The Cross Section of Bank Value*

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Abstract

We study the determinants of value creation within U.S. commercial banks. We begin by constructing two new measures of bank productivity: one focused on deposit-taking productivity and one focused on asset productivity. We then use these measures to evaluate the cross-section of bank value. Both productivity measures are strongly value-relevant, with variation in banks' deposit productivity responsible for the majority of variation in bank value. We also find evidence consistent with synergies between deposit-taking and lending activities: banks with high deposit productivity have high asset productivity, a relationship driven by the tendency of deposit-productive banks to hold illiquid loans. Our results suggest that both sides of the balance sheet contribute meaningfully to bank value creation, with the liability side playing a primary role.

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1 Introduction

How do commercial banks create value? Forty years of theoretical work has identified three potential answers to this question. First, banks can create value by providing safe and liquid liabilities to depositors (e.g., Gorton and Pennacchi, 1990; Dang, Gorton, and Holmstrom, 2015). Second, banks can create value through their ability to screen and monitor loans (e.g., Diamond, 1984). Finally, synergies between deposit-taking and lending may create value by allowing banks to make certain types of loans more easily than other intermediaries (e.g., Diamond and Dybvig 1983; Kashyap, Rajan, and Stein, 2002). To date, the empirical literature has documented evidence consistent with each channel: banks do appear to produce safe assets, to make information-intensive loans involving screening and monitoring, and to make loans that are synergistic with deposit-taking. However, little is known about the value implications of these channels, either individually or collectively.

In this paper, we construct novel measures of productivity for both sides of a bank's balance sheet and use these productivity measures to assess the key determinants of bank value creation. We begin by constructing estimates of banks' productivity at raising deposits. To do so, we estimate a demand system for bank deposits following Dick (2008) and Egan, Hortaçsu, and Matvos (2016). 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). Our demand estimates provide insight into consumer preferences for deposit rates and other banking services. We then use these demand estimates to quantify deposit productivity at the bank-year level. Intuitively, a bank with a high degree of deposit productivity is able to collect more deposits than a less-productive bank, holding fixed input variables such as the offered deposit rate and the number of branches the bank operates.

We next turn to the asset side of banks' balance sheets. Using standard methods, we flexibly estimate a bank's ability to produce interest and fee income as a function of its loan and securities portfolios. 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. Intuitively, a bank with higher asset productivity is able to generate higher levels of risk-adjusted revenue with the same asset base as a less-productive bank. Hence, 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 funds to generate revenue.

We use our productivity estimates to present four main results. First, our measures of productivity are strongly value-relevant in the cross section of banks. High deposit productivity is associated with low interest expense (as a fraction of assets) for banks. Similarly, high asset productivity is associated with high interest income, even after including a battery of controls for bank risk taking. Most importantly, our measures of productivity are strongly related to stock market-based measures of value like market-to-book ratios.

Our second main result is that cross-sectional variation in deposit productivity accounts for the majority of cross-sectional variation in bank value. Using the structure provided by our empirical framework, we are able to decompose bank value into the part attributable to deposit productivity and the part attributable to asset productivity. We find that variation in deposit productivity accounts for about twice as much variation in bank value as variation in asset productivity. We also find similar results in reduced-form empirical tests that do not rely on the structure of our framework. In particular, the relationship between deposit productivity and bank market-to-book ratios is about twice as strong as the relationship between asset productivity and market-to-book. 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. Collectively, these findings suggest that liability-driven theories of bank value creation explain more variation in the cross section of banks than asset-driven theories.

In our third set of results, we explore the drivers of variation in our productivity measures by examining cross-sectional variation in bank balance sheet composition. Consistent with intuition, we find that high deposit productivity is associated with balance sheet liabilities that are tilted towards deposits. A one-standard deviation increase in deposit productivity is associated with a 1.8 standard deviation increase in the fraction of bank liabilities that is made up of deposits. Interestingly, we find strong effects for both transaction and non-transaction deposits (e.g., savings and time deposits), with the strongest effect coming from savings deposits. Thus, while our estimates suggest that liabilities are an important source of bank value, the liabilities that are most strongly associated with deposit productivity are not necessarily those that provide the most transaction and liquidity services. 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 seem to be substituting non-deposit debt for deposits.

We also find that banks with high asset productivity tilt their balance sheet towards holding more illiquid assets. In particular, asset-productive banks hold more loans and fewer securities. A one-standard deviation increase in asset productivity is associated with an increase in the fraction of assets comprised of loans by 0.7 standard deviations (or approximately 9 percentage points). Furthermore, when we look within banks' loan portfolios, we find that more productive banks tend to hold higher levels of real estate and commercial and industrial (C&I) loans, which are arguably more information-intensive than other types of loans. Hence, 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.

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 different types of synergies in a manner distinct from the existing literature.

We find evidence of significant synergies between the asset and liability sides of bank balance sheets. Specifically, asset productivity is strongly correlated with deposit productivity. We use balance sheet composition to explore the sources of these synergies. We find that deposit-productive banks tend to offer more loan commitments and lines of credit, while holding less securities and cash. A one standard deviation in deposit productivity is associated with a 0.6 standard deviation increase in the fraction of bank assets comprised of loan commitments and lines of credit. Consistent with Kashyap, Rajan, and Stein (2002) and the empirical evidence in Gatev and Strahan (2006), this result suggests that deposit-productive banks find it relatively easy to meet unpredictable liquidity needs associated with providing commitments, likely because they tend to attract deposit inflows at the times when lines of credit are drawn down.

In addition, we find that banks with high deposit productivity tend to make more loans, particularly C&I loans. A one-standard deviation increase in deposit productivity is associated with an increase in the fraction of assets made up of C&I loans by 0.7 standard deviations (or approximately 5 percentage points). Since C&I loans are more illiquid than mortgage loans, 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.

