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THE CROSS SECTION OF BANK VALUE

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ABSTRACT

We study the determinants of value creation within U.S. commercial banks. We focus on three theoretically-motivated drivers of bank value: screening and monitoring, "safe" deposit production, and synergies between deposit-taking and lending. To assess the relative contributions of each, we develop novel measures of banks' deposit productivity and asset productivity and use these measures to evaluate the cross-section of bank value. We find that variation in deposit productivity explains the majority of variation in bank value, consistent with theories emphasizing safe-asset production. We also find evidence of meaningful value creation from synergies between deposit-taking and lending. Overall, our findings suggest that banks are primarily "special" due to their unique liability structure rather than their ability to screen and monitor borrowers.

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1 Introduction

What is the fundamental purpose of a bank? In a frictionless world, the Modigliani-Miller theorems hold, and banks are simply pass-through entities, no different than other financial intermediaries. In contrast, forty years of theoretical work has identified reasons that banks are "special" in the presence of frictions. This work can be grouped into three broad categories. One class of theories argues that banks exist to produce "safe", liquid, adverse-selection free liabilities, such as bank deposits (e.g., Gorton and Pennacchi, 1990). A second class of theories argues that banks produce valuable information about borrowers through the screening and monitoring of loans (e.g., Diamond, 1984). Finally, a third class of theories highlights synergies between deposit-taking and lending that allow banks to make certain types of loans more easily than other intermediaries (e.g., Kashyap, Rajan, and Stein, 2002). Collectively, these theories capture the primary economic differences between banks and other types of firms.

However, little is known about the relative importance of these explanations for the existence of banks. Banks clearly issue deposits and make loans, but is deposit-gathering or borrower screening more important in explaining bank specialness? The answer to this question is important for a number of reasons, including understanding the impact of new regulations on banks. To judge the relative contributions of different broad classes of theories, we need a measure that makes the contribution of each explanation comparable.

Bank value is the natural choice. In a Modigliani-Miller world, banks do not create economic value. However, each broad theory of banking involves frictions that violate the Modigliani-Miller theorems and hence has implications for bank value creation. For example, if information produced through the screening and monitoring process allows a bank to source positive-NPV projects, this should be reflected in the bank's value. Similarly, the production of safe debt can also create value for banks. As such, the cross-section of bank value is informative about which of these broad classes of theories best describes banks' business models and thus their fundamental purpose. However, little is currently known about the underlying factors that drive the cross-section of bank value.

In this paper, we systematically examine the cross-section of bank value to understand the quantitative contributions of different theories of banking. We begin by using tools from industrial organization to construct novel estimates of a bank's proficiency at producing deposits and risk-adjusted loan income. Our structural framework allows us to estimate "primitive" measures of deposit productivity and asset productivity. Intuitively, a bank with high deposit productivity is able to collect more deposits than a less productive bank, holding fixed inputs like its deposit rate and number of branches. Similarly, a bank with higher asset productivity is able to generate more risk-adjusted revenue with the same asset base.

Uncovering these primitives is important because the observable characteristics of a bank are endogenous functions of its productivity: all else equal, a more productive bank will grow at a faster rate than a less productive bank. Thus, in the presence of diminishing returns, variation in observable characteristics is likely to understate the amount of true variation in primitives across banks. Similarly, estimating simple cross-sectional regressions relating bank value to factors such as interest income or interest expense would be like relating the value of an industrial firm to the prices of its output goods. Such regressions would not have a natural economic interpretation in the context of the three broad classes of theories of banking. Overall, our ability to estimate primitive productivity differences across banks represents an important step forward in our ability to identify differences in banks' business models, both in the cross-section and over time.

We combine our productivity estimates with banks' market-to-book ratios (M/B) from 1994 to 2015 to identify the primary determinants of cross-sectional variation in bank value. Our main finding is that the liability side of the balance sheet drives the majority of cross-sectional variation in bank value. Consistent with theories of safe-asset production, we find that a one-standard deviation increase in deposit productivity is associated with an increase in M/B of 0.2 to 0.5 points. In contrast, a one-standard deviation increase in asset productivity is only associated with an increase in M/B of 0.1 to 0.2 points. Hence, variation in deposit productivity accounts for about twice as much variation in bank value as variation in asset productivity. This finding suggests that liability-driven theories of bank value creation explain more variation in the cross section of banks than asset-driven theories.

To better understand the economics behind this result, we further decompose asset and deposit productivity into their sub-components. On the deposit side, we separately measure a bank's ability to collect savings, transaction, and small/large time deposits. Our results suggest that variation in a bank's ability to collect savings and transaction deposits is the main driver of value creation. Savings deposit productivity explains over three times as much variation in market-to-book ratios as transaction deposit productivity, and five times as much variation as any other subcomponent of productivity. We find that the demand for savings and transaction deposits is highly inelastic; that is, these deposits tend to be "stickier." Evidence from an analysis of bank balance sheet composition reaffirms these results: we find that high deposit productivity is associated with having more deposits in general and, in particular, higher levels of savings deposits. In addition, we find that the impact of deposit productivity on overall bank leverage is relatively small in the cross section. Thus, banks that are particularly good at raising deposits are not significantly more levered than those that are not. Instead, they substitute non-deposit debt for deposits.

On the asset side, we find that variation in a bank's loan portfolios, rather than securities portfolios, is the main driver of bank productivity. Consistent with "information production" theories of banking, we also find that banks with high asset productivity tilt their balance sheet towards holding more illiquid assets. In particular, we find that asset-productive banks hold more loans and fewer securities, particularly real estate and commercial and industrial (C&I) loans, which are likely to be more information-intensive than other types of loans. Hence, our results are consistent with the idea that the screening and monitoring of information-intensive loans is an important source of bank value, though it accounts for far less variation in bank value than deposit productivity.

Finally, we utilize our productivity measures to assess the degree of synergies between banks' deposit-taking and lending activities. Intuitively, a bank that is good at producing deposits may be able to offer more loans or different types of loans than a bank that is less productive at raising deposits. By assessing the relationships between our two productivity measures, and by examining the relationship between each productivity measure and banks' balance sheet composition, we are able to uncover the full extent of balance sheet synergies in a manner distinct from the existing literature.

We find that asset productivity is strongly correlated with deposit productivity − about 25% of the cross-sectional variation in asset productivity can be explained by deposit productivity, consistent with the theoretical literature on synergies. All types of deposit productivity except for transactions deposits are positively correlated with asset productivity. This finding suggests that the ability to raise "sticky" short-term funding is a key source of bank synergies. In addition, we find that deposit-productive banks tend to offer more loan commitments and lines of credit, consistent with Kashyap, Rajan, and Stein (2002) and Gatev and Strahan (2006). In addition, we find that banks with high deposit productivity tend to make more illiquid C&I loans, consistent with Hanson, Shleifer, Stein, and Vishny (2016).

We also explore the relationships between banks' geographical footprints and our productivity measures. Intuitively, loan markets are likely to be regional or even national in scope, while deposit markets are likely to be more local in scope. Consistent with this intuition, we find that the demographic characteristics of where banks operate explain twice as much variation in deposit productivity as asset productivity. However, even after controlling for banks' geographic footprints, we still find that both of our productivity measures are strongly related to bank value, with deposit productivity again explaining significantly more variation than asset productivity in the cross-section of banks.

In summary, this paper represents the first attempt to empirically identify and quantify the primary determinants of cross-sectional variation in bank value. We focus on three theoretically motivated drivers of bank value: safety and liquidity services produced by deposits, screening and monitoring technologies for lending, and synergies between deposit-taking and lending. While we find that all three drivers play an important role, our results suggest that cross-sectional variation in deposit productivity accounts for the majority of cross-sectional variation in bank value. Consistent with the idea that bank liabilities are "special," we find that a bank's deposit productivity plays a central role in determining its funding structure, size, and ultimate value. The existing literature has largely focused on the potential social value associated with banks' safe-asset production activities. Here, we show that these activities have significant private value as well.

To estimate a bank's deposit productivity, we construct a consumer demand system for bank deposits that builds upon existing work by Dick (2008) and Egan, Hortaçsu, and Matvos (2016). In our framework, banks compete for deposits by setting interest rates in a standard Bertrand-Nash differentiated products setting, which we estimate using a common model of demand from the industrial organization literature (Berry, 1994; Berry, Levinsohn, and Pakes, 1995). To address the endogeneity of deposit rates in our demand specifications, we use two sets of instrumental variables. One set of instruments is based on the bank specific pass-through of 3-month LIBOR into deposit rates (Villas-Boas (2007), Egan, Hortaçsu, and Matvos (2016)).[1] Our second set of instruments is based on standard Berry, Levinsohn, and Pakes (1995) instruments where we instrument for deposit rates using the lagged average product characteristics of a bank's competitors in a given market.[2] We then use these demand estimates to quantify deposit productivity at the bank-year level.

To estimate asset productivity, we flexibly estimate a bank's ability to produce interest and fee income as a function of its loan and securities portfolios. We address the potential endogeneity of the primary production input (asset size) by instrumenting for size using the weighted average deposit productivity of the bank's competitors. The idea behind the instrument is that it is a cost shifter: all else equal, a bank that competes against more deposit-productive banks will be smaller. As in the literature on estimating total factor productivity (see Syverson, 2011), we use the residuals and bank fixed effects from the estimated production function as our measure of asset productivity for individual banks. Thus, our estimation procedure allows us to construct two complementary measures of bank productivity: a bank's skill at producing deposits, and the same bank's skill at using these

[1] In particular, we instrument for bank deposit rates using the fitted value of a bank-specific regression of deposit rates on the 3-month LIBOR rate. The idea behind this instrument is that a bank's average degree of pass-through in the time series is likely to be orthogonal to the deposit demand it faces at any one point in time.

[2] The idea behind this instrument is that there is unlikely to be a link between lagged competitors' product characteristics and the bank's own current-period deposit demand shock.

funds to generate revenue.

Our paper is related to several strands of the literature on banking. First, a large theoretical and empirical literature has argued that banks create value by producing safe, liquid liabilities that are useful for transaction purposes.[3] Our paper adds to this literature by quantifying the effects of safe-liability creation on bank value. We find strong evidence that bank value is linked to a bank's ability to produce safe, liquid deposits. However, while a bank's transaction deposit productivity is linked to its value, our strongest results are for savings deposits, which, while safe, are not completely liquid. In addition, we find no evidence that non-deposit debt creates value for banks. Second, our paper is related to a long literature on bank information production dating back to Leland and Pyle (1977) and Diamond (1984).[4] This literature has argued that part of a bank's purpose is to perform delegated information production and portfolio management (e.g. screening and monitoring) on behalf of its investors. Consistent with the broad themes of this literature, we find evidence that a bank's asset productivity is strongly linked to its value. However, we also find that differences in asset productivity across banks appear to be significantly less important in the cross-section relative to differences in banks' abilities to produce deposits. A third literature has argued that banks exist in part because of synergies between their deposit-taking and lending activities.[5] Consistent with this literature, we find that deposit-productive banks

[3]For the theoretical literature, see, e.g., Gorton and Pennacchi, 1990; Pennacchi, 2012; Stein, 2012; Gennaoili, Shleifer, and Vishny, 2013; DeAngelo and Stulz, 2015; Dang, Gorton, and Holmström, 2015; Dang, Gorton, Holmström, and Ordoñez, 2016; Moreira and Savov, 2016. The empirical literature in this area, e.g., Krishnamurthy and Vissing-Jorgensen, 2012; Gorton, Lewellen, and Metrick, 2012; Greenwood, Hanson, and Stein, 2015; Krishnamurthy and Vissing-Jorgensen, 2015; Sunderam, 2015; and Nagel, 2016, has largely focused on understanding whether bank liabilities are special by examining the behavior of equilibrium prices and quantities.

[4]Other asset-driven theories of bank value creation include Ramakrishnan and Thakor (1984), Boyd and Prescott (1986), Allen (1990), Diamond (1991), Rajan (1992), Winton (1995), and Allen, Carletti, and Marquez (2011). Empirical literature includes Petersen and Rajan (1994), Berger and Udell (1995), Demsetz and Strahan (1997), Shockley and Thakor (1997), Acharya, Hassan, and Saunders (2006), and Sufi (2007). A separate literature studies the "charter value" that accrues to banks due to entry restrictions that allowed incumbents to extract monopoly rents. See Keeley (1990) for a discussion of the decline in charter values and Jayaratne and Strahan (1996) for more information on the removal of branching restrictions. There is also a literature on estimating bank production functions, primarily for the purpose of understanding whether there are economies of scale in banking (e.g., Berger and Mester, 1997; Hughes and Mester, 1998; Stiroh, 2000; Berger and Mester, 2003; Rime and Stiroh, 2003; Wang, 2003). We extend this literature by estimating a bank's *liability* productivity in addition to introducing a new methodology to estimate bank asset productivity and studying the value implications of both measures.

[5]See, e.g., Diamond and Dybvig (1983), Calomiris and Kahn (1991), Berlin and Mester (1999), Diamond and Rajan (2000, 2001), Kashyap, Rajan, and Stein (2002), Gatev and Strahan (2006), and Hanson, Shleifer, Stein, and Vishny (2016). Mehran and Thakor (2011) argue that there are synergies between equity capital and lending and provide evidence from the cross section of bank valuations. Berger and Bouwman (2009) construct a measure of bank liquidity creation and show that their measure is positively correlated with banks' market-to-book ratios. Bai, Krishnamurthy, and Weymuller (2016) also link bank "liquidity mismatch," the difference in liquidity between the asset and liability sides of a bank's balance sheet, to bank stock returns.

also tend to be asset-productive. Finally, our paper is also related to the growing literature at the intersection of industrial organization and finance.[6]

The remainder of this paper is organized as follows. Section 2 presents a simple framework that highlights the economic linkages between deposit productivity, asset productivity, and bank value. Section 3 describes our estimation procedure and provides more details on our measures of bank productivity. Our main results are discussed in Section 4, which relates our productivity measures to bank characteristics and measures of bank value. Section 5 presents robustness exercises, and Section 6 concludes.

2 Economic Framework

In this section, we present a simple economic framework that allows us to link deposit productivity and asset productivity with bank value. Our framework contains two types of agents: consumers and banks. We begin by describing consumer preferences for bank deposits. We then turn to the problem of banks seeking to generate revenue from their assets.

