The Cross Section of Bank Value*

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Abstract

We study the determinants of value creation in U.S. commercial banks. We develop novel measures of individual banks' productivities at collecting deposits and making loans, which we relate to bank market values. We find that deposit productivity is responsible for two-thirds of the value of the median bank and most variation in value across banks. Variation in productivity is driven by differences across banks in technology, customer demographics, and market power. We also find evidence of synergies between deposit-taking and lending. Our findings suggest that there is significant heterogeneity in banks' abilities to capture value by manufacturing safe assets.

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Raising deposits and making loans are the central activities of banks. But how important is each activity to the business of banking, and what drives variation in the answer across banks? How much of a bank's value comes from its ability to issue information-insensitive deposits to consumers who value such debt? And how much comes from its ability to screen and monitor borrowers?

In this paper, we systematically examine the cross section of banks to understand the quantitative contributions of deposit-taking and lending to bank value. We begin by developing an economic framework in which banks have two divisions: (i) a deposit-producing division that raises funds by offering consumers services and interest payments, and (ii) a revenue-producing division that takes funding as an input and converts it into risk-adjusted revenue by making loans and holding securities. We focus on the traditional banking activities of deposit taking and lending, rather than on non-traditional banking activities like investment banking, trading, and private wealth management, because the banks in our sample are largely traditional banks.[1] We then use tools from industrial organization to construct novel estimates of a bank's productivity in each division in a manner analogous to the literature on the productivity of non-financial firms. Our framework therefore allows us to estimate "primitive" measures of deposit productivity and asset productivity for each bank at each point in time.

Intuitively, a bank with high deposit productivity is able to collect more deposits than a less productive bank, holding fixed the "inputs" it uses to collect those deposits, such as its deposit rate and number of branches. For example, BB&T and SunTrust each had about $150 billion of deposits in 2015Q4, and they paid similar deposit rates. 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 with fewer inputs. Analogously, a bank with higher asset productivity is able to generate more risk-adjusted revenue with the same asset base.[2] For example, given similar asset bases of approximately $200 billion, BB&T generated more revenue from traditional banking activities than SunTrust in 2015Q4 despite having lower levels of observable risk. Thus, our measures label BB&T as the more asset-productive bank.

To estimate how productive a bank is at raising deposits, we construct a consumer demand system for deposits that builds upon existing work by Dick (2008), Egan, Hortaçsu, and Matvos

[1] For the median bank in our sample, deposits comprise 86% of the bank's liabilities, and interest and deposit fee income comprise 90% of total income.

[2] We focus on traditional banking assets (i.e., interest on loans and securities held in the banking book) and not those associated with non-traditional banking (i.e., trading and investment banking).

(2017), and Xiao (2020). In our framework, banks compete for deposits by setting interest rates in a standard Bertrand-Nash differentiated products setting, which we estimate using a common model of demand from the industrial organization literature (Berry 1994; Berry, Levinsohn, and Pakes 1995). A bank with higher deposit productivity faces a consumer deposit demand curve that is shifted up, meaning it can raise more deposits, holding fixed the deposit services and interest rates it offers. To estimate a bank's asset productivity, we flexibly estimate its ability to produce interest and fee income as a function of the size of its loan and securities portfolios. Higher asset productivity allows a bank to produce more risk-adjusted income, holding fixed the size of its portfolio. Thus, our estimation procedure allows us to construct two complementary measures of bank productivity at the bank-quarter level that capture a bank's skill at raising deposits and its skill at using these funds to generate revenue.

Uncovering these primitive measures of productivity is important because metrics like interest income and interest expense are endogenous functions of productivity. For example, all else equal, a bank that is better at raising deposits will rationally choose to become larger. In the presence of diminishing returns, this will drive the rate the bank pays on deposits closer to the rates paid by less deposit-productive banks. Thus, variation in observables is likely to understate the 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 bank value. The benefit of looking at M/B is that it provides us with a natural economic benchmark: under the frictionless null hypothesis that banks create no value, all banks should have M/B equal to one. Hence, the use of M/B allows us to better understand the relative quantitative contributions of deposit taking and lending to bank value.

