The Cross Section of Bank Value*

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Abstract

We study the determinants of value creation within U.S. commercial banks. We focus on three theoretically-motivated drivers of bank value: screening and monitoring, "safe" deposit production, and synergies between deposit-taking and lending. To assess the relative contributions of each, we develop novel measures of banks' deposit productivity and asset productivity and use these measures to evaluate the cross-section of bank value. We find that variation in deposit productivity explains the majority of variation in bank value, consistent with theories emphasizing safe-asset production. We also find evidence of value creation from synergies between deposit-taking and lending. Overall, our findings suggest that there is significant heterogeneity in banks' abilities to capture value by manufacturing safe assets.

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1 Introduction

Forty years of theoretical work has identified a number of ways in which banks can create economic value, which can broadly be grouped into three categories. One class of theories argues that banks exist to produce "safe," liquid, adverse-selection free liabilities, such as bank deposits (e.g., Gorton and Pennacchi, 1990). A second class argues that banks produce valuable information about borrowers through the screening and monitoring of loans (e.g., Diamond, 1984). Finally, a third class of theories highlights synergies between deposit-taking and lending that allow banks to make certain loans more easily than other intermediaries (e.g., Kashyap, Rajan, and Stein, 2002). Collectively, these theories capture the primary economic differences between banks and other types of firms.

However, little is known about the relative importance of these theories for different banks. Banks issue deposits and make loans, but how important is each of these activities in explaining the economic value of a bank? And how does the answer vary across banks? The answers to these questions are important for a number of reasons, including understanding the impact of bank regulations. To judge the relative contributions of different theories for different banks, we need a measure that makes the contribution of each explanation comparable.

Bank value is the natural choice. In a frictionless world, the Modigliani-Miller theorems hold, and banks do not create economic value. However, each broad theory of banking involves frictions that violate the Modigliani-Miller theorems and hence has implications for bank value creation. For example, if information produced through the screening and monitoring process allows a bank to source profitable projects, this should be reflected in the bank's value. Similarly, the production of safe debt can also create value for banks. As such, the cross section of bank value can be informative about how important each broad class of theories is for different banks. However, little is currently known about the underlying factors that drive the cross section of bank value.

In this paper, we systematically examine the cross-section of bank value to understand the quantitative contributions of different theories of banking. We begin by using tools from industrial organization to construct novel estimates of a bank's proficiency at producing deposits and risk-adjusted loan income. Our framework allows us to estimate "primitive" measures of deposit productivity and asset productivity. Intuitively, a bank with high deposit productivity is able to collect more deposits than a less productive bank, holding fixed "inputs" like its deposit rate and number of branches. For instance, BB&T and SunTrust each had about $150 billion of deposits in Q4 2015, and they paid similar deposit rates to raise these deposits. However, SunTrust generated its deposits with 23% fewer branches. Thus, our measures label SunTrust the more deposit-productive bank, since it generated the same amount of deposits at the same market rate but with fewer inputs. Analogously, a bank with higher asset productivity is able to generate more risk-adjusted revenue with the same asset base. For example, given similar asset bases of approximately $200 billion, BB&T generated more revenue than SunTrust in Q4 2015 despite having lower levels of observable risk. Thus, our measures label BB&T as the more asset-productive bank.

Uncovering primitive measures of deposit and asset productivity is important because the observable characteristics of a bank are endogenous functions of its productivity. For example, all else equal, a more productive bank will rationally choose to become larger in size. Thus, in the presence of diminishing returns, variation in observables is likely to understate the amount of true variation in primitives across banks. We believe that our ability to estimate primitive productivity differences across banks represents an important step forward in our ability to identify differences in banks' business models.

We combine our asset and deposit productivity estimates with banks' market-to-book ratios (M/B) from 1994 to 2015 to identify the primary determinants of cross-sectional variation in bank value. Our main finding is that the liability side of the balance sheet drives the majority of cross-sectional variation in bank value. We find that a one-standard deviation increase in deposit productivity is associated with an increase in M/B of 0.2 to 0.5 points, consistent with there being significant heterogeneity in banks' abilities to capture value by manufacturing safe assets. In contrast, a one-standard deviation increase in asset productivity is only associated with an increase in M/B of 0.1 to 0.2 points. Hence, variation in deposit productivity accounts for about twice as much variation in bank value as variation in asset productivity. This finding suggests that liability-driven theories of bank value creation explain more variation in the cross section of banks than asset-driven theories. Under plausible additional assumptions, we reach similar conclusions about the level of bank value: it is primarily driven by the liability side.

To better understand the economics behind this result, we examine which products and business lines are most closely associated with variation in productivity and valuations. On the deposit side, we begin by separately measuring a bank's ability to collect savings, transaction, small time deposits, and large time deposits. We find that a bank's ability to collect savings deposits is the main driver of value. Savings deposit productivity explains over three times as much variation in market-to-book ratios as transaction deposit productivity, and five times as much variation as any other subcomponent of productivity. This suggests that much of the variation in value generated by bank deposits comes from heterogeneity in supplying safety rather than liquidity or transaction services that are free of adverse selection. In addition, we find that deposit productivity is only weakly correlated with overall bank leverage in the cross section. Thus, banks that are particularly good at raising deposits are not significantly more levered than those that are not. Instead, they substitute non-deposit debt for deposits.

On the asset side, we find that variation in loan, rather than securities, portfolios is the main driver of bank productivity. Consistent with "information production" theories of banking, we also find that banks with high asset productivity hold more real estate and commercial and industrial (C&I) loans, which are likely to be information intensive. This suggests that the screening and monitoring of loans is an important source of bank value, though it accounts for far less variation in bank value than deposit productivity.

We next seek to understand whether the underlying sources of variation in our productivity measures are due to technological differences across banks, or differences in customer demographics and market power. To get at differences in customer demographics and market power, we explore the relationships between banks' geographical footprints and our productivity measures. We find that the demographic characteristics of the areas banks operate in explain twice as much variation in deposit productivity as asset productivity. Banks with less sophisticated, older clients, operating in areas with less competition tend to score higher on our measures of productivity. However, even after controlling for banks' geographic footprints, we still find that both of our productivity measures are strongly related to bank value, with deposit productivity again explaining significantly more variation than asset productivity in the cross-section of banks. This suggests that differences in market power and customer demographics do not fully explain variation in our productivity measures.

To get at technological differences across banks, we use additional data from various sources to examine how technology, quality of labor, and firm structure impact productivity. Using data from the Consumer Financial Protection Bureau, we find that more deposit productive banks receive fewer customer complaints. More productive banks also appear to use more sophisticated pricing strategies when setting deposit and lending rates. These findings help validate our productivity estimates as well as illustrate how technology and quality of inputs drive productivity.

Finally, we utilize our productivity measures to assess the degree of synergies between banks' deposit-taking and lending activities. By assessing the relationships between our two productivity measures and banks' balance sheet composition, we shed light on synergies in a manner distinct from the existing literature. We find that asset productivity is strongly correlated with deposit productivity: about 25% of the cross-sectional variation in asset productivity can be explained by deposit productivity, consistent with the theoretical literature on synergies. All types of deposit productivity, except for transactions deposits, are positively correlated with asset productivity. This finding suggests that the ability to raise "sticky" short-term funding is a key source of bank synergies. In addition, we find that deposit-productive banks tend to offer more loan commitments and lines of credit, consistent with Kashyap, Rajan, and Stein (2002) and Gatev and Strahan (2006). We also find that banks with high deposit productivity tend to make more illiquid C&I loans, consistent with Hanson, Shleifer, Stein, and Vishny (2016).

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

To estimate a bank's deposit productivity, we estimate a bank's ability to raise deposits from consumers, building upon Dick (2008) and Egan, Hortaçsu, and Matvos (2017). We then use these estimates to quantify deposit productivity at the bank-quarter level. To estimate asset productivity, we flexibly estimate a bank's ability to produce interest and fee income as a function of the size of it 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. Thus, our estimation procedure allows us to construct two complementary measures of bank productivity: a bank's skill at producing deposits, and the same bank's skill at using these funds to generate revenue.

Our paper is closely 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.[1] Our paper adds to this literature by quantifying the effects of safe-liability creation on bank value. We find that bank value is strongly linked to a bank's ability to produce safe, liquid deposits in the cross section. In addition, our results shed light on the characteristics of bank debt that create value. Our strongest results are for savings deposits, which, while safe, are not fully 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).[2] This literature has argued that part of a bank's purpose is to perform 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 linked to its value. However, we find that differences in asset productivity across banks appear to be significantly less important in the cross-section relative to differences in banks' abilities to produce deposits.

A third literature has argued that banks exist in part because of synergies between their deposit-taking and lending activities.[3] Consistent with this literature, we find that deposit-productive banks also tend to be asset-productive. Our results shed light on the nature of synergies, highlighting the importance of savings and time deposits for supporting C&I lending and credit lines. Finally,

[1]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), and Moreira and Savov (2016). The empirical literature in this area, e.g., Krishnamurthy and Vissing-Jorgensen (2012), Gorton, Lewellen, and Metrick (2012), Greenwood, Hanson, and Stein (2015), Krishnamurthy and Vissing-Jorgensen (2015), Sunderam (2015), and Nagel (2016) has largely focused on understanding whether bank liabilities are special by examining the behavior of equilibrium prices and quantities.

[2]Other asset-driven theories of bank value creation include Ramakrishnan and Thakor (1984), Boyd and Prescott (1986), Allen (1990), Diamond (1991), Rajan (1992), Winton (1995), and Allen, Carletti, and Marquez (2011). Empirical literature includes Hoshi, Kashyap, and Scharfstein (1990, 1991), Petersen and Rajan (1994), Berger and Udell (1995), Demsetz and Strahan (1997), Shockley and Thakor (1997), Acharya, Hassan, and Saunders (2006), Sufi (2007), and Keys et. al. (2010). A separate literature studies the "charter value" that accrues to banks due to entry restrictions that allowed incumbents to extract monopoly rents. See Keeley (1990) for a discussion of the decline in charter values and Jayaratne and Strahan (1996) for more information on the removal of branching restrictions. There is also a literature on estimating bank production functions, primarily for the purpose of understanding whether there are economies of scale in banking (e.g., Berger and Mester, 1997; Hughes and Mester, 1998; Stiroh, 2000; Berger and Mester, 2003; Rime and Stiroh, 2003; Wang, 2003). We extend this literature by estimating a bank's *liability* productivity in addition to introducing a new methodology to estimate bank asset productivity and studying the value implications of both measures.

[3]See, e.g., Diamond and Dybvig (1983), Calomiris and Kahn (1991), Berlin and Mester (1999), Diamond and Rajan (2000, 2001), Kashyap, Rajan, and Stein (2002), Gatev and Strahan (2006), and Hanson, Shleifer, Stein, and Vishny (2016). Mehran and Thakor (2011) argue that there are synergies between equity capital and lending and provide evidence from the cross section of bank valuations. Berger and Bouwman (2009) construct a measure of bank liquidity creation and show that their measure is positively correlated with banks' market-to-book ratios. Bai, Krishnamurthy, and Weymuller (2016) also link bank "liquidity mismatch," the difference in liquidity between the asset and liability sides of a bank's balance sheet, to bank stock returns. Billett and Garfinkel (2004) also link banks' quantities of insured and uninsured deposits directly to their M/B ratios. However, none 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.

our paper is also related to the growing literature at the intersection of industrial organization and finance.[4]

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

2 Economic Framework

In this section, we present a simple economic framework that allows us to link deposit productivity and asset productivity with bank value. We treat a bank as a firm with two divisions: a deposit-producing division that raises funding by offering consumers services and interest payments and a revenue-producing division that takes funding as an input and converts it into risk adjusted revenue by making loans and holding securities. We begin by describing our framework for the deposit-producing function. We then turn to the problem of banks seeking to generate revenue from their assets.

2.1 Bank Deposits

Banks produce deposit products that are valued by consumers. The value consumers place on deposits 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 at time t earns the deposit rate i_{jt}, which yields utility αi_{jt}. The parameter $\alpha > 0$ measures the consumer's sensitivity to deposit rates. Depositors also derive utility from banking services produced by banks, given by $F_{jt}(X_{jt}) + \varepsilon_{jkt}$. The function $F_{jt}(X_{jt})$ is a bank-specific production function for turning costly inputs X_{jt}, such as capital, labor, and non-interest expenditures, into services valued by consumers. We parameterize the production function as $F_{jt}(X_{jt}) = \beta X_{jt} + \delta_j$. The parameter β reflects a technology that is common across

[4]Our deposit demand estimates relate most closely to Dick (2008) and Egan, Hortaçsu, and Matvos (2017). Similar tools have been used to estimate demand by Hortaçsu and Syverson (2004) for index mutual funds, Koijen and Yogo (2015) for investment assets, Koijen and Yogo (2016) for life insurance, and Hastings, Hortaçsu and Syverson (2016) for privatized social security. Our estimation of bank asset production functions uses techniques similar to those used by Maksimovic and Phillips (2001) and Schoar (2002) to study nonfinancial firms. An advantage in our setting is that we correct for the potential endogeneity of production inputs using cost shifters from the liability side of the bank as instruments.

banks for turning costly inputs into services valued by consumers. The bank-specific fixed effect, δ_j, denotes the bank's deposit productivity. Conditional on the other inputs, banks with higher deposit productivity offer superior services. As such, deposit productivity captures differences in efficiency across banks in producing deposits from costly inputs X_{jt}. Finally, the term ε_{jkt} is a consumer-bank-specific utility shock. This shock captures preference heterogeneity across consumers. Some consumers may inherently prefer Bank of America to Citibank (or vice versa). Thus, the total indirect utility derived by a depositor k from bank j at time t is given by

$$u_{jkt} = \alpha i_{jt} + \beta X_{jt} + \delta_j + \varepsilon_{jkt}. \tag{1}$$

The main object of interest in our analysis is deposit productivity. Conditional on the offered deposit rate i_{jt} and other bank characteristics (X_{jt}), banks that are more productive (higher δ_j) attract more depositors.