2.1 Consumers

There is a continuum of consumers, each of whom chooses to deposit their funds at one bank or purchase an outside option. Consumer demand for deposit services is a function of the deposit rate and quality of services provided by each bank $j = 1, ..., J$. A consumer depositing funds at bank j earns the deposit rate i_j, which yields utility αi_j.[7] The parameter $\alpha > 0$ measures the consumer's sensitivity to deposit rates. Depositors also derive utility from banking services, given by $\beta X_j + \delta_j + \varepsilon_{ij}$. This "service utility" depends on observable bank characteristics X_j, such as the number of bank branches. In addition, it depends on a bank-specific fixed effect, δ_j, which reflects bank quality differences: all else equal, some banks offer better services than others. Finally, the term ε_{ij} is a consumer-bank specific utility shock. This utility shock captures preference heterogeneity across consumers. Some

However, neither of these papers perform a comprehensive analysis of the determinants of bank value. To our knowledge, our paper is the first in the literature to do so.

[6] Our deposit demand estimates relate most closely to Dick (2008) and Egan, Hortaçsu, and Matvos (2016). Similar tools have been used to estimate demand by Hortaçsu and Syverson (2004) for index mutual funds, Koijen and Yogo (2015) for investment assets, Koijen and Yogo (2016) for life insurance, and Hastings, Hortaçsu and Syverson (2016) for privatized social security. Our estimation of bank asset production functions uses techniques similar to those used by Maksimovic and Phillips (2001) and Schoar (2002) to study nonfinancial firms. An advantage in our setting is that we correct for the potential endogeneity of production inputs using cost shifters from the liability side of the bank as instruments.

[7] While our empirical analysis uses panel data, we suppress time subscripts here for simplicity.

consumers may inherently prefer Bank of America to Citibank (or vice versa). Thus, the total indirect utility derived by a depositor i from bank j is given by:

$$u_{ij} = \alpha i_j + \beta X_j + \delta_j + \varepsilon_{ij}. \tag{1}$$

The bank specific fixed effects, δ_j, denote a bank's deposit productivity. Conditional on the offered deposit rate (i_j) and other bank characteristics (X_j), banks with a higher deposit productivity δ_j are able to attract more deposits.

Consumers select the bank that maximizes their utility. We follow the standard assumption in the industrial organization literature (Berry, 1994; Berry, Levinsohn, and Pakes, 1995) and assume that the utility shock ε_{ij} is independently and identically distributed across banks and consumers and follows a Type 1 Extreme Value distribution. Given this distributional assumption, the probability that a consumer selects bank j follows the multinomial logit distribution. We also assume that consumers have access to an outside good, which represents placing funds outside of the traditional depository banking sector. Without loss of generality, we normalize the utility of the outside good to zero ($u_0 = 0$). The market share for bank j, denoted s_j, is then

$$s_j\left(i_j, \mathbf{i_{-j}}\right) = \frac{exp(\alpha i_j + \beta X_j + \delta_j)}{\sum_{k=1}^{J} exp(\alpha i_k + \beta X_k + \delta_k) + 1}. \tag{2}$$

The total market size for deposits is denoted M. Hence, the total deposits collected by bank j is $s_j M$.

Our utility formulation closely follows that of Egan, Hortaçsu and Matvos (2016), with one notable exception. Previous research such as Rose (2015) and Egan, Hortaçsu and Matvos (2016) finds that depositors (particularly uninsured depositors) may be sensitive to the financial stability of a bank. In this paper, rather than explicitly modeling consumers' perceptions about bank solvency as a separate feature of their utility function, we account for banks' risk-taking and overall financial stability through our empirical implementation.

2.2 Banks

We next turn to the problem of banks. Banks collect deposits and other capital and invest them in a bank-specific technology. Banks have total assets equal to to the sum of the deposit it collects, Ms_j, and its other capital, K_j:

$$A_j = M_t s_j + K_j.$$

The bank's per-period profit function is given by

$$\pi_j = \phi_j A_j^{\theta} - i_j M_t s_j - r_j K_j. \tag{3}$$

The term $\phi_j A_j^{\theta}$ reflects the investment income the bank generates from assets A_j. In other words, $\phi_j A_j^{\theta}$ is the bank's asset production function. The parameter θ reflects returns to scale in production, and ϕ_j reflects bank j's asset productivity. Specifically, ϕ_j reflects excess risk-adjusted revenue the bank can earn on its loans and securities. These revenues may arise because the bank has a particularly good technology for screening and monitoring borrowers, or because it is particularly good at finding and holding mispriced securities. The remaining terms in the profit function, $i_j M s_j$ and $r_j K_j$, reflect the bank specific costs of raising deposits $M s_j$ and capital K_j. For ease of exposition, we assume that the income generated from the the bank's investment is deterministic. This allows us to abstract away from bank risk-taking, which we address in our empirical analysis.

Banks compete for deposits by playing a differentiated product Bertrand-Nash interest rate setting game. The bank sets the deposit rate to maximize

$$\max_{i} \phi_j A_j^{\theta} - i_j M s_j - r_j K_j.$$

The corresponding bank first order condition is given by[8]

$$\phi_j \theta A_j^{\theta-1} = i_j + \frac{1}{\alpha(1-s_j)}. \tag{4}$$

The left-hand side term, $\phi_j \theta A_j^{\theta-1}$, reflects the marginal return of an additional dollar of assets. The right-hand side term, $\frac{1}{\alpha(1-s_j)} + i_j$, reflects the marginal cost of collecting an additional dollar of deposits. All else equal, banks with better investment opportunities (higher marginal returns) will find it optimal to offer higher deposit rates.

2.3 Bank Value and Productivity

The primary objects of interest in our simple framework are deposit and asset productivity. We examine how these different measures of productivity create value for the bank. On the liability side, the parameter δ_j can be interpreted as a bank's total factor productivity for collecting deposits, or simply bank j's deposit productivity. Holding the offered deposit

[8] For simplicity, we assume a bank's only choice variable is the deposit rate. However, the model can be easily generalized to include additional choice variables, such as capital and risk. Provided that the additional bank choice variables and deposit rates are determined simultaneously, the bank's first order condition for deposit rates will remain the same because of the envelope theorem.

rate (i_j) and other bank characteristics (X_j) fixed, banks with a higher δ_j are able to attract more depositors. In other words, banks with higher deposit productivity can attract deposits more cheaply. To illustrate, suppose that bank j wishes to collect D deposits. It then needs to offer a deposit rate i^0 such that $D = Ms_j(i^0, \boldsymbol{i}_{-j})$. Bank j's interest expenditure is then given by

$$Di^0 = M\left(\frac{exp(\alpha i^0 + \beta X_j + \delta_j^0)}{\sum_{k=1}^{J} exp(\alpha i_k + \beta X_k + \delta_k) + 1}\right) i^0,$$

where δ_j^0 reflects bank j's initial deposit productivity. Now, suppose that bank j's deposit productivity increases from δ_j^0 to δ_j^1. Because of the increase in productivity, bank j can now offer a lower rate equal to $i^1 = i^0 - \frac{\delta_j^1 - \delta_j^0}{\alpha}$ and still raise the the same amount of deposits, D.[9] Bank $j's$ total interest expense of collecting D deposits falls by $D\left(\frac{\delta_j^1 - \delta_j^0}{\alpha}\right)$. All else equal, an increase in a bank's deposit productivity leads to an increase in the bank's net income and bank value.

On the asset side, the parameter ϕ_j reflects a bank's asset total factor productivity or simply a bank's asset productivity. Conditional on the bank's level of assets, a bank with higher asset productivity generates more revenue from its set of assets A_j. To illustrate, suppose a bank's asset productivity increases from ϕ_j^0 to ϕ_j^1. All else equal, the increase in asset productivity results in an increase in net income of $(\phi^1 - \phi^0)A_j^\theta$. Both increases in deposit productivity and asset productivity translate directly into higher net income and value.

3 Data and Estimation

3.1 Data

Our primary data source is the Federal Reserve FR Y-9C reports, which provide detailed quarterly balance sheet and income statement data for all U.S. bank holding companies. We supplement the Y-9C data with stock market data from CRSP and weekly branch-level data on advertised deposit rates from RateWatch. We also obtain branch-level deposit quantities from the annual FDIC Summary of Deposits files. Finally, we obtain county- and MSA-level demographic characteristics from the U.S. Census Bureau.

Our sample is the universe of public bank holding companies. Our primary data set consists of an unbalanced panel of 847 bank holding companies over the period 1994 through 2015.[10] Observations are at the bank holding company by quarter level. Table 1 provides

[9] Note that as illustrated by Eq. (4), a bank would find it optimal to increase the amount of deposits it collects in equilibrium after an increase in productivity.

[10] On average, we observe 327 banks in a given time period (quarter) and 52 observations (quarterly) for

summary statistics for the data set. On average, bank deposit interest expenditure is 2.19% and is 1.74% when measured net of fees. As discussed below, we measure the quality of services offered by a bank using the bank's non-interest expenditures, number of employees, and number of branches. Our two primary measures of bank risk taking are its equity beta and its standard deviation of return on assets. Following Baker and Wurgler (2015), we calculate the equity beta for each bank in our sample using monthly returns over the past twenty-four months. Similarly, we measure the standard deviation of return on assets using quarterly returns over the past two years. We provide further details and the source of each variable in the data appendix.

3.2 Bank Liabilities: Deposit Demand Estimation

We estimate the demand system described in Section 2.1 using our bank data set over the period 1994 through 2015. We can write the logit demand system in Eq. (2) as the following regression specification:

$$\ln M_t s_{jt} - \ln(M_t s_{0t}) = \alpha i_{jt} + \beta X_{jt} + \delta_{jt}. \tag{5}$$

Because we do not observe the characteristics of the outside good, s_0, we include a time fixed effect. This also allows us to estimate the key demand parameters without actually specifying the outside good. Thus, we estimate the following specification:

$$\ln M_t s_{jt} = \alpha i_{jt} + \beta X_{jt} + \mu_j + \mu_t + \xi_{jt}. \tag{6}$$

We estimate demand in two separate ways. First, in our baseline demand specifications, we define the market for deposits and compute the associated bank market shares at the aggregate US by quarter level. We also estimate a second demand system where we define the market for deposits at the county by year level.[11]

A standard issue in demand estimation is the endogeneity of prices, or in this case, deposit rates. The term ξ_{jt} in Eq. (6) represents an unobserved bank-time specific demand shock. If banks observe ξ_{jt} prior to setting deposit rates, the offered deposit rate will be correlated with the unobservable term ξ_{jt}. For example, suppose bank j experiences a demand shock such that ξ_{jt} is positive. Bank j will then find it optimal to offer a lower deposit rate (e.g., Eq. 4). This will cause our estimate of α to be biased downwards.

We use two sets of instruments to account for the endogeneity of deposit rates. First, fol-

each bank.

[11]Deposit market share data at the branch level is only available at an annual frequency through the FDIC's Summary of Deposits. Hence, we estimate demand at the county level using annual data.

lowing Villas-Boas (2007) and Egan, Hortaçsu, and Matvos (2016), we construct instruments from the bank specific pass-through of 3-month LIBOR into deposit rates. As documented by Hannan and Berger (1991), Neumark and Sharpe (1992), Driscoll and Judson (2013), and Drechsler, Savov, and Schnabl (2016), deposit rates at different banks respond differently to changes in short term interest rates. Investment opportunities are a key reason for this variation. Banks with good investment opportunities will not wish to lose deposit funding to competitors and thus will raise their deposit rates more when short rates rise. Hence, variation in investment opportunities will induce variation in deposit rates that is unrelated to the deposit demand conditions that banks face. Thus, we can instrument for i_{jt}, the deposit rate offered by bank j at time t, with the fitted value of a bank-specific regression of i_{jt} on 3-month LIBOR. The exclusion restriction here is that bank j's average degree of pass-through in the time series is orthogonal to the deposit demand it faces at time t.

Our second set of instruments are traditional Berry, Levinsohn, and Pakes (1995)-type instruments. We instrument for deposit rates using the average product characteristics of a bank's competitors. We use lagged competitor product characteristics and only use characteristics that are slower moving. Specifically, we use the number of bank branches, number of employees, non-interest expenditures, and banking fees of a bank's competitors, but we do not use the deposit rates they offer. We calculate the average product characteristic offered by each bank's competitor at the county by quarter level. We then form our instrument by taking the weighted average of a bank's competitors' product characteristics across all counties the bank operates in. The idea is that, all else equal, a bank must offer higher deposit rates if its competitors offer better products. The exclusion restriction in this setting is that the lagged average competitor product characteristics are orthogonal bank-quarter specific demand shocks.

Table 2 displays the corresponding demand estimates using aggregate bank-quarter data from the Y-9C reports. We measure deposit rates i_{jt} as interest expense on deposits, net of fees on deposit accounts, divided by total deposits. Column (1) of Table 2 displays the simple OLS estimates corresponding to Eq. (6). Column (2) uses the pass-through instruments. Column (3) uses competitors' deposit rates as instruments, and column (4) uses both sets of instruments. The instruments yield first stage F-statistics in excess of 25 for each specification. We estimate a positive and significant relationship between demand for deposits and the offered deposit rate. Moreover, as we would expect, the IV estimates tend to be higher than the OLS estimates. The coefficient 20.8 in column (4) implies that a one percentage point increase in the offered deposit rate is associated with a 1.8 percentage point increase in market share.[12] These point estimates are in line with the literature (Dick,

[12] Calculated assuming an initial market share of 10%.

2008; Egan, Hortaçsu, and Matvos, 2016). In Section 5.2.3 below, we show that our main findings are robust to a variety of alternative specifications of the demand system.

We use the estimated demand system to calculate each bank's deposit productivity. Specifically, we measure bank j's deposit productivity at time t, δ_{jt}, as

$$\hat{\delta}_{jt} = \ln M_t s_{jt} - \hat{\alpha} i_{jt} - \hat{\beta} X_{jt} - \hat{\mu}_t. \tag{7}$$

Our estimates of deposit productivity have a structural interpretation and are micro-founded in the consumer demand model described in Section 2.1. However, the estimates also have a reduced-form interpretation as well. In Eq. (6), we are regressing log deposits collected on inputs (number of branches, deposit rate, etc.) and then using the residuals to calculate deposit productivity. Hence, a reduced-form interpretation is that more productive banks can raise more deposits with the same inputs than less productive banks. Not surprisingly, bank deposit productivity is highly persistent in the data, with a quarterly auto-correlation of 0.99.

