local characteristics that may be related to local risk: the unemployment rate, income growth, and credit quality (measured by non-performing loans), these controls do not significantly affect the relationship between demographics and rates.

2.2.2 Competition

Another explanation may be competition. In an imperfectly competitive market, banks' choice of rates will be determined not just based on fundamentals, such as outside opportunities or risk, but also on their optimal choices in response to deposit and loan demand curves. In our baseline empirical results, we control for two measures of competition: the number of banks, and HHI. Our results are not significantly affected by these controls.

In the next section, we build a model of imperfectly competitive banks interacting with agents of different ages. The model suggests that the relationship between an MSAs demographics and its interest rates should depend on how competitive the banking sector is within the MSA. For this reason, in Tables 7 and 8, we repeat the same regressions on deposit and lending rates, but split the sample into high HHI MSAs (relatively uncompetitive) versus low HHI MSAs (relatively competitive) with the cutoff being the median HHI in each year.

The relationship between demographics and deposit rates appears stronger in less competitive markets. For all three groups, the coefficient falls in absolute magnitude as we move from high HHI (uncompetitive) to low HHI (competitive). In particular, the old coefficient falls from 0.019 to 0.004, the middle from 0.009 to 0.004, and the young from -0.010 to -0.003. The differences between high HHI and low HHI coefficients are statistically significant for the old and the young groups, with F-test p-values of 0.004 and 0.057, respectively. As will be discussed below, our model predicts that if demographic differences are driven solely by differences in birth rates, then competition should be unrelated to deposit rates. However, if demographic differences are driven at least partially by differences in life expectancy, then the positive (negative) relationship between the old (young) fraction and deposit rates should be stronger in less competitive markets, as in the data.

The effect of competition on the relationship between lending rates and demographics is not as strong. When we divide the data into low and high HHI markets, the estimated coefficients are greater in absolute values in MSAs with high HHI. For example, the estimated coefficient on old group ratio is -0.047 in high HHI markets and -0.029 in low HHI markets. The estimated coefficient on young group ratio is 0.041 in high HHI markets and 0.013 in low HHI markets. However, the differences between these coefficients are not statistically significant. The coefficient on the middle group changes from positive to significantly negative from low HHI to high HHI markets, and this difference is significant, with an F-test p-value of 0.055. These results are partially consistent with our model, which, like for deposit rates, predicts a stronger relationship in less competitive markets.

2.2.3 Alternate measures of demographics and robustness checks

Past literature has focused on the Middle-to-Young ratio for connecting demographics to asset prices. In Table 9 we present a regression with the same controls as before, but we replace our key explanatory variable by the middle-aged to young (MY) ratio. These results are mostly consistent with our previous findings. Higher MY ratio, which indicates an older population, predicts higher deposit rates and lower lending rates.

Another robustness check we perform is to use value-weighted deposit and lending rates as our dependent varialbes. All analysis so far compute the simple average of deposit and lending rates in an MSA. This would give higher relevance to small banks. Instead, we also compute the value-weighted average of deposit and lending rates in an MSA. The weights are based on a bank's deposit share in the MSA. We collect deposit shares from Summary of Deposits. Table 10 presents the results, which are qualitatively the same as the previous tables.

Finally, we also run regressions at the individual bank level with results presented in Table 11. The results are also consistent with our existing findings. Banks located in MSAs with an older population tend to have higher deposit rates, but lower lending rates. Overall, these results indicate that we have uncovered a robust positive (negative) relationship between population aging and deposit (lending) rates in the cross-section of US MSAs. The next section presents a model that explains these empirical findings.

3 Model

We model an endowment economy with overlapping generations. For simplicity, the economy is non-stochastic, with each city having a constant population growth rate g, and old-age survival probability p. These two variables fully determine demographics in a city, and may differ across cities. Although both a lower g and a higher p lead to an aging population, we show that their effects on interest rates may be different. The goal of the theoretical exercise is to show that for plausible parameter choices, the model can match the empirical observations of the previous section, namely that cities with an older population tend to have lower loan rates, but higher deposit rates.

Much of the intuition is similar to **?**, but we allow for imperfect competition in the financial sector.[3] In equilibrium, the per capita consumption, saving, and wealth of each age group is constant - only the size of the population is changing. Therefore, we suppress all time subscripts.

3.1 Househholds

Households live for a maximum of three periods: young workers (age=1), middle-aged workers (age=2), and retirees (age=3). We think of each period being roughly 23 years (19-41, 42-64, 65-87). Thus, at any time, there are three generations of households coexisting in the economy. All young workers survive to become middle-aged workers, but only a fraction p of middle-aged workers survive to become retirees, while the remaining $1-p$ die before reaching age=3. The survival probability p directly maps to life expectancy $64+23p$. The population grows at a rate g so that the total number of young workers is $1+g$ times higher than that of middle-aged workers, and $(1+g)^2/p$ times higher than that of retirees.

Households face no income uncertainty. All retirees earn no income $Y_3 = 0$, all middle-aged workers earn income Y_2, and all young workers earn income $Y_1 \leq Y_2$. Each period, households choose how much to consume C_i. The ratio $\frac{Y_1}{Y_1+Y_2}$ determines borrowing demand by the young. Households (except age=3 retirees who have no need for a bank) also choose which bank to do business with. As will be explained in more detail below, if household i chooses bank j, located a distance d_{ij} from the household, the household will pay a utility

[3] Another, similar, but perhaps better known model is **?**. There are two key differences between **?** and **?**. First, **?** has three generations, which allows for both saving and borrowing, while **?** has only two generations, which allows for borrowing only. Second, **?** has physical capital, while **?** is an endowment economy.

cost λd_{ij}.[4] A household may choose a bank a further distance away if that bank offers a better interest rate than the nearest bank. Below, we describe each household's problem, starting from the retiree.

3.1.1 Retirees, age 3

Any household which survives to retirement begin the period with wealth W_3 and simply consumes all of their wealth $C_3 = W_3$. The retiree's value function is

$$V_3(W_3) = \frac{W_3^{1-\rho}}{1-\rho} \tag{2}$$

Recall that only a fraction p of households survive to retirement. In our baseline calibration, we assume that the wealth of those who died before reaching retirement is simply wasted (i.e. end of life medical and funeral expenses). However, we also solve a case with bequests, where their wealth is transferred to the young generation; these are accidental bequests, so households have no utility from leaving wealth to the young. Because the size of accidental bequests is relatively small, the results in the model with accidental bequests are similar to the baseline model.

3.1.2 Middle-aged workers, age 2

Middle-aged workers decide how much to consume and which bank to leave their savings in. Each bank is a different distance d from the household, and may offer a different deposit rate $R_D(d)$. Households are aware that they will make it to retirement with probability p.

[4] As an alternative to the utility cost, the cost could have been written as a consumption equivalent cost $C_i - \lambda d_i$. The benefit of modeling it as a utility cost is that the consumption and saving of all households of age i is identical, regardless of their distance to the bank. In the alternative, each household would have a different C_i, which would require us to keep track of the entire distribution of households' choices.

The problem they solve is

$$
\begin{aligned}
V_2(W_2) &= \max_{C_2,d_2} \tfrac{C_2^{1-\rho}}{1-\rho} - \lambda d_2 + p\beta V_3(W_3) \\
W_3 &= (W_2 + Y_2 - C_2) R_D(d_2)
\end{aligned}
\tag{3}
$$

In the appendix, we show that the value function the age i household takes the form

$$
V_i(W_i) = A_i \frac{(W_i + Z_i)^{1-\rho}}{1-\rho} - \Lambda_i \tag{4}
$$

Similarly, their consumption function takes the form

$$
C_i = \frac{X_i}{1+X_i}(W_i + Z_i) \tag{5}
$$

where A_i, Z_i, X_i, and Λ_i depend only on age $i = \{\text{young, middle-aged, retired}\}$.

Note that for retirees, $A_3 = 1$, $Z_3 = 0$, $X_3 = \infty$, $\Lambda_3 = 0$. The appendix shows that for the middle-aged workers, conditional on the choice of bank, the constants are

$$
\begin{aligned}
X_2 &= (p\beta(R_D)^{1-\rho})^{-1/\rho} \\
A_2 &= \beta(R_D)^{1-\rho}\left(p^{1/\rho} + (\beta(R_D)^{1-\rho})^{-1/\rho}\right)^{\rho} \\
Z_2 &= Y_2 \\
\Lambda_2 &= \lambda d_2
\end{aligned}
\tag{6}
$$

3.1.3 Young workers, age 1

Like the middle-aged, young workers choose how much to consume C_1, and which bank to do business with, a distance d_1 from the household. Young workers may choose to either borrow from the bank ($C_1 > Y_1$) at rate $R_L(d_1)$, or to save through deposits ($C_1 < Y_1$) at rate $R_D(d_1)$. Becoming a borrower is related to higher expected income growth Y_2/Y_1, however the decision also depends on the favorability of the two rates; for example one may choose to not borrow if $R_L(d_1)$ is too high. Given the calibrated Y_2/Y_1, young workers always choose to be borrow. For this reason, to simplify notation, we focus only on the case where they are borrowers.