Each consumer selects 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_{jkt} 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

$$s_{jt}\left(i_{jt}, \mathbf{i_{-jt}}\right) = \frac{exp(\alpha i_{jt} + \beta X_{jt} + \delta_j)}{\sum_{l=1}^{J} exp(\alpha i_{lt} + \beta X_{lt} + \delta_l) + 1}. \tag{2}$$

The total market size for deposits at time t is denoted M_t. Hence, the total deposits collected by bank j is $s_{jt}M_t$.

Our formulation closely follows that of Egan, Hortaçsu and Matvos (2017), with one exception. Previous research such as Egan, Hortaçsu and Matvos (2017) and more recently Martin, Puri and Ufier (2017) finds that depositors (particularly uninsured depositors) may be sensitive to the financial stability of a bank. In this paper, we treat consumers' perceptions about bank solvency as part of the bank's deposit productivity. For example, if certain banks benefit from an implicit too-big-to-fail guarantee, the guarantee will be captured in our productivity measures.

2.2 Bank Assets

We next turn to the asset side of the bank. Banks collect deposits and other capital and invest them in a bank-specific technology. Banks have total assets equal to the sum of the deposit it collects, $M_t s_{jt}$, and its other capital, K_{jt}:

$$A_{jt} = M_t s_{jt} + K_{jt}.$$

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

$$\pi_{jt} = \phi_j A_{jt}^{\theta} - i_{jt} M_t s_{jt} - r_{jt} K_{jt}. \tag{3}$$

The term $\phi_j A_{jt}^{\theta}$ reflects the investment income the bank generates from assets A_{jt}. In other words, $\phi_j A_{jt}^{\theta}$ is the bank's asset production function. The parameter θ reflects returns to scale in production, and ϕ_j reflects bank j's asset productivity. Specifically, ϕ_j reflects excess risk-adjusted revenue the bank can earn on its loans and securities. These revenues may arise because the bank has a particularly good technology for screening and monitoring borrowers, or because it is particularly good at finding and holding mispriced securities. The remaining terms in the profit function, $i_{jt} M_t s_{jt}$ and $r_{jt} K_{jt}$, reflect the bank-specific costs of raising deposits $M_t s_{jt}$ and capital K_{jt}.

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, banks with higher deposit productivity can attract deposits more cheaply. To illustrate, suppose that bank j has initial deposit productivity δ_j^0 and wishes to collect D deposits. It then needs to offer a deposit rate i^0 such that $D = M s_j(i^0, \boldsymbol{i}_{-j})$. Bank j's interest expenditure is then given by

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

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 same amount of deposits, D. Bank $j's$ total interest expense of collecting D deposits falls by $D\left(\frac{\delta_j^1 - \delta_j^0}{\alpha}\right)$.

All else equal, an increase in a bank's deposit productivity leads to an increase in the bank's net income and bank value.

On the asset side, the parameter ϕ_j reflects a bank's asset total factor productivity or simply a bank's asset productivity. Conditional on the bank's level of assets, a bank with higher asset productivity generates more revenue from its 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 quarterly balance sheet and income statement data for all U.S. bank holding companies. We supplement the Y-9C data with stock market data from CRSP and weekly branch-level data on advertised deposit rates from RateWatch. We also obtain branch-level deposit quantities from the annual FDIC Summary of Deposits files. Finally, we obtain county- and MSA-level demographic characteristics from the U.S. Census Bureau.

Our sample is the universe of public bank holding companies. Our primary data set consists of an unbalanced panel of 847 bank holding companies over the period 1994 through 2015. Observations are at the bank holding company by quarter level.[5] Table 1 provides summary statistics for the data set. As discussed below, we proxy for 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.

3.2 Estimation: Bank Deposits

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

[5] On average, we observe 327 banks in a given quarter and have 52 observations for each bank.

specification:

$$\ln M_t s_{jt} - \ln(M_t s_{0t}) = \alpha i_{jt} + \beta X_{jt} + \delta_j. \tag{4}$$

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:

$$\ln M_t s_{jt} = \alpha i_{jt} + \beta X_{jt} + \mu_j + \mu_t + \xi_{jt}. \tag{5}$$

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.[6]

A standard issue in demand estimation is the endogeneity of prices, or in this case, deposit rates. The term ξ_{jt} in Eq. (5) represents an unobserved bank-time specific demand shock. If banks observe ξ_{jt} prior to setting deposit rates, the offered deposit rate will be correlated with the unobservable term ξ_{jt}. For example, suppose bank j experiences a demand shock such that ξ_{jt} is positive. Bank j will then find it optimal to offer a lower deposit rate. This will cause our estimate of α to be biased downwards.

We use two sets of instruments to account for the endogeneity of deposit rates. First, following Villas-Boas (2007) and Egan, Hortaçsu, and Matvos (2017), 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), Drechsler, Savov, and Schnabl (2016), and Gomez et al. (2016), deposit rates at different banks respond differently to changes in short-term interest rates, in part due to differences in market power. Banks with more market power need to raise deposit rates less to retain depositors as short-term interest rates rise. Hence, variation in market power will induce variation in deposit rates that is unrelated to the deposit demand conditions that banks face.[7] Thus, we can instrument for i_{jt}, the deposit rate

[6] Deposit market share data at the branch level is only available at an annual frequency through the FDIC's Summary of Deposits.

[7] Investment opportunities are another reason pass-through may vary. Banks with good investment opportunities will not wish to lose deposit funding to competitors and will thus raise their deposit rates more when short rates rise. Variation in pass-through induced by investment opportunities also induces variation in deposit rates that is unrelated to deposit demand.

offered by bank j at time t, with the fitted value of a bank-specific regression of i_{jt} on 3-month LIBOR. The exclusion restriction here is that bank j's average degree of pass-through in the time series interacted with 3-month LIBOR is orthogonal to the deposit demand it faces at time t.

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

Table 2 displays the corresponding demand estimates using aggregate bank-quarter data from the Y-9C reports. We measure deposit rates i_{jt} as interest expense on deposits, net of fees on deposit accounts, divided by total deposits. We proxy for the quality of services offered by a bank using the bank's non-interest expenditures, number of employees, and number of branches. Non-interest expenditures should capture investments made by the bank in providing higher-quality services to consumers, while the number of branches and number of employees may also factor into consumers' selection of a depository institution. Column (1) of Table 2 displays the simple OLS estimates corresponding to Eq. (5), while column (2) uses both sets of instruments (which yield first-stage F-statistics in excess of 25). 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 (2) implies that a one percentage point increase in the offered deposit rate is associated with a 1.8 percentage point increase in market share.[8] These point estimates are in line with the literature (Dick, 2008; Egan, Hortaçsu, and Matvos, 2016). In Section 5.1.1 below, we show that our main findings are robust to a variety of alternative specifications of the demand system.

We use the estimated demand system to calculate each bank's deposit productivity. Specifically,

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

we measure bank j's deposit productivity at time t, δ_{jt}, as

$$\hat{\delta}_{jt} = \ln M_t s_{jt} - \hat{\alpha} i_{jt} - \hat{\beta} X_{jt} - \hat{\mu}_t. \tag{6}$$

Our estimates of deposit productivity have an intuitive reduced-form interpretation. In Eq. (5), we are regressing log deposits collected on inputs (number of branches, deposit rate, etc.) and then using the residuals to calculate deposit productivity. Hence, more productive banks can raise more deposits with the same inputs than less productive banks. Bank deposit productivity is highly persistent in the data, with a quarterly auto-correlation of 0.99.

3.3 Estimation: Bank Assets

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

$$\ln Y_{jt} = \theta \ln A_{jt} + \phi_{jt}. \tag{7}$$

We parameterize and estimate the production function as

$$\ln Y_{jt} = \theta \ln A_{jt} + \Gamma X_{jt} + \phi_j + \phi_t + \epsilon_{jt}. \tag{8}$$

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. (8) 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. (8) 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. (8). 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.[9]

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.[10] The idea is that if a bank faces competitors that are better at raising deposits, it will naturally be smaller, so that competitor deposit productivity induces variation in bank size that is orthogonal to the bank's own asset productivity.

Table 3 displays the corresponding estimates. In columns (1) and (2), we report the OLS estimates, and in columns (3) and (4), we report the IV estimates. The instruments are empirically relevant and yield first stage F-statistics in excess of 20 for each specification. In each specification, we estimate a coefficient on $\ln A_{jt}$ (θ) that is less than one. This implies that banks face decreasing returns to scale. In columns (2) and (4), we measure risk using equity beta and the standard deviation of returns. We include both backward looking measures over the previous two years, as well as forward-looking measures of risk calculated from time t to time t plus two years.[11] The estimates in our IV specifications in columns (3) and (4) of Table 3 are quite similar to the OLS estimates. This suggests that within a quarter, banks either do not observe ϵ_{jt} prior to determining their asset size or that banks are unable to adjust their asset size within a quarter.

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

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

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

[10] 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.(6). The estimates of $\hat{\delta}_j$ are from the demand estimates reported in Appendix Table A7, which uses an expanded data set comprised of bank holding companies, rather than just the public companies we focus on in our main results. Put differently, our instruments are based on all competitors a bank faces, not just its competitors that are public firms. In our IV specifications, we winsorize $\overline{\delta_{-j}}$ at 1%, and we use the variables $\overline{\delta_{-j}}$ and $\overline{\delta_{-j}}^2$ to instrument for $\ln A_{kt}$.

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

Note that this construction implies that if there are differences in economies of scale (θ) across banks, our asset productivity measures will include them. In our main results, we calculate bank asset productivity using this equation based on the estimates in column (4) of Table 3. The reduced-form interpretation of our results is simply that more asset-productive banks generate more income with the same inputs than less productive banks. Asset 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 examining how our productivity measures relate to bank value. Our empirical framework described in Section 2 shows that both deposit and asset productivity directly contribute to a bank's cash flows. Here we examine how deposit productivity relates to a stock-market based measure of bank value, market-to-book.[12] It is worth noting up front that because we are using a market-based measure of value, our results only speak to private value created for shareholders, not total social value created.

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:

$$\left(\frac{M}{B}\right)_{jt} = \gamma_0 + \gamma_1 \hat{\delta}_{jt} + \gamma_2 \hat{\phi}_{jt} + \Gamma X_{jt} + \mu_t + \varepsilon_{jt}. \tag{9}$$

Table 4 displays the corresponding estimation results.[13] 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 as leverage, the bank's estimated equity beta, and the standard deviation of its return on assets (ROA) to account for risk.[14] We control for size as a proxy for growth expectations. Larger banks will tend to grow more slowly and thus have lower market-to-book ratios. The remaining controls are meant to account for any correlation between our productivity measures

[12] In our static framework in Section 2, there is an unambiguous positive relationship between market-to-book and both deposit and asset productivity. The relationship in a dynamic model can be ambiguous, depending upon the persistence of productivity and the functional form of the production function.

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

[14] Note that risk acts like measurement error in this setting. It may affect the independent variables, but it should not affect market-to-book because it increases cash flows and discount rates equally. Consistent with this intuition, find that our risk controls do not affect our point estimates very much. We discuss measurement error further in Section 5.3 below.

and risk.

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.[15] Columns (3) and (4) show the relationship between asset productivity and market-to-book. A one-standard deviation increase in asset productivity is associated with an increase in market-to-book of 0.14 to 0.22 points, an effect that is also economically significant.

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

4.2 Deposit-driven Value versus Asset-driven Value

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

We start by re-estimating our market to book regressions (Eq. 9), simultaneously including both deposit and asset productivity. Columns (5) and (6) of Table 4 display the corresponding estimates. Bank value loads positively on both asset and deposit productivity in both specifications. However, we find that an increase in deposit productivity has a much larger impact on a bank's market-to-book than asset productivity. The results in column (5) indicate that a one standard deviation increase deposit productivity is associated with an increase of 0.21 points in market-to-book, whereas a one standard deviation increase in asset productivity is associated with only an increase of 0.09 points in market-to-book. The impact of deposit productivity is about twice as large in column (5), where we only include time fixed effects, and nearly five times as large in column (6), where we include the full suite of controls. This suggests that liability-driven theories of bank value creation, which focus on the special services provided by bank deposits, explain more variation in the cross section of banks than asset-driven theories. Again, an important caveat is that the regression results reported in Table 4 focus on the explaining cross-sectional dispersion in bank value rather than the level of bank value or the social value created by banks.

The results suggest that deposit productivity plays a larger role in explaining the dispersion in bank value than asset productivity. What explains this difference? Variation in multiples must

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

be explained by variation in cash flows, growth rates, or returns. We find little evidence that our productivity measures have different associations with future growth rates or equity returns. The remaining possibility is that deposit productivity explains more variation in bank cash flows than asset productivity.