3.3 Bank Assets: Bank Production

We next estimate the bank asset production function to recover each bank's asset productivity in each quarter. We can write the bank's log production function as

$$\ln Y_{jt} = \theta \ln A_{jt} + \phi_{jt}. \tag{8}$$

We parameterize and estimate the production function as

$$\ln Y_{jt} = \theta \ln A_{jt} + \Gamma X_{jt} + \phi_j + \phi_t + \epsilon_{jt}. \tag{9}$$

The dependent variable Y_{jt} measures the interest and fee income generated by bank j at time t. We measure a bank's assets lagged by one year to capture the potential lag between the time an investment decision is made and returns are realized. We include additional control variables X_{jt}, including the bank's equity beta and standard deviation of its return on assets, to capture the riskiness of bank assets. In addition, we include time fixed effects to absorb common variation in bank asset productivity over time. Thus, our coefficients are identified from variation across banks in a given quarter. Although the functional form in Eq. (9) is motivated by the specific production function we wrote down in Section 2.2, it is a first-order approximation to any arbitrary production function (see, e.g., Syverson, 2011).

A well known challenge in estimating Eq. (9) is the potential endogeneity of bank size

($\ln A_{jt}$). If a bank observes its productivity ϕ_{jt} prior to determining its investments, then the variable $\ln A_{jt}$ is endogenous in Eq. (9). This is a well-known problem dating back to Marschak and Andrews (1944), and much of the industrial organization literature on production has been devoted to addressing this issue.[13]

Conceptually, we need an instrument that is correlated with size but is otherwise uncorrelated with the bank's asset productivity. We construct a set of cost-shifter instruments in the style of Berry, Levinsohn, and Pakes (1995). Specifically, we instrument for $\ln A_{jt}$ using the weighted average of the deposit productivity of bank j's competitors.[14] The idea is that if a bank faces competitors that are better at raising deposits, it will naturally be smaller, so that competitor deposit productivity induces variation in bank size that is orthogonal to the bank's own asset productivity.

Table 3 displays the corresponding estimates. In columns (1) and (2), we report the OLS estimates, and in columns (3) and (4), we report the IV estimates. The instruments are empirically relevant and yield first stage F-statistics in excess of 20 for each specification. In each specification, we estimate a coefficient on $\ln A_{jt}$ (θ) that is less than one. This implies that banks face decreasing returns to scale.[15] In columns (2) and (4), we measure risk using equity beta and the standard deviation of returns. We include both backward looking measures over the previous two years, as well as forward-looking measures of risk calculated from time t to time t plus two years.[16] The estimates in our IV specifications in columns (3) and (4) of Table 3 are quite similar to the OLS estimates. This suggests that within a quarter, banks either do not observe ϵ_{jt} prior to determining their asset size or that banks are unable to adjust their asset size within a quarter.

[13]For example Olley and Pakes (1996), Levinsohn and Petrin (2003), in addition to many others. For an overview of the literature see Griliches and Mairesse (1998), Ackerberg et al. (2007), and Van Biesebroeck (2008).

[14]Specifically, we construct instruments based on the quality of services offered by a bank's competitors where we define a bank's competitors based at the county by year level. We denote the set of counties bank j operates in K, and the set of banks in each county k is denoted L_k. Our instrument $\overline{\delta_{-j}}$ is then constructed as follows (note time subscripts t are omitted for ease of notation):

$$\overline{\delta_{-j}} = \overline{\sum_{k \in K} \frac{M_k}{M} \sum_{l \in L_{-jk}} \hat{\delta}_l}.$$

The term $\hat{\delta}_l$ corresponds to Eq.(7). The estimates of $\hat{\delta}_j$ are from the demand estimates reported in Appendix Table A7 using the expanded data set. In our IV specifications, we winsorize $\overline{\delta_{-j}}$ at the 1% we use the variables $\overline{\delta_{-j}}$ and $\overline{\delta_{-j}}^2$ to instrument for $\ln A_{kt}$.

[15]We obtain coefficients around one if we exclude bank fixed effects. This suggests that within a bank there are decreasing returns to scale. In addition, it suggests that the endogeneity of bank size is mostly a concern across banks rather than within bank over time. In the cross section, more profitable banks are larger. However, as a bank grows, our data suggests that its profitability declines.

[16]We obtain similar results if we only use the backward-looking measures.

We use the estimated production function system to calculate each bank's assets productivity. Specifically, we compute bank j's asset productivity at time t, ϕ_{jt}, as

$$\hat{\phi}_{jt} = \ln Y_{jt} - \hat{\theta} \ln A_{jt} - \hat{\Gamma} X_{jt}.$$

In our main results, we calculate bank asset productivity using this equation based on the estimates in column (6) of Table 3. Our estimates of asset productivity have a structural interpretation as described by the model of bank profit maximization in Section 2.2. However, as with deposit productivity, a reduced-form interpretation of our results is simply that more asset-productive banks generate more income with the same inputs than less productive banks. Not surprisingly, bank deposit productivity is highly persistent in the data, with a quarterly auto-correlation of 0.95.

4 Results

4.1 Bank Productivity and Value

We begin by showing that our productivity measures are value relevant to validate them. We first show that our productivity measures are related to interest income and interest expense. Fig. 1 displays the estimated relationship between interest expense (normalized by assets) and bank deposit productivity. We estimate a negative, significant, and roughly linear relationship between the two variables. Throughout our analysis, we standardize our productivity measures so that the units show the effect of a one-standard deviation change in productivity. A one standard deviation increase in deposit productivity is correlated with a 24 basis point (bp) decrease in interest expense (t-statistic of 14 clustering by bank). This is economically significant compared to the cross-sectional standard deviation of interest expense of 58 bps.

Fig. 2 shows that there is a positive, significant, and roughly linear relationship between interest income (normalized by assets) and bank asset productivity. A one standard deviation increase in asset productivity is correlated with a 43 basis point (bp) increase in interest income (t-statistic of 15 clustering by bank). This is economically significant compared to the cross-sectional standard deviation of interest income of 45 bps. Furthermore, in untabulated results, we find that both deposit productivity and asset productivity are strongly positively correlated with bank size (as measured by total assets). This is to be expected: all else equal, more productive banks should grow at a faster rate than less productive banks, and should hence be larger.

We next examine how our productivity measures relate to stock-market based measures of bank value. We regress a bank's market-to-book on our estimates of deposit and asset productivity as well as time fixed effects and additional bank-level controls:

$$\left(\frac{M}{B}\right)_{jt} = \gamma_0 + \gamma_1\hat{\delta}_{jt} + \gamma_2\hat{\phi}_{jt} + \Gamma X_{jt} + \mu_t + \varepsilon_{jt}. \quad (10)$$

Table 4 displays the corresponding estimation results.[17] Column (1) shows the univariate relationship between deposit productivity and market-to-book. In column (2), we add controls X_{jt}: lagged (log) assets, as well leverage, the bank's estimated equity beta, and the standard deviation of its ROA to account for risk. We control for size as a proxy for the growth expectations of the bank. Larger banks will tend to grow more slowly and thus have lower market-to-book ratios. The remaining controls are meant to account for any correlation between our productivity measures and bank risk taking, which will tend to reduce market-to-book.

The results show that a one-standard deviation increase in deposit productivity is associated with an increase in market-to-book of 0.2 to 0.5 points, an economically significant effect. The cross-sectional standard deviation of market-to-book is 0.69 in our sample.[18] Columns (3) and (4) show the relationship between asset productivity and market-to-book. The results show that a one-standard deviation increase in asset productivity is associated with an increase in market-to-book of 0.14 to 0.22 points, an effect that is also economically significant.

Overall, these results show that our productivity measures are strongly value relevant.

4.2 Deposit-driven Value versus Asset-driven Value

We next compare the relative importance of deposit and asset productivity in determining bank value. We use two distinct approaches to examine the relative importance of the liability and asset side of a bank. First, we examine how market-to-book loads on deposit and asset productivity. Second, we use our framework from Section 2 to calculate the model-implied relative contribution of asset and deposit productivity to bank value.

We start by re-estimating our market to book regressions (Eq. 10), simultaneously including both deposit and asset productivity. Columns (5) and (6) of Table 4 display the corresponding estimates. Bank value loads positively on both asset and deposit productivity in both specifications. However, we find that an increase in deposit productivity has a much

[17]We winsorize M/B at the 1% level, after which the distribution of this variable looks approximately Normal. All of our main results are robust to using ln(M/B); if anything, most results are stronger.

[18]This number is within-time and therefore lower than the overall standard deviation of M/B reported in Table 1.

larger impact on a bank's market-to-book than asset productivity. The results in column (5) indicate that a one standard deviation increase deposit productivity is associated with a 0.21 increase in market-to-book, whereas a one standard deviation increase in asset productivity is associated with only a 0.09 increase in market-to-book.[19] The impact of deposit productivity is about twice as large in column (5), where we only include time fixed effects, and nearly five times as large in column (6), where we include the full suite of controls. This suggests that liability-driven theories of bank value creation, which focus on the special services provided by bank deposits, explain more variation in the cross section of banks than asset-driven theories. One important caveat is that the regression results reported in Table 4 focus on the explaining cross-sectional dispersion in bank value rather than the level of bank value or social value created by banks.

The results suggest that deposit productivity plays a larger role in explaining the dispersion in bank value than asset productivity. What explains this difference? Variation in multiples must be explained by variation in cash flows, growth rates, or returns. We find little evidence that our productivity measures have different associations with future growth rates or equity returns. The remaining possibility is that deposit productivity explains more variation in bank cash flows than asset productivity.

We use our economic framework from Section 2 to examine this possibility. As discussed in Section 2.3, our two productivity measures directly affect bank cash flows. For example, if a bank's deposit productivity increases from δ^0 to δ^1, the bank can offer a lower deposit rate and still collect the same amount of deposits. The cost savings of increasing deposit productivity are given by

$$Cost\,Savings = Deposits \times \frac{\Delta\delta}{\alpha}.$$

Similarly, if a bank's asset productivity increases from ϕ^0 to ϕ^1, its returns increase by

$$\Delta Y = \left[exp(\phi^1) - exp(\phi^0)\right] exp(\Gamma X_j) A_j^{\theta}.$$

Fig. 3 uses these equations to decompose the dispersion in net income across banks. The red shaded histogram shows how much the average bank's net income changes as we vary bank deposit productivity (δ_{jt}) across its observed distribution in the data. Similarly, the blue histogram shows how much the average bank's net income changes as we vary asset productivity across its distribution in the data. [20] Consistent with the evidence presented in

[19] In terms of partial R^2, deposit productivity explains 7% of the residual variation in market-to-book whereas asset productivty explains 1% of the residual variation in market-to-book (Table 4 column 5).

[20] In Fig. 3, we normalize the distributions based on the risk-free return and benchmark bank borrowing

our market-to-book regressions (Table 4, columns 5 and 6), Fig. 3 suggests that heterogeneity in deposit productivity explains about twice as much of variation in bank net income as heterogeneity in asset productivity.

Fig. 4 presents a similar plot that discards the structure of Fig. 3 and simply plots the variation in interest income and interest expense, normalized by assets. In this accounting-based decomposition of bank value, the contributions of the asset-side (interest income) and liability-side (interest expense) measures look comparable. The stark differences between Fig. 3 and Fig. 4 therefore highlight the value of a more rigorous economic analysis. In particular, by ignoring *how* banks (1) obtain funding and (2) convert that funding into income, the accounting-based decomposition obscures the "primitives" that enter the bank's optimization problem and are responsible for determining a bank's value.

We can also use the joint distribution of deposit and asset productivity to determine the share of net income coming from deposits for each bank. Fig. 5 shows the results. The figure suggests that deposit productivity on average accounts for about twice as much of bank value relative to asset productivity. The mean and median deposit value share is 63% and 70%, respectively. However, the figure also shows that there is significant variation, indicating that there is a great deal of heterogeneity in bank business models.

Overall, a variety of different approaches suggest that variation in deposit productivity accounts for a larger share of the dispersion in bank value than variation in asset productivity. This suggests that liability-driven theories of bank value creation explain more variation in the cross section of banks than asset-driven theories.

4.3 Decomposing Bank Productivity

Why does deposit productivity explain more variation in bank cash flows than asset productivity? One potential explanation is that product differentiation and competition allow banks to extract more value from their deposit activities relative to their lending activities. For example, if lending products are more homogeneous and competitive than deposit markets, then deposit productivity may have a larger impact on bank value. In this section, we examine this possibility.

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rates. Specifically, we normalize the level of asset productivity relative to 3-month LIBOR such that the small set of banks earning returns below 3-month LIBOR have negative asset productivity. Similarly, we also normalize the deposit total factor productivity distribution relative to 3-month LIBOR. We use deposit productivity to predict the bank's offered deposit rate. Specifically, we regress a bank's deposit rate (net of fees) on our measure of deposit productivity and time fixed effects. The results imply that the bottom 13% of banks in terms of deposit productivity offer deposit rates (net of fees) that are greater than 3-month LIBOR. We normalize the deposit productivity distribution under the assumption that the bottom 13% of banks in terms of deposit productivity in each quarter do not generate any value on the deposit side of the bank.

We start by decomposing our productivity measures to ask which types of assets and deposits most affect these overall measures in Table 5. Specifically, we compute more refined measures of deposit and asset productivity for various types of deposits and assets using the emprical framework described in Section 3.[21] We then assess the correlations between these more specialized productivity measures and our broader deposit and asset productivity measures, as well as market-to-book ratios.

Columns (1) and (2) of Table 5 examine the relationship between overall deposit productivity and our deposit subcategory measures: savings deposit productivity, small time deposit productivity, large time deposit productivity, and transaction deposit productivity. All of the subcategory measures are positively correlated with our overall deposit productivity measure. As before, all variables are standardized such that the coefficients correspond to a one-standard deviation increase in our productivity measures.

The overall deposit productivity measure is most strongly correlated with savings deposit productivity and transactions deposit productivity. This is not simply driven by the composition of bank deposits. A one standard deviation increase in savings deposit productivity is associated with a 0.74 standard deviation increase in total deposit productivity, though savings deposits make up only 41% of a bank's total deposits on average. Similarly, we find that a one standard deviation increase in transaction deposit productivity is associated with a 0.41 standard deviation increase in total deposit productivity, despite transaction deposits making up only 19% of total deposits on average.