Our first 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 0.8 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 associated with an increase in M/B of 0.1 to 0.2 points. Hence, variation in deposit productivity accounts for more than twice as much variation in bank value as variation in asset productivity.

With a few additional assumptions, we reach our second finding: the levels of bank net income and value are also primarily driven by the liability side. To go from the cross section to the level of net income, we need a normalization that maps a single level of productivity to zero value. For asset productivity, we assume that for a bank earning an asset yield equal to the 5-year Treasury yield, asset productivity's contribution to value is zero. For deposit productivity, we assume that if a bank pays depositors a rate equal to 3-month LIBOR, deposit productivity's contribution to value is zero. Under these assumptions, we find that the share of net income attributable to deposits for the median bank in our sample is 70%. There is substantial heterogeneity across banks: deposits contribute more to net income for 60-70% of banks, while lending is more important for the remaining 30-40%. While both sides of the balance sheet are important, our overall results suggest that the liability side is quantitatively more important than the asset side for most banks.

We shed further light on the economic sources of bank value creation by disaggregating these results, asking which products and business lines are most closely associated with bank valuations. We find that a bank's ability to collect savings deposits is the main driver of value, explaining over three times as much variation in M/B as any other factor. The strength of our results for savings deposits compared to transaction deposits suggests that safety provision plays a particularly important role in creating bank value compared to providing liquidity services. On the asset side, we find that banks with high asset productivity hold more real estate and offer more loan commitments, consistent with the idea that information production about borrowers is an important source of bank value.

We next examine the main drivers of our productivity measures. Our estimation approach closely follows the literature on total factor productivity in non-financial firms (see, e.g., Syverson 2011), and therefore our measures by design capture more than just technological differences; they also capture the effects of managerial and employee skill, market power, and geographic and demographic factors. We group these various effects into two categories: (i) differences in banks' exposures to different types of customers, and (ii) differences in banks' production technologies, which capture variation in productivity holding customer exposures fixed.

We show that both categories of potential drivers are important for explaining our productivity measures and bank value. To explore variation in productivity driven by customer demographics and market power, we analyze the relationships between banks' geographical footprints and our productivity measures. We find that the demographic characteristics of the areas banks operate in are twice as important for explaining deposit productivity as asset productivity. Banks with less sophisticated clients that operate in areas with less competition tend to be more productive at both gathering deposits and investing. Our results suggest bank location matters and is correlated with a bank's ability to collect deposits and invest. However, even after flexibly controlling for banks' geographic footprints, we still find that both of our productivity measures are strongly related to bank value, with deposit productivity continuing to be more strongly related to value than asset productivity. This suggests that differences in market power and customer demographics alone do not fully explain variation in our productivity measures or the explanatory power of our measures for value. Technological differences in productivity also play an important role.

Finally, to examine technological differences across banks, we use additional data on the quality and pricing of bank services. Banks that are deposit-productive receive fewer customer complaints. These banks also appear to use more sophisticated, decentralized pricing strategies in setting deposit and mortgage rates. These findings help to validate our productivity measures and illustrate how firm structure, technology, and the quality of inputs drive productivity.

Our results are robust to a variety of potential concerns. We consider alternative constructions of productivity, measures of asset-side output beyond revenue, and other measures of shareholder value such as profitability and total market capitalization, and find that our main results do not change. We also show that our results are not driven by the largest banks, the financial crisis, or banks that do not primarily engage in traditional banking activities.

In summary, this paper empirically quantifies the primary determinants of bank value for traditional banks that primarily take deposits and make loans. We find that the asset and liability sides both play an important role, with deposits, and savings deposits in particular, accounting for the majority of value for the median bank. However, there is considerable heterogeneity in how banks create value. For 30-40% of banks, assets account for the majority of value.