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

$$Cost\,Savings = Deposits \times \frac{\Delta\delta}{\alpha} \tag{10}$$

where α is the elasticity of demand for deposits. Similarly, if a bank's asset productivity increases from ϕ^0 to ϕ^1, its returns increase by

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

Figure 1 uses these equations to decompose the dispersion in net income across banks. The red shaded histogram shows how much the average bank's net income changes as we vary bank deposit productivity (δ_{jt}) across its observed distribution in the data. Similarly, the blue histogram shows how much the average bank's net income changes as we vary asset productivity across its distribution in the data. Consistent with the evidence presented in our market-to-book regressions (Table 4, columns 5 and 6), Figure 1 suggests that heterogeneity in deposit productivity explains about twice as much of the variation in bank net income as heterogeneity in asset productivity.

Figure 2 presents a similar plot that discards the structure of Figure 1 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 Figure 1 and Figure 2 therefore highlight the value of a more rigorous economic analysis. In particular, by ignoring *how* banks (1) obtain funding and (2) convert that funding into income, the accounting-based decomposition obscures the "primitives" that enter the bank's optimization problem and are responsible for determining a bank's value.

4.2.1 From the Cross Section to Levels

Our main empirical analysis focuses on the cross-section of bank value. With additional normalizing assumptions, Figure 1 can be interpreted in terms of the level of bank value. We normalize the level of asset productivity such that the small set of banks earning risk adjusted returns below the five-year Treasury yield have negative asset productivity. Similarly, we also normalize the deposit productivity distribution such that the small set of banks that pay deposit rates above 3-month LIBOR have negative deposit productivity.[16] The results suggest that deposit productivity not only explains more of the cross section of bank value than asset productivity, but also contributes more to the level of bank value.

We can also use the joint distribution of deposit and asset productivity to determine the share of net income coming from deposits for each bank. Figure 3 shows the distribution of deposit's share of net income across banks. On average, deposit productivity accounts for about twice as much of bank value as asset productivity. The mean and median deposit value share is 71% and 79%, respectively.[17] However, there is a great deal of heterogeneity across banks: for some banks, the majority of value comes from asset productivity.

Overall, a variety of different approaches suggest that deposit productivity is more important than asset productivity for explaining both the level of bank value and variation in value across banks.

4.3 Bank Productivity and Business Lines

Why does deposit productivity explain more variation in bank cash flows than asset productivity? In this section, we explore this question by determining the products and business lines that are most closely associated with variation in productivity and valuations.

[16] We normalize the level of asset productivity relative to the five-year Treasury yield because bank balance sheet estimates from Begenau and Stafford (2017) suggest that the average maturity of bank assets is five years. This normalization means that 17% of banks do not generate any value on the asset side of the balance sheet. Our normalization of the deposit productivity distribution means that the bottom 13% of banks in terms of deposit productivity in each quarter do not generate any value on the deposit side of the bank.

[17] We obtain similar estimates if we do a back-of-the-envelope calculation using our market-to-book regressions in Table 4. Specifically, banks create value if their market-to-book ratio exceeds one. We can thus use the regressions to ask how much of the fact that market-to-book ratios exceed one on average is due to deposit productivity versus asset productivity.

4.3.1 Decomposing Bank Productivity

We start by asking whether certain types of assets and deposits contribute particularly strongly to our overall asset and deposit productivity measures in Table 5. Specifically, we compute productivity measures for different subcategories of assets and deposits using the empirical framework described in Section 3.[18] These disaggregated productivity measures tell us whether, for instance, a bank is particularly good at raising savings deposits given the rate it pays on savings deposits and other inputs. We then assess the correlations between these more disaggregated productivity measures and our broader overall deposit and asset productivity measures, as well as market-to-book ratios.

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

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

Columns (3) and (4) of Table 5 display the relationship between asset productivity and our subcategory measures: lending productivity and securities productivity.[19] The estimates indicate that our asset productivity measure is significantly more correlated with banks' loan productivity than their securities productivity. This accords with intuition: there is more scope for banks to use their screening and monitoring technologies to generate excess returns in the context of loans than securities. If securities are relatively standardized and homogeneous relative to bank loans, it

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

[19]Interest income is only disaggregated into interest income from loans and interest income from securities, so this is the most granular decomposition we can do on the asset side.

is natural that variation in bank productivity would be driven by a bank's lending portfolio rather than its securities portfolio.

Finally, columns (5) and (6) assess the correlations between our subcategory 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.[20] Hence, consistent with the results in Table 4, Table 5 shows that bank value is more sensitive to deposit productivity than to asset productivity.

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

Why are saving deposits so strongly correlated with value? A key part of the answer is that depositors behave as though they are highly differentiated products. They act as though savings deposits at one bank are not a good substitute for savings deposits at another bank, so savings deposits are very "sticky" or inelastic. We find that demand for savings deposits is almost completely inelastic.[21] Thus since demand is almost completely inelastic to the rate a bank offers, a bank that is good at gathering savings deposits can gather them at very low rates. In contrast, if demand for deposits were completely elastic, deposit productivity would create no value for the bank; a less productive bank could always offer a deposit rate slightly higher than the most productive bank and collect all deposits. Consistent with this intuition, demand for transaction deposits is also quite inelastic, while demand for time deposits is quite elastic. As can be seen in Eq. (10), the more elastic the demand for a particular type of deposit, the less it contributes to bank value.

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

[20] The negative coefficient on small time deposits is a product of running a multiple regression. The univariate correlation between market-to-book and small time deposit productivity is positive. However, this result is consistent with the claim that banks lose money on smaller accounts: [http://www.fool.com/investing/general/2014/03/10/do-the-big-banks-not-want-small-customers.aspx, accessed 2/24/2017].

[21] Our demand estimates for each type of deposit are in Table A1a.

services but are primarily safe stores of value.

4.3.2 Bank Productivity and Balance Sheet Composition

Another way to understand what products and business lines drive our productivity measures is to examine how they correlate with balance sheet composition. This is particularly useful on the asset side of the balance sheet, where data limitations prevented us from doing fine-grain productivity decompositions in the previous section. Here, we instead use a revealed preference argument. If banks with high productivity tilt their balance sheets towards certain assets and liabilities, this suggests that those assets and liabilities create substantial value. In other words, our methodology can be viewed as a tool to identify a bank's particular specialty or specialties. All else equal, if a bank is particularly good at, say, producing savings deposits, we would expect the bank to hold an abnormally large quantity of savings deposits relative to its peers.

In Table 6a, we examine the correlations between our deposit productivity measure and the composition of the liability side of banks' balance sheets. Both the dependent and independent variables are standardized. Column (1) shows that our deposit productivity measures are not strongly correlated with bank leverage.[22] Interestingly, banks that are particularly good at raising deposits do not appear to lever up much more than other banks. Columns (2)-(7) show that banks with higher deposit productivity tend to have significantly more deposits as a fraction of their total liabilities, as expected. Given that leverage does not change with deposit productivity, this implies that more productive banks substitute non-deposit debt for deposits. Thus, it appears that non-deposit debt is not an important source of value for banks.

Table 6b displays correlations between our asset productivity measure and banks' asset composition. Columns (1)-(3) show that more productive banks tend to hold more real estate loans, more C&I loans, and more loan commitments (credit lines). This is consistent with the idea that more productive banks have better screening and monitoring technologies that allow them to make loans with high risk-adjusted returns. Columns (4)-(6) show that productive banks also tend to have lower quantities of securities and liquid assets, where there is presumably less scope for banks to use their screening and monitoring technologies to generate excess returns. 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.

[22]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.

Overall, we find strong evidence that our productivity measures are capturing meaningful information about bank-specific business line specialization.

4.4 Sources of Bank Productivity

What are the underlying sources of variation in our productivity measures? The literature considers a number of variables, including technology, quality of inputs, and firm structure decisions to be some of the main drivers of productivity (Syverson 2011). In broad terms, explanations for differences in productivity across banks can be categorized as either "technological" or "customer-based." To be precise, "customer-based" explanations for variation in bank productivity are ones in which two banks would have the same productivity if they had the same customers. This would include differences in productivity that are due to differences across banks in market power, in customer sophistication, or in customer price elasticities. "Technological" explanations for variation in productivity are ones in which two banks would have different productivities even if they had the same customers. This would include differences in quality of inputs, variety of products, or sophistication in price setting.

In this section, we use additional external data to show that our deposit and asset productivity measures appear to be driven by both technological and customer-based explanations. While fully attributing variation in our productivity measures to either customer-based or technological sources is difficult given that we only have rough proxies for different sources of variation and that the two may be intimately related (Syverson 2004, Holmes et al. 2012), these results provide additional insights into what factors are driving productivity.

4.4.1 Customers

To examine customer-based explanations for variation in our productivity measures, we analyze the demographic and geographic correlates of our productivity measures in Table 7a. We combine county-level Census data with the FDIC's summary of deposits to generate average demographic characteristics of the counties where each bank operates, weighted by the fraction of the bank's deposits in each county. Column (1) shows the correlation between asset productivity and these demographic characteristics. There is a concave relationship between asset productivity and both population and average local wages. Banks in low-population, low-wage areas have low asset productivity, but the relationship fades as population and wages increase. Banks in high house price areas have higher asset productivity. We do not find any evidence of non-linearity in the relationship and therefore only report the linear relation. Market power also appears to matter. Banks with high asset productivity tend to operate in less competitive areas, as measured by the Herfindahl-Hirschman index (HHI) of mortgage originations from Home Mortgage Disclosure Act (HMDA) data.

In column (2), we add geographic fixed effects to control non-parametrically for other unobservables. Specifically, we regress bank asset productivity on 387 dummy variables, each of which indicates whether the bank operates in a particular MSA. We use MSA dummies, rather than county dummies, in order to have enough variation in the regression. The within-time R^2 of the regression in column 2 is 39%, suggesting that demographic and geographic variation explains a significant fraction of asset productivity. Columns (3) and (4) repeat these exercises for deposit productivity with similar results. We find that demographic and geographic variable explain even more of the variation in deposit productivity than asset productivity. The within-time R^2 of the regression in column 4 is 70%. Interestingly, the age of bank branches is strongly correlated with deposit productivity. This could reflect that older branches have over time isolated the stickiest deposits.

Table 7b shows that our main results hold even controlling for MSA fixed effects and even after directly including demographic characteristics and market concentration variables in our regressions. Despite the fact that geography explains much of the variation in our productivity measures, our measures are still strongly related to bank value, and deposit productivity continues to have a much larger impact than asset productivity. In total, demographic and geographic variables explain about 40% of the variation in market-to-book. Hence, it is not the case that our productivity measures are only correlated with a small residual part of value; they have important explanatory power for an important part of bank value.

Overall, while the geographic and demographic characteristics of where banks operate explain significant variation in asset and deposit productivity, they are not a full explanation for our main results. Technological factors appear to play a role as well. In Section 5.1.1 below, we further explore demographic and geographic variation using deposit productivity estimates based on county level deposit data and reach the same conclusion.

4.4.2 Technology: Consumer Complaints

We next turn to technological sources of variation in productivity by examining the quality of services offered by the bank. We supplement our bank holding company data with consumer complaint data from the Consumer Financial Protection Bureau's (CFPB) Consumer Complaint Database. The CFPB collects data on consumer complaints filed over the period 2011-2015 on various financial products. We manually match firm names in the CFPB database to 79 bank holding companies in our baseline data set. We measure the quality of services a bank offers as the number of complaints it receives in a given year per dollar of deposits it collects ($CFPB\,Complaints_{jt}$), winsorized at the 5% level.

Columns (1)-(2) of Table 8 display the correlations between deposit productivity and our external measure of bank quality, CFPB complaints. The results suggest that banks that are more deposit productive offer higher quality products. In other words, banks that are good at producing deposit have better quality inputs. This result is consistent with Egan, Hortaçsu, and Matvos (2017), who find that banks with larger brand effects receive fewer complaints per depositor. Columns (3)-(4) of Table 8 examine the relationship between asset productivity and CFPB complaints. There is little relationship between asset productivity and the number of CFPB complaints a firm receives. To the extent that asset productivity measures the investment and risk management skill of a bank, it is not surprising that we find a relationship between asset productivity and CFPB complaints. Conversely, the results suggest that customer service appears to be a key driver of deposit productivity.

4.4.3 Technology: Rate Setting

Finally, we examine another technological source of variation in productivity: firm structure decisions and pricing technology. Specifically, we look at the relationship between a bank's rate setting technology and productivity.

We first examine the variation in deposit and mortgage rates offered by a bank. The idea is that banks with more sophisticated rate setting technology will offer location specific deposit rates that depend on local demand conditions. Specifically, we first calculate the median 3-month certificate of deposit rate and 30-year fixed mortgage rate offered at the bank by year by county level.[23] We then calculate the standard deviation of certificate of deposit and mortgage rates across the counties a bank operates in for each year, σ_{CDjt} and σ_{MTGjt}. Table 9 displays the correlations between asset and deposit productivity and our corresponding measures of rate setting sophistication. Banks that set more heterogeneous deposit and mortgage rates are more deposit- and asset-productive respectively.

[23]We examine mortgage rates for a $175,000 loan with no origination fees or mortgage points.

Overall, the results in this section suggest that both customer-based and technological sources of variation are important in driving our productivity measures.

4.5 Synergies

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

Table 10a presents regressions relating our asset productivity measures to our deposit productivity measures. Specifically we run regressions of the form

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

The table shows that the two measures are strongly correlated. Column (1) shows that a one-standard deviation increase in deposit productivity is associated with a 0.33 standard deviation increase in asset productivity. This is economically significant: 25% of the variation in our asset productivity measure can be explained by variation in deposit productivity.[24] 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 10a suggests that there are important synergies between deposit productivity and asset productivity, particularly loan productivity.