Columns (3) and (4) of Table 5 display the relationship between asset productivity and our subcategory measures: lending productivity and securities productivity.[22] The estimates indicate that our asset productivity measure is significantly more correlated with banks' loan productivity than their securities productivity. This accords with intuition: as noted above, there is more scope for banks to use their screening and monitoring technologies to generate excess returns in the context of loans than securities. If securities are relatively standardized and homogeneous relative to bank loans, it is natural that variation in bank productivity would be driven by a bank's lending portfolio rather than its securities portfolio.

Finally, columns (5) and (6) assess the correlations between our detailed productivity measures and banks' market-to-book ratios. These columns show that bank value is more sensitive to loan productivity than securities productivity, but that neither asset-side productivity measure is particularly important relative to our deposit productivity measures.[23]

[21] The corresponding estimates are reported in Table A1.

[22] This is the most granular decomposition we can do on the asset side because of data availability.

[23] The negative coefficient on small time deposits is a product of running a multiple regression. The univariate correlation between market-to-book and small time deposit productivity is positive. However, this result is consistent with the claim that banks report losing money on smaller accounts

Hence, consistent with the results in Table 4, Table 5 shows that bank value is more sensitive to deposit productivity than to asset productivity.

The results in Table 5 also suggest that not all deposits are created equal. Columns (5) and (6) suggest that the main drivers of value on the liability side are savings deposits with transaction deposits a distant second. In column (6), savings deposit productivity explains over three times as much variation in market-to-book as transaction deposit productivity, and five times as much variation as any other subcategory productivity measure.

Why are saving deposits so strongly correlated with value? A key part of the answer is that depositors behave as though they are highly differentiated products. They act as though savings deposits at one bank are not a good substitute for savings deposits at another bank. In other words, savings deposits are very "sticky." Thus, demand is almost completely inelastic to the rate a bank offers, so a bank that is good at gather savings deposits can gather them at very low rates.[24] In contrast, if demand for deposits were completely elastic, deposit productivity would create no value for the bank; a less productive bank could always offer a deposit rate ϵ higher than the most productive bank and collect all deposits. Consistent with this intuition, demand for transaction deposits is also quite inelastic, while demand for time deposits is quite elastic. The more elastic the demand for a particular type of deposit, the less it contributes to bank value.

These value decompositions have interesting implications for mapping our results back to theories of bank value creation. Our results in Section 4.2 suggest that liabilities are an important source of bank value. However, the liabilities that are most strongly associated with deposit productivity are not transaction deposits, which provide the most liquidity services. Instead, the source of most liability-side bank value comes from savings deposits, liabilities that provide some limited liquidity services but are primarily safe stores of value.

4.4 Bank Productivity and Balance Sheet Composition

Another way to understand what drives our productivity measures is to look at how they correlate with balance sheet composition. This is particularly useful on the asset side of the balance sheet, where data limitations prevented us from doing fine-grain decompositions in the previous section. Here, we instead use a revealed preference argument. If banks with high productivity tilt their balance sheets towards certain assets and liabilities, this suggests that those assets and liabilities create substantial value.

[http://www.fool.com/investing/general/2014/03/10/do-the-big-banks-not-want-small-customers.aspx, accessed 2/24/2017]

[24] We show this formally in Appendix Table A1a, which re-estimates our basic deposit demand system from Eq.(6) for each type of deposit. That is, in Table A1a, we treat each deposit type as a separate product and estimate a demand system for each product.

In Table 6a, we examine the correlations between our deposit productivity measure and the composition of the liability side of banks' balance sheets. Column (1) shows that our deposit productivity measures are not strongly correlated with bank leverage (defined as liabilities over assets).[25] Interestingly, banks that are particularly good at raising deposits do not appear to lever up much more than other banks. Columns (2)-(7) show that banks with higher deposit productivity tend to have significantly higher quantities of deposits as a fraction of their total liabilities, as expected. Given that leverage does not change with deposit productivity, this implies that non-deposit debt falls with deposit productivity. Instead, they substitute non-deposit debt for deposits. Thus, it appears that non-deposit debt is not an important source of value for banks, suggesting that this debt does not provide safety or liquidity services that are valuable to investors.

Table 6b displays correlations betwen our asset productivity measure and banks' asset composition. Columns (1)-(3) show that more productive banks tend to hold more real estate loans, more C&I loans, and more loan commitments (credit lines) than less productive banks. This is consistent with the idea that more productive banks have better screening and monitoring technologies that allow them to make loans with high risk-adjusted returns. Columns (4)-(6) show that productive banks also tend to have lower quantities of securities and liquid assets than less productive banks. This also makes sense – there is presumably more scope for banks to use their screening and monitoring technologies to generate excess returns in the context of loans, where there can be substantial asymmetric information, than securities, which are more standardized. Thus, it is not surprising that variations in productivity are correlated with variations in relative loan quantities across banks. Collectively, our findings indicate that high-productivity banks tend to have a higher fraction of their balance sheet made up of loans and a lower fraction of their balance sheet made up of securities and liquid assets.

4.5 Synergies

In previous sections, we have examined a bank's deposit productivity and its asset productivity separately. However, because of potential synergies between collecting deposits and lending, a bank's asset productivity may be intimately linked to it's deposit productivity. Here, we examine the synergies between the two dimensions of a bank.

Table 7a presents regressions relating our asset productivity measures to our deposit

[25] Note that our standard suite of controls includes lagged leverage. If we omit this control from the regression, we still obtain a small and statistically insignificant correlation.

productivity measures. Specifically we run regressions of of the form

$$\hat{\phi}_{jt} = \gamma_0 + \gamma_1 \hat{\delta}_{jt} + \Gamma X_{jt} + \mu_t + \varepsilon_{jt}. \tag{11}$$

The table shows that the two measures are strongly correlated. Column (1) shows that a one-standard deviation increase in deposit productivity is associated with a 0.33 standard deviation increase in asset productivity. This is economically significant: the within time (i.e., excluding time fixed effects) R^2 of the regression is 25%, indicating that 25% of the variation in our measure of asset productivity can be explained by variation in deposit productivity. Once we include controls in column (2), the association between asset productivity and deposit productivity strengthens somewhat. Columns (3)-(6) break asset productivity into its constituent pieces: loan productivity and securities productivity. Both are correlated with deposit productivity, though the effect for securities productivity becomes insignificant once we add controls. Overall, Table 7a suggests that there are important synergies between deposit productivity and asset productivity, and that those synergies are more related to loans than securities.

To better understand the fundamentals driving the observed synergies between asset and deposit productivity, we examine the correlations between our subcategory measures of productivity in Table 7b . We separately examine the relationship between overall asset (columns 1-2), loan (columns 3-4), and securities (columns 5-6) productivity and the subcategory deposit productivity measures. In general, we find a positive relationship between savings and time deposit productivity and our various measures of asset productivity. However, we do not find a relationship between transaction deposits productivity and our different measures of asset productivity. The results suggest that the nature of synergies may have to do with the term structure of deposits. Banks that are more productive in collecting long-term deposits appear to have more productive lending and securities portfolios.

In Table 8, we use variation in bank balance sheet composition to explore the sources of these synergies in more detail. Table 8a relates bank asset composition to deposit productivity. Column (1) shows that there is no correlation between deposit productivity and real estate lending. In contrast, column (2) shows there is a strong correlation between deposit productivity and C&I lending. Since C&I loans are more illiquid than mortgages, this suggests that the ability to raise deposits in a cost-effective manner is important for banks that wish to make profitable, illiquid loans. This is consistent with Hanson, Shleifer, Stein, and Vishny (2016), who argue that the fact that deposits are stickier than other types of short-term debt is a key source of value for banks because it allows them to hold more illiquid assets than they otherwise could. Column (3) shows that banks with higher deposit productivity also tend to write more loan commitments. This is consistent with Kashyap, Rajan, and Stein (2002) and Gatev and Strahan (2006), who argue that there are synergies between taking deposits and writing loan commitments because in bad times deposits tend to flow into banks while loan commitments are simultaneously drawn down. Our results suggest that this effect is particularly strong for banks that are good at gathering deposits.

In Table 8b, we examine the relationship between bank liability composition and asset productivity. The strongest correlation that arises here is in column (4), which shows that banks with productive assets tend to gather more large time deposits. This suggests that banks with strong asset productivity may be viewed more favorably by depositors, allowing them to raise more funding at better rates. The results also suggest that the term structure of deposits may also play an important factor. We find a positive relationship between asset productivity and term deposits. Conversely, we find a negative relationship between transaction deposits and asset productivity.

5 Robustness

We find that banks that are more productive in raising deposits and generating asset income are more valuable. Although deposit and asset productivity are closely related, we find that variation in deposit productivity accounts for more than twice the variation in bank value relative to asset productivity. In this section, we provide a variety of robustness tests examining the importance of the geographical distribution of bank operations, using alternative measures of productivity, accounting for potential measurement error, and using different subsets of the banks in our data set. Overall, we find that our main results discussed in Section 4 are robust to these alternative specifications.

5.1 Geography

Beyond the theory-based explanations we examined in the previous sections, variation in bank value and bank productivity may also be driven by differences in the areas where banks operate. To examine this question, we begin by analyzing the geographic and demographic correlates of our productivity measures in Table A2a. We combine county-level Census data with the FDIC's summary of deposits to generate average characteristics of the counties where each bank operates, weighted by the fraction of the bank's deposits in each county. Column (1) shows the correlation between asset productivity and these demographic characteristics. There is a concave relationship between asset productivity and both population and average local wages. Banks in low-population, low-wage areas have low asset productivity, but the relationship fades as population and wages increase. Banks in high house price areas have higher asset productivity. We do not find any evidence of nonlinearity in the relationship and therefore only report the linear relation. Similarly, banks with high asset productivity tend to operate in less competitive areas, as measured by the Herfindahl-Hirschman index (HHI) of mortgage originations from Home Mortgage Disclosure Act (HMDA) data. In column (2), we replace specific demographic characteristics with fixed effects. Specifically, we regress bank asset productivity on 387 dummy variables, each of which indicates whether the bank operates in a particular MSA. The within time R^2 of the regression is 35%, suggesting that the areas where banks operate explains a significant fraction of their asset productivity. Columns (3) and (4) repeat these exercises for deposit productivity with similar results. We find that geographic variation explains 70% of the variation in deposit productivity.

Table A2b shows that our main results hold even controlling for MSA fixed effects. Despite the fact that geography explains much of the variation in our productivity measures, these measures are still strongly related to market-to-book ratios after controlling for geographic variation, and deposit productivity continues to have a much larger impact than asset productivity. In addition, asset productivity remains strongly correlated with deposit productivity, even after controlling for MSA fixed effects.

Overall, while the geographic and demographic characteristics of where banks operate explain a substantial part of the variation in asset and deposit productivity, geographic and demographic characteristics cannot explain our main results.

5.2 Alternative Production Function and Demand Estimates

In our baseline analysis, we estimate the deposit demand system and asset side production function using standard methods from the industrial organization literature. Here, we run several robustness checks, where we allow for a more flexible asset income production function, use additional measures of risk, and use alternative demand estimates.

5.2.1 Alternative Production Function Estimates - Spline Estimation

We estimate the bank's asset side production function using a first order Taylor series approximation to any arbitrary production function. One potential concern with our asset production function estimates is that our empirical specification may not be flexible enough to capture a bank's true production function. In our baseline estimates, we find that there are decreasing returns to scale in production. Here, we re-estimate the bank's production function, where we allow for a more flexible model in terms of the economies of scale. Specifically, we estimate the production function where we use a spline with $K = 5$ and $K = 10$ knot points

$$\ln Y_{jt} = \theta \ln A_{jt} + \sum_{k=1}^{K-1} (\theta_k \max(\ln A_{jt} - q_k, 0)) + \Gamma X_{jt} + \phi_j + \phi_t + \epsilon_{jt}. \tag{12}$$

The term q_k represents the kth quantile of the distribution of bank asset holdings in the data. We report the alternative production function estimates in the Internet Appendix (Column 1 of Table A8). In general, the results suggest that our baseline specification captures the curvature of a bank's production function quite well.[26]

We next replicate our main findings using the new production function estimates. These findings are reported in Table A3a. We construct an alternative asset productivity measure using our spline production function estimates with five knot points. Columns (1) and (2) display the relationship between a banks' market-to-book ratio and our alternative measure of asset productivity. Our baseline results remain the same. Both asset and deposit productivity are both positively correlated with a bank's market-to-book ratio; however, deposit productivity has a larger impact on market-to-book relative to asset productivity. Similarly, columns (3) and (4) indicate that there are strong synergies between deposit productivity and our alternative measure of asset productivity.

5.2.2 Alternative Production Function Estimates - Additional Risk Controls

We control for risk in our baseline specification using a bank's equity beta, leverage, and standard deviation of returns. As discussed in Section 4.1, we find substantial evidence that banks with higher asset productivity create more value. These results suggests that our measures of asset productivity are not simply picking up differences in a bank's risk exposure. As a robustness check, we re-estimate our bank asset income production function where we control for the Fama and French (1992, 1993) factors as well as a bank's asset composition. We report the alternative production function estimates in the Internet Appendix (Column 2 of Table A8). The production function estimates are comparable to our baseline estimates.

Using our alternative asset productivity estimates, we next replicate our main results. The results of this exercise are documented in Table A3b. The alternative set of results are both qualitatively and quantitatively similar to those in our baseline analysis. Columns (1) and (2) show that our alternative measure of asset productivity is positively associated with a bank's market-to-book, but market-to-book loads more on deposit productivity relative to asset productivity. We also find evidence of strong synergies between deposit productivity

[26] We do find evidence that the dis-economies of scale are slightly greater for banks in the top decile of the sample.

and our alternative measure of asset productivity as reported in Columns (3) and (4).

5.2.3 Alternative Demand Estimates

In this section, we examine the robustness of our main findings to the alternative demand specifications. We begin by re-estimating our demand system using more granular county-by-year data from RateWatch, which reports deposit rates directly, in Table A4a. The data runs from 2002 to 2012.[27] We now include county × time fixed effects in estimating the county-year analog of Eq. (6). The estimates are very similar to those we find at the aggregate level in Table 2.

We then recompute our measure of deposit productivity using these estimates.[28] Demand for bank deposits and bank competition may occur at a much more localized level, which is consistent with these county level demand estimates.

Table A4b displays our baseline set of tests, where we use this alternative measure of deposit productivity. The results are comparable to our baseline results. We find that a bank's market-to-book is positively correlated with our alternative measures of deposit productivity. The results displayed in columns (1) and (2) of Table A4b again suggest that deposit productivity has a greater impact on market-to-book relative to asset productivity. Columns (3) and (4) of Tables A4b indicate that there are strong synergies between asset and deposit productivity.