Our paper is related to several strands of the literature on what makes banks "special," which highlights frictions that break the Modigliani-Miller irrelevance result and allow banks to create value. While the theoretical literature is largely concerned with the total social value created by banks, we examine private value accruing to bank shareholders, which is the only component of total value that is empirically observable. As such, we believe our analysis is an important step forward in empirically understanding the total social value created by banks. One strand of the literature argues that banks produce "safe," liquid, and adverse-selection free liabilities, such as bank deposits.[3] Our paper adds to this literature by quantifying the effects of liability creation on

[3]For theoretical literature, see, e.g., Gorton and Pennacchi (1990), Pennacchi (2012), Stein (2012), Gennaoili,

bank value. We find strong links between a bank's value and its ability to produce deposits. 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.

A second strand of the literature argues that banks produce valuable information about borrowers through the screening and monitoring of loans.[4] Consistent with this literature, we find evidence that a bank's skill at investing in information sensitive assets is linked to its value, though asset productivity appears to be less important for value than deposit productivity. A related literature focuses on estimating bank production functions.[5] These papers have largely focused on total cost and profit efficiency, with the aim of assessing economies of scale in banking, rather than separately examining the asset and deposit production functions of a bank. As we discuss further in Section 5.2, our deposit and asset productivity measures are conceptually distinct from existing estimates of bank cost and profit efficiency, such as Berger and Mester (1997), and measure different aspects of a bank's production function. Our productivity estimates follow standard methodologies from the industrial organization literature, and our paper joins the growing literature at the intersection of industrial organization and finance.[6]

There is also a large literature on synergies between bank assets and liabilities.[7]Consistent with this literature, we find that a bank's asset productivity is correlated with its deposit productivity.

Shleifer, and Vishny (2013), DeAngelo and Stulz (2015), Dang, Gorton, and Holmström (2015), Dang, Gorton, Holmström, and Ordoñez (2017), and Moreira and Savov (2017). Empirical work in this area, e.g., Calomiris and Nissim (2007, 2014), Krishnamurthy and Vissing-Jorgensen (2012, 2015), Gorton, Lewellen, and Metrick (2012), Bai, Krishnamurthy, and Weymuller (2016), Berger and Bouwman (2009), Billett and Garfinkel (2004), Greenwood, Hanson, and Stein (2015), Sunderam (2015), and Nagel (2016) has largely studied whether bank liabilities are special by examining aggregate prices and quantities. Recent empirical and theoretical work by Chen, Goldstein, Huang, and Vashishtha (2018), Dreschler, Savov, and Schnabl (2017), Dreschler, Savov, and Schnabl (2021) and Gomes, Grotteria, and Wachter (2018) highlight the importance of the deposit franchise in banking activities.

[4]Asset-driven theories of bank value creation include Leland and Pyle (1977), Diamond (1984), 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), Acharya, Hasan, and Saunders (2006), Sufi (2007), Calomiris and Nissim (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 rents (e.g., Keeley 1990; Jayaratne and Strahan 1996). In addition, Atkeson et al. (2018) argue that most variation in the time series of bank value is driven by the changing value of government guarantees. In contrast, we show that most variation in the cross section stems from differences in banks' deposit productivities.

[5]See, e.g., Berger and Humphrey (1997), Berger and Mester (1997), Hughes and Mester (1998), Stiroh (2000), Berger and Mester (2003), Rime and Stiroh (2003), and Wang (2003).

[6]Our deposit demand estimates relate most closely to Dick (2008), Egan, Hortaçsu, and Matvos (2017), and Xiao (2020). Similar tools have been used by Hortaçsu and Syverson (2004) for index mutual funds, Koijen and Yogo (2015) for investment assets, Koijen and Yogo (2016) for life insurance, Egan (2019) for retail bonds, 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 non-financial firms.

[7]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), Mehran and Thakor (2011), Ben-David, Palvia, and Spatt (2017), and Hanson, Shleifer, Stein, and Vishny (2016).

Synergies make it challenging to separately assign value to a bank's deposit and lending businesses since being deposit productive might raise a bank's asset productivity and vice versa. We show that our treatment of synergies does not affect our overall conclusions about value creation. Even when we ascribe the part of deposit productivity that is correlated with asset productivity to asset productivity, deposit productivity is still responsible for the majority of bank value.

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 productivity. Section 4 relates our productivity measures to bank value in order to understand economic sources of value. Section 5 explores the determinants of productivity. Section 6 presents robustness exercises, and Section 7 concludes.