To better understand the drivers of these observed synergies, we examine the correlations between our subcategory measures of productivity in Table 10b . We separately examine the relationship between overall asset (columns 1-2), loan (columns 3-4), and securities (columns 5-6) productivity and the subcategory deposit productivity measures. We find positive relationships between savings and time deposit productivity and our various measures of asset productivity. However, we do not find a relationship between transaction deposits productivity and our measures of asset productivity. Thus, synergies may have to do with the term structure of deposits. Banks

[24] This provides an upper bound on the strength of synergies, as correlation between deposit and asset productivity can be explained by factors like good management, in addition to the bank-specific synergies focused by the theoretical literature.

that are more productive in collecting long-term deposits appear to have more productive lending and securities portfolios.

In Table 11, we use variation in bank balance sheet composition to explore the sources of these synergies in more detail. Table 11a relates bank asset composition to deposit productivity. Column (1) shows that there is no correlation between deposit productivity and real estate lending. In contrast, column (2) shows there is a strong correlation between deposit productivity and C&I lending. Since C&I loans are more illiquid than mortgages, this suggests that the ability to raise deposits in a cost-effective manner is important for banks that wish to make profitable, illiquid loans, as argued by Hanson, Shleifer, Stein, and Vishny (2016). Column (3) shows that banks with higher deposit productivity also tend to write more loan commitments. This is consistent with Kashyap, Rajan, and Stein (2002) and Gatev and Strahan (2006), who argue that there are synergies between taking deposits and writing loan commitments because in bad times deposits tend to flow into banks while loan commitments are simultaneously drawn down. Our results suggest that this effect is particularly strong for banks that are good at gathering deposits.

In Table 11b, 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.

5 Robustness

We find that banks that are more productive in raising deposits and generating asset income are more valuable. Although deposit and asset productivity are closely related, we find that variation in deposit productivity accounts for more than twice the variation in bank value relative to asset productivity. In this section, we provide a variety of robustness tests 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 use alternative demand estimates, allow for a more flexible asset income production function, and use additional measures of risk.

5.1.1 Alternative Demand Estimates

In this section, we examine the robustness of our main findings to the alternative demand specifications. We begin by re-estimating our demand system using more granular county-by-year data in Table A3a where we define the market for deposits at the county level. The data runs from 2002 to 2012.[25] We now include county by time fixed effects in estimating the county-year analog of Eq. (5). The county by time fixed effects absorb market level characteristics such consumer demographics and competition. In addition, we allow consumers' sensitivity with respect to deposit rates to vary with county demographics such as wages, age, and education. The estimates in all three specifications are very similar to those we find at the aggregate level in Table 2.

We use these estimates in two ways. First, we use the estimates in Table A3a to compute an alternative measure of deposit productivity that is purged of geography.[26] Table A3b displays our baseline set of tests using this alternative measure of deposit productivity. The results are comparable to our main results. Market-to-book is positively correlated with our alternative measure of deposit productivity. The results displayed in columns (1) and (2) of Table A3b again suggest that deposit productivity has a greater impact on market-to-book relative to asset productivity. Columns (3) and (4) of Tables A3b indicate that there are strong synergies between asset and deposit productivity.

Second, we examine how the average demand elasticity a bank faces impacts the contribution of deposit productivity to value. Recall from Eq. (10) that the value implications of deposit productivity depend on the elasticity of demand. All else equal, deposit productivity is more valuable if a bank faces an inelastic demand curve. We augment Eq. (9) to include the interaction of deposit productivity with the average demand sensitivity faced by a bank ($\bar{\alpha}_{jt}$). Table A3c

[25]County level deposit rate data comes from RateWatch, covering 447 of the 847 banks in our main sample.

[26]We construct county by firm by year measures of deposit productivity using our county level demand estimates. Let $\hat{\delta}_{jlt}$ denote the estimated deposit productivity of firm j in county l at time t where

$$\hat{\delta}_{jlt} = \ln M_{lt} s_{jlt} - \hat{\alpha} i_{jt} - \hat{\mu}_{lt}.$$

By subtracting off the county-time effect $\hat{\mu}_{lt}$,we purge the estimate of geographic effects. We then aggregate the firm's deposit productivity across counties as

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

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

displays the corresponding estimates. The independent variable of interest is the interaction of deposit productivity and the average deposit rate elasticity. The coefficient on the interaction term is negative and significant in each specification, indicating that deposit productivity creates more value when banks face relatively inelastic demand for deposits. The results in column (1) indicate that a one standard deviation increase in demand elasticity decreases the value of deposit productivity by 25%.

5.1.2 Alternative Production Function Estimates - Spline Estimation

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

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

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

We next replicate our main findings using the new production function estimates. These findings are reported in Table A2a. 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, and deposit productivity has a larger impact than asset productivity. Similarly, columns (3) and (4) indicate that there are strong synergies between deposit productivity and our alternative measure of asset productivity.

5.1.3 Alternative Production Function Estimates - Additional Risk Controls

We next 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 Appendix (Column 2 of Table A8). The production function estimates are comparable to our baseline estimates.

Using our alternative asset productivity estimates, we next replicate our main results. The results of this exercise are documented in Table A2b. 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 deposit productivity still has a larger impact. We also find evidence of strong synergies between deposit productivity and our alternative measure of asset productivity as reported in Columns (3) and (4).

5.2 Alternative Measures of Value and Return

In our baseline analysis we document the relationship between a bank's market-to-book and its deposit and asset productivity. Our main findings are robust to other measures of bank value and return such as Tobin's q and return on equity (ROE).[27] Tables A4a and A4b display the results corresponding to our main specification (Eq. 9) with alternative value and return measures. The estimates displayed in Table A4a show that, as with market-to-book, there is a strong positive relationship between Tobin's q and deposit productivity. In contrast, while we find a positive relationship between Tobin's q and asset productivity, this relationship is economically and statistically insignificant. Hence, as with market-to-book, deposit productivity explains a larger portion of the cross section of Tobin's q than asset productivity. The results in Table A4b show that our main findings hold for ROE as well. Both deposit and asset productivity are positively correlated with ROE, but ROE loads about twice as much on deposit productivity relative to asset productivity. Since market-to-book can be mechanically decomposed into the product of ROE and the price-earnings ratio, these results also show that our main results using the market-to-book cannot be explained by correlation between our productivity measures and components of the price-earnings ratio: expectations of future growth, risk, and returns.

[27] We calculate Tobin's q as equity market capitalization plus book value of liabilities divided by its book value of assets.

5.3 Measurement Error

Because our productivity estimates are estimated, they inherently contain measurement error. This may lead us to overstate the amount of variation in productivity and bias down the relationship between productivity and value. 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 alternatives.

5.3.1 Instrumental Variables

We instrument for our measures of deposit and asset productivity using our subcategory measures of productivity. Specifically, we instrument for total deposit productivity using our productivity estimates for savings deposits, small time deposits and other types of deposits. Similarly, we instrument for total asset productivity using our separate estimates of loan and asset productivity. As discussed in Section 4.3.1, our instruments are clearly relevant (Table 5 columns 1-4). Provided that the measurement error in our productivity estimates (assets and deposits) is orthogonal to the subcategory productivity measures, our instrumental variable strategy is valid and will correct for any bias caused by measurement error.

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

5.3.2 Empirical Bayes Estimation

We construct empirical Bayes estimates of deposit and asset productivity as an additional robustness check. Much of our analysis is focused on the distributions of deposit and asset productivity in the population of banks. If our estimates of productivity suffer from classical measurement error, then the estimated distributions productivity will overstate the true variance of productivity.[28] As is common in the education and labor literature (e.g., Jacob and Lefgren, 2008; Kane and Staiger, 2008; and Chettty, Friedman, and Rockhoff, 2014), we shrink the estimated distributions of asset and deposit productivity to match the true distribution of asset and deposit productivity.

Here, we examine a bank's average deposit and asset productivity in our sample using the estimated bank specific fixed effect in Eqs. (5) and (8). We shrink the estimated distribution of fixed effects by the factor λ, which is estimated from the data. Under the assumption that the variance of the estimation error is homoskedastic, the appropriate scaling factor is $\lambda = \frac{F-1-\frac{2}{k-1}}{F}$, 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 Figure 1 using our empirical Bayes estimates of deposit and asset productivity and display the corresponding results in Figure A1. Figure 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 effects on net income of deposit productivity (red shaded area) and asset productivity (blue shared area) are nearly identical in Figs. 1 and A1. Again, about twice as much of the variation in bank net income can be explained by productivity heterogeneity on the deposit side relative to productivity heterogeneity on the asset side.

5.4 Sub-sample Analysis

We run several robustness checks regarding the set of banks in our sample, excluding the largest banks, observations from the financial crisis, and nontraditional banks with business models not centered around branch deposit taking and lending.

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

5.4.1 Excluding Large Banks

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

5.4.2 Excluding the Financial Crisis

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) in Table A6b. 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.

5.4.3 Excluding Non-traditional Banks

The scope of business activities that bank holding companies engage in has broadened over time. We separately examine those banks that follow a traditional deposit taking and lending business model. Specifically, in Table A6c, we restrict our data set to bank-quarter observations for which the bank operated at least two branches and generated at least two-thirds (90% of obs.) of its income from interest. The results indicate that our main findings holding hold for the set of traditional banks and are not driven by the growth of the non-traditional banking sector. Among traditional banks we find that both deposit and asset productivity contribute to value but value loads more heavily on deposit productivity, and that there are strong synergies between deposit and asset productivity.

6 Conclusion

What are the key cross-sectional determinants of bank value? In this paper, we draw upon the industrial organization literature to develop a simple empirical framework to answer this question. In our framework, banks can create value through three primary mechanisms: through excelling at the gathering of deposits, through excelling at the production of loans and other assets, and through synergies between loan and deposit production.

We find evidence that all three channels affect bank value and that their contributions vary across bank. 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. Moreover, we find that savings deposit productivity is particularly important for explaining bank value: the liabilities that are most strongly associated with value are not those that provide the most transaction and liquidity services; instead safety seems to be the key service banks provide. All together, our paper represents the first attempt to provide evidence on all three sources of potential bank value creation within a unified framework, and to assess which theoretical levers are most important in explaining the cross-section of value.

Our results also have implications for financial regulation and the future of the banking industry. Without quantitatively understanding the main drivers of bank value, it is difficult to determine the costs and benefits of financial regulations. Similarly, understanding the sources of bank value sheds light on how the industry may evolve as customer demographics change and competitor products emerge.

References

Acharya, Viral V., Iftekhar Hasan and Anthony Saunders. 2006. "Should Banks Be Diversified? Evidence from Individual Bank Loan Portfolios." *Journal of Business* 79(3): 1355-1412.

Ackerberg, Daniel, C. Lanier Benkard, Steven Berry, and Ariel Pakes. 2007. "Econometric Tools for Analyzing Market Outcomes." In *Handbook of Econometrics, Volume 6A*, ed. James J. Heckman and Edward E. Leamer, 4171–276. Amsterdam and Boston: Elsevier, North-Holland.

Aguirregabiria, Victor, Robert Clark, and Hui Wang. 2017. "The Geographic Flow of Bank Funding: Branch Networks and Local-Market Competition." Working Paper.

Allen, Franklin. 1990. "The Market for information and the Origin of Financial Intermediation." *Journal of Financial Intermediation* 1(1): 3-30.

Allen, Franklin, Elena Carletti, and Robert Marquez. 2011. "Credit Market Competition and Capital Regulation." *Review of Financial Studies* 24(4): 983-1018.

Bai, Jennie, Arvind Krishnamurthy, and Charles-Henri Weymuller. 2016. "Measuring Liquidity Mismatch in the Banking Sector." Stanford Working Paper.

Baker, Malcolm and Jeffrey Wurgler. 2015. "Do strict capital requirements raise the cost of capital? Bank regulation, capital structure, and the low-risk anomaly." *American Economic Review* 105(5): 315-320.

Ben-David, Itzhak, Ajia Palvia, and Chester Spatt. 2016. "Banks' Internal Capital Markets and Deposit Rates." *Journal of Financial and Quantitative Analysis*, forthcoming.

Berger, Allen N. and Christa H. S. Bouwman. 2009. "Bank Liquidity Creation." *Review of Financial Studies* 22(9): 3779-3837.

Berger, Allen N. and Loretta J. Mester. 1997. "Inside the black box: What explains differences in the efficiencies of financial institutions?" *Journal of Banking and Finance* 21: 895-947.

Berger, Allen N. and Loretta J. Mester. 2003. "Explaining the dramatic changes in performance of US banks: technological change, deregulation, and dynamic changes in competition." *Journal of Financial Intermediation* 12: 57-95.

Berger, Allen N. and Gregory F. Udell. 1995. "Relationship Lending and Lines of Credit in Small Firm Finance." *Journal of Business* 68(3): 351-381.

Berlin, Mitchell and Loretta J. Mester. 1999. "Deposits and Relationship Lending." *Review of Financial Studies* 12(3): 579-607.

Berry, Steven. 1994. "Estimating discrete-choice models of product differentiation." *RAND Journal of Economics* 25(2): 242-262.

Berry, Steven, James Levinsohn, and Ariel. Pakes. 1995. "Automobile prices in market equilibrium." *Econometrica* 63(4): 841-890.

Billett, Matthew T. and Jon A. Garfinkel. 2004. "Financial Flexibility and the Cost of External Finance for U.S. Bank Holding Companies." *Journal of Money, Credit, and Banking* 36(5): 827-852.

Bulow, Jeremy, and Paul Klemperer. 2013. "Market-based bank capital regulation." Working Paper.

Boyd, John H. and Edward Prescott. 1986. “Financial intermediary-coalitions.” *Journal of Economic Theory* 38(2): 211-232.