5.3 Measurement Error

We measure deposit and asset productivity using estimates from our demand and production function regressions. Because productivity is estimated, our deposit and asset productivity measures may inherently contain measurement error. We employ two well-known methods to address measurement error. First, we instrument for our deposit and asset productivity measures using alternative measures of productivity. Second, we construct empirical Bayes estimates of productivity. Our main findings are robust to these alternative estimation strategies.

[27] Our RateWatch data includes 447 of the 847 banks in our main sample.

[28] We construct county by firm by year measures of deposit productivity using our county level demand estimates. Let δ_{ljt} denote the deposit productivity of firm j in county l at time t. Following our demand specification, we calculate the firm's aggregate deposit productivity at time t as

$$\delta_{jt} = \ln\left(\sum_{k\in K} M_k exp(\delta_{kjt})\right)$$

where we denote the set of counties bank j operates in as K.

5.3.1 Instrumental Variables

We instrument for our measures of deposit and asset productivity using our subcategory measures of productivity. Specifically, we instrument for total deposit productivity using our productivity estimates for savings deposits, small time deposits and other types of deposits. Similarly, we instrument for total asset productivity using our separate estimates of loan and asset productivity. As discussed in Section 4.3, our instruments are clearly relevant (Table 5 columns 1-4). Provided that the measurement error in our productivity estimates (assets and deposits) is orthogonal to the subcategory productivity measures, our instrumental variable strategy is valid and will correct for any bias caused by measurement error.

Table A5 displays the corresponding instrumental variables estimates corresponding to our baseline set of results. Consistent with our previous results, we find a positive relationship between deposit productivity and a bank's market-to-book and asset productivity and a bank's market-to-book (columns 1 and 2). However, the estimated relationship between asset productivity and a bank's market-to-book is no longer statistically significant. The IV estimates reaffirm our earlier finding that market-to-book loads more heavily on deposit productivity relative to asset productivity. The IV estimates reported in columns (3) and (4) of Table A5 again indicate there are strong synergies between asset and deposit productivity.

5.3.2 Empirical Bayes Estimation

We construct empirical Bayes estimates of deposit and asset productivity as an additional robustness check. Much of our analysis is focused on the distributions of deposit and asset productivity in the population of banks. If our estimates of productivity suffer from classical measurement error, then the estimated distributions productivity will overstate the true variance of productivity.[29] As is common in the education and labor literature (e.g., Jacob and Lefgren, 2008; Kane and Staiger, 2008; and Chettty, Friedman, and Rockhoff, 2014), we shrink the estimated distributions of asset and deposit productivity to match the true distribution of asset and deposit productivity.

Here, we examine a bank's average deposit and asset productivity in our sample using the estimated bank specific fixed effect in Eqs. (6) and (9). We shrink the estimated distribution of fixed effects by the factor α, which is estimated from the data. Under the assumption

[29] For example, suppose our estimates of deposit productivity are unbiased estimates of true deposit productivity $\hat{\delta}_j = \delta_j + \epsilon_j$ and assume that the measurement error is uncorrelated with deposit productivity. The variance of the estimated distribution of total factor productivity is then equal to the true variance of deposit total factor productivity plus the variance of the measurement error, $\sigma^2_{\hat{\delta}} = \sigma^2_{\delta} + \sigma^2_{\epsilon}$. We address this concern by "shrinking" the estimated distribution of total factor productivity by the factor $\frac{\sigma^2_{\delta}}{\sigma^2_{\delta}+\sigma^2_{\epsilon}}$ to account for measurement error. Conceptually, the greater σ^2_{ϵ} is relative to σ^2_{δ}, the more we want to shrink the estimated distribution of productivity.

that the variance of the estimation error is homoskedastic, the appropriate scaling factor is $\alpha = \frac{F-1-\frac{2}{k-1}}{F}$, where F is the F-test statistic corresponding to the a joint test of the statistical significance of the fixed effects and k is the number of fixed effects (Cassella, 1992). The estimated shrinkage factors are close to one for both deposit and asset productivity (0.998 and 0.971), which suggests that most of the variation in our productivity estimates is driven by true variation in productivity rather than measurement error.

We replicate Fig. 3 using our empirical Bayes estimates of deposit and asset productivity and display the corresponding results in Fig. A1. Fig. A1 allows us to determine how much of the dispersion in net income across banks can be explained by heterogeneity in terms of deposit and asset productivity. The estimated dispersion in net income created by deposit productivity (red shaded area) is nearly identical in Figs. 3 and A1. Similarly, the estimated dispersion in net income created by asset productivity (blue shared area) is nearly identical in Figs. 3 and A1. However, the dispersion asset productivity is slightly lower in Fig. A1 relative to Fig. 3. Consistent with the evidence presented above, Fig. A1 suggests that about twice as much of the variation in bank net income can be explained by productivity heterogeneity on the deposit side relative to productivity heterogeneity on the asset side.

5.4 Sub-sample Analysis

We run several robustness checks regarding the set of banks in our sample. First, we replicate our findings where we exclude the largest banks. Second, we replicate our main findings where we exclude observations from the financial crisis.

5.4.1 Excluding Large Banks

We replicate our main findings where we exclude the the largest 5% of banks. Specifically, we drop all observations of those banks that appear among the top 5% of the sample in terms of assets at any point in time. In total, we drop 41 of the largest banks from the sample. We then replicate our baseline tests using the alternative set of banks. Table A6a reports the corresponding estimates. The alternative set of results are both qualitatively and quantitatively similar to those in our baseline analysis. Columns (1) and (2) show that our alternative measure of asset productivity is positively associated with a bank's market-to-book, but market-to-book loads more on deposit productivity relative to asset productivity. The results in column (4) suggest that the synergies between asset and deposit productivity may actually be larger for the smaller banks in our sample. The results in column (4) indicate that a one standard deviation increase in deposit productivity is associated with a 0.98 standard deviation increase in asset productivity. In untabulated results, we also drop all observations for the acquiring bank in the year following bank mergers and acquisitions and verify that our findings are not driven by sharp productivity gains or losses stemming from mergers and acquisitions.

5.4.2 Excluding the Financial Crisis

We show that our findings are not driven by the recent financial crisis. Although we include time fixed effects in all of our analysis, one may still be concerned that abnormal variation in bank productivity and valuations during the financial crisis could be driving our main results. We replicate our baseline tests where we exclude the period surrounding the financial crisis (2008 and 2009). Table A6b displays the corresponding estimates. Again, we find that both asset and deposit total factor productivity are both positively correlated with a bank's market-to-book and that deposit total factor productivity has a relatively larger impact on a bank's market-to-book. We also find comparable evidence suggesting that there are strong synergies between asset and deposit productivity.

6 Conclusion

What are the key cross-sectional determinants of bank value? In this paper, we draw upon the literature in industrial organization to develop a simple empirical framework. In our framework, banks can create value through three primary mechanisms: though excelling at the gathering of deposits, through excelling at the production of loans and other assets, and through synergies between loan and deposit production. These mechanisms correspond with the three most widely-cited theoretical channels of bank value creation.

We find evidence that all three channels affect bank value. Of the three channels, however, we find that a bank's ability to produce deposits is by far the most important in explaining cross-sectional variation in bank value. In particular, we find that variation in deposit productivity accounts for about twice as much variation in bank value as variation in asset productivity. A one-standard deviation increase in deposit productivity is associated with an increase in market-to-book ratios of 0.2 to 0.5 points, while a one-standard deviation increase in asset productivity is associated with an increase in market-to-book of 0.1 to 0.2 points. We also find evidence of significant synergies between banks' lending and deposit-taking activities, with high-deposit productivity banks holding a significantly greater fraction of illiquid assets than low-deposit productivity banks. Collectively, these results shed significant light on the determinants of bank value.

We also explore the drivers of variation in our measures of bank productivity. While bank leverage is not strongly linked to deposit productivity, we find that high deposit productivity is associated with higher fractions of savings deposits and large time deposits as a function of total liabilities. Thus, while our estimates suggest that liabilities are an important source of bank value, the liabilities that are most strongly associated with productivity are not those that provide the most transaction and liquidity services. We also find that high asset productivity is associated with a tilt towards illiquid assets. Thus, our results are consistent with the idea that screening and monitoring of information-intensive loans is an important source of bank value, though it accounts for less variation in bank value than deposit productivity.

All together, our paper represents the first attempt to provide evidence on all three sources of potential bank value creation within a unified framework, and to assess which theoretical levers are most important in explaining the cross-section of value. Our results also have important implications for financial regulation. Without quantitatively understanding the main drivers of bank value creation, its difficult to determine the costs and benefits of financial regulations. Hence, we believe our findings have implications across a wide range of specific bank regulatory topics. For example, so-called "narrow banking" proposals might need to be re-evaluated in light of our finding that deposit productivity and asset productivity are synergistic.[30] Among other avenues for future research, it is also an open question how monetary policy affects banks' deposit and asset productivity. For now, however, our cross-sectional findings give credence to the argument that banks are "special" entities that generate value by providing unique services through their liabilities.

[30] There has a been a resurgence of narrow banking proposals among academics and policy makers (Kay 2009; Gorton and Metrick 2010, Chamley, Kotlikoff, and Polemarchakis 2012; Bulow and Klemperer 2013; and Cochrane 2014). The implications of narrow banking differ drastically depending on how banks create value. We find strong fundamental linkages between the asset and liability sides of bank balance sheets, suggesting that narrow banking proposals could be quite costly. In a similar vein, the costs and benefits of other bank regulations, such as increased captial requirements, hinge on how banks create value.

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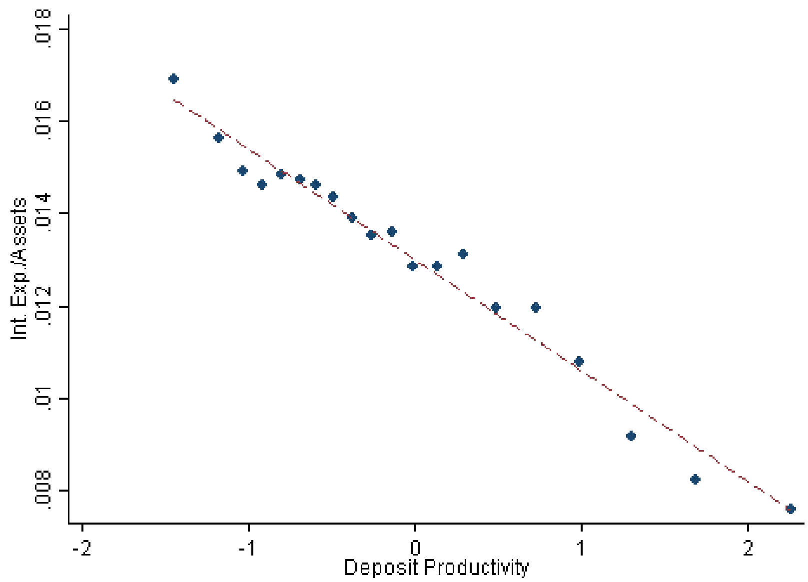
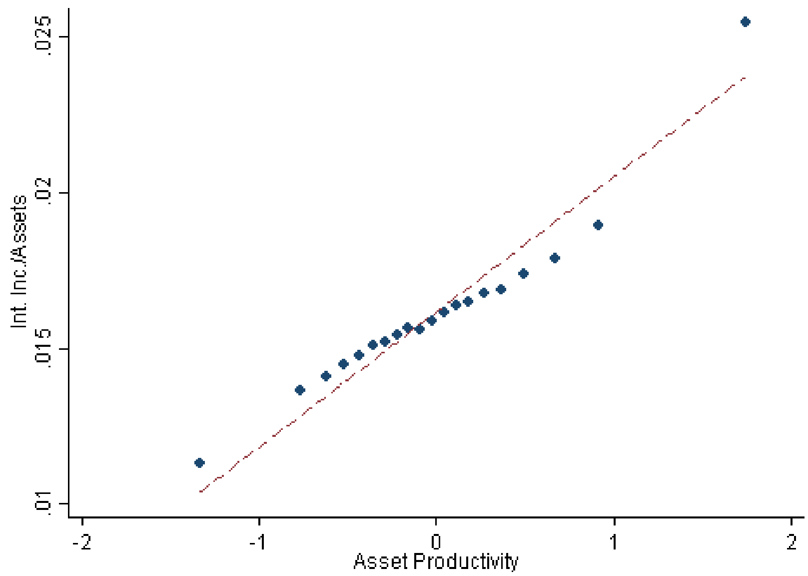
Figures

Figure 1: Deposit Productivity vs. Interest Expense



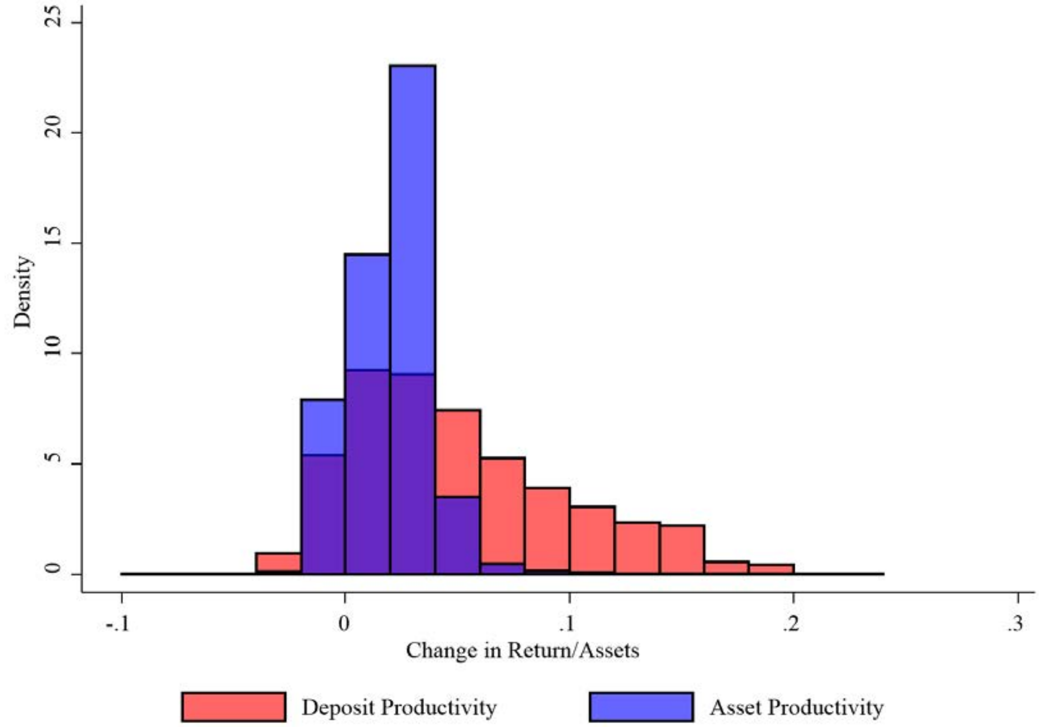
Note: Fig. 1 displays a binscatter plot of a bank's interest expense (normalized by assets) versus a bank's deposit productivity. Deposit productivity is standardized and is constructed from the deposit demand estimates reported in column (4) of Table 2. Interest expense is annualized (quarterly interest expense multiplied by 4). Observations are at the bank by quarter level over the period 1994-2015. In the figure, both interest expense and deposit productivity are measured within a given year and quarter (i.e., the binscatter plot includes year by quarter fixed effects).