1 Economic Framework

In this section, we present a simple economic framework linking a bank's value with its productivity at raising deposits and its skill at investing its assets. Let A_{jt} be the total assets of bank $j = 1, ..., J$ at time t. Banks fund their assets by raising deposits D_{jt} and with equity E_{jt}. Per-period bank profits are then given by

$$\pi_{jt} = f(A_{jt}; \phi_{jt}) - c(D_{jt}; \delta_{jt}). \tag{1}$$

Here $f(\cdot;\cdot)$ gives the bank's revenue as a function of its assets, $c(\cdot;\cdot)$ gives the bank's funding costs as a function of the quantity of deposits it raises, and $A_{jt} = D_{jt} + E_{jt}$.

The primitives are asset productivity ϕ_{jt} and deposit productivity δ_{jt}, which the bank takes as given. Asset productivity ϕ_{jt} reflects bank j's skill in making loans and holding securities. Higher values of ϕ_{jt} mean that the bank is better at lending – it generates more revenue from a fixed asset base. Deposit productivity δ_{jt} captures differences in efficiency across banks in raising deposits. Higher values of δ_{jt} mean that the bank is better at raising deposits – it can raise a fixed amount of deposits at a lower cost. In our empirical analysis below, we explore the drivers of differences in productivity primitives across banks. Conceptually these differences can arise for a variety of reasons, including differences in technologies for making loans or serving depositors, differences in human capital of loan officers or bank tellers, differences in management quality, differences in market power or customers served, and other factors.[8]

[8]For simplicity, this setup does not directly account for the possibility of synergies between the asset and liability sides

Bank j takes ϕ_{jt} and δ_{jt} as given and chooses its assets and deposits to maximize eq. (1). The first order condition from this optimization implicitly defines the bank's equilibrium assets, deposits, and profits in terms of ϕ_{jt} and δ_{jt}. We assume that fraction λ of profits are paid out to shareholders and that profits grow at rate g. In addition, we assume the market for equity is competitive and profits are discounted at required rate of return k. The market value of bank j's equity is then

$$M_{jt}(\phi_{jt}, \delta_{jt}) = \frac{\lambda \pi^*_{jt}(\phi_{jt}, \delta_{jt})}{k - g}$$

where $\pi^*_{jt}(\phi_{jt}, \delta_{jt})$ is the bank's equilibrium profits. The market-to-book (M/B) ratio is obtained by dividing by book equity E_{jt}. Equilibrium profits, market values, and M/B ratios are all determined by the primitives ϕ_{jt} and δ_{jt}.[9]

This simple framework demonstrates why we need to recover productivity primitives in order to decompose bank value between lending and deposit taking. The bank's equilibrium assets and deposits depend on both primitives. Similarly, the return on assets the bank earns and the cost of deposits the bank pays depend on both primitives. If a bank is good at gathering deposits, it will optimally scale up. If it faces diminishing returns, as the bank scales up, it will earn less on its assets and pay more on its deposits. Similarly, if a bank is good at lending, it will optimally scale up, and as it scales up, it will earn less on its assets and pay more on its deposits. Thus, the bank's equilibrium balance sheet, as well as its equilibrium interest income and interest expense, mix how good the bank is at raising deposits with how good it is at lending. In order to attribute bank value to deposit taking or lending, we must therefore first recover the primitives ϕ_{jt} and δ_{jt}.

1.1 Bank Assets

We now describe how we use a standard, flexible framework from the industrial organization literature to recover the primitives ϕ_{jt} and δ_{jt} in the data. On the asset side, we model bank j as generating revenue of $Y_{j,t} = f(A_{j,t}; \phi_{j,t})$ from making loans and holding securities, where total assets A_{jt} equal the sum of the deposits and other capital.

We approximate the bank's asset production function as

$$Y_{jt} = \phi_{jt} A^{\theta}_{jt}. \tag{2}$$

of the balance sheet. Below we discuss how such synergies might affect our estimates and conduct a bounding exercise to show that they do not qualitatively change our main conclusions.

[9] While we are assuming here for simplicity that k and g are not functions of ϕ_{jt} and δ_{jt}, we do not impose this restriction in our empirics below.