Calomiris, Charles W. and Charles M. Kahn. 1991. “The Role of Demandable Debt in Structuring Optimal Banking Arrangements.” *American Economic Review* 81(3): 497-513.

Casella, George. 1992. “Illustrating empirical Bayes methods.” *Chemometrics and Intelligent Laboratory Systems* 16(2): 107-125.

Chamley, Christophe, Laurence J. Kotlikoff, and Herakles Polemarchakis. 2012. "Limited-purpose banking—moving from “trust me” to “show me” banking." *The American Economic Review: Papers & Proceedings,* 102(3): 113-119.

Chetty, Raj, John Friedman, and John Rockhoff. 2014. “Measuring the Impacts of Teachers I: Evaluating Bias in Teacher Value-Added Estimates.” *American Economic Review* 104(9): 2593-2632

Cochrane, John H. 2014. "Toward a run-free financial system." Working Paper.

Corbae, Dean and Pablo D’Erasmo. “A Simple Quantitative General Equilibrium Model of Banking Industry Dynamics.” Working Paper.

Dang, Tri Vi, Gary Gorton, and Bengt Holmström. 2015. “Ignorance, Debt, and Financial Crises.” MIT Working Paper.

Dang, Tri Vi, Gary Gorton, Bengt Holmström, and Guillermo Ordoñez. 2016. “Banks as Secret Keepers.” NBER Working Paper 20255.

DeAngelo, Harry and Rene M. Stulz. 2015. “Liquid-claim production, risk management, and bank capital structure: Why high leverage is optimal for banks.” *Journal of Financial Economics* 116(2): 219-236.

Demsetz, Rebecca S. and Philip E. Strahan. 1997. “Diversification, Size, and Risk at Bank Holding Companies.” *Journal of Money, Credit and Banking* 29(3): 300-313.

Diamond, Douglas W. 1984. “Financial Intermediation and Delegated Monitoring.” *Review of Economic Studies* 51(3): 393-414.

Diamond, Douglas W. 1991. “Monitoring and Reputation: The Choice between Bank Loans and Directly Placed Debt.” *Journal of Political Economy* 99(4): 689-721.

Diamond, Douglas W. and Philip Dybvig. 1983. “Bank Runs Deposit Insurance, and Liquidity.” *Journal of Political Economy* 91(3): 401-419.

Diamond, Douglas W. and Raghuram G. Rajan. 2000. “A Theory of Bank Capital.” *Journal of Finance* 55(6): 2431-2465.

Diamond, Douglas W. and Raghuram G. Rajan. 2001. “Liquidity Risk, Liquidity Creation, and Financial Fragility: A Theory of Banking.” *Journal of Political Economy* 109(2): 287-327.

Dick, Astrid. 2008. “Demand estimation and consumer welfare in the banking industry.” *Journal of Banking and Finance* 32: 1661-1676.

Donaldson, Jason, Giorgia Piacentino, and Anjan Thakor. 2017. “Warehouse Banking.” Journal of Financial Economics, forthcoming.

Drechsler, Itamar, Alexi Savov, and Philipp Schnabl. 2016. "The Deposits Channel of Monetary Policy." NYU Stern Working Paper.

Driscoll, John C. and Ruth Judson. 2013. "Sticky Deposit Rates." FRB FEDS Working Paper 2013-80.

Egan, Mark, Ali Hortaçsu and Gregor Matvos. 2017. "Deposit Competition and Financial Fragility: Evidence form the US Banking Sector". *American Economic Review*,107(1): 169-216.

Fama, Eugene F. and Kenneth R. French. 1992. "The cross-section of expected stock returns." *Journal of Finance* 47(2): 427-465.

Fama, Eugene F. and Kenneth R. French. 1993. "Common risk factors in the returns on stocks and bonds." *Journal of Financial Economics* 33(1): 3-56.

Gatev, Evan and Philip E. Strahan. 2006. "Banks' Advantage in Hedging Liquidity Risk: Theory and Evidence from the Commercial Paper Market." *Journal of Finance* 61(2): 867-892

Gennaioli, Nicola, Andrei Shleifer, and Robert W Vishny. 2013. "A Model of Shadow Banking." *Journal of Finance* 68 (4): 1331-1363.

Gomez, Matthieu, Augustin Landier, David Sraer and David Thesmar. 2016. "Banks Exposure to Interest Rate Risk and The Transmission of Monetary Policy." Working paper.

Gorton, Gary, Stefan Lewellen, and Andrew Metrick. 2012. "The Safe-Asset Share." *American Economic Review: Papers and Proceedings* 102(3): 101-106.

Gorton, Gary and Andrew Metrick. 2010. "Regulating the Shadow Banking System." *Brookings Papers on Economic Activity* 2010 (2), 261-297.

Gorton, Gary and George Pennacchi. 1990. "Financial Intermediaries and Liquidity Creation." *Journal of Finance* 45(1): 49-71.

Granja, Joao, Gregor Matvos, and Amit Seru. 2016. "Selling Failed Banks." *Journal of Finance*, forthcoming.

Greenwood, Robin, Samuel G Hanson, and Jeremy C Stein. 2015. "A Comparative-Advantage Approach to Government Debt Maturity." Journal of Finance 70 (4): 1683-1722.

Griliches, Zvi, and Jacques Mairesse. 1998. "Production Functions: The Search for Identification." In *Econometrics and Economic Theory in the Twentieth Century: The Ragnar Frisch Centennial Symposium, ed. Steinar Strøm,* 169–203. Cambridge; New York and Melbourne: ambridge University Press.

Gurun, Umit,Gregor Matvos and Amit Seru. 2016. Advertising Expensive Mortgages. *Journal of Finance*, forthcoming.

Hadad, Valentin and David Sraer. 2015. "The Banking View of Bond Risk Premia." Working paper.

Hastings, Justine, Ali Hortaçsu and Chad Syverson. 2016. "Sales Force and Competition in Financial Product Markets: The Case of Mexico's Social Security Privatization." *Econometrica,* Forthcoming.

Hannan, Timothy H. and Allen N. Berger. 1991. "The Rigidity of Prices: Evidence from the Banking Industry." *American Economic Review* 81(4), 938-945.

Hanson, Samuel, Andrei Shleifer, Jeremy Stein, and Robert Vishny. 2016. “Banks as Patient Fixed-Income Investors.” *Journal of Financial Economics* 117: 449-469.

Holmes, Thomas, David Levine, and James Schmitz. 2012. “Monopoly and the Incentive to Innovate When Adoption Invovles Switchover Disruptions.” *American Economic Journal: Microeconomics,* 4(3): 1-33

Hortaçsu, Ali and Chad Syverson. 2004. “Product Differentiation, Search Costs, and Competition in the Mutual Fund Industry: A Case Study of S&P 500 Index Funds,” *Quarterly Journal of Economics*, 119(2): 403-456.

Hoshi, Takeo, Anil Kashyap, and David Scharfstein. 1990. “The role of banks in reducing the costs of financial distress in Japan.” *Journal of Financial Economics,* 27. 67-88. North-Holland.

Hoshi, Takeo, Anil Kashyap, and David Scharfstein. 1991. “Corporate Structure, Liquidity, and Investment: Evidence from Japanese Industrial Groups.” *Quarterly Journal of Economics,* 106(1). 33-60.

Hughes, Joseph P. and Loretta J. Mester. 1998. “Bank Capitalization and Cost: Evidence of Scale Economies in Risk Management and Signaling.” *Review of Economics and Statistics* 80(2): 314-325.

Jacob, Brian and Lars Lefgren. 2008. “Principals as Agents: Subjective Performance Assessment in Education.” *Journal of Labor Economics* 26(1): 101-136

Jayaratne, Jith and Philip E. Strahan. 1996. “The Finance-Growth Nexus: Evidence from Bank Branch Deregulation.” *Quarterly Journal of Economics* 111(3): 639-670.

Kane, Thomas J. and Douglas O. Staiger. 2008. “Estimating teacher impacts on student achievement: An experimental evaluation.” NBER Working Paper 14607.

Kay, John. 2009. “Narrow Banking: The Reform of Banking Regulation.” Working Paper.

Koijen, Ralph SJ, and Motohiro Yogo. 2015. “An Equilibrium Model of Institutional Demand and Asset Prices.” NBER Working Paper w21749.

Koijen, Ralph SJ, and Motohiro Yogo. 2016. "Shadow insurance." *Econometrica*, 84(3) : 1265-1287.

Kashyap, Anil K., Raghuram Rajan, and Jeremy C. Stein. 2002. “Banks as Liquidity Providers: An Explanation for the Coexistence of Lending and Deposit-taking.” *Journal of Finance* 57(1): 33-73.

Keeley, Michael C. 1990. “Deposit Insurance, Risk, and Market Power in Banking.” *American Economic Review* 80(5), 1183-1200.

Keys, Benjamin, Tanmoy Mukherjee, Amit Seru, and Vikrant Vig. “Did Securitization Lead to Lax Screening? Evidence From Subprime Loans.” *Quarterly Journal of Economics*, 2010, 125(1), pp. 307-362.

Krishnamurthy, Arvind and Annette Vissing-Jorgensen. 2012. “The Aggregate Demand for Treasury Debt.” *Journal of Political Economy* 120(2), 233-267.

Krishnamurthy, Arvind and Annette Vissing-Jorgensen. 2015. “The Impact of Treasury Supply on Financial Sector Lending and Stability.” *Journal of Financial Economics*, forthcoming.

Leland, Hayne E. and David H. Pyle. 1977. "Informational Asymmetries, Financial Structure, and Financial Intermediation." *Journal of Finance* 32(2): 371-387.

Levinsohn, James and Amil Petrin. 2003. "Estimating Production Functions Using Inputs to Control for Unobservables." *Review of Economic Studies* 70(2): 317–41.

Marschak, Jacob and William Andrews. 1944. "Random simultaneous equations and the theory of production." *Econometrica* 12, 143–205.

Maksimovic, Vojislav and Gordon Phillips. 2001. "The market for corporate assets: Who engages in mergers and asset sales and are there efficiency gains?" *Journal of Finance* 56(6): 2019-2065.

Martin, Chris, Manju Puri, and Alex Ufier. 2017. "On Deposit Stability in Failing Banks." Working Paper.

Mehran, Hamid and Anjan Thakor. 2011. "Bank Capital and Value in the Cross-Section." *Review of Financial Studies* 24(4): 1019-1067.

Mian, Atif and Amir Sufi. 2009. "The Consequences of Mortgage Credit Expansion: Evidence from the U.S. Mortgage Default Crisis." *Quarterly Journal of Economics* 124(4): 1449-1496.

Mian, Atif and Amir Sufi. 2010. "Household Leverage and the Recession of 2007 to 2009." *IMF Economic Review* 58(1): 74-117.

Mian, Atif and Amir Sufi. 2013. "House Prices, Home Equity-Based Borrowing, and the U.S. Household Leverage Crisis." *American Economic Review* 101(5): 2132-2156.

Mian, Atif and Amir Sufi. 2015. "Foreclosures, House Prices, and the Real Economy." *Journal of Finance* 70(6): 2587-2634.

Mian, Atif, Kamalesh Rao and Amir Sufi. 2013. "Household Balance Sheets, Consumption, and the Economic Slump." *Quarterly Journal of Economics* 128(4): 1687-1726.

Mian, Atif, Amir Sufi and Emil Verner. 2017. "Household Debt and Business Cycles Worldwide." *Quarterly Journal of Economics* forthcoming.

Minton, Bernadette, Rene Stulz, and Alvaro Taboada. 2017. "Are Larger Banks Valued More Highly?" Working paper.

Moreira, Alan and Alexi Savov. 2016. "The Macroeconomics of Shadow Banking." *Journal of Finance,* forthcoming.

Nagel, Stefan, 2016. "Liquidity Premia of Near-Money Assets." *Quarterly Journal of Economics*, forthcoming.

Neumark, David and Steven A. Sharpe. 1992. "Market Structure and the Nature of Price Rigidity: Evidence from the Market for Consumer Deposits." *Quarterly Journal of Economics* 107(2): 657-680.

Olley, G. Steven, and Ariel Pakes. 1996. "The Dynamics of Productivity in the Telecommunications Equipment Industry." *Econometrica* 64(6): 1263–97.

Pennacchi, George. 2012. "Narrow Banking." *Annual Review of Financial Economics* 4: 141-159.

Petersen, Mitchell A. and Raghuram G. Rajan. 1994. "The Benefits of Lending Relationships: Evidence from Small Business Data." *Journal of Finance* 49(1): 3-37.

Rajan, Raghuram. 1992. “Insiders and Outsiders: The Choice between Informed and Arm’s-Length Debt.” *Journal of Finance* 47(4): 1367-1400.

Ramakrishnan, Ram T. S. and Anjan V. Thakor. 1984. “Information Reliability and a Theory of Financial Intermediation.” *Review of Economic Studies* 51(3): 415-432.

Rime, Bertrand and Kevin J. Stiroh. 2003. “The performance of universal banks: Evidence from Switzerland.”*Journal of Banking and Finance* 27: 2121-2150.

Schoar, Antoinette. 2002. “Effects of corporate diversification on productivity.” *Journal of Finance* 57(6): 2379-2403.

Shockley, Richard L. and Anjan V. Thakor. 1997. “Bank Loan Commitment Contracts: Data, Theory, and Tests.” *Journal of Money, Credit and Banking* 29(4): 517-534.

Stein, Jeremy C. 2012. “Monetary Policy as Financial-Stability Regulation.” *Quarterly Journal of Economics* 127 (1): 57-95.