The young worker's problem is

$$\begin{aligned} V_1(W_1) &= \max_{C_1,d_1} \tfrac{C_1^{1-\rho}}{1-\rho} - \lambda d_1 + \beta V_2(W_2) \\ W_2 &= (W_1 + Y_1 - C_1)R_L(d_1) \end{aligned} \tag{7}$$

As for the other ages, the solution to this problem is given by equations 4 and 5. Conditional on the choice of bank d_1 this period, and the expected choice of bank d_2 next period, the constants are:

$$\begin{aligned} X_1 &= (\beta(R_L)^{1-\rho} A_2^{-1/\rho} \\ A_1 &= \beta(R_L)^{1-\rho}\left(A_2^{1/\rho} + (\beta(R_L)^{1-\rho})^{-1/\rho}\right)^{\rho} \\ Z_1 &= Y_1 + \tfrac{Y_2}{R_L} \\ \Lambda_2 &= \lambda(d_1 + \beta d_2) \end{aligned} \tag{8}$$

3.2 Banks

There are multiple cities, which may differ in their demographics g and p. There are n oligopolistic banks, each bank operates in all cities and faces local demand curves for deposits and loans in each city. The banks engage in Bertrand competition by offering a price (interest rate) for its product. The bank competition is similar to the Klein-Monti model, **?**, and to the circular city model of **?**. However, we embed these banks in an OLG setting similar to **?** and **?**, where the demand curve arise endogenously from household's saving demand over the life cycle.

Initially, we assume that the banks' quantity of deposits taken need not be equal to the quantity of loans given. While this may seem inconsistent with how real world banks operate, this is exactly how banks would operate in a **?** and **?** style OLG model.[5] Later, we will relax this assumption and introduce a constraint forcing loans given to equal to deposits taken, either city by city, or globally across all cities.

Each bank lives for two periods only – it raises deposits (makes loans) in the first period, and then repays the deposits (collects loan repayments) in the second period. The bank maximizes the present value of profits by discounting the second period profits by β_B.

When the bank's quantity of deposits is not constrained by its quantity of loans, the bank faces two independent problems in each city.[6] The profit of the deposit taking arm in any city is $\Pi_D(R_D) = (1 - \beta_B R_D)D(R_D)$, while that of the loan giving arm is $\Pi_L(R_L) = (-1 + \beta_B R_L)L(R_L)$ where $D(R_D)$ and $L(R_L)$ are the quantities of deposits and loans as a function of interest rates offered by the bank. In the appendix, we show that if banks are infinitely lived with discount rate β_B, but are unconstrained, they will solve independent, local, myopic problems to maximize profits, like the two period problem above. This is because today's choice of deposits, or loans, in a particular city, by an unconstrained bank, has no effect on that bank's profit in other cities, or in future time periods.

There are two ways to justify the bank's discount rate β_B. First, one can think of $R = 1/\beta_B$ as the bank's competitive cost of capital and return on investments in a global market. The inequality $R_L < R < R_D$ implies that the deposit taking arm is raising capital locally cheaper than it could globally, and the loan giving arm is investing in higher yielding projects locally than it could globally. Perfect competition would change the inequality to equality. However, with imperfect competition, the unconstrained bank maximizes profits by limiting its lending and deposit taking; it has no interest in lending (borrowing) more than the profit maximizing level, even if the lending (deposit) rate is above (below) its cost

[5] Both **?** and **?** consider competitive economies where households can trade with each other directly, therefore they do not explicitly model banks. However in **?** both saving and borrowing are present, and do not need to equal each other. In **?** saving is present, but borrowing is zero. This is possible because in these models, savings are a (welfare improving) Ponzi scheme, with the savings of the young used to repay the old.

[6] The choice of deposits is also separate from the choice of loans in **?**. **?** extends the Monti-Klein model to study when the deposit decision can be separated from the loan decision.

of capital. Second, consider models such as **?**, **?** and **?** which do not explicitly model banks, but where competitive banks, if modeled, would be infinitely lived, welfare improving Ponzi schemes which facilitate inter-generational risk sharing. In such models, banks repay last period's depositors using current deposits, and lend to current borrowers using last period's repaid loans. In these models, the natural rate of interest is equal to the rate of population growth g. In our model, if we set the bank's discount rate equal to the natural rate of interest $\frac{1}{\beta_B} - 1 = g$, and we increase the number of banks $n \to \infty$ (or equivalently decrease the search cost $\lambda \to 0$) to the limit of perfect competition, then our economy will converge exactly to **?**, with the local deposit and loan rates both equaling g. In other words, if **?** were to explicitly introduce competitive, profit maximizing banks into his model, they would have to have a discount rate $\frac{1}{\beta_B} - 1 = g$.

When the bank's quantity of deposits is constrained by its quantity of loans $D(R_D) = L(R_L)$, then β_B is irrelevant. Total profit is $\Pi = \Pi_D(R_D) + \Pi_L(R_L) = \beta_B D(R_D)(R_L - R_D)$, thus β_B is just a constant that affects the valuation of the bank's profit, but not the bank's optimization problem. This is true whether the bank is constrained locally, or globally. However, since the bank's problem can no longer be separated into deposit taking and loan giving, the two arms of the bank must be treated jointly. We argue below that this is the most empirically relevant case, therefore the choice of β_B is irrelevant for our main result.

3.2.1 The imperfectly competitive environment

As is well known, a standard Bertrand setup collapses to perfect competition with $n \geq 2$ banks, unless frictions are introduced. We follow **?** and consider a circular city model. Households are uniformly distributed on a circle with radius $\frac{1}{2\pi}$ and circumference 1. The n banks are evenly spread out on the same circle, therefore the distance between any two banks is $1/n$ and the distance from any household to its nearest two banks is $0 < d < 1/n$ and $1/n - d$. We assume that the household would never travel further than $1/n$, and therefore only considers its two nearest banks when making its choice.

As discussed above, households choose which bank to use. First, consider the middle-aged worker. This household is indifferent between a bank at a distance d offering R_D and a bank at a distance $1/n - d$ offering $R_{D,*}$ if

$$A_2(R_D)\frac{(W_2 + Z_2)^{1-\rho}}{1-\rho} - \lambda d_2 = A_2(R_{D,*})\frac{(W_2 + Z_2)^{1-\rho}}{1-\rho} - \lambda(1/n - d_2) \tag{9}$$

In this equation, we explicitly note that dependence of A_2 on R_D, as shown in equation 6. Solving this for d_2 as a function of R_D and $R_{D,*}$

$$d_2 \quad = \quad \tfrac{1}{2n} + \tfrac{1}{2\lambda_2}\tfrac{(W_2+Z_2)^{1-\rho}}{1-\rho}\left(A_2(R_D) - A_2(R_{D,*})\right) \tag{10}$$

Next, consider the young worker, who borrows from the bank. This household is indifferent if

$$A_1(R_L)\frac{Z_1(R_L)^{1-\rho}}{1-\rho} - \lambda d_1 = A_1(R_{L,*})\frac{Z_1(R_L,*)^{1-\rho}}{1-\rho} - \lambda(1/n - d_2) \tag{11}$$

In this equation, we explicitly note that dependence of both A_1 and Z_1 on R_L, as shown in equation 8. Solving this for d_1 as a function of R_L and $R_{L,*}$

$$d_1 \quad = \quad \tfrac{1}{2n} + \tfrac{1}{2\lambda}\left(A_1(R_L)\tfrac{Z_1(R_L)^{1-\rho}}{1-\rho} - A_1(R_{L,*})\tfrac{Z_1(R_{L,*})^{1-\rho}}{1-\rho}\right) \tag{12}$$

Note that d for savers (borrowers) increases (decreases) in R_D (R_L) because they are willing to travel further for a higher (lower) interest rate.[7] If $R_D = R_{D,*}$ and $R_L = R_{L,*}$, as is the case in a symmetric equilibrium, households simply travel to the nearest bank, and each bank's customers live on the interval of length $\frac{1}{n}$ around the bank.

We solve this problem as a Nash equilibrium, where the bank takes the rates offered by all other banks as given, and determines a best response. The deposit taking arm's profit,

[7] $A_i(R)$ is increasing in R, but Z_i is decreasing in R.

as a function of its interest rate R_D and its competitors' $R_{D,*}$ is

$$\Pi_D = \big((1+g)^{-1}(W_2 + Y_2 - C_2(R_D)) * 2d_2(R_D, R_{D,*})\big)(1 - \beta_B R_D) \tag{13}$$

The quantity in the first parentheses is the total dollar deposits, where the population of the age=1 generation is normalized to 1. To compute total dollar deposits, we multiply the population size of depositors $(1+g)^{-1}$ by the saving per depositor $W_2 + Y_2 - C_2(R_D)$, and by the fraction of total population captured by the bank $2d_2$. The quantity in the second parentheses is the profit per dollar of deposits. Note that we explicitly write d_2 and C_2 as functions of the bank's chosen interest rate R_D.