This functional form corresponds to a first-order Taylor series approximation of any production function (see, e.g., Syverson 2011). The parameter θ reflects returns to scale in production, and ϕ_{jt} is bank j's asset productivity, reflecting the excess risk-adjusted revenue the bank can earn on its loans and securities. Variation in ϕ_{jt} may arise from skill in underwriting loans or trading securities, selection of markets to operate in, and other factors.

Asset productivity translates directly to bank profits and value in our framework. To illustrate, suppose a bank's asset productivity increases from ϕ_j^0 to ϕ_j^1. All else equal, this increase in asset productivity results in an increase in profits of $(\phi_j^1 - \phi_j^0)A_{jt}^\theta$. In other words, the partial derivative of profits with respect to asset productivity is simply $\frac{\partial \pi}{\partial \phi_{jt}} = A_{jt.}^\theta$

1.2 Bank Deposits

On the deposit side, we model banks as producing 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. A consumer depositing funds at bank j at time t earns the net-of-fee deposit rate i_{jt}, which yields utility αi_{jt}. The parameter $\alpha > 0$ measures the consumer's sensitivity to deposit rates. Depositor k also derives utility from deposit 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 like ATMs and checking services. We parameterize the production function as $F_{jt}(X_{jt}) = \beta X_{jt} + \delta_{jt}$. The parameter β reflects a technology that is common across banks for turning costly inputs into services valued by consumers. We assume that these non-interest inputs X_{jt} are fixed on a short-term (quarter-to-quarter) basis, while deposit rates are flexibly adjusted. The bank-specific effect, δ_{jt}, denotes the bank's productivity at raising deposits. Conditional on the other inputs, banks with higher deposit productivity offer superior services and hence higher utility to consumers. Thus, deposit productivity captures differences in efficiency across banks in producing deposits from costly inputs X_{jt}. Variation in productivity could be driven by differences in production technologies (i.e., physical productivity), brand/franchise value, selection of markets to operate in, and other factors. Finally, the term ε_{jkt} is a consumer-bank-specific utility shock capturing 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:

$$u_{jkt} = \alpha i_{jt} + \beta X_{jt} + \delta_{jt} + \varepsilon_{jkt}. \tag{3}$$

Our analysis focuses on deposit productivity, δ_{jt}. Conditional on the offered net-of-fee deposit rate i_{jt} and other bank characteristics (X_{jt}), more productive banks attract more depositors.[10] From the bank's perspective, a more productive bank faces a demand curve for deposits that is shifted up.

Each consumer selects the bank from the set of banks indexed $j = 1, ..J$ that maximizes their utility. We also assume that consumers have access to an outside good, which represents placing funds outside the traditional banking sector. Without loss of generality, we normalize the utility of the outside good to zero $(u_0 = 0)$. 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 a multinomial logit distribution. The market share for bank j, denoted s_{jt}, is then

$$s_{jt}\left(i_{jt}, \mathbf{i_{-jt}}; \boldsymbol{\delta_t}\right) = \frac{\exp(\alpha i_{jt} + \beta X_{jt} + \delta_{jt})}{\sum_{l=1}^{J} \exp(\alpha i_{lt} + \beta X_{lt} + \delta_{lt}) + 1}. \tag{4}$$

The total market size for deposits at time t is denoted N_t, so bank j raises $s_{jt}N_t$ deposits.

Deposit productivity has a direct effect on the cost of raising deposits. Let $c(D_{jt}; \mathbf{i_{-jt}}; \boldsymbol{\delta_t})$ denote the interest cost of collecting D_{jt} deposits. One can show that a one unit increase in deposit productivity decreases the cost of collecting D_{jt} deposits by $\frac{1}{\alpha}D_{jt}$, i.e., $\frac{\partial c(D_{jt}; \mathbf{i_{-jt}}; \boldsymbol{\delta_t})}{\partial \delta_{jt}} = -\frac{1}{\alpha}D_{jt}$. Thus, a one unit increase in deposit productivity leads to a $\frac{1}{\alpha}D_{jt}$ increase in profits.