Stiroh, Kevin J. 2000. “How did bank holding companies prosper in the 1990s?.” *Journal of Banking and Finance* 24: 1703-1745.

Sufi, Amir. 2007. “Information Asymmetry and Financing Arrangements: Evidence from Syndicated Loans.” *Journal of Finance* 62(2): 629-668.

Sunderam, Adi. 2015. “Money Creation and the Shadow Banking System.” *Review of Financial Studies*, 28 (4): 939-977.

Syverson, Chad. 2004. “Market Structure and Productivity: A Concrete Example.” *Journal of Political Economy,* 112(6): 1181-1222.

Syverson, Chad. 2011. “What Determines Productivity?” *Journal of Economic Literature* 49(2): 326-65.

van Biesebroeck, Johannes. 2008. “Aggregating and Decomposing Productivity.” *Review of Business and Economics* 53(2): 122-146.

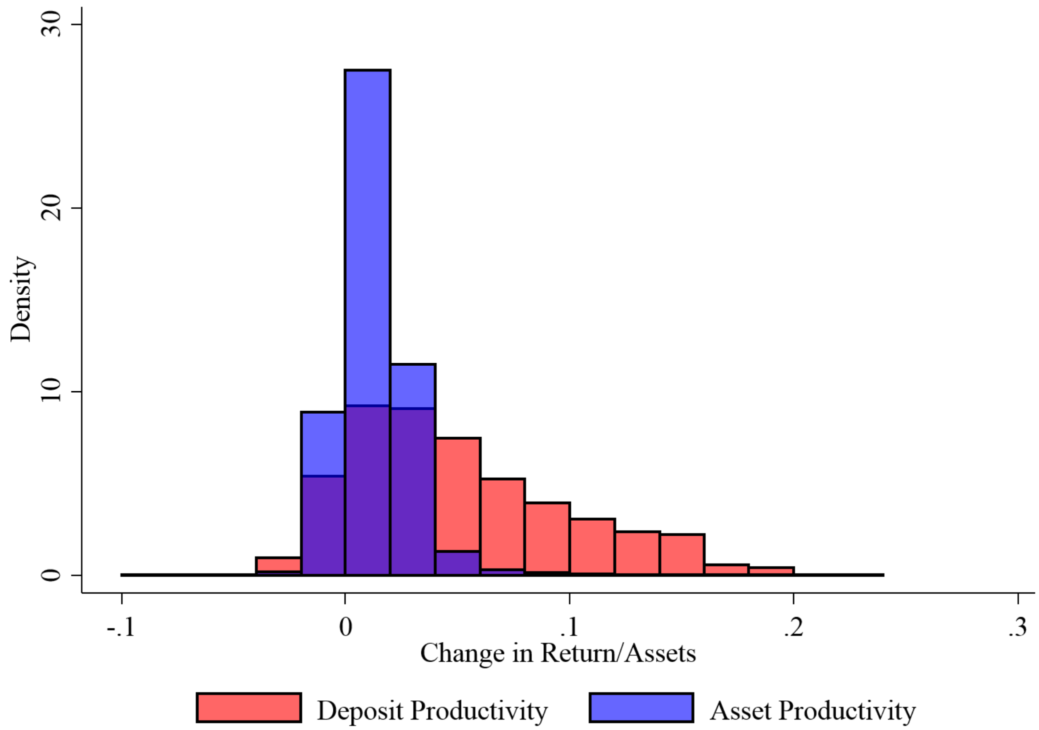
Villas-Boas, S.B. 2007. “Vertical relationships between manufacturers and retailers: Inference with limited data.” *Review of Economic Studies* 74(2): 625-652.

Wang, J. Christina. 2003. “Productivity and Economies of Scale in the Production of Bank Service Value Added.” FRB of Boston Working Paper 03-7.

Winton, Andrew. 1995. “Delegated Monitoring and Bank Structure in a Finite Economy.” *Journal of Financial Intermediation* 4(2): 158-187.

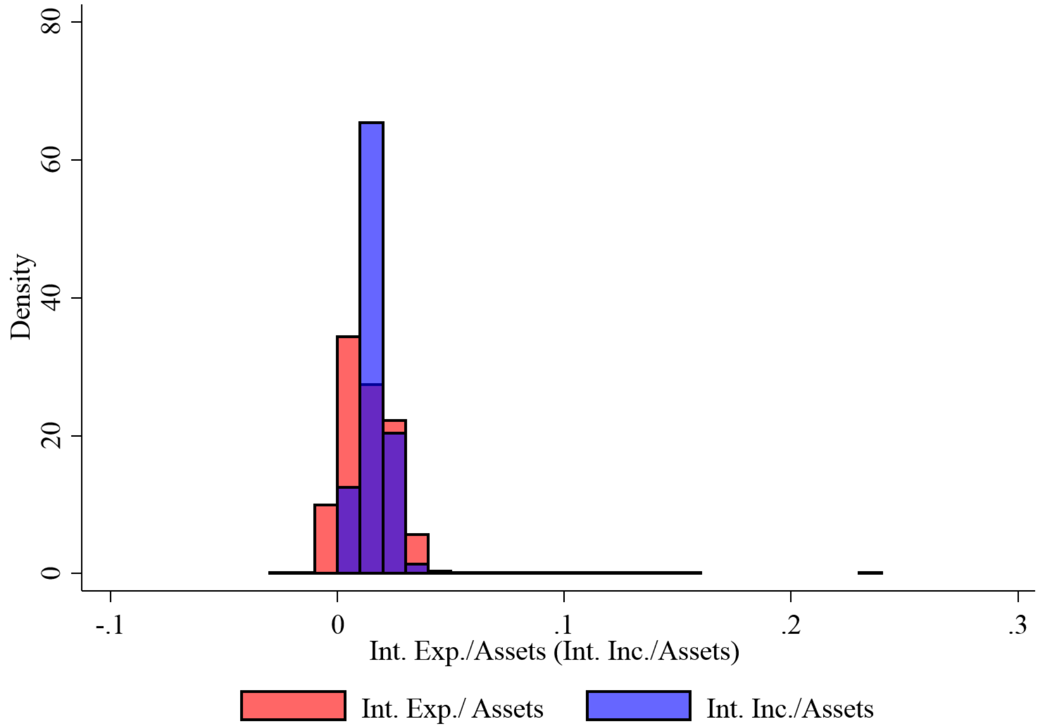
Figures

Figure 1: Value Creation: Asset Productivity vs. Deposit Productivity



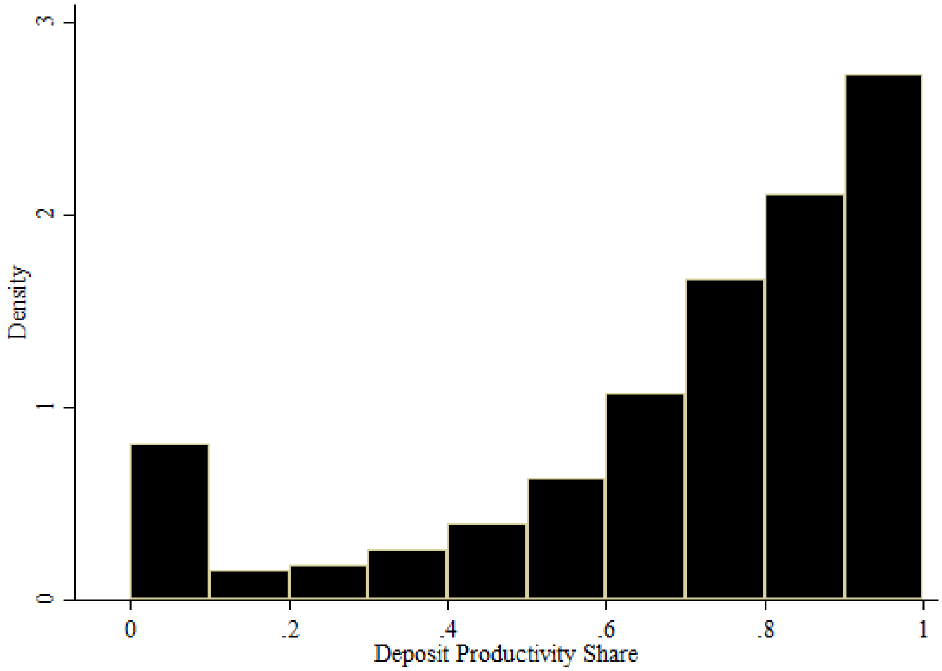
Note: Figure 1 displays the estimated distributions of asset and deposit productivity. The red shaded histogram plots the distribution of bank deposit productivity weighted by $\overline{\frac{Deposits}{Assets}\frac{1}{\alpha}}$. The blue histogram displays the scaled distribution of asset productivity $\frac{\overline{Assets}^{\theta}}{Assets} exp(\phi_{jt} + \overline{\Gamma X_{jt}})$. We normalize the level of asset productivity relative to five year constant maturity treasury rates such that the small set of banks earning risk adjusted returns below the five year treasury rate have negative asset productivity. Similarly, we also normalize the deposit productivity distribution relative to 3-month LIBOR such that the small set of banks that offer deposit rates above 3-month LIBOR have negative deposit productivity.. The deposit productivity estimates correspond to the specification reported in column (4) of Table 2. The asset productivity estimates correspond to specification reported in column (4) of Table 3.

Figure 2: Interest Expense vs Interest Income



Note: Figure 2 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 3: Deposit Productivity Share



Note: Figure 3 displays the distribution of the deposit value share of each bank. The deposit value share reflects the percentage of bank value that is generated by deposit productivity relative to asset productivity. We censor those observations with negative deposit value shares at zero and those observations with deposit value shares greater than 1 at 1. To construct Figure 3 we normalize the level of asset productivity relative to five year constant maturity treasury rates such that the small set of banks earning risk adjusted returns below the five year treasury rate have negative asset productivity. Similarly, we also normalize the deposit productivity distribution relative to 3-month LIBOR such that the small set of banks that offer deposit rates above 3-month LIBOR have negative deposit productivity. The deposit and asset productivity estimates correspond the specifications reported in columns (4) of Table 2 and Table 3.

Tables

Table 1: Summary Statistics

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

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

Table 2: Deposit Demand

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

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

Table 3: Bank Production Function (Asset Income)

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

Note: We report our asset income production function estimates (Eq. 8) in Table 3. The unit of observation is at the bank by quarter level over the period 1994 through 2015. The dependent variable is the logged value of interest income earned by the bank. The key independent variable of interest is the log value of a bank's assets lagged by one year. Because of the potential endogeneity of assets, we instrument for assets in columns (3) and (4). Specifically, we instrument for assets using the weighted average of the deposit product characteristics of a bank 's competitors as described in Section 3.3. We also control for the bank's equity beta, standard deviation of return on assets (standardized), and leverage. We measure equity beta on a rolling basis using monthly equity returns over the previous 24 months using data from CRSP and Kenneth French. We measure the standard deviation of return on assets on a rolling basis using quarterly income statement/balance sheet data over the previous eight quarters. Standard errors are clustered at the bank level and are reported in parentheses. The symbols *,**, 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***
	(0.0187)	(0.0996)			(0.0311)	(0.0922)
Asset Productivity			0.225***	0.144***	0.0878***	0.100***
			(0.0273)	(0.0296)	(0.0332)	(0.0301)
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.9). The dependent variable is the bank's market-to-book ratio. The key independent variables of interest are deposit and asset productivity. Both deposit and asset productivity are standardized. The deposit productivity estimates correspond to specification reported in column (4) of Table 2. The asset productivity estimates correspond to specification reported in column (4) of Table 3. The unit of observation is at the bank by quarter level over the period 1994 through 2015. Other controls include assets (lagged by one year), leverage (lagged by one quarter), three-month returns (lagged by one quarter), equity beta, and the standard deviation of return on assets. The standard errors are reported in parenthesis and are cluster bootstrapped at the bank level (n=1,000) to account for the two stage estimation procedure. The symbols *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 5: Deposit and Asset Productivity Subcategories

Dep. Var	Deposit Productivity		Asset Productivity		Market to Book	
	(1)	(2)	(3)	(4)	(5)	(6)
Deposit Prod.:						
Savings	0.734***	0.628***			0.252***	0.368***
	(0.0517)	(0.0634)			(0.0433)	(0.0644)
Small Time	0.125***	0.0945***			-0.228***	-0.180***
	(0.0357)	(0.0265)			(0.0473)	(0.0491)
Large Time	0.179***	0.156***			0.0379	0.0724**
	(0.0289)	(0.0170)			(0.0299)	(0.0284)
Transaction	0.414***	0.371***			0.0594*	0.104***
	(0.0327)	(0.0282)			(0.0324)	(0.0332)
Asset Prod.:						
Loans			0.166***	0.161***	0.0675**	0.0749***
			(0.0247)	(0.0172)	(0.0322)	(0.0278)
Securities			0.0154	0.0159***	0.0294	0.0697***
			(0.0233)	(0.00433)	(0.0242)	(0.0228)
Time F.E.	X	X	X	X	X	X
Other Controls		X		X		X
Observations	22,345	22,345	18,323	18,323	16,724	16,724
R-squared	0.979	0.981	0.668	0.681	0.460	0.492