Similarly, the loan giving bank's profit, as a function of its interest rate R_L and its competitors' $R_{L,*}$ is

$$\Pi_L = \big((C_1(R_L) - Y_1) * 2d_1(R_L, R_{L,*})\big)(\beta_B R_L - 1) \tag{14}$$

The bank chooses the interest rates R_D and R_L to maximize each arm's profit.

3.3 Equilibrium

We solve for a symmetric Nash equilibrium, where all banks offer the same $R_{L,*}$, the same $R_{D,*} \leq R_{L,*}$, and where all households choose their nearest bank, so that $d \in (0, 0.5/n)$. This equilibrium consists of scalars for consumption choices by households $C_{1,*}$, $C_{2,*}$, and interest choices by banks $R_{D,*}$, and $R_{L,*}$ in each city. These choices must be such that: i) $C_{1,*}$ and $C_{2,*}$ satisfy the household's optimization equations 5, 6, and 8, given $R_{D,*}$ and $R_{L,*}$; ii) $R_{D,*}$ and $R_{L,*}$ maximize the bank's profit equations 13 and 14, given the household's behavior summarized by equations 5, 6, 8, 10, and 12, and given the beliefs of the bank about other banks' policies $R_{D,*}$ and $R_{L,*}$.

3.3.1 Constrained Banks

We consider two constraints. First, if banks are constrained to have their deposits be equal to their loans city by city, then instead of maximizing equations 13 and 14 independently, we maximize the sum of the two equations, with the additional constraint

$$(1+g)^{-1}(W_2+Y_2-C_2(R_D))*2d_2(R_D,R_{D,*})=(C_1(R_L)-Y_1)*2d_1(R_L,R_{L,*}) \quad (15)$$

In this case, as in the unconstrained case, banks in individual cities set their policies independently of each other, thus we can solve this problem city by city.

Second, if banks are constrained to have their total deposits across all cities be equal to their total loans across all cities, but not necessarily in any individual city, then we must solve the problem jointly across all cities. The bank will jointly choose all interest rates across all cities to maximize $\sum \Pi_D^j + \Pi_L^j$ subject to the constraint

$$\sum(1+g)^{-1}(W_2^j+Y_2-C_2^j(R_D^j))*2d_2^j(R_D^j,R_{D,*}^j)=\sum(C_1^j(R_L^j)-Y_1)*2d_1^j(R_L^j,R_{L,*}^j) \quad (16)$$

where j indicates each city.

We have also solved a case where total loans must equal to total deposits, as specified by equation 16, that there may be a mismatch of loans to deposits in any individual city, but there is a quadratic cost paid for any mismatch, implying that moving funds from one city to another is costly. We do not report this case, but, as might be expected, these results fall in between the first and the second cases.

Note that without any such constraints, maximizing $\Pi_D + \Pi_L$ jointly yields exactly the same optimal interest rates as maximizing Π_D and Π_L independently.

3.3.2 Numerical solution

We solve this model numerically. Starting with beliefs about $R_{D,*}$ and $R_{L,*}$, we can solve for the household's behavior analytically. Since we are solving for a Nash equilibrium, we must also solve for the household behavior and value functions for any off-equilibrium action by the bank $R_D \neq R_{D,*}$ and $R_L \neq R_{L,*}$. For example, from equations 5 and 6, $C_2(R_D) = \frac{X_2(R_D)}{1+X_2(R_D)}(W_{2,*} + Y_2)$ where $X_2 = (p\beta(R_D)^{1-\rho})^{-1/\rho}$ for any R_D. Note that the bank takes the household's wealth at the start of the period $W_{2,*}$ as given, because the bank has no control over it. From this, we can solve for each bank's demand as a function of both its choices (R_D,R_L) and its beliefs ($R_{D,*}$,$R_{L,*}$). We then choose (R_D,R_L) to maximize the bank's profits; the bank's optimal (R_D,R_L) is used to update ($R_{D,*}$,$R_{L,*}$), and the procedure repeats until convergence.

3.4 Calibration

Though the model is simple and we are mostly interested in its qualitative implications, we nevertheless try to choose reasonable parameters reflecting the model's analogs in the data.

We do not model childhood, and adulthood lasts for 3 periods. We think of each of these as being roughly 23 years: ages 19-41, 42-64, and 65-87. We vary the survival probability p between 0.1 and 0.9, implying a life expectancy between 66 and 85, with $p = 0.5$ being the baseline value. Actual U.S. life expectancy has increased from 70.8 to 78.7 years for those born in 1970 compared to 2016 (**?**), We vary the annual growth rate of the population g between 0% and 2%, with 1% being the baseline value, implying $g = 0.257$ over 23 years. Actual U.S. population growth has averaged very close to 1% between 1970 and 2017, peaking at 1.39% in 1992, and falling to 0.64% in 2017 (World Bank data). There are likely to be significant cross-sectional differences across U.S. MSAs in both life expectancy and growth rates. We set time preference to have a 1% annual discount, implying $\beta = 0.794$ over 23 years. We set the inverse of the IES $\rho = 0.5$.

In the model, retirees earn no labor income. Based on the Survey of Consumer Finance (SCF), we set the income earned while young to be 37% of lifetime income; we also experiment with this number and it does not affect our key results.[8]

We set the number of banks $n = 5$ in the baseline model. We set the search cost $\lambda = 0.2$. The parameters n and λ are isomorphic with respect to the model – doubling n is equivalent to halving λ. This implies a net interest margin of 1% in the baseline model. From 1984 to 2019, U.S. banks' interest margin has averaged a significantly higher 3.8% (St. Louis Fed), however, in our model this margin is solely due to market power, whereas real world banks are also compensated for risk, liquidity transformation, and maturity transformation, all of which are outside of our model. We also experiment with alternative values for n, the empirical pattern we aim to explain is qualitatively present as long as competition is imperfect ($n < \infty$), and strengthens in less competitive environments (low n, high interest margin).

3.5 Results

We are interested in the effect of demographics on interest rates in the presence of imperfect competition in the banking sector. There are two aspects of demographics we consider, a decrease in the birth rate and an increase in life expectancy. Although both lead to an older population, their effects on interest rates can be very different. In particular, as will be shown below, a decrease in the birth rate is associated with lower loan rates and deposit rates; this is consistent with the intuition in the existing literature, but not consistent with the cross-

[8]Unfortunately, the SCF does not follow households over time, but just gives a cross-section of different households every three years. Therefore we cannot calculate the fraction of total income a particular individual earns while young. Instead, for each of the three age groups, we define the share of lifetime income as the average income of that age group, divided by the sum of the average incomes of all three age groups. In the data, roughly 10% of total income is earned by the 65 and up group. The fraction of total labor income earned by the 19-41 age group fell from 43% to 37% between 1983 and 1995, and has remained relatively steady around 37% since 1995.

sectional empirical evidence in Section 2. On the other hand, when banking competition is imperfect, an increase in life expectancy is associated with lower loan rates, but higher deposit rates; this is consistent with the empirical evidence. Both decreasing birth rates and increasing life expectancy are contributing to an older population in the data. We interpret our model results to suggest that quantitatively, it is the later effect that is most relevant for interest rates. Our model is also a proof of concept – previously, every theoretical study of demographics and interest rates has argued that the relationship between interest rates and average age is negative, our model shows that this is not necessarily the case.

3.5.1 Life expectancy

We first study differences in life expectancy across cities. The main results are presented in Figure 2. We believe that the most empirically relevant case is the 'Global Constraint' model, where banks must keep their total lending equal to their total deposits, but are not constrained at each city's level. This is because U.S. capital markets are well developed, and banks likely have little trouble moving capital across locations. At the same time, typically banks are unable to lend more capital than they raise, and tend to lend as much as they can up to the capital requirement.[9] However, to build intuition, we begin by describing the model where banks are unconstrained.

The 'No Constraint' line shows the deposit and loan rates as a function of the Old/Middle population ratio[10] in the unconstrained model.[11] The cities differ in their life expectancy p but all have the same annual growth rate g, this implies that the Old/Middle ratio is linear

[9]In the U.S., FDIC-supervised institutions must maintain common equity tier 1 capital to total risk-weighted assets ratio of 4.5%. To keep the model simple, we ignore bank equity and assume banks' lending is equal to deposits. We believe that this is a reasonable approximation, especially since there is no risk in the model, therefore banks cannot default.

[10]Our baseline model, calibrated to average growth and life expectancy between 1970 and 2016, implies an Old/Middle population ratio of 0.4. This ratio is currently 0.55 in the U.S. (Census bureau), it is higher than in our baseline model because of exceptionally high birth rates post-WW2 (the Baby Boomer generation). At the MSA level, we observe ratios as low as 0.2 and as high as 1.3 with a mean of 0.51.