Our four main findings are robust to a battery of additional tests and empirical specifications. For example, we find similar results when we re-estimate deposit demand using different definitions of a deposit market and re-estimate our asset income production function using a host of additional controls for risk. We also address potential measurement error issues with our productivity measures by using instrumental variables and constructing empirical Bayes estimates.[1] Finally, we show that our results are not driven by the financial crisis and are not an artifact of extreme outliers in our data.

In summary, this paper represents the first attempt to empirically identify 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 an extremely important role in determining its funding structure, its size, and its ultimate value.

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.[2] Our paper adds to this literature by evaluating the effects of safe-liability creation on bank value. Consistent with this literature, 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).[3] This literature has argued that part of

[1]Recent work in the education and labor literature has used empirical Bayes estimates to measure value added (e.g., Jacob and Lefgren, 2008; Kane and Staiger, 2008; and Chetty, Friedman, and Rockhoff, 2014).

[2]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, 2016; 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.

[3]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 (2013). Empirical literature on the subject 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 argued that banks historically possessed "charter value" due to entry restrictions that allowed incumbents to extract monopoly rents. However, charter values in the U.S. have effectively disappeared as a result of the removal of entry restrictions in the 1980s and 1990s. 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

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 built-in synergies between their deposit-taking and lending activities.[4] Consistent with this literature, we find that deposit-productive banks also tend to be asset-productive. In particular, we document two types of synergies. First, we find a positive correlation between banks' deposit productivity and the quantity of loan commitments and lines of credit on their balance sheets. Second, we find that deposit-productive banks hold a higher quantity of illiquid loans. Hence, our results are broadly consistent with the notion that both sides of the balance sheet contribute significantly to bank value.

Finally, our paper is related to the growing literature at the intersection of industrial organization and finance. Our paper relates to a recent set of papers that build on the industrial organization literature to estimate demand for financial products.[5] On the asset side, we estimate a bank's asset production function and productivity using a first order approximation, similar to the techniques Maksimovic and Phillips (2001) and Schoar (2002) use 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.

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

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.

[4]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 a bank's "liquidity mismatch" – roughly, the difference in liquidity between the asset and liability sides of a bank's balance sheet – to the bank's stock returns. 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.

[5]Our deposit demand estimates relate most closely to Dick (2008) and Egan, Hortaçsu, and Matvos (2016). Similar tools have been employed to estimate demand for other financial products such as 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.

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.[6]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 consumers may inherently prefer Bank of America to Citibank (or vice versa). Thus, the total indirect utility[7] derived by a depositor i from bank j is given by:

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

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.

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

[7] Our utility formulation closely follows that of Egan, Hortaçsu and Matvos (2016) with one notable exception. Previous research such as Egan, Hortaçsu and Matvos (2016) and Rose (2015) find that depositors (particularly uninsured depositors) may be sensitive to the financial stability of a bank. Here we treat consumers' perceptions about the bank's solvency as part of the bank's deposit productivity.

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 $s_j M$.

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. 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. 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 Ms_j and capital K_j.

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]

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

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 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

[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.

[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.

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.

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 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

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

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. Alternatively, it could be viewed as the unobserved time varying component of bank j's deposit service quality at time t. 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 employ an instrumental variables strategy to account for the endogeneity of deposit rates. We have two sets of instruments. First, following 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 in this setting is that bank j's average degree of pass-through in the time series

[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.

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. To help rule out potential endogeneity concerns, we use the competitor product characteristics from the previous quarter and only use product characteristics that are generally thought to be 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 to ξ_{jt}, the bank-quarter specific demand shock for bank j in quarter t.

Table 2 displays the corresponding demand estimates. In Table 2a, we estimate consumer demand 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 2a 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, 2008; Egan, Hortaçsu, and Matvos, 2016).

In Table 2b, we re-estimate the demand system using more granular county-by-year data from RateWatch, which reports deposit rates directly. The data runs from 2002 to 2012. We now include county $\times$ 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 2a. In our main specifications, we use the results from Table 2a because the sample spans a longer time period and a larger sample of banks.[13] However, as discussed further in Section 5.1.3 below, all of our main findings are also robust to using demand productivity estimates derived from

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

[13] Our RateWatch data is available from 2002 to 2012 and includes 447 of the 847 banks in our sample.

Table 2b.

We use the estimated demand systems in Table 2 to calculate each bank's deposit productivity. Specifically, we measure bank j's deposit productivity at time t, δ_{jt}, as

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

In our main results, we calculate bank deposit productivity using this equation based on the estimates in column (4) of Table 2a. 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.[14] 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.[15] 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)-(3), we report the OLS estimates, and in columns (4)-(6), 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.[16] In columns (2) and (4), we measure risk using equity beta and the standard deviation of returns, both measured over the previous two years. In columns (3) and (6), we also include forward looking measures of risk where we calculate equity beta and the standard deviation of returns from time t to time t plus two years. We also find that interest income loads positively on risk as measured by our forward looking measure of equity beta. The results in column (6) indicate that increasing beta by one is associated with a 1.5 percentage point increase in interest income. The estimates in our IV specifications in columns (4)-(6) 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

[14] 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).

[15] 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 A5 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 $\ln A_{kt}$.

[16] 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.

their asset size or that banks are unable to adjust their asset size within a quarter.

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. 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.

We next examine the estimated relationship between interest income (normalized by assets) and bank asset productivity. Fig. 2 shows that there is a positive, significant, and roughly linear relationship between the two. 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 bank. Larger banks will tend to grow more slowly and thus have lower market-to-book ratios.[18] 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. 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 first present reduced-form empirical evidence before turning to measures of value creation derived from the economic framework in Section 2.