Note: Table 5 displays the relationship between our more refined measures of productivity, overall productivity, and market-to-book. Overall deposit productivity is the dependent variable columns (1) and (2). We measure overall deposit productivity using the demand estimates reported in column (4) of Table 2. Overall asset productivity is the dependent variable columns (3) and (4). We measure overall asset productivity using the production function estimates reported in column (4) of Table 3. Market-to-book is the dependent variable in columns (5) and (6). We measure deposit productivity for savings deposits, small time deposits, large deposits, and transaction deposits using the corresponding demand estimates reported in Table A1a. We measure asset productivity for loans and savings deposits using the corresponding production function estimates reported in Table A1b. Observations are at the bank by quarter level over the period 1994-2015. Other controls include assets (lagged by one year), leverage (lagged by one quarter), 3-month returns (lagged by one quarter), equity beta, and sd of roa. The standard errors are reported in parenthesis and are cluster bootstrapped at the bank level (n=1,000) to account for the two stage estimation procedure. The symbols *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 6: Productivity vs. Composition of Assets and Liabilities

(a) Composition of Liabilities and Deposit Productivity

Dep. Var	Leverage	$\frac{\text{Deposits}}{\text{Liabilities}}$	$\frac{\text{Small Time}}{\text{Liabilities}}$	$\frac{\text{Large Time}}{\text{Liabilities}}$	$\frac{\text{Savings}}{\text{Liabilities}}$	$\frac{\text{Trans.}}{\text{Liabilities}}$	$\frac{\text{FF+Repo}}{\text{Liabilities}}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Deposit Prod.	0.0225***	1.773***	-0.347*	0.137	1.354***	0.432**	-0.320
	(0.00815)	(0.252)	(0.183)	(0.146)	(0.201)	(0.174)	(0.281)
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	$\frac{\text{RE Loans}}{\text{Assets}}$	$\frac{\text{C\&I Loan}}{\text{Assets}}$	$\frac{\text{Loan Commit.}}{\text{Assets}}$	$\frac{\text{Securities}}{\text{Assets}}$	$\frac{\text{Cash}}{\text{Assets}}$	$\frac{\text{FF+Repo}}{\text{Assets}}$
	(1)	(2)	(3)	(4)	(5)	(6)
Asset Prod.	0.348***	0.157***	0.0938*	-0.462***	-0.338***	-0.295***
	(0.0461)	(0.0451)	(0.0525)	(0.0495)	(0.0325)	(0.0668)
Time F.E.	X	X	X	X	X	X
Other Controls	X	X	X	X	X	X
Observations	24,633	23,685	26,742	26,713	26,732	18,047
R-squared	0.353	0.057	0.134	0.147	0.235	0.116

Note: Table 6 panels (a) and (b) display the relationship between productivity and a bank's liability and asset structure. In Table 6a, we regress bank leverage and the composition of its deposits on deposit productivity. We measure deposit productivity using the demand estimates reported in column (4) of Table 2. In Table 6b, we regress the composition of a bank's assets on asset productivity. We measure asset productivity using the estimates reported in column (4) of Table 3. Observations in both Tables 6a and 6b are at the bank by quarter level over the period 1994-2015. Other controls include assets (lagged by one year), leverage (lagged by one quarter), three-month returns (lagged by one quarter), equity beta, and the standard deviation of return on assets. The standard errors are reported in parenthesis and are cluster bootstrapped at the bank level (n=1,000) to account for the two stage estimation procedure. The symbols *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 7: Demographic Characteristics

(a) Productivity and Demographic Characteristics

Dep. Var.	Asset Productivity		Deposit Productivity	
	(1)	(2)	(3)	(4)
ln(Population)	0.235***	0.201***	0.611***	0.352***
	(0.0342)	(0.0336)	(0.0571)	(0.0430)
ln(Population)^2	-0.0467***	-0.010	-0.126***	-0.037**
	(0.0159)	(0.0144)	(0.0252)	(0.0199)
ln(Wage)	-0.203***	-0.154***	-0.179**	-0.005
	(0.0494)	(0.0553)	(0.0790)	(0.0757)
ln(Wage)^2	-0.0452**	-0.024*	0.0257	0.001
	(0.0216)	(0.0175)	(0.0250)	(0.0208)
ln(Branch Age)	-0.00839	-0.101***	0.413***	0.142***
	(0.0267)	(0.0284)	(0.0403)	(0.0358)
ln(House Prices)	0.119***	0.085**	0.107*	0.032
	(0.0432)	(0.0410)	(0.0644)	(0.057)
HMDA HHI	0.103***	0.064***		
	(0.0289)	(0.0263)		
Deposit HHI			0.189***	0.068***
			(0.0352)	(0.0250)
Time F.E.	X	X	X	X
MSA F.E.		X		X
Observations	26,742	26,742	26,742	26,742
R-squared	0.557	0.707	0.331	0.767

(b) Controlling for Geography

Dep. Var.	Market-to-Book		Asset Productivity	
	(1)	(2)	(3)	(4)
Deposit Productivity	0.340***	0.495***	0.350**	0.718**
	(0.0611)	(0.104)	(0.173)	(0.283)
Asset Productivity	0.173***	0.168***		
	(0.0396)	(0.0385)		
Time F.E.	X	X	X	X
MSA F.E.	X	X	X	X
Demographic Controls	X	X	X	X
Other Controls		X		X
Observations	23,617	23,617	23,617	23,617
R-squared	0.609	0.628	0.745	0.758

Note: In Table 7a we show how deposit and asset productivity correlate with the geographic characteristics of areas where banks operate. In Table and 7b, we replicate our baseline set of results controlling for fixed effects for each MSA a bank operates in. We measure deposit and asset productivity using the estimates reported in columns (4) of Table 2 and 3. Observations are at the bank by quarter level over the period 1994-2015. Other controls include assets (lagged by one year), leverage (lagged by one quarter), three-month returns (lagged by one quarter), equity beta, and the standard deviation of return on assets. Standard errors in panel (a) are clustered at the bank level and are reported in parentheses. The demographic controls used in panel (b) are the same variables shown in panel (a). The standard errors in panel (b) are cluster bootstrapped at the bank level (n=1,000) to account for the two stage estimation procedure for the independent variables. The symbols *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 8: Productivity and Quality

	Deposit Productivity		Asset Productivity	
	(1)	(2)	(3)	(4)
CFPB Complaints	-0.274**	-0.0961***	0.0813	-0.0109
	(0.108)	(0.0247)	(0.165)	(0.148)
Time F.E.	X	X	X	X
Other Controls		X		X
Observations	222	222	222	2222
R-squared	0.100	0.923	0.042	0.187

Note: Tables 8 displays the relationship between productivity and the quality of services a bank offers. The dependent variable in columns (1)-(2) is deposit productivity and the dependent variable columns (3)-(4) is asset productivity. We measure deposit and asset productivity using the estimates reported in columns (4) of Tables 2 and 3. The key independent variable of interest is CFPB Complaints. CFPB Complaints measures the number of complaints a bank receives in a given year per dollar of deposits collected and is standardized. Observations are at the bank by year level. 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. The symbols *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 9: Productivity and Rate Setting Technology

Dep. Var	Deposit Productivity		Asset Productivity	
	(1)	(2)	(3)	(4)
Variation in Deposit Rates (σ_{CD})	0.237***	0.0299**		
	(0.0359)	(0.0131)		
Variation in Mortgage Rates (σ_{MTG})			0.123***	0.0223
			(0.0437)	(0.0191)
Time F.E.	X	X	X	X
Other Controls		X		X
Observations	3,141	3,141	1,282	1,282
R-squared	0.059	0.910	0.390	0.624

Note: Table 9 displays the relationship between productivity and the variation in rates set by a bank. Each column corresponds to a separate linear regression. The dependent variable in columns (1)-(2) is deposit productivity as measured using the demand estimates reported in column (4) of Table 2. The dependent variable in columns (3)-(4) is asset productivity as measured using the production function estimates reported in column (4) of Table 3. The independent variables Variation in Deposit Rates and Variation in Mortgage Rates are standardized and measure the standard deviation of deposit and mortgage rates offered by a bank across the counties it operates in a given year. The symbols *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 10: Deposit and Asset Synergies

(a) Deposit vs. Asset Productivity

Dep. Var	Asset Productivity		Loan Productivity		Sec. Productivity	
	(1)	(2)	(3)	(4)	(5)	(6)
Deposit Productivity	0.328***	0.441***	0.504***	0.340**	0.692***	0.0985
	(0.108)	(0.116)	(0.0594)	(0.149)	(0.0404)	(0.0751)
Time F.E.	X	X	X	X	X	X
Other Controls		X		X		X
Observations	26,742	26,742	18,360	18,360	19,467	19,467
R-squared	0.630	0.644	0.409	0.420	0.612	0.647

(b) Deposit vs. Asset Productivity - Subcategory Measures

Dep. Var	Asset Productivity		Loan Productivity		Sec. Productivity	
	(1)	(2)	(3)	(4)	(5)	(6)
Deposit Prod.:						
Savings	0.136**	0.275***	0.215***	0.215***	0.448***	0.0667
	(0.0638)	(0.0632)	(0.0569)	(0.0757)	(0.0474)	(0.0475)
Small Time	0.164***	0.194***	0.292***	0.296***	0.122***	0.00589
	(0.0509)	(0.0509)	(0.0463)	(0.0545)	(0.0400)	(0.0331)
Large Time	0.121**	0.124**	0.100*	0.109**	0.0890**	0.0193
	(0.0486)	(0.0504)	(0.0524)	(0.0536)	(0.0360)	(0.0252)
Transaction	-0.0188	0.0414	-0.0164	-0.0172	0.0798**	-0.0510
	(0.0418)	(0.0360)	(0.0418)	(0.0426)	(0.0368)	(0.0332)
Time F.E.	X	X	X	X	X	X
Other Controls		X		X		X
Observations	22,345	22,345	16,753	16,753	17,269	17,269
R-squared	0.646	0.666	0.602	0.607	0.607	0.650

Note: Tables 10a and 10b display the relationship between deposit productivity and asset productivity (Eq. 11). Each column corresponds to a separate linear regression. The dependent variable in columns (1)-(2) is overall productivity as measured using the production function estimates reported in column (4) of Table 3. The dependent variable in columns (3)-(4) is loan productivity as measured using the production function estimates reported in column (1) of Table A1b. The dependent variable in columns (5)-(6) is securities productivity as measured using the production function estimates reported in column (2) of Table A1b. The key independent variable of interest is deposit productivity. We measure overall deposit productivity using the demand estimates reported in column (4) of Table 2 and deposit productivity for each type of deposit using the demand estimates reported in Table A1a. Observations are at the bank by quarter level over the period 1994-2015. Other controls include assets (lagged by one year), leverage (lagged by one quarter), three-month returns (lagged by one quarter), equity beta, and the standard deviation of return on assets. The standard errors are reported in parenthesis and are cluster bootstrapped at the bank level (n=1,000) to account for the two stage estimation procedure. The symbols *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table 11: Productivity vs. Composition of Assets and Liabilities

(a) Composition of Assets and Deposit Productivity

Dep. Var	$\frac{\text{RE Loans}}{\text{Assets}}$	$\frac{\text{C\&I Loan}}{\text{Assets}}$	$\frac{\text{Loan Commit.}}{\text{Assets}}$	$\frac{\text{Securities}}{\text{Assets}}$	$\frac{\text{Cash}}{\text{Assets}}$	$\frac{\text{FF+Repo}}{\text{Assets}}$
	(1)	(2)	(3)	(4)	(5)	(6)
Deposit Prod.	0.165	0.705***	0.255**	-0.0280	-0.131	-0.665**
	(0.138)	(0.153)	(0.115)	(0.169)	(0.0812)	(0.275)
Time F.E.	X	X	X	X	X	X
Other Controls	X	X	X	X	X	X
Observations	24,633	23,685	26,742	26,713	26,732	18,047
R-squared	0.314	0.090	0.136	0.068	0.193	0.123

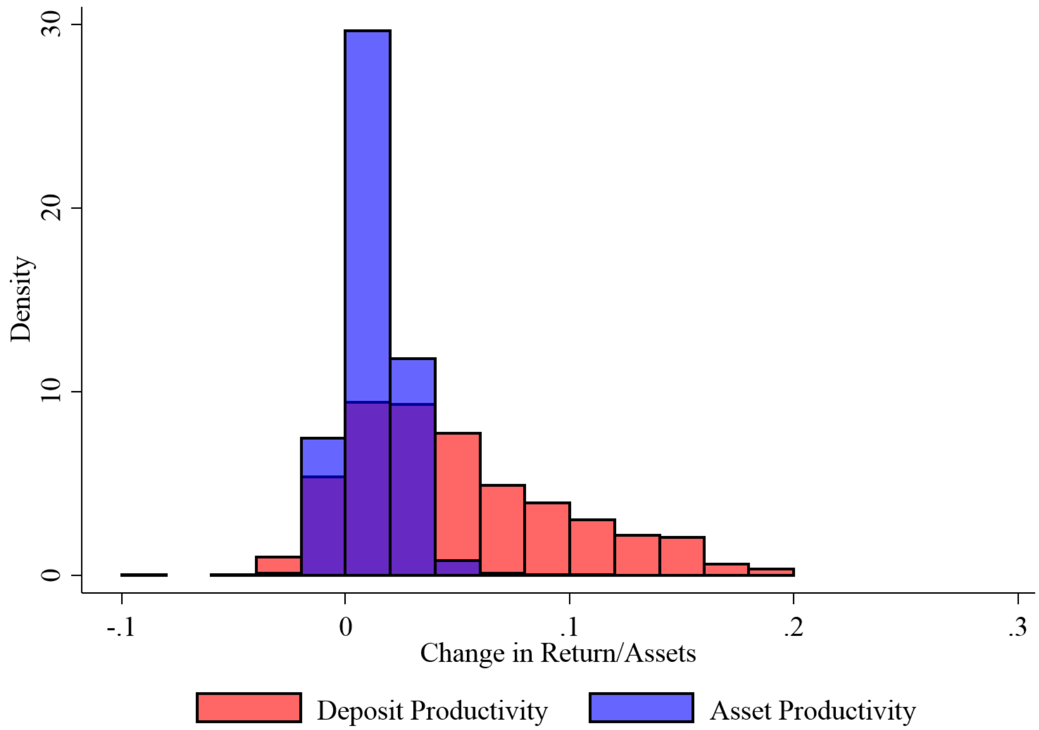
(b) Composition of Liabilities and Asset Productivity