1.3 Summary

Putting together the asset side and deposit side, the specific version of the profit function eq. (1) we work with empirically is:

$$\pi_{jt} = \phi_{jt}A_{jt}^{\theta} - i_{jt} \times \underbrace{N s_{jt}\left(i_{jt}; \mathbf{i_{-jt}}; \boldsymbol{\delta_j}\right)}_{D_{jt}} - X_{jt}.$$

[10]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 do not control for a bank's probability of default for both practical and theoretical reasons. The practical reason is that the high-quality CDS data used by Egan, Hortaçsu, and Matvos (2017) to measure bank default probabilities is unavailable for about 95% of the banks in our sample. Even if CDS data were available for all of our banks, it is not clear conceptually we would want to control for a bank's implied probability of default. For example, suppose that JPMorgan Chase is perceived to be safer than, and consequently, JPMorgan Chase collects more deposits. Given that much of the theoretical banking literature emphasizes the liquidity and safety of deposits, in our current analysis we treat the perceived differences in liquidity and safety of deposits across banks as part of deposit productivity and what makes banks "special."

Note that bank profits are linear in both deposit and asset productivity, $\frac{\partial \pi_{jt}}{\partial \phi_{jt}} = A_{jt}^{\theta} > 0$ and $\frac{\partial \pi_{jt}}{\partial \delta_{jt}} = \frac{1}{\alpha} D_{jt} > 0$. In the empirics, we use these specifications to recover each bank's deposit and asset productivity in the data and then examine how variation in bank deposit and asset productivity contribute to bank value.

2 Data and Estimation

2.1 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 and data on consumer complaints from the Consumer Financial Protection Bureau. Finally, we obtain county- and MSA-level demographic characteristics from the U.S. Census Bureau, and mortgage originations from Home Mortgage Disclosure Act (HMDA) data.

Our sample is the universe of publicly-listed U.S. 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. Table 1 provides summary statistics for our main data set. Our three primary measures of bank risk are equity beta, the standard deviation of return on assets, and the standard deviation of the net return on loan and securities (net of losses). Following Baker and Wurgler (2015), we calculate the equity beta for each bank using monthly returns over the past two years. Similarly, we measure the standard deviation of return on assets and net return on loans and securities using quarterly data over the past two years. Variable definitions are provided in Appendix E.

2.2 Estimation: Bank Deposits

We estimate the demand system described in Section 1.2 using our bank data set over the period 1994 through 2015. Using eq. (4), we write a bank's log market share s_{jt} as:

$$\ln s_{jt} = \alpha i_{jt} + \beta X_{jt} + \delta_{jt} - \ln\left(\sum_{l=1}^{J} \exp(\alpha i_{lt} + \beta X_{lt} + \delta_{lt}) + 1\right). \tag{5}$$

Note that the non-linear term $\ln\left(\sum_{l=1}^{J}\exp(\alpha i_{lt}+\beta X_{lt}+\delta_{lt})+1\right)$ is constant across banks j in a given time period t. Consequently, if we include a time fixed effect, eq. (5) is linear in the parameters of interest and can be estimated using ordinary least squares. In our empirical analysis estimate the empirically equivalent specification:

$$\ln s_{jt} = \alpha i_{jt} + \beta X_{jt} + \underbrace{\mu_j + \xi_{jt}}_{\delta_{jt}}. + \underbrace{\mu_t}_{-\ln\left(\sum_{l=1}^{J}\exp(\alpha i_{lt}+\beta X_{lt}+\delta_{lt})+1\right)}, \tag{6}$$

where μ_t is a time fixed effect; μ_j is a bank fixed effect; X_{jt} and i_{jt} are bank characteristics; and ξ_{jt} is an unobserved bank-time specific residual. In our baseline specification, we define market shares at the aggregate U.S.-by-quarter level such that each quarter in the U.S. constitutes a market and observations in eq. (6) are at the bank-by-quarter level. As robustness checks, we estimate alternative demand systems where we define market shares at the county-by-year level and where we define market shares based on the type of deposit (e.g., checking deposits, savings, etc.) in Sections 3.4.1 and 5.