[11]Recall that these banks are modeled in the spirit of **?**, **?** and **?**. They finance new loans with last period's repaid loans, and last period's deposit payouts with new deposits.

in p and equal to $p(1+g)^{-23}$.

Our key result is that consistent with the empirical evidence, the loan rate (bottom panel) is decreasing in the age of the city's population, while the deposit rate (bottom panel) is increasing in this age. The bank is a local monopolist, so it sets prices to maximize profits, taking the demand functions for loans and deposits as given. The shape of the demand functions is what determines the behavior of interest rates.[12]

The general equation for demand is non-linear, and the general equation for the interest rate is complicated; we provide an implicit equation for R_D in the appendix. However, for a fairly large and realistic range of parameters, the above intuition still holds. [13]

Next, consider banks whose loan supply is constrained by the deposits they raise, but only at the aggregate (national) level, labeled 'Global Constraint' in Figure 2. That is, banks can costlessly move money across MSAs, but cannot be Ponzi schemes as in **?**.[14] The equilibrium loan and deposit rates look very similar to the unconstrained case. This is because when unconstrained, cities with an older population tend to demand more deposits than loans, while cities with a younger population tend to demand more loans than deposits. On the net, the two balance out, therefore the global constraint does not shift the banks' optimal

[12]For example, consider linear demand functions $D(R_D,p) = -A_D(p) + B_D(p)R_D$ for deposits and $L(R_D,p) = A_L(p) - B_L(p)R_L$. The bank chooses interest rates to maximize profit for each loan type $\Pi_D = (1-\beta_B R_D)D(R_D,p)$ and $\Pi_L = (\beta_B R_L - 1)D(R_L,p)$. It is easy to show that the bank chooses $R_D = 0.5\left(\frac{1}{\beta} + \frac{A_D(p)}{B_D(p)}\right)$ and $R_L = 0.5\left(\frac{1}{\beta} + \frac{A_L(p)}{B_L(p)}\right)$. As the demand shifts in response to a change in p, the bank may lower or raise interest rates depending on the ratios $\frac{A_D(p)}{B_D(p)}$ and $\frac{A_L(p)}{B_L(p)}$.

[13]This is not a general result, for some extreme parameters, interest rates may decline with p. Among all parameter combinations we attempted, the only way we were able to get deposit rates to decline in life expectancy was to set a very low ρ (high IES) and a very high λ (high market power), for example $rho = 0.2$ and $\lambda = 5$. When ρ is low, households are less concerned with smoothing consumption over time, therefore a high p has a smaller effect on borrowing and lending demand. Furthermore, a high λ implies large spreads, reducing the benefit to do business with a bank.

[14]We solve the unconstrained model for 9 different cities. However, since banks are unconstrained, they set their interest rates optimally within each city, and do not interact across cities, therefore the solution method is equivalent to solving each city's problem independently and one could solve the unconstrained model for a much larger number of cities. This is also true for the model with local constraints, presented below, because locally constrained cities also do not interact. On the other hand, due to computational constraints, the model with a global constraint is solved for only 7 cities. This is because when cities interact, the bank must simultaneously solve the problem across all cities, leading to 2^n choice variables, where n is the number of cities.

behavior significantly from the unconstrained case.

Finally, we consider is the locally constrained case, labeled 'Local Constraint' in Figure 2, though we do not believe this to be empirically relevant. The interest rate on loans falls with age much faster than in the other two cases. The interest rate on deposits is non-monotonic, first rising, and then falling with age. Alternative parameter choices can lead to alternative patterns of interest rates.

We have also solved our model under several alternative assumptions about parameters. Imperfect competition is crucial for the above results. As the environment becomes more competitive – either through a higher number of banks n, or a lower travel cost λ – both the deposit rate and loan rate become flatter as a function of the city's age. In the limit of perfect competition, both are equal to the growth rate g, and independent of life expectancy p. We have added bequests, by assuming that the wealth of dead agents is evenly distributed among the young; as discussed above, because the size of accidental bequests is relatively small, the results in the model with accidental bequests are similar to the baseline model. We have also experimented with a steeper and a flatter age-income profile and with alternative IES; for a reasonable range of these parameters, the main results are qualitatively similar to the ones in the baseline model.

3.5.2 Growth

Unlike the case where differences in across cities are due to life expectancy, if differences are due to birth rates, then the model cannot match the observed empirical pattern of deposit rates that rise, and lending rates that fall with a city's average age.

First, consider the unconstrained case. If there is perfect competition, then both interest rates are exactly equal to the inverse of the bank's discount factor $1/\beta_B$. Thus, if the bank's discount factor in each city is equal to the inverse of that city's birth rate $1+g$, then interest rates decline in g. On the other hand, if the bank's discount factor is the same across all cities (for example, it could be equal to the average of $1/(1+g)$ across all cities), then both interest rates are constant across all cities.

If we add imperfect competition, the interest rates are equal to the bank's discount factor plus or minus a spread. However, for the parameter combinations we have tried, this spread does not strongly depend on g, therefore the deposit and lending rates as a function of g still look much like the perfectly competitive case.

Next, consider the two constrained cases. As explained above, when banks are constrained, the banks β_B is irrelevant because when deposits are equal to loans, β_B drops out of the bank's optimization problem. We are unable to solve the case where there is a global constraint on all banks, but cities have different birth rates. This is because the model becomes non-stationary as the highest g city eventually dominates the model. On the other hand, if banks are locally constrained to have deposits equal to loans, then both interest rates and deposit rates decline with a city's birth rate g.

4 Conclusion

Changing demographics, in the form of lower birth rates and longer life spans have been blamed for the decline in global interest rates and for secular stagnation. We provide novel empirical evidence from the cross-section of U.S. MSAs which suggests that the relationship between demographics and interest rates is more complicated than previously thought. While older MSAs indeed have lower lending rates, they also have higher deposit rates. We build a model with imperfect competition in the banking sector which can rationalize these findings.

A Appendix

B Model

B.1 Retired household

The retired household (age=3) starts off with wealth W_3 and consumes all of it before dying. Its value function is:

$$\begin{aligned}
&V_3(W_3) = A_3 \tfrac{(W_3+Z_3)^{1-\rho}}{1-\rho} \\
&C_3 = \tfrac{X_3}{1+X_3}(W_3 + Z_3) \\
&A_3 = 1, Z_3 = 0, X_3 = \infty
\end{aligned} \tag{17}$$

B.2 Middle-aged household

The middle-aged household (age=2) starts off with wealth W_2. It earns Y_2 in labor income, consumes C_2, and saves $S_2 = W_2 + Y_2 - C_2$ for retirement. It will survive to retirement and consume these savings with probability p. It will choose a bank at a distance d_2 from its location, which offers a deposit rate R_D, as will be explained below. Conditional on d_2 and R_D, its maximization problem is:

$$\begin{aligned}
V_2(W_2) &= \max_{C_2} \tfrac{C_2^{1-\rho}}{1-\rho} - \lambda_2 d_2 + p\beta \tfrac{((W_2+Y_2-C_2)R_D)^{1-\rho}}{1-\rho} \\
&= \max_{C_2} \tfrac{C_2^{1-\rho}}{1-\rho} - \lambda_2 d_2 + X_2^{-\rho} \tfrac{(W_2+Y_2-C_2)^{1-\rho}}{1-\rho}
\end{aligned} \tag{18}$$

The solution to this problem is:

$$\begin{aligned}
&V_2(W_2) = A_2 \tfrac{(W_2+Z_2)^{1-\rho}}{1-\rho} - \lambda_2 d_2 \\
&C_2 = \tfrac{X_2}{1+X_2}(W_2 + Z_2) \\
&A_2 = (1 + X_2^{-1})^{\rho}, Z_2 = Y_2, X_2 = \left(p\beta R_D^{1-\rho}\right)^{-1/\rho}
\end{aligned} \tag{19}$$

B.3 Young household

The young household (age=1) starts off with zero wealth. It earns Y_1 in labor income, consumes C_1, and saves $S_1 = Y_1 - C_1$, which may be negative. It will choose a bank at a distance d_1 from its location, which offers a deposit rate R_D and a loan rate R_L, as will be explained below. Conditional on d_1 and R (R_D or R_L depending on whether it chooses to save or borrow), its maximization problem is:

$$\begin{aligned} V_1 &= \max_{C_1} \tfrac{C_1^{1-\rho}}{1-\rho} - \lambda_1 d_1 + \beta A_2 \tfrac{((Y_1 - C_1)R + Z_2)^{1-\rho}}{1-\rho} - \beta\lambda_2 d_2 \\ &= \max_{C_1} \tfrac{C_1^{1-\rho}}{1-\rho} - \lambda_1 d_1 + X_1^{-\rho} \tfrac{(Y_1 - C_1 + Z_2/R)^{1-\rho}}{1-\rho} - \beta\lambda_2 d_2 \end{aligned} \tag{20}$$