Dep. Var	Leverage	$\frac{\text{Deposits}}{\text{Liabilities}}$	$\frac{\text{Small Time}}{\text{Liabilities}}$	$\frac{\text{Large Time}}{\text{Liabilities}}$	$\frac{\text{Savings}}{\text{Liabilities}}$	$\frac{\text{Trans.}}{\text{Liabilities}}$	$\frac{\text{FF+Repo}}{\text{Liabilities}}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Asset Prod.	0.00278	0.162***	0.100**	0.284***	0.0409	-0.202***	-0.115
	(0.00519)	(0.0406)	(0.0415)	(0.0408)	(0.0404)	(0.0359)	(0.0703)
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 11 (a) and (b) display the relationship between productivity and a bank's liability and asset structure. In Table 11a, we regress the composition of a bank's assets on deposit productivity. We measure deposit productivity using the demand estimates reported in column (4) of Table 2. In Table 11a, 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 11a and 11b 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. The standard errors are reported in parenthesis and are cluster bootstrapped at the bank level (n=1,000) to account for the two stage estimation procedure. The symbols *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Online Appendix – Figures and Tables

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



Note: Figure A1 displays the distributions of our empirical Bayes estimates of asset and deposit productivity as discussed in Section 5.3.2. Specifically, we "shrink" the estimated distribution of asset and deposit productivity to account for measurement error. The red shaded histogram plots the distribution of our empirical Bayes estimates of bank deposit productivity weighted by $\overline{\frac{Deposits}{Assets}}\frac{1}{\alpha}$. The blue histogram displays the distribution of our empirical Bayes estimates of asset productivity $\frac{\overline{Assets}^{\theta}}{Assets}exp(\phi_{jt}+\overline{\Gamma X_{jt}})$. We normalize the level of asset productivity relative to five year constant maturity treasury rates such that the small set of banks earning risk adjusted returns below the five year treasury rate have negative asset productivity. Similarly, we also normalize the deposit productivity distribution relative to 3-month LIBOR such that the small set of banks that offer deposit rates above 3-month LIBOR have negative deposit productivity. The deposit productivity estimates correspond to specification reported in column (4) of Table 2. The asset productivity estimates correspond to specification reported in column (4) of Table 3.

Table A1: Refined Demand and Production Function Estimates

(a) Demand for Deposits by Type of Deposit

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

(b) Bank Production Function by Asset Type

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

Note: Table A1a reports our baseline demand estimates for each type of deposit. The key independent variable of interest is the deposit rate offered for each bank. Because of the potential endogeneity of the deposit rate, we instrument for the deposit rate using two sets of instruments. We construct our first instrument (IV-1) as the estimated deposit rate from a bank specific pass-through regression of deposit rates on 3-month LIBOR. We construct our second instrument (IV-2) as the average of the product characteristics offered by a bank's competitors in the previous quarter (branches, employees, non-interest expense, and fees). Specifically, we calculate the average product characteristics of a bank's competitors in each county the bank operates in a given year, and then we calculate the average across all counties the bank operates in. We winsorize all independent variables at the 1% to help control for outliers in the sample. Standard errors are clustered by bank and are reported in parentheses. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.
Table A1b reports our asset production function estimates for loans and securities. The unit of observation is at the bank by quarter level over the period 1994 through 2015. The dependent variable in column (1) (column 2) is the logged value of loan (securities) interest income earned by the bank. The key independent variable of interest in column (1) (column 2) is the log value of the bank loans (securities) lagged by one year. We also control for the bank's equity beta, standard deviation of return on assets (standardized), and leverage. We measure equity beta on a rolling basis using monthly equity returns over the previous 24 months using data provided by CRSP and Kenneth French. We measure the standard deviation of return on assets on a rolling basis using quarterly income statement/balance sheet data over the previous eight quarters. Standard errors are clustered at the bank level and are reported in parentheses. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table A2: 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**
	(0.0320)	(0.116)	(0.0467)	(0.194)
Asset Productivity	0.0281	0.118***		
	(0.0364)	(0.0324)		
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***	0.373***	0.351***
	(0.0424)	(0.103)	(0.141)	(0.108)
Asset Productivity	0.0947*	0.107**		
	(0.0486)	(0.0467)		
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 A2a and A2b, we replicate our baseline set of results using our alternative measures of asset productivity. To construct the measure of asset productivity reported In Table A2a, we estimate the bank's asset income production function using a spline with five knot points as discussed in Section 5.1.2. To construct the measure of asset productivity reported In Table A2b, we estimate the bank's asset income production function where we control for the Fama French risk factors and the proportion of a bank's assets held in both loans and securities (both lagged by one year). We measure deposit productivity using the demand estimates reported in column (4) of Table 2. Observations in both Tables A2a and 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. The standard errors are reported in parenthesis and are cluster bootstrapped at the bank level (n=1,000) to account for the two stage estimation procedure. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table A3: Alternative Demand Estimates

(a) County Level Demand Estimates

	(1)	(2)	(3)
Deposit Rate	20.33	18.19**	21.02**
	(13.59)	(8.213)	(8.812)
Deposit Rate × Avg. Weekly Wage			11.78***
			(2.353)
Deposit Rate × Pct College			-10.87***
			(1.762)
Deposit Rate × Pct Over 65			6.013***
			(1.916)
No. of Branches (County Level)		1.257***	1.256***
		(0.0272)	(0.0269)
County×Year Fixed Effects	X	X	X
Bank Fixed Effects	X	X	X
IV	X	X	X
Observations	260,881	260,881	254,662
R-squared	0.659	0.779	0.777

(b) Alternative Demand Estimates - County Level Demand

Dep. Var.	Market-to-Book		Asset Productivity	
	(1)	(2)	(3)	(4)
Deposit Productivity	0.127***	0.138***	0.408***	0.227***
	(0.0321)	(0.0383)	(0.0373)	(0.0428)
Asset Productivity	0.0748**	0.0765**		
	(0.0348)	(0.0372)		
Time F.E.	X	X	X	X
Other Controls		X		X
Observations	3,045	3,045	3,045	3,045
R-squared	0.435	0.487	0.487	0.505

Table A3: Alternative Demand Estimates

(c) Market to Book and Average Elasticity

	(1)	(2)
Deposit Productivity	0.133***	0.154***
	(0.0330)	(0.0389)
Deposit Productivity × Deposit Rate Sensitivity	-0.0606***	-0.0612***
	(0.0202)	(0.0192)
Deposit Rate Sensitivity	-0.0181	-0.00990
	(0.0274)	(0.0260)
Asset Productivity	0.0744**	0.0782**
	(0.0351)	(0.0377)
Time F.E.	X	X
Other Controls		X
Observations	3,045	3,045
R-squared	0.440	0.491

Note: We report our demand estimates (Eq. 5) in Table A3a where 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.

In Table A3b, we replicate our baseline set of results using our alternative measure of deposit productivity. We measure deposit productivity using the demand estimates reported in column (3) of Table A3a. The asset productivity estimates correspond to specification reported in column (4) of Table 3.

Table A3c displays the relationship between a bank's market to book ratio and productivity (Eq. 9). The key independent variable of interest is the interaction between Deposit Productivity and Deposit Rate Sensitivity. Deposit Rate Sensitivity is standardized and measures the average deposit rate demand sensitivity $\bar{\alpha}_{jt}$ faced bank j in year t as per the demand estimates reported in column (3) of Table A3a. Observations in Tables A3b and A3c are at the bank by year level over the period 2002-2012. Other controls include assets (lagged by one year), leverage (lagged by one quarter), three-month returns (lagged by one quarter), equity beta, and the standard deviation of return on assets. Standard errors are clustered at the bank level and are reported in parentheses. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table A4: Alternative Measures of Value

(a) Tobin's q

	(1)	(2)	(3)	(4)	(5)	(6)
Deposit Productivity	0.232***	0.527***			0.246***	0.520***
	(0.0229)	(0.107)			(0.0315)	(0.107)
Asset Productivity			0.118***	0.0660**	-0.0446	0.0160
			(0.0289)	(0.0330)	(0.0427)	(0.0355)
Time F.E.	X	X	X	X	X	X
Other Controls		X		X		X
IV	X	X	X	X		
Observations	26,742	26,742	26,742	26,742	26,742	26,742
R-squared	0.388	0.462	0.343	0.441	0.388	0.462

(b) Return on Equity

	(1)	(2)	(3)	(4)	(5)	(6)
Deposit Productivity	0.113***	0.313***			0.0778***	0.261***
	(0.0127)	(0.0780)			(0.0222)	(0.0762)
Asset Productivity			0.159***	0.146***	0.107***	0.122***
			(0.0205)	(0.0216)	(0.0246)	(0.0218)
Time F.E.	X	X	X	X	X	X
Other Controls		X		X		X
IV	X	X	X	X		
Observations	26,742	26,742	26,742	26,742	26,742	26,742
R-squared	0.194	0.223	0.194	0.223	0.198	0.228

Note: In Tables A4a and A4b, we replicate our baseline set of results from eq. (9) using alternative measures of bank value and return. The dependent variable in Table A4a is Tobin's q and the dependent variable in Table A4b is the bank's return on equity (ROE). Tobin's q and ROE are standardized. The key independent variables of interest are deposit and asset productivity. Both deposit and asset productivity are standardized. The deposit productivity estimates correspond to specification reported in column (4) of Table 2. The asset productivity estimates correspond to specification reported in column (4) of Table 3. The unit of observation is at the bank by quarter level over the period 1994 through 2015. Other controls in Tables A4a and A4b include assets (lagged by one year), leverage (lagged by one quarter), three-month returns (lagged by one quarter), and equity beta. We also control for standard deviation of return on assets in table A4a. The standard errors are reported in parenthesis and are cluster bootstrapped at the bank level (n=1,000) to account for the two stage estimation procedure. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table A5: Measurement Error - Instrumental Variables

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

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

Table A6: Subsample Analysis

(a) Subsample Analysis - Excluding the Largest Banks

Dep. Var.	Market-to-Book		Asset Productivity	
	(1)	(2)	(3)	(4)
Deposit Productivity	0.224***	0.465***	0.341***	0.983***
	(0.0341)	(0.108)	(0.0990)	(0.236)
Asset Productivity	0.0957***	0.104***		
	(0.0314)	(0.0342)		
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***
	(0.0323)	(0.0919)	(0.108)	(0.119)
Asset Productivity	0.107***	0.113***		
	(0.0330)	(0.0308)		
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

(c) Subsample Analysis - Traditional Banks

Dep. Var.	Market-to-Book		Asset Productivity	
	(1)	(2)	(3)	(4)
Deposit Productivity	0.162***	0.766***	0.393***	0.533***
	(0.0311)	(0.0922)	(0.108)	(0.116)
Asset Productivity	0.207***	0.203***		
	(0.0332)	(0.0301)		
Time F.E.	X	X	X	X
Other Controls		X		X
Observations	23,942	23,942	23,942	23,942
R-squared	0.468	0.534	0.705	0.709

Note: In Tables A6a, A6b, and A6c we replicate our baseline set of results using different subsets of the data. In Table A6a, we replicate our baseline set of results where we exclude the largest banks from our sample. Specifically, we drop all observations of those banks that appear among the top 5% of the sample in terms of assets at any point in time. In Table A6a, we replicate our baseline set of results where we exclude all observations from the years surrounding the financial crisis (years 2008 and 2009). In Table A6c we replicate our baseline set of results where we restrict our data set to those banks who follow a traditional deposit taking and lending business model. Specifically, we restrict the data set to those observations in which a bank has at least two branches and generates roughly 2/3s (90% of obs.) of its income in the form of interest income. We measure deposit and asset productivity using the estimates reported in columns (4) of Table 2 and 3. Observations are at the bank by quarter level over the period 1994-2015. Other controls include assets (lagged by one year), leverage (lagged by one quarter), three-month returns (lagged by one quarter), equity beta, and the standard deviation of return on assets. The standard errors are reported in parenthesis and are cluster bootstrapped at the bank level (n=1,000) to account for the two stage estimation procedure. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table A7: Alternative Deposit Demand Estimates - Extended Data Set

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

Note: We report our demand estimates (Eq. 5) in Table A7. Here we re-estimate demand using our extended data set of over 32,000 bank by quarter observations. In our baseline demand estimates (Table 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-interest expense, and fees). Specifically, we calculate the average product characteristics of a bank's competitors in each county the bank operates in in a given year, and we then calculate the average across all counties the bank operates in. We winsorize all independent variables at the 1% to help control for outliers in the sample. Standard errors are clustered by bank and are reported in parentheses. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table A8: Alternative Production Function Estimates

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

Note: Table A8 displays our alternative production function estimates. The unit of observation is at the bank by quarter level over the period 1994 through 2015. The dependent variable is the logged value of interest income earned by the bank. The key independent variable of interest is the log value of a bank's assets lagged by one year. In column (1) we estimate a bank's asset production function using a spline with five knot points (Eq. 12) as described in Section 5.1.2. 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.