We start by examining the relative magnitudes in our market-to-book regressions reported in Table 4. Focusing on columns (5) and (6), where we simultaneously include deposit

[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) on the left-hand side (and if anything, most results are even stronger).

[18] In the context of our model, size is an endogenous function of deposit and asset productivity. Controlling for size therefore changes the interpretation of the regression slightly. Within the context of our model, regressions without size controls reveal the full endogenous relationship between average productivity and value, including the fact that more productivity banks are endogenously larger. Regressions with size controls are analogous to revealing the relationship between marginal productivity and value, controlling for average productivity. In our initial setup displayed in Eq. (3) and (9), average productivity is given by $\phi_{jt}\ln(A_{jt})^{\theta-1}$.

productivity and asset productivity, we see that an increase in deposit productivity has a much larger impact of market-to-book than an increase in asset productivity. 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.

What explains the different impacts of asset and deposit productivity on bank value? Part of the difference is due to differences in the persistence of deposit and asset productivity. To see why persistence might impact our findings, consider the extreme case where innovations in deposit productivity are permanent while innovations in asset productivity are transitory, lasting only one quarter. In that case, we would expect market-to-book to load more heavily on deposit productivity than asset productivity even if both were equally important for bank income. Both deposit and asset productivity are highly persistent in the data, exhibiting quarterly auto-correlations of 0.99 and 0.95. At reasonable discount rates (e.g., 10%), these differences in persistence cannot fully explain the greater impact of deposit productivity on bank value.

Our economic framework points to another reason deposit productivity has a larger impact on bank value. In particular, the structure the framework provides allows us to map the distributions of productivity measures into the distributions of their profit impact. As discussed in Section 2.3, our two productivity measures directly affect the profitability of the bank. 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 costs 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

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

This type of analysis 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. Fig. 3 provides some graphical evidence. The red shaded histogram plots the dispersion of bank deposit productivity (δ_{jt}) weighted by $\frac{\overline{Deposits}}{Assets}\frac{1}{\alpha}$, while the blue histogram displays the dispersion of $\frac{\overline{Assets}^\theta}{Assets} exp(\phi_{jt} + \overline{\Gamma X_{jt}})$. In Fig. 3, we normalize the distributions based on the risk-free return and benchmark bank borrowing rates.[19] Consistent with the evidence

[19]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

presented in our market-to-book regressions (Table 4, columns 5 and 6), Fig. 3 suggests that about twice as much of the variation in bank net income can be explained by heterogeneity on the deposit side relative to heterogeneity on the asset side.

Fig. 4 presents a similar plot that discards the structure of 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 the model. 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 how much of a bank's value comes from deposit productivity relative to asset productivity. We calculate the share of firm value (or specifically net risk-adjusted income) coming from deposits as:

$$\text{Deposit Productivity Share}_{jt} = \frac{\overline{\frac{Deposits}{Assets}}\frac{1}{\alpha}(\tilde{\delta}_{jt})}{\overline{\frac{Deposits}{Assets}}\frac{1}{\alpha}(\tilde{\delta}_{jt}) + \overline{\frac{Assets}{Assets}}^{\theta} exp(\overline{\Gamma X_{jt}})(exp(\tilde{\phi_{jt}}))}, \quad (11)$$

where $\tilde{\delta}_{jt}$ and $\tilde{\phi}_{jt}$ are the normalized[19] levels of deposit and asset productivity. Fig. 5 displays the distribution of the share of bank value coming from the deposit side of the bank. 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 Fig. 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 variation 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.

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 bottom 13% of banks in terms of deposit productivity in each quarter do not generate any value on the deposit side of the bank.

4.3 Bank Productivity and Balance Sheet Composition

To understand what drives variation in our productivity measures, we next examine the correlations between our asset and deposit productivity measures and bank balance sheet compositions. In untabulated results, we have explored the correlations between our productivity measures and the demographic and economic characteristics of the locations where different banks operate. A bank's productivity is correlated with the level and growth rate of population and wages in the areas where the bank operates, as well as the competitiveness of those areas as measured by the Herfindahl-Hirschman index computed over deposit market shares and mortgage origination market shares. However, controlling for these demographic and economic characteristics has virtually no effect on the correlation between our productivity measures and market-to-book. Therefore, we focus on bank-specific, rather than demographic and economic, determinants of value creation.

This analysis is presented in Table 5. As discussed previously, all variables are standardized such that the coefficients correspond to a one-standard deviation increase in our productivity measures. In Table 5a, 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).[20] Interestingly, banks that are particularly good at raising deposits do not appear to lever up much more than other banks. 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.

Columns (2)-(7) show that deposit productivity also has a significant impact on the composition of banks' debt liabilities. In particular, banks with higher deposit productivity tend to have significantly higher quantities of deposits as a fraction of their total liabilities. This makes sense; all else equal, we would expect banks that are good at producing deposits to have more deposits on their balance sheet relative to other liabilities. A one-standard deviation increase in deposit productivity is associated with a 1.8 standard deviation increase in the fraction of bank liabilities that is made up of deposits. The relationship is largely driven by savings deposits and large time deposits. Given that leverage does not change with deposit productivity, Table 5a implies that non-deposit debt falls with deposit productivity.

Table 5b displays the results corresponding to a similar exercise for our asset productivity measure and the asset side of banks' balance sheets. Columns (1)-(4) show that more productive banks tend to have greater relative quantities of loans than less-productive banks.

[20]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.

In particular, 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 (5)-(7) show that productive banks also tend to have lower quantities of securities and liquid assets than less productive banks. This 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.