The solution to this problem is:

$$\begin{aligned} &V_1 = A_1 \tfrac{Z_1^{1-\rho}}{1-\rho} - \lambda_1 d_1 - \beta\lambda_2 d_2 \\ &C_1 = \tfrac{X_1}{1+X_1} Z_1 \\ &A_1 = (1 + X_1^{-1})^{\rho}, Z_1 = Y_1 + Z_2/R, X_1 = \left(\beta A_1 R^{1-\rho}\right)^{-1/\rho} \\ &\text{If } C_1 > Y_1 \text{ then } R = R_L, \text{ otherwise } R = R_D \end{aligned} \tag{21}$$

B.4 Bank's optimization

The bank's profit from deposits can be written as:

$$\Pi_D = (1 - \beta_B R_D) \tfrac{W_2 + Z_2}{1 + X_2} \left(\tfrac{1}{n} + \tfrac{1}{\lambda_2} \tfrac{(W_2 + Z_2)^{1-\rho}}{1-\rho} \left((1 + X_2^{-1})^{\rho} - (1 + X_{2,*}^{-1})^{\rho} \right) \right) \tag{22}$$

In equilibrium, W_2, X_2, and $X_{2,*}$ all depend on R_D. However, from the bank's point of view, W_2 and $X_{2,*}$ are exogenous, and by changing R_D, the bank can only affect X_2, which is given by equation 19. Taking the first order conditions with respect to R_D and noting that in equilibrium $R_D = R_{D,*}$, the equilibrium R_D must satisfy the below equation

$$\frac{\beta_B}{n} = -(1-\beta_B R_D)\frac{\partial X_2}{\partial R_D}\left(\frac{1}{1+X_2}\frac{1}{n} + \frac{1}{\lambda_2}\frac{(W_2+Z_2)^{1-\rho}}{1-\rho}\rho(1+X_2^{-1})^{\rho-1}X_2^{-2}\right) \tag{23}$$

This can be further rewritten:

$$1+X_2 = -(\frac{1}{\beta_B} - R_D)\frac{\partial X_2}{\partial R_D}\left(1 + \frac{n}{\lambda_2}\frac{(W_2+Z_2)^{1-\rho}}{1-\rho}\rho(1+X_2)^{\rho}X_2^{-\rho-1}\right) \tag{24}$$

Using $\frac{\partial X_2}{\partial R_D} = (1-\frac{1}{\rho})X_2 R^{-1}$ this can be rewritten as:

$$1+X_2 = (\frac{1}{R_D\beta_B} - 1)(\frac{1}{\rho} - 1)\left(X_2 + \frac{n}{\lambda_2}\frac{(W_2+Z_2)^{1-\rho}}{1-\rho}\rho(1+X_2^{-1})^{\rho}\right) \tag{25}$$

where $X_2 = \left(p\beta R_D^{1-\rho}\right)^{-1/\rho}$. Thus, this equation gives an implicit relationship between p and R_D.

Table 1: Model summary

This table summarizes our model's key results. The subscript i indicates a unit of observation, which may be a city or a time period. The first row describes models where demographic differences are driven by the birth rate g_i (p is held constant), while the second row describes models where these differences are driven by life expectancy p_i (g is held constant). The left column describes models with perfect competition, and the right column with imperfect competition. r^D is the deposit rate and r^L is the lending rate.

Demographic	Competition	
differences	Perfect	Imperfect
Growth rate g_i	$r_i^D = g_i = r_i^L$ $Corr(r_i^L, Age_i) < 0$ $Corr(r_i^D, Age_i) < 0$	$r_i^D < g_i < r_i^L$ $Corr(r_i^L, Age_i) < 0$ $Corr(r_i^D, Age_i) < 0$
Life expectancy p_i	$r_i^D = g = r_i^L$ $Corr(r_i^L, Age_i) = 0$ $Corr(r_i^D, Age_i) = 0$	$r_i^D < g < r_i^L$ $Corr(r_i^L, Age_i) < 0$ $Corr(r_i^D, Age_i) > 0$

Figure 1: Trends of demographics and bank interest rates

This figure plots the population fraction and interest rates over time. Young is the 20-42 year old fraction of total population, middle and old is 43 years old and above fraction of total population. We plot three different interest rates: Fed fund rate is from Fed H.15 release (1970-2013), deposit and lending rates are calculated from Call Report (1984-2010).

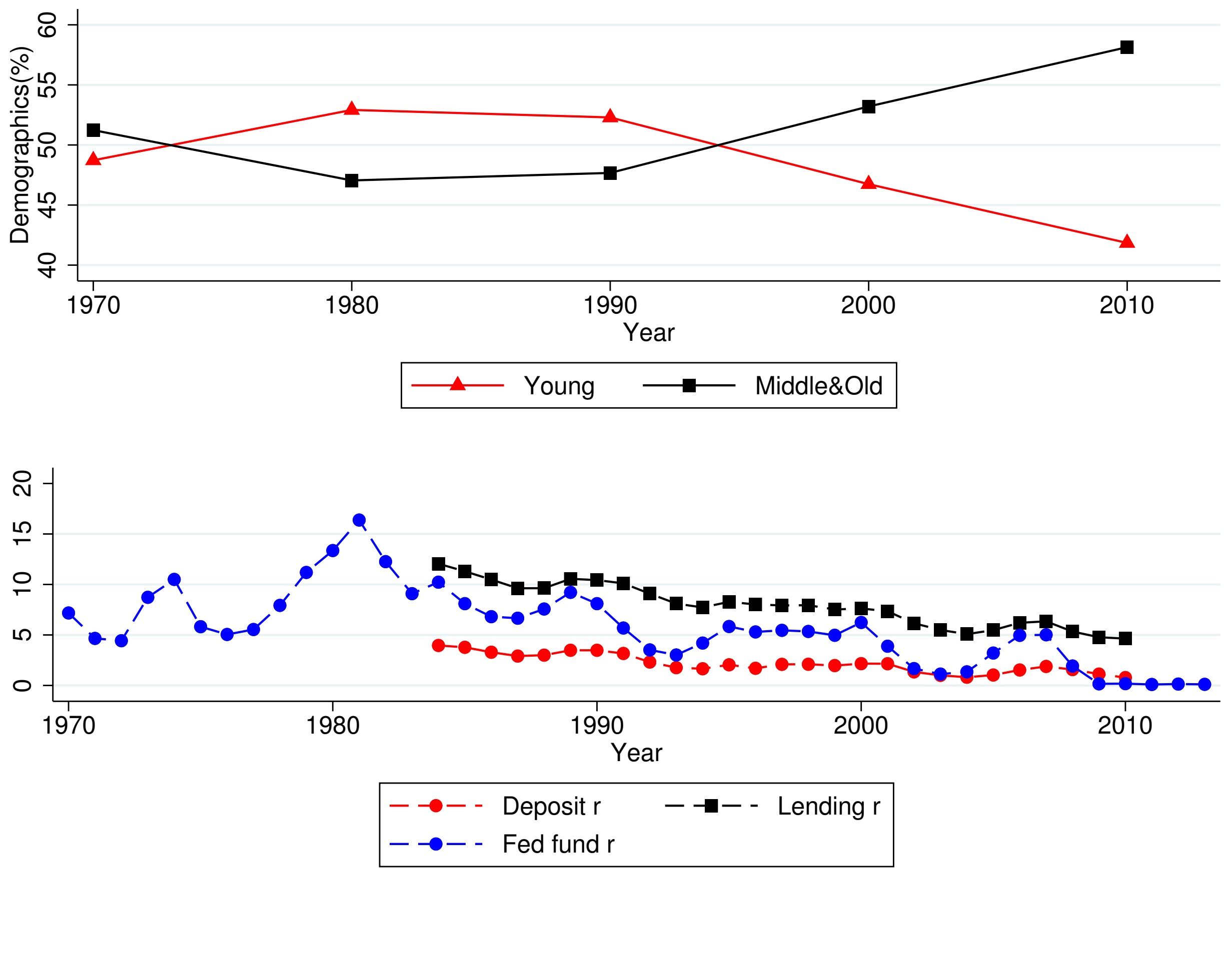

Figure 2: Interest rates and life expectancy in the model

This figure plots the interest rate as a function of a city's Old to Middle Aged ratio in the model. The top panel plots the deposit rate, and the bottom panel plots the lending rate. The dotted blue line represents a model where banks are unconstrained, the solid black line represents a model where there is a global constraint such that total loans are equal to total deposits, and the dashed red line represents a model where there is a local constraint such that loans are equal to deposits city by city.