Figure 2: Asset Income vs. Interest Income



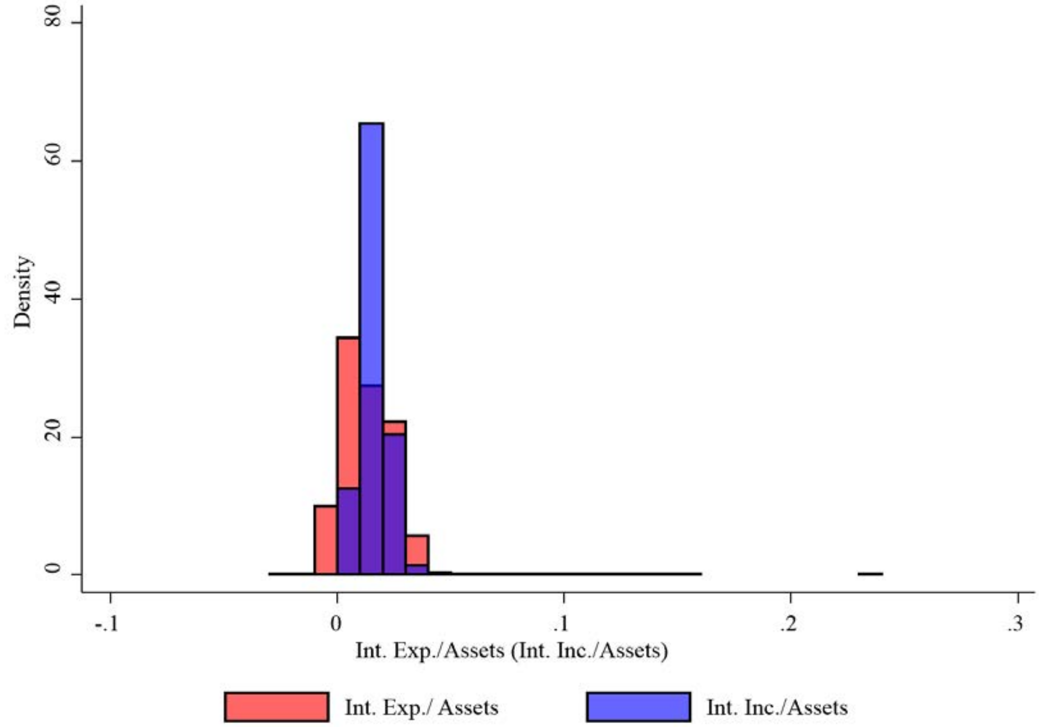
Note: Fig. 2 displays a binscatter plot of a bank's interest income (normalized by assets) versus a bank's asset productivity. Asset productivity is standardized and is constructed from the asset income production function estimates reported in column (4) of Table 3. Interest income is annualized (quarterly interest income multiplied by 4) Observations are at the bank by quarter level over the period 1994-2015. In the figure, both interest income and deposit productivity are measured within a given year and quarter (i.e., the binscatter plot includes year by quarter fixed effects).

Figure 3: Value Creation: Asset Productivity vs. Deposit Productivity



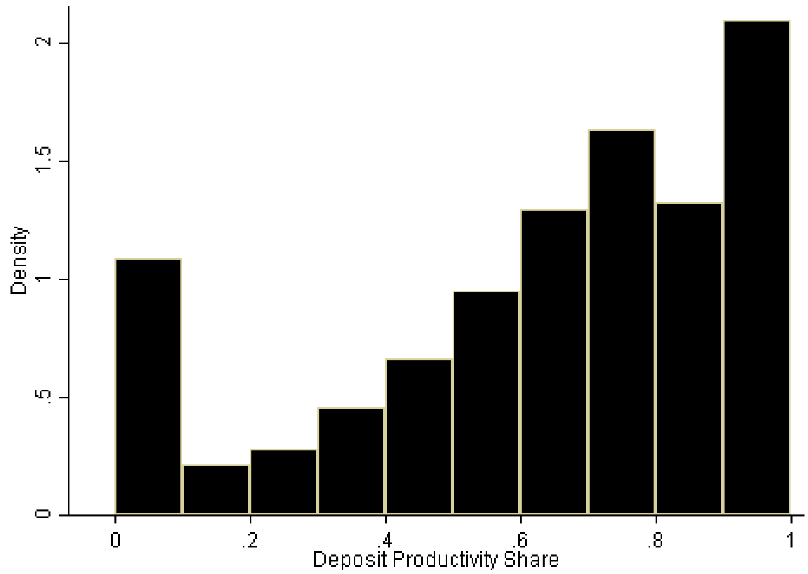
Note: Fig. 3 displays the estimated distributions of asset and deposit productivity. The red shaded histogram plots the distribution of bank deposit productivity weighted by $\frac{\overline{Deposits}}{Assets}\frac{1}{\alpha}$. The blue histogram displays the scaled distribution of asset productivity $\frac{\overline{Assets}^{\theta}}{Assets} exp(\phi_{jt} + \overline{\Gamma X_{jt}})$. We normalize the level of asset productivity relative to 3-month LIBOR such that the small set of banks earning returns below 3-month LIBOR have negative asset productivity. Similarly, we also normalize the deposit productivity distribution relative to 3-month LIBOR. We find that 16% of banks offer deposit rates (net of fees) that are greater than 3-month LIBOR. We normalize the deposit productivity distribution under the assumption that the bottom 16% of banks in terms of deposit productivity in each quarter do not generate any value on the deposit side of the bank. The deposit productivity estimates correspond to the specification reported in column (4) of Table 2. The asset productivity estimates correspond to specification reported in column (4) of Table 3.

Figure 4: Interest Expense vs Interest Income



Note: Fig. 4 displays the distributions of deposit interest expense and interest income. The red shaded histogram plots the distribution of deposit interest expense divided by assets. The blue shaded histogram plots the distribution of interest income divided by assets. Both deposit interest expense and interest income are annualized (multiplied by 4).

Figure 5: Deposit Productivity Share



Note: Fig. 5 displays the distribution of the deposit value share of each bank. The deposit value share reflects the percentage of bank value that is generated by deposit productivity relative to asset productivity. We censor those observations with negative deposit value shares at zero and those observations with deposit value shares greater than 1 at 1. The deposit and asset productivity estimates correspond the specifications reported in columns (4) of Table 2 and Table 3.

Tables

Table 1: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Deposit Int. Expense	26,742	2.18%	1.34%	0.11%	6.53%
Deposit Int. Expense (Net of Fees)	26,742	1.73%	1.36%	-0.46%	6.16%
Non Int. Expense (Millions)	26,742	142.44	517.53	1.27	3,662.00
No. Branches	26,742	119.50	307.73	1.00	2,024.00
No Employees	26,742	3,456.47	10,511.54	54.00	68,396.00
Assets (Billions)	26,742	26.50	161.00	0.10	2,580.00
Interest Income (Millions)	26,742	281.85	1,524.57	1.50	33,000.00
Deposits (Billions)	26,742	14.20	78.90	0.01	1,370.00
Leverage	26,742	0.91	0.04	0.19	1.02
Beta	26,742	0.63	0.58	-0.66	2.46
Std. Dev. ROA	26,742	0.14%	0.18%	0.01%	0.91%
Market-to-Book	26,742	1.71	0.85	0.18	5.30
Liabilities (Relative to Total Liabilities)					
Deposits	26,742	0.83	0.13	0.00	1.00
Small Time Deposits	26,736	0.20	0.11	0.00	0.68
Large Time Deposits	26,736	0.13	0.08	0.00	0.89
Savings Deposits	24,633	0.34	0.15	0.00	0.89
Transaction Deposits	24,627	0.15	0.10	-0.30	0.81
FF+Repo	18,051	0.04	0.06	0.00	0.69
Assets (Relative to Total Assets)					
Loans	26,742	0.65	0.13	0.00	0.96
RE Loans	24,633	0.46	0.16	0.00	0.91
C&I Loan	23,685	0.11	0.07	0.00	0.58
Loan Commitments	26,742	0.14	0.17	0.00	21.10
Securities	26,713	0.22	0.12	0.00	0.94
Cash	26,732	0.02	0.04	0.00	0.41
FF+Repo	18,047	0.01	0.03	0.00	0.45

Note: Table 1 reports the summary statistics for our sample. Observations are at the bank by quarter level over the period 1994-2015. Deposit interest expense and deposit interest expense net of fees are both annualized (multiplied by 4). The following variables are winsorized at the 1% level: Deposit Int. Expense, Deposit Int. Expense (Net of Fees), Non Int. Expense, No. Branches, No Employees, Assets, Interest Income Deposits, Leverage, Beta, Std. Dev. ROA.

Table 2: Deposit Demand

	(1)	(2)
Deposit Rate	12.61***	20.88***
	(1.848)	(4.620)
No. Branches (hundreds)	0.0405***	0.0441***
	(0.0093)	(0.0096)
No. Empl (thousands)	0.0271***	0.0278***
	(0.0082)	(0.0084)
Non-Int. Exp. (billions)	-0.0886	-0.120
	(0.101)	(0.104)
Time Fixed Effects	X	X
Bank Fixed Effects	X	X
IV-1		X
IV-2		X
Observations	26,742	26,742
R-squared	0.981	0.981

Note: We report our demand estimates (Eq. 6). In Table 2, we define the market for deposits at the aggregate US by quarter level. The unit of observation is at the bank by quarter level over the period 1994 through 2015. The key independent variable of interest is the deposit rate offered for each bank. We measure the deposit rate as the bank's quarterly deposit interest expense net of fees (scaled by 4) divided by the bank's level of deposits. Because of the potential endogeneity of the deposit rate, we instrument for the deposit rate using two sets of instruments. We construct our first instrument (IV-1) as the estimated deposit rate from a bank specific pass-through regression of deposit rates on 3-month LIBOR. We construct our second instrument (IV-2) as the average of the product characteristics offered by a bank's competitors in the previous quarter (branches, employees, non-interest expense, and fees). Specifically, we calculate the average product characteristics of a bank's competitors in each county the bank operates in in a given year, and we then calculate the average across all counties the bank operates in. We winsorize all independent variables at the 1% to help control for outliers in the sample. Standard errors are clustered by bank and are reported in parentheses. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 3: Bank Production Function (Asset Income)

	(1)	(2)	(3)	(4)
$\ln A_{kt}$ (θ)	0.848***	0.847***	0.894***	0.888***
	(0.0132)	(0.0143)	(0.0361)	(0.0379)
Beta		-0.0081		-0.0094
		(0.0059)		(0.0061)
Beta (fwd 2 yr)		0.0164***		0.0150***
		(0.0050)		(0.0051)
SD ROA		-0.0258***		-0.0266***
		(0.0034)		(0.0034)
SD ROA (fwd 2 yr)		0.0021		0.0008
		(0.0030)		(0.0032)
Bank F.E.	X	X	X	X
Time F.E.	X	X	X	X
IV			X	X
Observations	26,742	21,289	26,742	21,289
R-squared	0.992	0.992	0.992	0.992

Note: We report our asset income production function estimates (Eq. 9) in Table 3. The unit of observation is at the bank by quarter level over the period 1994 through 2015. The dependent variable is the logged value of interest income earned by the bank. The key independent variable of interest is the log value of a bank's assets lagged by one year. Because of the potential endogeneity of assets, we instrument for assets in columns (3) and (4). Specifically, we instrument for assets using the weighted average of the deposit product characteristics of a bank 's competitors as described in Section 3.3. We also control for the bank's equity beta, standard deviation of return on assets (standardized), and leverage. We measure equity beta on a rolling basis using monthly equity returns over the previous 24 months using data from CRSP and Kenneth French. We measure the standard deviation of return on assets on a rolling basis using quarterly income statement/balance sheet data over the previous eight quarters. Standard errors are clustered at the bank level and are reported in parentheses. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 4: Market to Book vs. Bank Productivity

	(1)	(2)	(3)	(4)	(5)	(6)
Deposit Productivity	0.236***	0.496***			0.207***	0.452***
	(0.0235)	(0.0792)			(0.0287)	(0.0810)
Asset Productivity			0.225***	0.144***	0.0878*	0.100***
			(0.0523)	(0.0373)	(0.0529)	(0.0377)
Time F.E.	X	X	X	X	X	X
Other Controls		X		X		X
Observations	26,742	26,742	26,742	26,742	26,742	26,742
R-squared	0.420	0.453	0.378	0.436	0.424	0.458

Note: Table 4 displays the estimation results corresponding to a linear regression model (Eq.10). The dependent variable is the bank's market-to-book ratio. The key independent variables of interest are deposit and asset productivity. Both deposit and asset productivity are standardized. The deposit productivity estimates correspond to specification reported in column (4) of Table 2. The asset productivity estimates correspond to specification reported in column (4) of Table 3. The unit of observation is at the bank by quarter level over the period 1994 through 2015. Other controls include assets (lagged by one year), leverage (lagged by one quarter), three-month returns (lagged by one quarter), equity beta, and the standard deviation of return on assets. Standard errors are clustered at the bank level and are reported in parentheses. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 5: Deposit and Asset Productivity Subcategories