4.4 Specialized Bank Productivity Measures

Our deposit and asset productivity measures capture broad variations in banks' abilities to generate value from their assets and deposits. But which types of assets and deposits most affect these overall productivity measures? We address this question in Table 6. Specifically, we recompute deposit productivity and asset productivity for subcategories of deposits and assets (Table 7a and 7b). 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 6 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. The overall deposit productivity measure is most strongly correlated with savings deposit productivity and transactions deposit productivity. Although a bank's deposits are largely comprised of savings and transaction deposits, this does not seem to be driving the results. We find that a one standard deviation in savings deposit productivity is associated with a 0.74 standard deviation in total deposit productivity. To put that number in perspective, savings deposits make up 41% of a bank's total deposits on average. Similarly, we find that a one standard deviation in transaction deposit productivity is associated with a 0.41 standard deviation in total deposit productivity, despite transaction deposits making up only 19% of total deposits on average.

Similarly, columns (3) and (4) show that our asset productivity measure is significantly more correlated with banks' loan productivity than their securities productivity. This again 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.

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.[21] Hence, consistent with the results in Table 4, Table 6 shows that bank value is more sensitive to deposit productivity than to asset productivity.

The results in Table 6 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. Why are these two types of deposits most strongly correlated with value? We study this question by examining the demand estimates in Table 7a, which re-estimates our basic deposit demand system from Eq.(6) for each type of deposit. That is, in Table 7a, we treat each deposit type as a separate product and estimate a demand system for each product.

The table shows that demand for savings deposits and transaction deposits is almost completely inelastic. All else equal, deposit productivity is more valuable when demand is inelastic, as demand for deposits is "sticky" in this case. In contrast, demand for time deposits is quite elastic and banks often report losing money on smaller accounts.[22]

These findings are largely consistent with our earlier balance sheet decompositions reported in Table 5. We found that more productive banks held a higher fraction of savings deposits. Similarly, less productive banks held less deposits in general and their deposits were more likely to be comprised of small time deposits.

These value and balance sheet 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 checking and transaction deposits, which provide the most transaction and 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.

[21] 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.

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

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 deposit productivity may be intimately linked to it's asset productivity. Here, we examine the synergies between the two dimensions of a bank.

Table 8 presents regressions relating our asset productivity measures to our deposit productivity measures. Specifically we run regressions of of the form

$$\hat{\phi}_{jt} = \gamma_0 + \gamma_1 \hat{\delta}_{jt} + \Gamma X_{jt} + \mu_t + \varepsilon_{jt}. \tag{12}$$

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 bank (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 8 suggests that there are important synergies between deposit productivity and asset productivity, and that those synergies are more related to loans than securities.

In Table 9, we use variation in bank balance sheet composition to explore the sources of these synergies in more detail. Table 9a relates bank asset composition to deposit productivity. Column (1) shows that high deposit productivity is associated with having more loans overall. Columns (2) and (3) show that this effect is particularly concentrated in C&I loans. Since C&I loans are more illiquid than mortgage loans, 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 (4) 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.

Overall, these results suggest that there are important synergies between deposit taking and certain types of lending. In untabulated results, we find that this relationship is strongest for savings deposit productivity, indicating that this type of funding is particularly synergistic with lending.

In Table 9b, 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 do not find a statistically significant relationship between savings deposits and asset productivity and 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 intimately related, we find that variation in deposit productivity accounts for more than twice of the variation in bank value relative to asset productivity. In this section, we replicate our baseline set of empirical tests, 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 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.

5.1.1 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

$$\ln Y_{jt} = \theta \ln A_{jt} + \sum_{k=1}^{K-1} \left(\theta_k \max(\ln A_{jt} - q_k, 0)\right) + \Gamma X_{jt} + \phi_j + \phi_t + \epsilon_{jt}. \qquad (13)$$

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 A6). In general, the results suggest that our baseline specification captures the curvature of a bank's production function quite well.[23]

We next replicate our main findings using the new production function estimates. These findings are reported in Table A1a. 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.

5.1.2 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 A6). 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 A1b. The alternative set of results are

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

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

5.1.3 Alternative Demand Estimates

We estimate several demand specifications in Section 3.2 where we allow for various market definitions and utilize two different sets of instruments. Although the parameter estimates displayed in Tables 2a and 2b are relatively stable, we examine the robustness of main our findings to the alternative demand specifications. We recompute our measure of deposit productivity to using the estimates from two additional demand specifications. First, we measure deposit productivity using the demand estimates where we estimate demand at the county (rather than the aggregate US) level (Table 2b).[24] Demand for bank deposits and bank competition may occur at a much more localized level which is consistent with these county level demand estimates. Second, we measure deposit productivity using the demand estimates where we estimate demand using the traditional Berry, Levinsohn, and Pakes (1995) instruments. As shown in column (3) of Table 2a, the estimated demand elasticity is higher when we exclusively use the Berry, Levinsohn, and Pakes (1995) instruments relative to to our baseline demand specification (column 4 of Table 2a).

Tables A2a and A2b display our baseline set of tests where we use our alternative measures of deposit productivity. The results in both tables are comparable to each other and 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 Tables A2a and A2b again suggest that deposit productivity has a greater impact on market-to-book relative to asset productivity. Columns (3) and (4) of Tables A2a and A2b indicate that there are strong synergies between asset and deposit productivity.

[24]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 agregate deposit productivity at time t as

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

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

5.2 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.

5.2.1 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 4.4, our instruments are clearly relevant (Table 6 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 A3 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 A3 again indicate there are strong synergies between asset and deposit productivity.

5.2.2 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.[25] As is common in the education and labor literature (e.g., Jacob

[25] 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.

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 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.

5.3 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.

5.3.1 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

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.