Our objective is to estimate each bank's deposit productivity, which measures a bank's ability to collect deposits conditional on its inputs. Consequently, it is important that we control for a bank's inputs into the deposit collection process, such as the deposit interest expense and number of bank branches. We measure deposit interest expense i_{jt} as total interest expense on deposits, net of fees on deposit accounts, divided by total deposits. We account for all other expenses reported in the Y-9C reports in X_{jt}, which include banks' 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, such as better ATMs or longer branch hours. In addition, the number of branches and number of employees may also factor into a consumer's selection of a depository institution. The coefficient β on X_{jt} captures how well banks are able to transform these inputs into utility/services valued by consumers.[11]

We also include bank fixed effects to capture persistent differences in a bank's ability to collect deposits. All else equal, a bank with a higher fixed effect collects more deposits for a fixed set of deposit-related expenses and inputs (i_{jt}, X_{jt}). This is conceptually similar to the distribution free approach suggested in Berger (1993). The term ξ_{jt} reflects within bank variation in its ability to collect deposits over time. Deposit productivity of bank j at time t is then the sum of the bank's

[11]Note that since we do not allow β to vary across banks, any differences in β (i.e., differences in how good banks are at converting inputs like branches into deposits) will be captured by our productivity measure.

fixed effect μ_j and its residual ξ_{jt}.

A standard issue in demand estimation is the endogeneity of prices, which in our case are deposit rates.[12] The term ξ_{jt} in eq. (6) represents an unobserved bank-time specific 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 so that ξ_{jt} is positive. It will then optimally 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), Gomez, Landier, Sraer, and Thesmar (2016), and Drechsler, Savov, and Schnabl (2017), deposit rates at different banks respond differently to changes in short-term interest rates. As Drechsler, Savov, and Schnabl (2017) show, variation in pass-through is driven by market power, a supply-side characteristic, not by consumer demand. Thus, we can instrument for i_{jt}, the deposit rate offered by bank j at time t, with the fitted value of a bank-specific regression of i_{jt} on 3-month LIBOR. The exclusion restriction here is that bank j's average degree of pass-through in the time series 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: 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 characteristics offered by each bank's competitor at the county-by-quarter level. We then form our instrument by taking the average of a bank's competitors' product characteristics across all counties the bank operates in.[13] Intuitively, a bank must offer higher deposit rates if its competitors offer better products. The exclusion re-

[12]The X_{jt} terms reflect slow-moving inputs such as the number of branches a bank operates. It is unlikely that banks can change these slow-moving inputs in response to an unobservable, unanticipated bank-quarter specific demand shock; hence, we do not need to instrument for the X_{jt} terms.

[13]To construct our instruments, we first take the unweighted average of a bank's competitors' characteristics at the county l by quarter level, $Z_{jlt}^{BLP} = (\overline{Branches_{-jlt}}, \overline{Employees_{-jlt}}, \overline{Non-Int.Exp_{-jlt}}, \overline{Fees_{-jlt}})$. Given the county-level averages Z_{jlt}^{BLP}, we then form our instrument at the bank- by-quarter level by taking the weighted average of Z_{jlt}^{BLP} across all counties a bank operates in to form Z_{jt}^{BLP}, where we weight by the size of the county in terms of the total amount of deposits across all banks. Because of potential nonlinearities in how banks set deposit rates as a function of their competitors' characteristics, we also include the corresponding quadratic terms ($Z_{jlt}^{BLP(2)}$) in our instrument set.

striction in this setting is that lagged average competitor product characteristics are orthogonal to current bank-quarter specific demand shocks. We provide more detail on the instruments in Appendix A.

Table 2 displays the corresponding demand estimates using aggregate bank-quarter data from the Y-9C reports. Column (1) of Table 2 displays the simple OLS estimates corresponding to eq. (6), while column (2) uses both sets of instruments (which yields a first-stage F-statistic in excess of 100). We estimate a positive and significant relationship between demand for deposits and the net-of-fee deposit rate. Moreover, as we would expect, the IV estimates tend to be higher than the OLS estimates. For a bank with an initial market share of 10%, the coefficient 17.85 in column (2) implies that a one percentage point increase in the offered deposit rate is associated with a 1.6 percentage point increase in market share. These demand elasticities are in line with the existing literature (Dick 2008; Egan, Hortaçsu, and Matvos 2017; Xiao 2020). In Section 5, we show robustness to a variety of alternate demand specifications.