Dep. Var	Deposit Productivity		Asset Productivity		Market to Book	
	(1)	(2)	(3)	(4)	(5)	(6)
Deposit Prod.:						
Savings	0.734***	0.628***			0.252***	0.368***
	(0.0279)	(0.0422)			(0.0360)	(0.0535)
Small Time	0.125***	0.0945***			-0.228***	-0.180***
	(0.0286)	(0.0264)			(0.0279)	(0.0314)
Large Time	0.179***	0.156***			0.0379	0.0724***
	(0.0196)	(0.0151)			(0.0331)	(0.0272)
Transaction	0.414***	0.371***			0.0594*	0.104***
	(0.0219)	(0.0323)			(0.0326)	(0.0331)
Asset Prod.:						
Loans			0.166**	0.161**	0.0675**	0.0749**
			(0.0674)	(0.0788)	(0.0325)	(0.0334)
Securities			0.0154	0.0159	0.0294	0.0697***
			(0.0147)	(0.0235)	(0.0244)	(0.0244)
Time F.E.	X	X	X	X	X	X
Other Controls		X		X		X
Observations	22,345	22,345	18,323	18,323	16,724	16,724
R-squared	0.979	0.981	0.668	0.681	0.460	0.492

Note: Table 5 displays the relationship between our more refined measures of productivity, overall productivity, and market-to-book. Overall deposit productivity is the dependent variable columns (1) and (2). We measure overall deposit productivity using the demand estimates reported in column (4) of Table 2. Overall asset productivity is the dependent variable columns (3) and (4). We measure overall asset productivity using the production function estimates reported in column (4) of Table 3. Market-to-book is the dependent variable in columns (5) and (6). We measure deposit productivity for savings deposits, small time deposits, large deposits, and transaction deposits using the corresponding demand estimates reported in Table A1a. We measure asset productivity for loans and savings deposits using the corresponding production function estimates reported in Table A1b. Observations are at the bank by quarter level over the period 1994-2015. Other controls include assets (lagged by one year), leverage (lagged by one quarter), 3-month returns (lagged by one quarter), equity beta, and sd of roa. Standard errors are clustered at the bank level and are reported in parentheses. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 6: Productivity vs. Composition of Assets and Liabilities

(a) Composition of Liabilities and Deposit Productivity

Dep. Var	Leverage	Deposits / Liabilities	Small Time / Liabilities	Large Time / Liabilities	Savings / Liabilities	Trans. / Liabilities	FF+Repo / Liabilities
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Deposit Prod.	0.0225*	1.773***	-0.347***	0.137	1.354***	0.432***	-0.320
	(0.0127)	(0.134)	(0.126)	(0.0834)	(0.160)	(0.106)	(0.239)
Time F.E.	X	X	X	X	X	X	X
Other Controls	X	X	X	X	X	X	X
Observations	26,742	26,742	26,736	26,736	24,633	24,627	18,051
R-squared	0.969	0.558	0.376	0.160	0.383	0.232	0.142

(b) Composition of Assets and Asset Productivity

Dep. Var	RE Loans / Assets	C&I Loan / Assets	Loan Commit. / Assets	Securities / Assets	Cash / Assets	FF+Repo / Assets
	(1)	(2)	(3)	(4)	(5)	(6)
Asset Prod.	0.348***	0.157***	0.0938***	-0.462***	-0.338***	-0.295***
	(0.0479)	(0.0454)	(0.0234)	(0.0483)	(0.118)	(0.113)
Time F.E.	X	X	X	X	X	X
Other Controls	X	X	X	X	X	X
Observations	24,633	23,685	26,742	26,713	26,732	18,047
R-squared	0.353	0.057	0.134	0.147	0.235	0.116

Note: Table 6 panels (a) and (b) display the relationship between productivity and a bank's liability and asset structure. In Table 6a, we regress bank leverage and the composition of its deposits on deposit productivity. We measure deposit productivity using the demand estimates reported in column (4) of Table 2. In Table 6b, we regress the composition of a bank's assets on asset productivity. We measure asset productivity using the estimates reported in column (4) of Table 3. Observations in both Tables 6a and 6b are at the bank by quarter level over the period 1994-2015. Other controls include assets (lagged by one year), leverage (lagged by one quarter), three-month returns (lagged by one quarter), equity beta, and the standard deviation of return on assets. Standard errors are clustered at the bank level and are reported in parentheses. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 7: Deposit and Asset Synergies

(a) Deposit vs. Asset Productivity

Dep. Var	Asset Productivity		Loan Productivity		Sec. Productivity	
	(1)	(2)	(3)	(4)	(5)	(6)
Deposit Productivity	0.328***	0.441***	0.504***	0.340***	0.692***	0.0985
	(0.0304)	(0.0937)	(0.0543)	(0.110)	(0.0242)	(0.0966)
Time F.E.	X	X	X	X	X	X
Other Controls		X		X		X
Observations	26,742	26,742	18,360	18,360	19,467	19,467
R-squared	0.630	0.644	0.409	0.420	0.612	0.647

(b) Deposit vs. Asset Productivity - Subcategory Measures

Dep. Var	Asset Productivity		Loan Productivity		Sec. Productivity	
	(1)	(2)	(3)	(4)	(5)	(6)
Deposit Prod.:						
Savings	0.136***	0.275***	0.215***	0.215***	0.448***	0.0667
	(0.0362)	(0.0429)	(0.0355)	(0.0676)	(0.0515)	(0.0506)
Small Time	0.164***	0.194***	0.292***	0.296***	0.122**	0.00589
	(0.0304)	(0.0270)	(0.0543)	(0.0645)	(0.0482)	(0.0255)
Large Time	0.121***	0.124***	0.100***	0.109***	0.0890**	0.0193
	(0.0403)	(0.0268)	(0.0373)	(0.0339)	(0.0347)	(0.0226)
Transaction	-0.0188	0.0414	-0.0164	-0.0172	0.0798	-0.0510
	(0.0390)	(0.0406)	(0.0454)	(0.0408)	(0.0614)	(0.0381)
Time F.E.	X	X	X	X	X	X
Other Controls		X		X		X
Observations	22,345	22,345	16,753	16,753	17,269	17,269
R-squared	0.646	0.666	0.602	0.607	0.607	0.650

Note: Tables 7a and 7b display the relationship between deposit productivity and asset productivity (eq. 11). Each column corresponds to a separate linear regression. The dependent variable in columns (1)-(2) is overall productivity as measured using the production function estimates reported in column (4) of Table 3. The dependent variable in columns (3)-(4) is loan productivity as measured using the production function estimates reported in column (1) of Table A1b. The dependent variable in columns (5)-(6) is securities productivity as measured using the production function estimates reported in column (2) of Table A1b. The key independent variable of interest is deposit productivity. We measure overall deposit productivity using the demand estimates reported in column (4) of Table 2 and deposit productivity for each type of deposit using the demand estimates reported in Table A1a. Observations are at the bank by quarter level over the period 1994-2015. Other controls include assets (lagged by one year), leverage (lagged by one quarter), three-month returns (lagged by one quarter), equity beta, and the standard deviation of return on assets. Standard errors are clustered at the bank level and are reported in parentheses. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 8: Productivity vs. Composition of Assets and Liabilities

(a) Composition of Assets and Deposit Productivity

Dep. Var	RE Loans / Assets (1)	C&I Loan / Assets (2)	Loan Commit. / Assets (3)	Securities / Assets (4)	Cash / Assets (5)	FF+Repo / Assets (6)
Deposit Prod.	0.165	0.705***	0.255***	-0.0280	-0.131	-0.665*
	(0.129)	(0.117)	(0.0769)	(0.192)	(0.127)	(0.348)
Time F.E.	X	X	X	X	X	X
Other Controls	X	X	X	X	X	X
Observations	24,633	23,685	26,742	26,713	26,732	18,047
R-squared	0.314	0.090	0.136	0.068	0.193	0.123

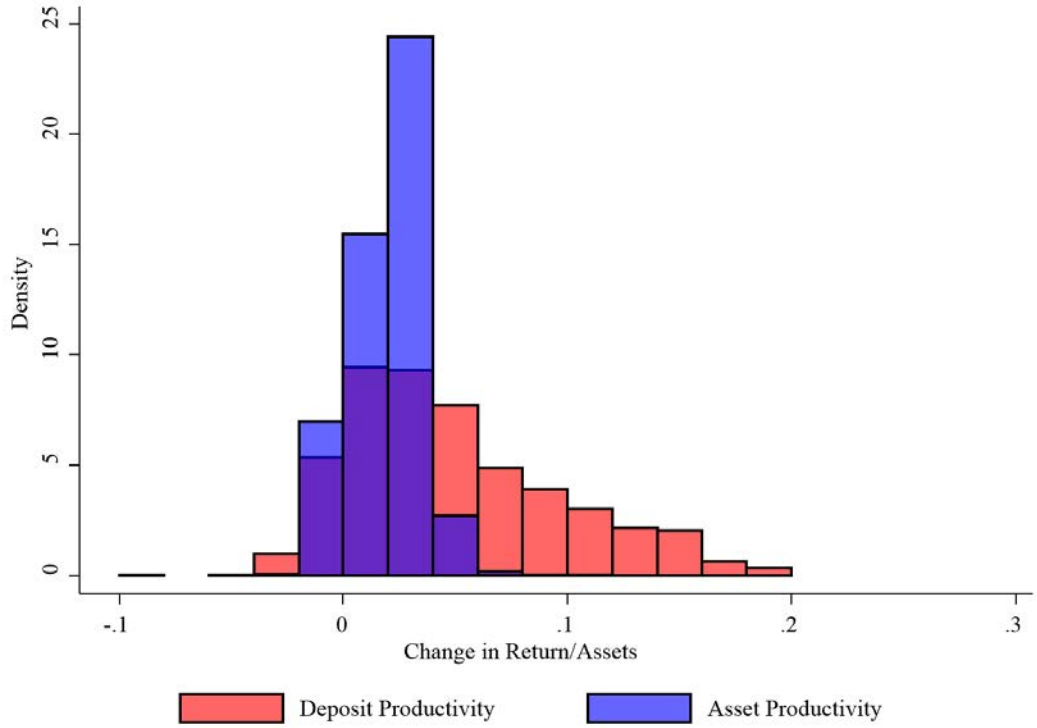
(b) Composition of Liabilities and Asset Productivity

Dep. Var	Leverage (1)	Deposits / Liabilities (2)	Small Time / Liabilities (3)	Large Time / Liabilities (4)	Savings / Liabilities (5)	Trans. / Liabilities (6)	FF+Repo / Liabilities (7)
Asset Prod.	0.00278	0.162***	0.100***	0.284***	0.0409	-0.202**	-0.115**
	(0.00484)	(0.0571)	(0.0358)	(0.0390)	(0.0597)	(0.0837)	(0.0521)
Time F.E.	X	X	X	X	X	X	X
Other Controls	X	X	X	X	X	X	X
Observations	26,742	26,742	26,736	26,736	24,633	24,627	18,051
R-squared	0.969	0.328	0.370	0.189	0.233	0.231	0.138

Note: Table 8 (a) and (b) display the relationship between productivity and a bank's liability and asset structure. In Table 8a, we regress the composition of a bank's assets on deposit productivity. We measure deposit productivity using the demand estimates reported in column (4) of Table 2. In Table 8a, we regress bank leverage and the composition of its deposits on asset productivity. We measure asset productivity using the estimates reported in column (4) of Table 3. Observations in both Tables 8a and 8b are at the bank by quarter level over the period 1994-2015. Other controls include assets (lagged by one year), leverage (lagged by one quarter), three-month returns (lagged by one quarter), equity beta, and the standard deviation of return on assets. Standard errors are clustered at the bank level and are reported in parentheses. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Appendix Figures and Tables

Figure A1: Value Creation: Asset Productivity vs. Deposit Productivity



Note: Fig. A1 displays the distributions of our empirical Bayes estimates of asset and deposit productivity as discussed in Section 5.3.2. Specifically, we "shrink" the estimated distribution of asset and deposit productivity to account for measurement error. The red shaded histogram plots the distribution of our empirical Bayes estimates of bank deposit productivity weighted by $\frac{\overline{Deposits}}{Assets}\frac{1}{\alpha}$. The blue histogram displays the distribution of our empirical Bayes estimates of asset productivity $\frac{\overline{Assets}^{\theta}}{Assets}exp(\phi_{jt}+\overline{\Gamma X_{jt}})$. We normalize the level of asset productivity relative to 3-month LIBOR such that the small set of banks earning returns below 3-month LIBOR have negative asset productivity. Similarly, we also normalize the deposit total factor productivity distribution relative to 3-month LIBOR. We find that 16% of banks offer net deposit rates (net of fees) that are greater than 3-month LIBOR. We normalize the deposit productivity distribution under the assumption that bottom 16% of banks in terms of deposit productivity in each quarter do not generate any value on the deposit side of the bank. The deposit productivity estimates correspond to specification reported in column (4) of Table 2. The asset productivity estimates correspond to specification reported in column (4) of Table 3.