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 A4a 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 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.

5.3.2 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 A4b 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? The theoretical literature has described a number of channels through which banks create value on both sides of the balance sheet, yet there is little empirical work assessing the drivers of bank valuation in the cross-section. 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. While we have focused on exploring the cross-section of bank value, exploring time series variation would be an interesting avenue for future work. For instance, it is 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.

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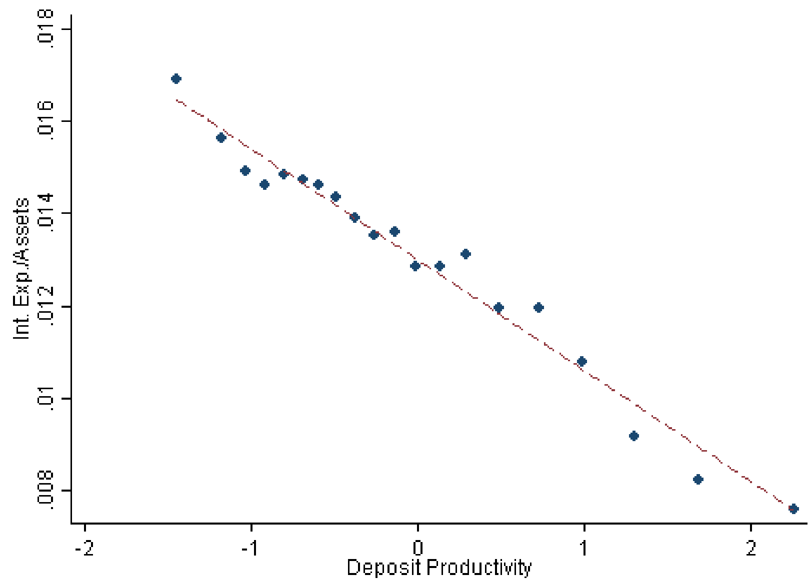
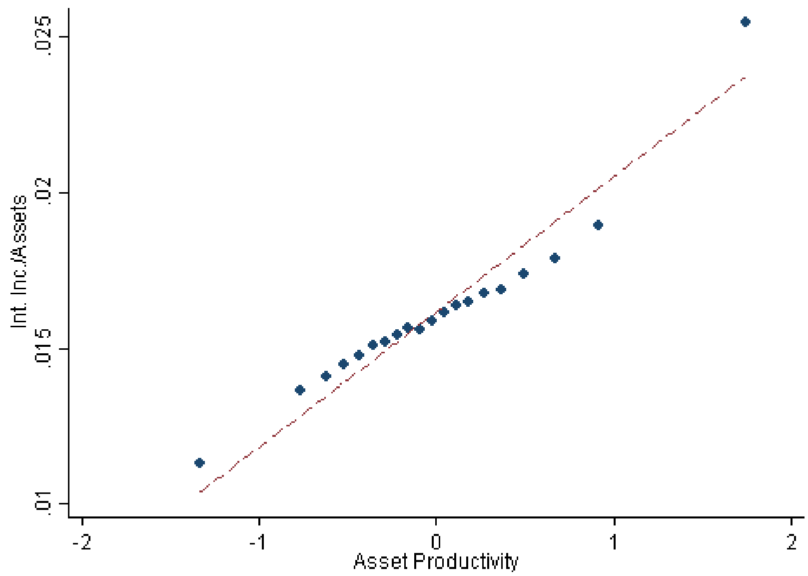
Figures

Figure 1: Deposit Productivity vs. Interest Expense



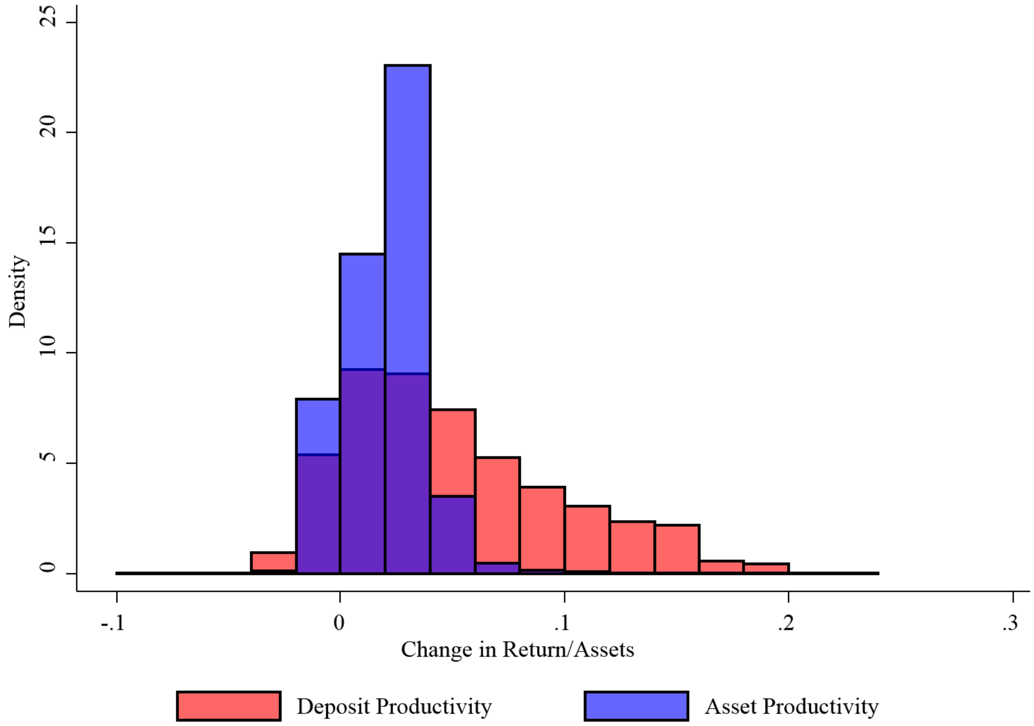
Note: Fig. 1 displays a binscatter plot of a bank's interest expense (normalized by assets) versus a bank's deposit productivity. Deposit productivity is standardized and is constructed from the deposit demand estimates reported in column (4) of Table 2a. Interest expense is annualized (quarterly interest 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