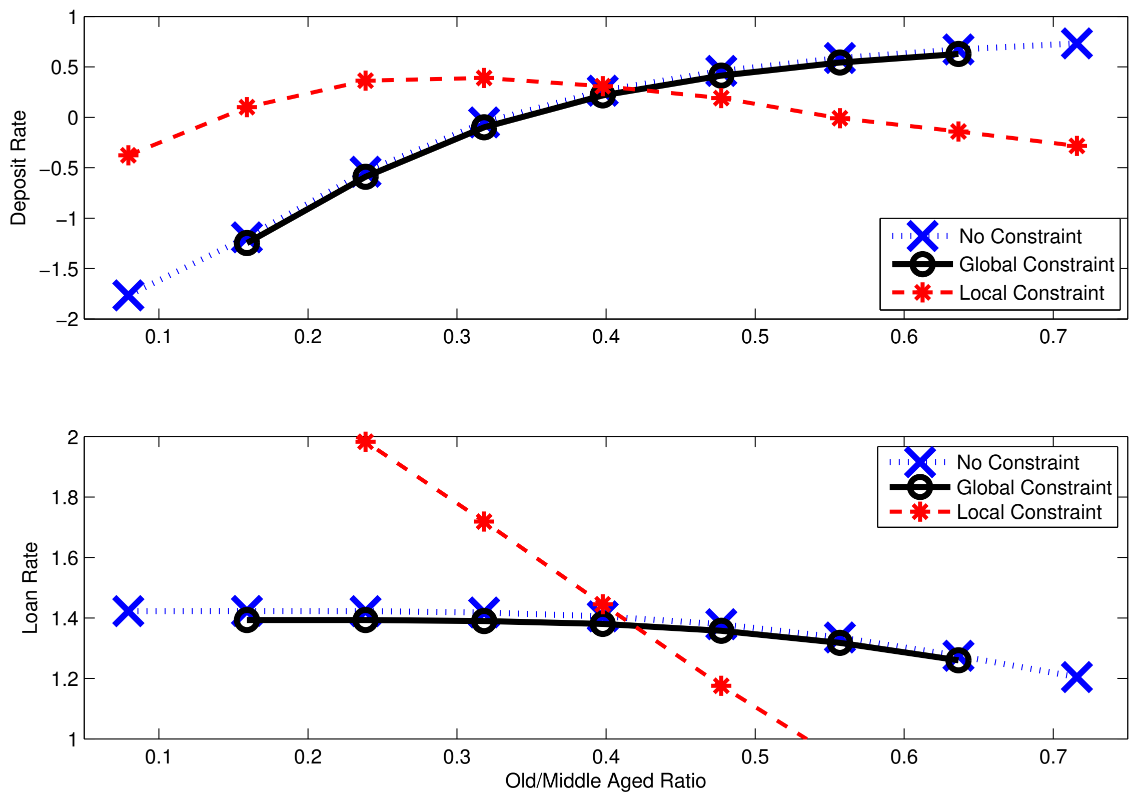

Table 2: Summary statistics

This table reports the summary statistics of the sample for all three years: 1990, 2000, and 2010. All variables are the average value at MSA level. Deposit rates and loan rates are calculated from Call Report. Spread is the difference between loan and deposit rates. Demographics variables (young, middle, and old group ratio) are from US Census data. Young, middle and old groups are defined as ages 20-42, 43-64, and 65 and above, respectively. For each group, the ratio is the number of people in that group divided by the total population (excluding those younger than 20 years old). The unemployment rate is from Bureau of Labor Statistics. Income growth is from Bureau of Economic Analysis and defined as the change of personal income per capital in each MSA. Housing price index is from The Federal Housing Finance Agency. HHI is the bank deposit market concentration measure, defined as the sum of square of share of deposit.

	N	Mean	SD	P5	P25	P50	P75	P95
Deposit rates (%)	932	2.14	1.16	0.55	0.90	2.17	3.31	3.79
Loan rates (%)	932	7.77	3.31	3.97	4.87	7.17	9.65	13.60
Spread (%)	932	5.63	2.68	3.08	3.88	4.89	6.48	10.36
Young (%)	932	47.53	6.97	36.89	42.67	47.41	52.19	59.28
Middle (%)	932	34.72	4.69	27.55	30.78	35.11	38.48	41.82
Old (%)	932	17.70	4.04	12.30	15.29	17.30	19.43	24.03
Middle-to-young ratio (%)	932	75.94	20.74	47.03	59.80	73.40	89.10	111.57
Unemployment rate (%)	932	6.44	3.08	2.82	4.07	5.65	8.40	12.15
Income growth (%)	932	4.31	2.63	0.14	2.50	4.40	5.95	8.31
Number of banks	932	40.52	54.25	8.00	14.00	22.00	44.00	129.00
Housing price index	932	292.12	150.92	135.94	193.03	249.96	339.76	594.41
HHI	932	0.21	0.10	0.10	0.15	0.19	0.26	0.41

Table 3: Summary statistics by year

This table reports the summary statistics of the sample for each year in 1990, 2000, and 2010. All variables are the average value at MSA level. Deposit rates and loan rates are calculated from Call Report. Spread is the difference between loan and deposit rates. Demographics variables (young, middle, and old group ratio) are from US Census data. Young, middle and old groups are defined as ages 20-42, 43-64, and 65 and above, respectively. For each group, the ratio is the number of people in that group divided by the total population (excluding those younger than 20 years old).

	N	Mean	SD	P5	P25	P50	P75	P95
Panel A: 1990								
Deposit rates (%)	313	3.50	0.35	2.84	3.30	3.55	3.69	4.04
Loan rates (%)	313	10.70	2.42	8.18	9.14	10.09	11.33	15.53
Spread (%)	313	7.21	2.53	4.37	5.67	6.61	7.88	12.39
Young (%)	313	52.78	5.59	43.53	49.73	52.69	55.64	62.35
Middle (%)	313	29.77	2.30	25.31	28.76	30.12	31.27	32.87
Old (%)	313	17.41	4.16	11.94	14.97	16.99	19.36	23.90
Middle-to-young ratio (%)	313	57.40	9.81	41.70	52.20	57.18	62.80	72.78
Panel B: 2000								
Deposit rates (%)	313	2.14	0.33	1.57	1.94	2.17	2.36	2.64
Loan rates (%)	313	7.80	2.54	5.84	6.51	7.09	8.09	12.17
Spread (%)	313	5.67	2.63	3.55	4.31	4.90	6.01	10.43
Young (%)	313	47.26	5.45	39.05	44.18	47.24	50.27	56.79
Middle (%)	313	35.08	2.44	30.09	34.17	35.56	36.57	37.82
Old (%)	313	17.60	4.13	11.92	15.23	17.18	19.32	24.28
Middle-to-young ratio (%)	313	75.65	12.87	52.84	68.32	75.71	83.13	96.98
Panel C: 2010								
Deposit rates (%)	306	0.76	0.20	0.40	0.63	0.78	0.90	1.06
Loan rates (%)	306	4.74	1.71	3.66	4.10	4.42	4.85	6.28
Spread (%)	306	3.98	1.73	2.83	3.32	3.67	4.13	5.66
Young (%)	306	42.45	5.62	34.43	38.98	42.14	45.47	52.87
Middle (%)	306	39.44	2.84	33.62	38.41	40.14	41.23	42.85
Old (%)	306	18.11	3.80	13.14	15.64	17.82	19.62	23.56
Middle-to-young ratio (%)	306	95.22	17.87	64.41	84.50	96.09	105.95	121.99

Table 4: Demographics and deposit rates

This table presents results from a panel regression of deposit rates across MSAs and time on demographic characteristics and controls. In columns 1 and 2, the demographic characteristic is old (65+) share of the population; in columns 3 and 4 it is the middle-aged (42-64) share; in columns 5 and 6 it is the young (20-41) share. The text provides a more detailed description of all variables. Superscripts ***, **, * correspond to statistical significance at the 1, 5, and 10 percent levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variables				Deposit rate		
Old group ratio (%)	0.011***	0.010***				
	(4.48)	(4.12)				
Middle group ratio (%)			0.006	0.007*		
			(1.59)	(1.88)		
Young group ratio (%)					-0.007***	-0.007***
					(-4.07)	(-3.90)
Unemployment rate (%)		-0.022***		-0.020***		-0.022***
		(-4.93)		(-4.49)		(-4.90)
Income growth (%)		-0.023***		-0.025***		-0.024***
		(-5.22)		(-5.59)		(-5.42)
Housing price index		-0.000***		-0.001***		-0.000***
		(-6.36)		(-6.93)		(-6.54)
HHI		-0.244**		-0.313***		-0.274**
		(-2.13)		(-2.72)		(-2.40)
Number of banks		0.000		0.000		0.000
		(1.24)		(0.57)		(0.97)
Bank size		0.076***		0.077***		0.075***
		(5.67)		(5.66)		(5.54)
Credit quality (%)		0.020***		0.020***		0.020***
		(3.41)		(3.45)		(3.45)
Constant	1.950***	1.448***	1.927***	1.396***	2.485***	1.971***
	(44.12)	(8.98)	(14.15)	(7.28)	(29.31)	(10.71)
Observations	932	932	932	932	932	932
Adj. R2	0.933	0.940	0.932	0.940	0.933	0.940
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes

Table 5: Demographics and lending rates

This table presents results from a panel regression of lending rates across MSAs and time on demographic characteristics and controls. In columns 1 and 2, the demographic characteristic is old (65+) share of the population; in columns 3 and 4 it is the middle-aged (42-64) share; in columns 5 and 6 it is the young (20-41) share. The text provides a more detailed description of all variables. Superscripts ***, **, * correspond to statistical significance at the 1, 5, and 10 percent levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variables			Lending rate			
Old group ratio (%)	-0.051***	-0.041**				
	(-2.78)	(-2.16)				
Middle group ratio (%)			-0.048	-0.048		
			(-1.64)	(-1.62)		
Young group ratio (%)					0.035***	0.030**
					(2.67)	(2.20)
Unemployment rate (%)		-0.003		-0.009		-0.003
		(-0.09)		(-0.25)		(-0.07)
Income growth (%)		0.118***		0.126***		0.121***
		(3.32)		(3.56)		(3.42)
Housing price index		-0.000		-0.000		-0.000
		(-0.40)		(-0.11)		(-0.33)
HHI		0.491		0.813		0.610
		(0.54)		(0.90)		(0.67)
Number of banks		0.002		0.003*		0.002
		(1.42)		(1.82)		(1.57)
Bank size		-0.224**		-0.220**		-0.216**
		(-2.09)		(-2.05)		(-2.02)
Credit quality (%)		0.053		0.050		0.052
		(1.14)		(1.08)		(1.12)
Constant	8.673***	10.444***	9.432***	11.199***	6.088***	8.151***
	(26.13)	(8.16)	(9.28)	(7.41)	(9.57)	(5.59)
Observations	932	932	932	932	932	932
Adj. R2	0.540	0.545	0.537	0.544	0.539	0.545
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes

Table 6: Demographics and lending-deposit spread

This table presents results from a panel regression of lending - deposit spreads across MSAs and time on demographic characteristics and controls. In columns 1 and 2, the demographic characteristic is old (65+) share of the population; in columns 3 and 4 it is the middle-aged (42-64) share; in columns 5 and 6 it is the young (20-41) share. The text provides a more detailed description of all variables. Superscripts ***, **, * correspond to statistical significance at the 1, 5, and 10 percent levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variables			Lending-deposit spread			
Old group ratio (%)	-0.062***	-0.051***				
	(-3.27)	(-2.61)				
Middle group ratio (%)			-0.054*	-0.055*		
			(-1.79)	(-1.81)		
Young group ratio (%)					0.043***	0.037***
					(3.11)	(2.62)
Unemployment rate (%)		0.019		0.011		0.020
		(0.52)		(0.31)		(0.53)
Income growth (%)		0.141***		0.151***		0.145***
		(3.86)		(4.14)		(3.99)
Housing price index		0.000		0.000		0.000
		(0.39)		(0.75)		(0.48)
HHI		0.735		1.126		0.884
		(0.78)		(1.21)		(0.95)
Number of banks		0.002		0.002*		0.002
		(1.23)		(1.69)		(1.40)
Bank size		-0.300***		-0.297***		-0.291***
		(-2.73)		(-2.69)		(-2.64)
Credit quality (%)		0.033		0.030		0.031
		(0.69)		(0.63)		(0.66)
Constant	6.724***	8.995***	7.505***	9.802***	3.603***	6.179***
	(19.63)	(6.83)	(7.15)	(6.30)	(5.49)	(4.12)
Observations	932	932	932	932	932	932
Adj. R2	0.248	0.260	0.242	0.258	0.247	0.261
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes

Table 7: Demographics, deposit rates, and competition

This table presents results from a panel regression of deposit rates across MSAs and time on demographic characteristics and controls. In columns 1 and 2, the demographic characteristic is old (65+) share of the population; in columns 3 and 4 it is the middle-aged (42-64) share; in columns 5 and 6 it is the young (20-41) share. The difference from Table 4 is that for each of the three demographic groups, we separate all data into high HHI (columns 1, 3, and 5) and low HHI (columns 2, 4, and 6). The text provides a more detailed description of all variables. P-values of F-test that compares the coefficients on demographic characteristics are in the last row. Superscripts ***, **, * correspond to statistical significance at the 1, 5, and 10 percent levels, respectively.

	(1) High HHI	(2) Low HHI	(3) High HHI	(4) Low HHI	(5) High HHI	(6) Low HHI
Old group ratio (%)	0.019***	0.004				
	(4.99)	(1.20)				
Middle group ratio (%)			0.009*	0.004		
			(1.87)	(0.73)		
Young group ratio (%)					-0.010***	-0.003
					(-4.12)	(-1.31)
Unemployment rate (%)	-0.032***	-0.018***	-0.027***	-0.017***	-0.030***	-0.018***
	(-4.65)	(-2.86)	(-3.85)	(-2.78)	(-4.42)	(-2.87)
Income growth (%)	-0.024***	-0.024***	-0.027***	-0.025***	-0.026***	-0.024***
	(-3.63)	(-3.88)	(-4.14)	(-3.98)	(-4.03)	(-3.89)
Housing price index	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***
	(-4.00)	(-5.32)	(-4.21)	(-5.63)	(-4.04)	(-5.41)
HHI	-0.425**	0.042	-0.501***	0.033	-0.469***	0.037
	(-2.52)	(0.10)	(-2.90)	(0.08)	(-2.77)	(0.09)
Number of banks	0.000	0.000	0.000	0.000	0.000	0.000
	(1.44)	(0.74)	(0.47)	(0.55)	(0.92)	(0.69)
Bank size	0.046***	0.123***	0.044**	0.124***	0.043**	0.122***
	(2.72)	(5.71)	(2.55)	(5.76)	(2.52)	(5.67)
Credit quality (%)	0.030***	0.017**	0.025***	0.017**	0.028***	0.017**
	(3.38)	(2.10)	(2.80)	(2.21)	(3.16)	(2.11)
Observations	465	467	465	467	465	467
Adj. R2	0.945	0.938	0.942	0.938	0.944	0.938
F-test p-value	0.004		0.441		0.057	

Table 8: Demographics, lending rates, and competition

This table presents results from a panel regression of lending rates across MSAs and time on demographic characteristics and controls. In columns 1 and 2, the demographic characteristic is old (65+) share of the population; in columns 3 and 4 it is the middle-aged (42-64) share; in columns 5 and 6 it is the young (20-41) share. The difference from Table 8 is that for each of the three demographic groups, we separate all data into high HHI (columns 1, 3, and 5) and low HHI (columns 2, 4, and 6). The text provides a more detailed description of all variables. P-values of F-test that compares the coefficients on demographic characteristics are in the last row. Superscripts ***, **, * correspond to statistical significance at the 1, 5, and 10 percent levels, respectively.

	(1) High HHI	(2) Low HHI	(3) High HHI	(4) Low HHI	(5) High HHI	(6) Low HHI
Old group ratio (%)	-0.047	-0.029				
	(-1.32)	(-1.46)				
Middle group ratio (%)			-0.095**	0.020		
			(-2.07)	(0.55)		
Young group ratio (%)					0.041*	0.013
					(1.82)	(0.81)
Unemployment rate (%)	-0.009	0.035	-0.008	0.027	-0.003	0.032
	(-0.13)	(0.88)	(-0.13)	(0.69)	(-0.05)	(0.81)
Income growth (%)	0.159***	0.115***	0.177***	0.121***	0.165***	0.118***
	(2.61)	(2.88)	(2.92)	(3.04)	(2.73)	(2.95)
Housing price index	0.003**	-0.001	0.003**	-0.000	0.003**	-0.000
	(2.14)	(-0.96)	(2.17)	(-0.73)	(2.11)	(-0.81)
HHI	-1.164	-0.774	-0.783	-0.755	-1.064	-0.738
	(-0.74)	(-0.29)	(-0.50)	(-0.28)	(-0.68)	(-0.28)
Number of banks	0.001	0.002	0.002	0.002*	0.001	0.002*
	(0.35)	(1.53)	(0.68)	(1.71)	(0.43)	(1.67)
Bank size	-0.010	-0.591***	0.020	-0.619***	0.005	-0.598***
	(-0.06)	(-4.31)	(0.13)	(-4.51)	(0.03)	(-4.35)
Credit quality (%)	0.051	0.060	0.051	0.052	0.048	0.056
	(0.62)	(1.18)	(0.63)	(1.04)	(0.59)	(1.11)
Observations	465	467	465	467	465	467
Adj. R2	0.463	0.661	0.466	0.659	0.465	0.660
F-test p-value	0.714		0.055		0.302	