Table A1: Refined Demand and Production Function Estimates

(a) Demand for Deposits by Type of Deposit

	Deposit Type			
	Savings	Small Time	Large Time	Transaction
	(1)	(2)	(3)	(4)
Deposit Rate	-9.594	63.17***	75.39***	-1.188
	(12.73)	(23.21)	(18.25)	(12.51)
No. Branches (hundreds)	0.0825***	0.113***	0.0265	0.0142
	(0.0211)	(0.0412)	(0.0263)	(0.0143)
No. Empl (thousands)	0.00932	0.0241	0.0479***	0.0377***
	(0.0102)	(0.0185)	(0.0135)	(0.0104)
Non-Int. Exp. (billions)	-0.192	-0.920***	-0.656***	0.0724
	(0.154)	(0.347)	(0.247)	(0.0881)
Time Fixed Effects	X	X	X	X
Bank Fixed Effects	X	X	X	X
IV	X	X	X	X
Observations	24,609	24,500	24,556	22,345
R-squared	0.970	0.868	0.809	0.941

(b) Bank Production Function by Asset Type

	Asset Type	
	Loans	Securities
	(1)	(2)
$\ln(\text{Loans}_{kt})$ (θ_L)	0.853***	
	(0.0193)	
$\ln(\text{Securities}_{kt})$ (θ_S)		0.754***
		(0.0214)
Beta	-0.0101	-0.00335
	(0.00618)	(0.0104)
SD ROA	-0.0303***	-0.0226***
	(0.00375)	(0.00703)
Bank F.E.	X	X
Time F.E.	X	X
Observations	18,360	19,467
R-squared	0.989	0.978

Note: Table A1a reports our baseline demand estimates for each type of deposit. The key independent variable of interest is the deposit rate offered for each bank. Because of the potential endogeneity of the deposit rate, we instrument for the deposit rate using two sets of instruments. We construct our first instrument (IV-1) as the estimated deposit rate from a bank specific pass-through regression of deposit rates on 3-month LIBOR. We construct our second instrument (IV-2) as the average of the product characteristics offered by a bank's competitors in the previous quarter (branches, employees, non-int expense, and fees). Specifically, we calculate the average product characteristics of a bank's competitors in each county the bank operates in in a given year ,and then we calculate the average across all counties the bank operates in. We winsorize all independent variables at the 1% to help control for outliers in the sample. Standard errors are clustered by bank and are reported in parentheses. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table A1b reports our asset production function estimates for loans and securities. The unit of observation is at the bank by quarter level over the period 1994 through 2015. The dependent variable in column (1) (column 2) is the logged value of loan (securities) interest income earned by the bank. The key independent variable of interest in column (1) (column 2) is the log value of the bank loans (securities) lagged by one year. We also control for the bank's equity beta, standard deviation of return on assets (standardized), and leverage. We measure equity beta on a rolling basis using monthly equity returns over the previous 24 months using data provided by CRSP and Kenneth French. We measure the standard deviation of return on assets on a rolling basis using quarterly income statement/balance sheet data over the previous eight quarters. Standard errors are clustered at the bank level and are reported in parentheses. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table A2: Geographic Characteristics

(a) Productivity and Geographic Characteristics

Dep. Var.	Asset Productivity		Deposit Productivity	
	(1)	(2)	(3)	(4)
ln(Population)	0.235***		0.611***	
	(0.0342)		(0.0571)	
ln(Population)^2	-0.0467***		-0.126***	
	(0.0159)		(0.0252)	
ln(Wage)	-0.203***		-0.179**	
	(0.0494)		(0.0790)	
ln(Wage)^2	-0.0452**		0.0257	
	(0.0216)		(0.0250)	
ln(Branch Age)	-0.00839		0.413***	
	(0.0267)		(0.0403)	
ln(House Prices)	0.119***		0.107*	
	(0.0432)		(0.0644)	
HMDA HHI	0.103***			
	(0.0289)			
Deposit HHI			0.189***	
			(0.0352)	
Time F.E.	X	X	X	X
MSA F.E.		X		X
Observations	26,742	26,742	26,742	26,742
R-squared	0.557	0.695	0.331	0.716

(b) Robustness to Controlling for Geography

Dep. Var.	Market-to-Book		Asset Productivity	
	(1)	(2)	(3)	(4)
Deposit Productivity	0.317***	0.424***	0.337***	0.714***
	(0.0323)	(0.0695)	(0.0507)	(0.177)
Asset Productivity	0.152***	0.158***		
	(0.0417)	(0.0298)		
Time F.E.	X	X	X	X
MSA F.E.	X	X	X	X
Other Controls		X		X
Observations	26,742	26,742	26,742	26,742
R-squared	0.581	0.602	0.727	0.742

Note: In Table A2a we show how deposit and asset productivity correlate with the geographic characteristics of areas where banks operate. In Table and A2b, we replicate our baseline set of results controlling for fixed effects for each MSA a bank operates in. We measure deposit and asset productivity using the estimates reported in columns (4) of Table 2 and 3. Observations are at the bank by quarter level over the period 1994-2015. Other controls include assets (lagged by one year), leverage (lagged by one quarter), three-month returns (lagged by one quarter), equity beta, and the standard deviation of return on assets. Standard errors are clustered at the bank level and are reported in parentheses. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table A3: Alternative Asset Production Fuction Estimates

(a) Alternative Production Function Estimates - Spline

Dep. Var.	Market-to-Book		Asset Productivity	
	(1)	(2)	(3)	(4)
Deposit Productivity	0.242***	0.343***	0.553***	0.451***
	(0.0363)	(0.105)	(0.0369)	(0.131)
Asset Productivity	0.0281	0.118**		
	(0.0516)	(0.0459)		
Time F.E.	X	X	X	X
Other Controls		X		X
Observations	21,362	21,362	21,362	21,362
R-squared	0.413	0.454	0.655	0.705

(b) Alternative Production Function Estimates - Asset Composition

Dep. Var.	Market-to-Book		Asset Productivity	
	(1)	(2)	(3)	(4)
Deposit Productivity	0.222***	0.500***	0.374***	0.351***
	(0.0373)	(0.0955)	(0.0336)	(0.0846)
Asset Productivity	0.0939	0.107**		
	(0.0627)	(0.0440)		
Time F.E.	X	X	X	X
Other Controls		X		X
Observations	18,564	18,564	18,564	18,564
R-squared	0.429	0.463	0.654	0.666

Note: In Tables A3a and A3b, we replicate our baseline set of results using our alternative measures of asset productivity. To construct the measure of asset productivity reported In Table A3a, we estimate the bank's asset income production function using a spline with five knot points as discussed in Section 5.2.1. To construct the measure of asset productivity reported In Table A3b, we estimate the bank's asset income production function where we control for the Fama French risk factors and the proportion of a bank's assets held in both loans and securities (both lagged by one year). We measure deposit productivity using the demand estimates reported in column (4) of Table 2. Observations in both Tables A3a and A3b are at the bank by quarter level over the period 1994-2015. Other controls include assets (lagged by one year), leverage (lagged by one quarter), three-month returns (lagged by one quarter), equity beta, and the standard deviation of return on assets. Standard errors are clustered at the bank level and are reported in parentheses. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table A4: Alternative Demand Estimates

(a) County Level Demand Estimates

	(1)	(2)
Deposit Rate	20.33	18.19**
	(13.59)	(8.213)
No. of Branches (County Level)		0.184***
		(0.00398)
County×Year Fixed Effects	X	X
Bank Fixed Effects	X	X
IV	X	X
Observations	260,881	260,881
R-squared	0.659	0.779

(b) Alternative Demand Estimates - County Level Demand

Dep. Var.	Market-to-Book		Asset Productivity	
	(1)	(2)	(3)	(4)
Deposit Productivity	0.112***	0.162**	0.317***	0.471***
	(0.0345)	(0.0812)	(0.0241)	(0.101)
Asset Productivity	0.108**	0.106**		
	(0.0502)	(0.0501)		
Time F.E.	X	X	X	X
Other Controls		X		X
Observations	3,050	3,050	3,050	3,050
R-squared	0.431	0.482	0.511	0.525

Note: We report our demand estimates (Eq. 6). In Table A4a we define the market for deposits at the county by year level. The unit of observation is at the bank by county by year level over the period 2002 through 2012. We instrument for the deposit rate using the estimated deposit rate from a bank by county specific pass-through regression of deposit rates on 3-month LIBOR. We winsorize all independent variables at the 1% to help control for outliers in the sample. Standard errors are clustered at the bank level and are reported in parentheses. In Table A4b, we replicate our baseline set of results using our alternative measure of deposit productivity. We measure deposit productivity using the demand estimates reported in column (2) of Table A4a. The asset productivity estimates correspond to specification reported in column (4) of Table 3. Observations are at the bank by year level over the period 1994-2015. Other controls include assets (lagged by one year), leverage (lagged by one quarter), three-month returns (lagged by one quarter), equity beta, and the standard deviation of return on assets. Standard errors are clustered at the bank level and are reported in parentheses. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table A5: Measurement Error - Instrumental Variables

Dep. Var.	Market-to-Book		Asset Productivity	
	(1)	(2)	(3)	(4)
Deposit Productivity	0.205***	0.513***	0.353***	0.567***
	(0.0301)	(0.106)	(0.0270)	(0.108)
Asset Productivity	0.0128	0.0596		
	(0.0427)	(0.0435)		
Time F.E.	X	X	X	X
Other Controls		X		X
IV	X	X	X	X
Observations	16,724	16,724	22,345	22,345
R-squared	0.428	0.469	0.624	0.640

Note: In Table A5, we replicate our baseline set of results using instrumental variables to address potential measurement error issues. Specifically, we instrument for deposit productivity using the subcategory deposit productivity measures that we construct from the estimates reported in Table A1a. Similarly, we instrument for asset productivity using the subcategory asset productivity that we construct from the estimates reported in Table A1b. We measure deposit and asset productivity using the estimates reported in columns (4) of Table 2 and 3. Observations are at the bank by quarter level over the period 1994-2015. Other controls include assets (lagged by one year), leverage (lagged by one quarter), three-month returns (lagged by one quarter), equity beta, and the standard deviation of return on assets. Standard errors are clustered at the bank level and are reported in parentheses. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table A6: Subsample Analysis

(a) Subsample Analysis - Excluding the Largest Banks

Dep. Var.	Market-to-Book		Asset Productivity	
	(1)	(2)	(3)	(4)
Deposit Productivity	0.224***	0.465***	0.341***	0.983***
	(0.0299)	(0.124)	(0.0210)	(0.113)
Asset Productivity	0.0957	0.104***		
	(0.0641)	(0.0360)		
Time F.E.	X	X	X	X
Other Controls		X		X
IV	X	X	X	X
Observations	24,881	24,881	24,881	24,881
R-squared	0.426	0.459	0.650	0.686

(b) Subsample Analysis - Excluding the Financial Crisis

Dep. Var.	Market-to-Book		Asset Productivity	
	(1)	(2)	(3)	(4)
Deposit Productivity	0.213***	0.464***	0.329***	0.453***
	(0.0287)	(0.0795)	(0.0302)	(0.0991)
Asset Productivity	0.107**	0.113***		
	(0.0517)	(0.0385)		
Time F.E.	X	X	X	X
Other Controls		X		X
Observations	24,211	24,211	24,211	24,211
R-squared	0.402	0.432	0.642	0.654

Note: In Tables A6a and A6b, we replicate our baseline set of results using different subsets of the data. In Table A6a, we replicate our baseline set of results where we exclude the largest banks from our sample. Specifically, we drop all observations of those banks that appear among the top 5% of the sample in terms of assets at any point in time. In Table A6a, we replicate our baseline set of results where we exclude all observations from the years surrounding the financial crisis (years 2008 and 2009). We measure deposit and asset productivity using the estimates reported in columns (4) of Table 2 and 3. Observations are at the bank by quarter level over the period 1994-2015. Other controls include assets (lagged by one year), leverage (lagged by one quarter), three-month returns (lagged by one quarter), equity beta, and the standard deviation of return on assets. Standard errors are clustered at the bank level and are reported in parentheses. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table A7: Alternative Deposit Demand Estimates - Extended Data Set

	(1)	(2)	(3)	(4)
Deposit Rate	13.66***	8.943**	48.25***	19.67***
	(1.721)	(4.363)	(9.091)	(4.664)
No. Branches (hundreds)	0.0330***	0.0328***	0.0338***	0.0320***
	(0.00955)	(0.00949)	(0.0100)	(0.00925)
No. Empl (thousands)	0.0366***	0.0345***	0.0527***	0.0403***
	(0.0109)	(0.0111)	(0.0117)	(0.0106)
Non-Int. Exp. (billions)	-0.163	-0.148	-0.254**	-0.165
	(0.117)	(0.117)	(0.127)	(0.115)
Time Fixed Effects	X	X	X	X
Bank Fixed Effects	X	X	X	X
IV-1		X		X
IV-2			X	X
Observations	33,145	33,145	32,083	32,083
R-squared	0.976	0.976	0.971	0.977

Note: We report our demand estimates (Eq. 6) in Table A7. Here we re-estimate demand using our extended data set of over 32,000 bank by quarter observations. In our baseline demand estimates (Table **??**), we restrict our data set to the 26,742 bank/quarter observations for which data is available to estimate both deposit demand and the asset production function. The unit of observation is then at the bank by quarter level over the period 1994 through 2015. We define the market for deposits at the aggreate US by quarter level. The key independent variable of interest is the deposit rate offered for each bank. We measure the deposit rate as the bank's quarterly deposit interest expense net of fees (scaled by 4) divided by the bank's level of deposits. Because of the potential endogeneity of the deposit rate, we instrument for the deposit rate using two sets of instruments. We construct our first instrument (IV-1) as the estimated deposit rate from a bank specific pass-through regression of deposit rates on 3-month LIBOR. We construct our second instrument (IV-2) as the average of the product characteristics offered by a bank's competitors in the previous quarter (branches, employees, non-int expense, and fees). Specifically, we calculate the average product characteristics of a bank's competitors in each county the bank operates in in a given year, and we then calculate the average across all counties the bank operates in. We winsorize all independent variables at the 1% to help control for outliers in the sample. Standard errors are clustered by bank and are reported in parentheses. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table A8: Alternative Production Function Estimates

	(1)	(2)
$\ln A_{kt}$ (θ)	0.879***	0.891***
	(0.0369)	(0.0547)
θ_1	-0.00276	
	(0.0447)	
θ_2	-0.00527	
	(0.0326)	
θ_3	0.0190	
	(0.0282)	
θ_4	-0.108***	
	(0.0297)	
Beta	-0.00656	
	(0.00500)	
Beta (fwd 2 yr)		0.0128**
		(0.00499)
SD ROA	-0.0290***	
	(0.00299)	
SD ROA (fwd 2 yr)		0.00132
		(0.00339)
SMB (fwd 2 yr)		0.00407
		(0.00269)
HML (fwd 2 yr)		-0.000365
		(0.00259)
Bank F.E.	X	X
Time F.E.	X	X
IV		X
Observations	26,742	18,564
R-squared	0.992	0.993

Note: Table A8 displays our alternative production function estimates. The unit of observation is at the bank by quarter level over the period 1994 through 2015. The dependent variable is the logged value of interest income earned by the bank. The key independent variable of interest is the log value of a bank's assets lagged by one year. In column (1) we estimate a bank's asset production function using a spline with five knot points (eq. 12) as described in Section 5.2.1. In column (2) we estimate a bank's asset production function using our basline log-linear specification and instrument for assets using the weighted average of the deposit product characteristics of a bank 's competitors as described in Section 3.3. In both specifications, we control for the bank's equity beta, standard deviation of return on assets (standardized), and leverage. In column (2), we also control for the other Fama French Factors, HML and SMB. We measure equity beta, HML, and SMB on a rolling basis using monthly equity returns over the previous 24 months using data provided by CRSP and Kenneth French. We measure the standard deviation of return on assets on a rolling basis using quarterly income statement/balance sheet data over the previous eight quarters. Standard errors are clustered at the bank level and are reported in parentheses. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.