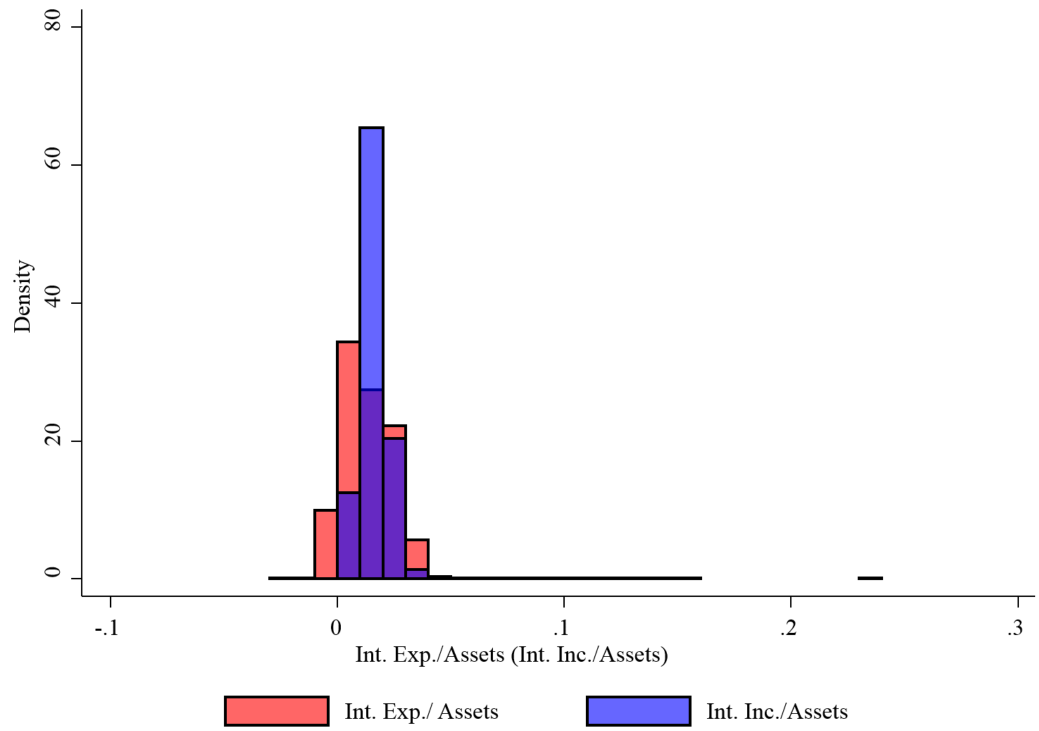
Note: Fig. 2 displays a binscatter plot of a bank's interest income (normalized by assets) versus a bank's asset productivity. Asset productivity is standardized and is constructed from the asset income production function estimates reported in column (4) of Table 3. Interest income is annualized (quarterly 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



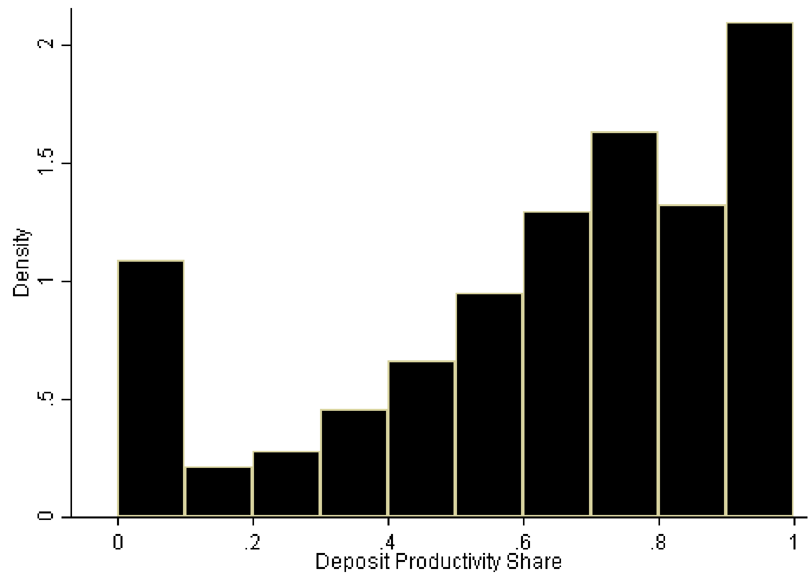
Note: Fig. 3 displays the estimated distributions of asset and deposit productivity. The red shaded histogram plots the distribution of bank deposit productivity weighted by $\overline{\frac{Deposits}{Assets}}\frac{1}{\alpha}$. The blue histogram displays the scaled distribution of asset productivity $\frac{\overline{Assets}^{\theta}}{\overline{Assets}} exp(\phi_{jt} + \overline{\Gamma X_{jt}})$. 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 2a. 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 as defined in Eq. (11). 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 2a 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

(a) Deposit Demand - Aggregate Level Demand

	(1)	(2)	(3)	(4)
Deposit Rate	12.61***	11.53***	44.35***	20.88***
	(1.848)	(4.331)	(8.960)	(4.620)
No. Branches (hundreds)	0.0405***	0.0401***	0.0540***	0.0441***
	(0.00934)	(0.00940)	(0.0110)	(0.00957)
No. Empl (thousands)	0.0271***	0.0270***	0.0297***	0.0278***
	(0.00816)	(0.00818)	(0.00910)	(0.00839)
Non-Int. Exp. (billions)	-0.0886	-0.0845	-0.209*	-0.120
	(0.101)	(0.103)	(0.114)	(0.104)
Time Fixed Effects	X	X	X	X
Bank Fixed Effects	X	X	X	X
IV-1		X		X
IV-2			X	X
Observations	26,742	26,742	26,742	26,742
R-squared	0.981	0.981	0.976	0.981

(b) Deposit Demand - County Level Demand

	(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

Note: We report our demand estimates (Eq. 6) in Tables 2a and 2b. In Table 2a, 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-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.