Table 9: Alternative demographic measure

This table presents results from a panel regression of interest rates (deposit rates in columns 1 and 2, lending rates in 3 and 4, and lending - deposit spreads in 5 and 6) across MSAs and time on demographic characteristics and controls. The demographic variable is the middle-aged-to-young ratio. The middle-aged are between 42 and 64 and the young are between 20 and 41. The text provides a more detailed description of all variables. Superscripts ***, **, * correspond to statistical significance at the 1, 5, and 10 percent levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variables	Deposit rates		Loan rates		Spread	
Middle-to-Young ratio (%)	0.002***	0.002***	-0.014**	-0.012**	-0.016***	-0.014**
	(2.96)	(2.80)	(-2.57)	(-2.25)	(-2.87)	(-2.53)
Unemployment rate (%)		-0.021***		-0.004		0.017
		(-4.67)		(-0.12)		(0.46)
Income growth (%)		-0.025***		0.123***		0.148***
		(-5.51)		(3.48)		(4.06)
Housing price index		-0.001***		-0.000		0.000
		(-6.69)		(-0.30)		(0.53)
HHI		-0.289**		0.655		0.944
		(-2.52)		(0.72)		(1.01)
Number of banks		0.000		0.002		0.002
		(0.84)		(1.60)		(1.45)
Bank size		0.076***		-0.217**		-0.293***
		(5.63)		(-2.03)		(-2.66)
Credit quality (%)		0.020***		0.053		0.034
		(3.38)		(1.16)		(0.71)
Constant	1.982***	1.495***	8.809***	10.477***	6.827***	8.982***
	(36.07)	(9.21)	(21.46)	(8.18)	(16.10)	(6.81)
Observations	932	932	932	932	932	932
Adj. R2	0.932	0.940	0.539	0.545	0.246	0.260
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes

Table 10: Value-weighted deposit and lending rates

This table presents results from a panel regression of interest rates (deposit rates in columns 1 to 3 and lending rates in 4 to 6) across MSAs and time on demographic characteristics and controls. Deposit and lending rates are computed as the value-weighted deposit and lending rates in an MSA. Weights are the deposit share of a bank in the MSA. The text provides a more detailed description of all variables. Superscripts ***, **, * correspond to statistical significance at the 1, 5, and 10 percent levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variables		Deposit rate			Lending rate	
Old group ratio (%)	0.010***			-0.041**		
	(4.12)			(-2.16)		
Middle group ratio (%)		0.007*			-0.048	
		(1.88)			(-1.62)	
Young group ratio (%)			-0.007***			0.030**
			(-3.90)			(2.20)
Unemployment rate (%)	-0.022***	-0.020***	-0.022***	-0.003	-0.009	-0.003
	(-4.93)	(-4.49)	(-4.90)	(-0.09)	(-0.25)	(-0.07)
Income growth (%)	-0.023***	-0.025***	-0.024***	0.118***	0.126***	0.121***
	(-5.22)	(-5.59)	(-5.42)	(3.32)	(3.56)	(3.42)
Housing price index	-0.000***	-0.001***	-0.000***	-0.000	-0.000	-0.000
	(-6.36)	(-6.93)	(-6.54)	(-0.40)	(-0.11)	(-0.33)
HHI	-0.244**	-0.313***	-0.274**	0.491	0.813	0.610
	(-2.13)	(-2.72)	(-2.40)	(0.54)	(0.90)	(0.67)
Number of banks	0.000	0.000	0.000	0.002	0.003*	0.002
	(1.24)	(0.57)	(0.97)	(1.42)	(1.82)	(1.57)
Bank size	0.076***	0.077***	0.075***	-0.224**	-0.220**	-0.216**
	(5.67)	(5.66)	(5.54)	(-2.09)	(-2.05)	(-2.02)
Credit quality (%)	0.020***	0.020***	0.020***	0.053	0.050	0.052
	(3.41)	(3.45)	(3.45)	(1.14)	(1.08)	(1.12)
Constant	1.448***	1.396***	1.971***	10.444***	11.199***	8.151***
	(8.98)	(7.28)	(10.71)	(8.16)	(7.41)	(5.59)
Observations	932	932	932	932	932	932
Adj. R2	0.940	0.940	0.940	0.545	0.544	0.545
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes

Table 11: Deposit and lending rates of individual banks

This table presents results from a panel regression of bank-level interest rates (deposit rates in columns 1 to 3, lending rates in 4 to 6) across MSAs and time on demographic characteristics and controls. The demographic variables are the Old-to-Middle ratio, and the Young-to-Middle ratio. The text provides a more detailed description of all variables. Superscripts
***, **, * correspond to statistical significance at the 1, 5, and 10 percent levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variables		Deposit rate			Lending rate	
Old group ratio (%)	0.021***			-0.062***		
	(4.44)			(-3.62)		
Middle group ratio (%)		0.010			-0.035	
		(1.47)			(-0.93)	
Young group ratio (%)			-0.014***			0.042***
			(-4.61)			(3.04)
Unemployment rate (%)	-0.015**	-0.008	-0.013*	0.076***	0.056*	0.072**
	(-2.21)	(-1.05)	(-1.92)	(2.71)	(1.82)	(2.49)
Income growth (%)	-0.033***	-0.036***	-0.034***	0.127***	0.134***	0.131***
	(-3.47)	(-3.73)	(-3.58)	(4.06)	(4.24)	(4.13)
Housing price index	-0.000	-0.000	-0.000	-0.001	-0.001	-0.001
	(-0.40)	(-0.62)	(-0.38)	(-1.60)	(-1.46)	(-1.63)
HHI	0.136	0.025	0.075	0.576	0.920	0.759
	(0.68)	(0.12)	(0.36)	(0.44)	(0.69)	(0.59)
Number of banks	0.000	0.000	0.000	-0.001	-0.000	-0.001
	(0.74)	(0.08)	(0.53)	(-1.32)	(-0.57)	(-1.10)
Bank size	0.033***	0.036***	0.033***	-0.304***	-0.311***	-0.304***
	(4.99)	(5.18)	(4.98)	(-6.87)	(-6.78)	(-6.81)
Credit quality (%)	0.011***	0.010**	0.011***	-0.001	0.001	-0.001
	(2.69)	(2.46)	(2.71)	(-0.05)	(0.03)	(-0.05)
Constant	1.869***	1.873***	2.948***	12.067***	12.204***	8.886***
	(13.13)	(7.47)	(15.83)	(11.92)	(9.97)	(8.15)
Observations	13,780	13,780	13,780	13,797	13,797	13,797
Adj. R2	0.744	0.741	0.743	0.310	0.308	0.309
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes

Table 12: Model results

This table presents interest rates from various versions of the model; all interest rates are over one model period, equivalent to 23 years. The top panel presents deposit rates, and the bottom panel loan rates. Each row contains a different version of the model (i.e. Baseline, Same IES, etc), differences between versions of the model are described in the text. For each version of the model, the columns present results for a short lifespan ($p = 0.4$, life expectancy is 73 years), a long lifespan ($p = 0.8$, life expectancy 82 years), and the difference between long and short; a high growth rate ($g = 2.1\%$ per year), a low growth rate ($g = 1.9\%$ per year), and the difference between high and low.

Panel A: Deposit rates

	Lifespan			Growth rate		
	Short	Long	Δ	High	Low	Δ
Baseline	8.7%	13.8%	5.1%	16.5%	11.1%	-5.4%
Same IES	29.7%	24.9%	-4.8%	30.4%	24.8%	-5.6%
High competition	54.6%	54.7%	0.1%	58.3%	51.4%	-6.9%
Same IES, high comp.	55.9%	55.5%	-0.4%	59.3%	52.5%	-6.8%
Bequests	8.3%	13.6%	5.3%	16.2%	10.8%	-5.4%
Steeper income gr.	9.2%	14.0%	4.8%	16.8%	11.4%	-5.4%
Flatter income gr.	8.6%	13.8%	5.2%	16.4%	11.1%	-5.3%
Alt. IES heterogen.	8.7%	11.4%	2.7%	14.4%	9.3%	-5.1%

Panel B: Loan rates

	Lifespan			Growth rate		
	Short	Long	Δ	High	Low	Δ
Baseline	70.7%	65.2%	-5.5%	70.6%	65.7%	-4.9%
Same IES	69.2%	64.2%	-5.0%	69.5%	64.4%	-5.1%
High competition	58.5%	58.3%	-0.2%	61.7%	54.8%	-6.9%
Same IES, high comp.	58.3%	57.9%	-0.4%	61.7%	54.9%	-6.8%
Bequests	69.6%	64.2%	-5.4%	69.2%	64.3%	-4.9%
Steeper income gr.	80.7%	74.5%	-6.2%	80.4%	75.2%	-5.2%
Flatter income gr.	68.6%	63.2%	-5.4%	68.5%	63.6%	-4.9%
Alt. IES heterogen.	71.4%	65.5%	-5.9%	71.1%	66.2%	-4.9%