In Table 2b 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. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 3: Bank Production Function (Asset Income)

	(1)	(2)	(3)	(4)	(5)	(6)
$\ln A_{kt}$ (θ)	0.848***	0.852***	0.847***	0.894***	0.905***	0.888***
	(0.0132)	(0.0133)	(0.0143)	(0.0361)	(0.0354)	(0.0379)
Beta		-0.00172	-0.00813		-0.00352	-0.00939
		(0.00524)	(0.00594)		(0.00526)	(0.00607)
Beta (fwd 2 yr)			0.0164***			0.0150***
			(0.00503)			(0.00514)
SD ROA		-0.0277***	-0.0258***		-0.0288***	-0.0266***
		(0.00301)	(0.00338)		(0.00301)	(0.00337)
SD ROA (fwd 2 yr)			0.00213			0.000776
			(0.00299)			(0.00320)
Bank F.E.	X	X	X	X	X	X
Time F.E.	X	X	X	X	X	X
IV				X	X	X
Observations	26,742	26,742	21,289	26,742	26,742	21,289
R-squared	0.992	0.992	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 (4)-(6). 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. 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 2a. 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: Productivity vs. Composition of Assets and Liabilities

(a) Composition of Liabilities and Deposit Productivity

Dep. Var	Leverage	$\frac{\text{Deposits}}{\text{Liabilities}}$	$\frac{\text{Small Time Dep.}}{\text{Liabilities}}$	$\frac{\text{Large Time Dep.}}{\text{Liabilities}}$	$\frac{\text{Savings Dep.}}{\text{Liabilities}}$	$\frac{\text{Trans. Dep.}}{\text{Liabilities}}$	$\frac{\text{FF+Repo}}{\text{Liabilities}}$
	(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	$\frac{\text{Loans}}{\text{Assets}}$	$\frac{\text{RE Loans}}{\text{Assets}}$	$\frac{\text{C\&I Loan}}{\text{Assets}}$	$\frac{\text{Loan Commit.}}{\text{Assets}}$	$\frac{\text{Securities}}{\text{Assets}}$	$\frac{\text{Cash}}{\text{Assets}}$	$\frac{\text{FF+Repo}}{\text{Assets}}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Asset Prod.	0.675***	0.348***	0.157***	0.0938***	-0.462***	-0.338***	-0.295***
	(0.0522)	(0.0479)	(0.0454)	(0.0234)	(0.0483)	(0.118)	(0.113)
Time F.E.	X	X	X	X	X	X	X
Other Controls	X	X	X	X	X	X	X
Observations	26,742	24,633	23,685	26,742	26,713	26,732	18,047
R-squared	0.288	0.353	0.057	0.134	0.147	0.235	0.116

Note: Table 5 panels (a) and (b) display the relationship between productivity and a bank's liability and asset structure. In Table 5a, 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 2a. In Table 5b, 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 5a and 5b 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 6: 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 6 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 2a. 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 7a. We measure asset productivity for loans and savings deposits using the corresponding production function estimates reported in Table 7b. 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 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 7: 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 7a 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 7b 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 8: Deposit and Asset Synergies

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

Note: Table 8 displays the relationship between deposit productivity and asset productivity (eq. 12). 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 7b. The dependent variable in columns (5)-(6) is securities productivity as measured using the production function estimates reported in column (2) of Table 7b. The key independent variable of interest is deposit productivity. We measure deposit productivity using the demand estimates reported in column (4) of Table 2a. 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 9: Productivity vs. Composition of Assets and Liabilities

(a) Composition of Assets and Deposit Productivity

Dep. Var	$\frac{\text{Loans}}{\text{Assets}}$ (1)	$\frac{\text{RE Loans}}{\text{Assets}}$ (2)	$\frac{\text{C\&I Loan}}{\text{Assets}}$ (3)	$\frac{\text{Loan Commit.}}{\text{Assets}}$ (4)	$\frac{\text{Securities}}{\text{Assets}}$ (5)	$\frac{\text{Cash}}{\text{Assets}}$ (6)	$\frac{\text{FF+Repo}}{\text{Assets}}$ (7)
Deposit Prod.	0.497***	0.165	0.705***	0.255***	-0.0280	-0.131	-0.665*
	(0.176)	(0.129)	(0.117)	(0.0769)	(0.192)	(0.127)	(0.348)
Time F.E.	X	X	X	X	X	X	X
Other Controls	X	X	X	X	X	X	X
Observations	26,742	24,633	23,685	26,742	26,713	26,732	18,047
R-squared	0.139	0.314	0.090	0.136	0.068	0.193	0.123

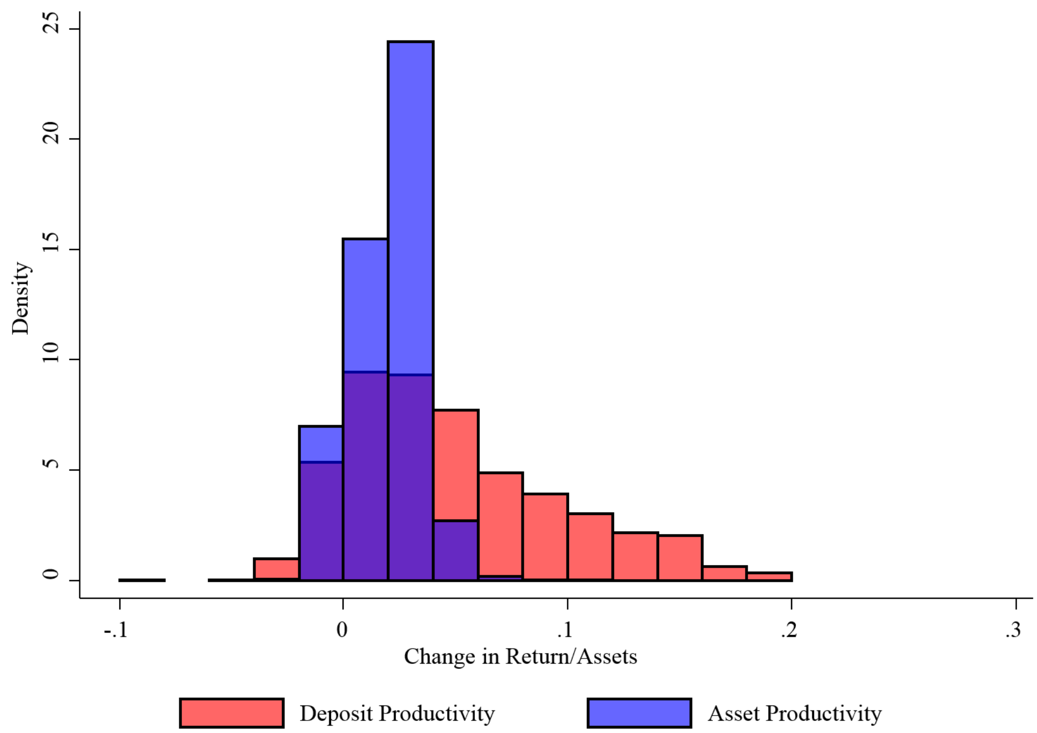
(b) Composition of Liabilities and Asset Productivity

Dep. Var	Leverage (1)	$\frac{\text{Deposits}}{\text{Liabilities}}$ (2)	$\frac{\text{Small Time Dep.}}{\text{Liabilities}}$ (3)	$\frac{\text{Large Time Dep.}}{\text{Liabilities}}$ (4)	$\frac{\text{Savings Dep.}}{\text{Liabilities}}$ (5)	$\frac{\text{Trans. Dep.}}{\text{Liabilities}}$ (6)	$\frac{\text{FF+Repo}}{\text{Liabilities}}$ (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 9 (a) and (b) display the relationship between productivity and a bank's liability and asset structure. In Table 9a, 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 2a. In Table 9a, 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 9a and 9b 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 5.2.2. Specifically, we "shrink" the estimated distribution of asset and deposit productivity to account for measurement error. The the red shaded histogram plots the distribution of our empirical Bayes estimates of bank deposit productivity weighted by $\overline{\frac{Deposits}{Assets}}\frac{1}{\alpha}$. The blue histogram displays the distribution of our empirical Bayes estimates of asset productivity $\overline{\frac{Assets}{Assets}}^{\theta} exp(\phi_{jt}+\overline{\Gamma X_{jt}})$. 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 2a. The asset productivity estimates correspond to specification reported in column (4) of Table 3.

Table A1: 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 A1a and A1b, we replicate our baseline set of results using our alternative measures of asset productivity. To construct the measure of asset productivity reported In Table A1a, we estimate the bank's asset income production function using a spline with five knot points as discussed in Section 5.1.1. To construct the measure of asset productivity reported In Table A1b, 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 2a. Observations in both Tables A1a and A1b 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 A2: Alternative Demand Estimates

(a) 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

(b) Alternative Demand Estimates - Alternative Instruments

Dep. Var.	Market to Book		Asset Productivity	
	(1)	(2)	(3)	(4)
Deposit Productivity	0.218***	0.435***	0.314***	0.180***
	(0.0277)	(0.0672)	(0.0302)	(0.0654)
Asset Productivity	0.0910*	0.120***		
	(0.0520)	(0.0379)		
Time F.E.	X	X	X	X
Other Controls		X		X
Observations	26,742	26,742	6,358	26,742
R-squared	0.431	0.465	0.628	0.632

Note: In Tables A2a and A2b, we replicate our baseline set of results using our alternative measure of deposit productivity. In Table A2a, we measure deposit productivity using the demand estimates reported in column (1) of Table 2b as described in Section 5.1.3. In Table A2b, we measure deposit productivity using the demand estimates reported in column (3) of Table 2a. Standard errors are clustered at the bank level and are reported in parentheses. The asset productivity estimates correspond to specification reported in column (4) of Table 3. Observations in Table A2a are at the bank by year level over the period 1994-2015. Observations in Table A2b 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: 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 A3, 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 7a. Similarly, we instrument for asset productivity using the subcategory asset productivity that we construct from the estimates reported in Table 7b. We measure deposit and asset productivity using the estimates reported in columns (4) of Table 2a 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 A4: 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 A4a and A4b, we replicate our baseline set of results using different subsets of the data. In Table A4a, 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 A4a, 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 2a 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 A5: 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 A5. Here we re-estimate demand using our extended data set of over 32k bank by quarter observations. In our baseline demand estimates (Table 2), 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 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 A6: 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 A6 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. 13) as described in Section 5.1.1. 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.