We use our estimated demand system to calculate each bank's deposit productivity at each point in time. Specifically, we measure bank j's deposit productivity at time t as

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

Our estimates of deposit productivity have an intuitive reduced-form interpretation. More productive banks are raising 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.

2.3 Estimation: Bank Assets

We next estimate the asset production function to recover each bank's asset productivity at a given point in time. We focus on assets associated with traditional banking–namely, loans and securities held outside the trading book–because these are the main assets held by the banks in our sample.

We can write the bank's log production function as:

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

We treat the asset and liability sides of the bank differently because in contrast to the liability side, where banks have one main product (deposits), on the asset side banks produce many different products (e.g. mortgages, commercial loans, securities and other trading assets, etc.). We measure asset-side output using income because it aggregates across all products. Given that securities holdings and other investments make up the a large portion of a bank's balance sheet, we believe income is a natural measure of output for the asset side of the balance sheet.

We parameterize and estimate the production function as:

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

The dependent variable Y_{jt} measures interest income net of realized losses on loans and securities generated by bank j at time t.[14] We measure a bank's assets A_{jt} as the average of the bank's interest-bearing assets over the previous four quarters to capture the potential lag between the time an investment decision is made and initial returns are realized.[15] Additional control variables X_{jt} include the bank's equity beta, leverage, standard deviation of its return on assets, and standard deviation of the net return on interest-bearing assets (Y_{jt}/A_{jt}), to capture the riskiness of bank assets. As in our deposit demand estimation, we also control for the other production inputs in X_{jt}, including banks' non-interest expenditures, number of employees, and number of branches. The regression includes time fixed effects γ_t to absorb common variation in bank asset productivity over time.

We include bank fixed effects γ_j to capture persistent differences in a bank's ability to generate risk-adjusted returns. All else equal, a bank with a higher fixed effect generates more income for a given level of assets and risk. The term ϵ_{jt} reflects variation in bank $j's$ ability to generate risk-adjusted income over time. Collectively, the bank fixed effect and residual term are equal to bank asset productivity, such that $\phi_{jt} = \gamma_j + \epsilon_{jt}$.

A 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 size is endogenous in eq. (8). This is a well-known problem dating back to Marschak and Andrews (1944), which much of the industrial organization literature on production has been devoted to addressing.[16]

Conceptually, we need an instrument that is correlated with bank size but is otherwise uncorre-

[14] We omit noninterest income to focus our analysis on traditional banking activities, i.e., lending and investing in interest-bearing securities. In Section 5, we show that our results are robust to excluding banks for which noninterest income is a significant fraction of total income.

[15] We also exlcude interest income and assets from trading when constructing Y_{jt} and A_{jt}, but find quantitatively similar results if we include include these variables.

[16] For example, Olley and Pakes (1996), 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).

lated with the bank's asset productivity. We construct cost-shifter instruments in the style of Berry, Levinsohn, and Pakes (1995). Specifically, we instrument for bank interest-bearing assets ($\ln A_{jt}$) using the average deposit productivity of bank j's competitors.[17] In addition, we also include the fixed deposit characteristics of a bank's competitors (i.e. our BLP instruments from Section 2.2) in our instrument set. The idea is that if a bank faces competitors that are better at raising deposits, it will naturally be smaller, so competitor deposit productivity induces variation in bank size that is orthogonal to the bank's own asset productivity.

Table 3 displays the corresponding estimates. In columns (1)-(3), we report OLS estimates, and in columns (4)-(6), we report the IV estimates. Our instruments are empirically relevant and yield first stage F-statistics in excess of 75 for each specification. In each specification, we also estimate a coefficient on $\ln A_{jt}$ (θ) that is less than one, implying that banks face decreasing returns to scale.[18]

We use the estimated production function to compute bank j's asset productivity at time t as

$$\hat{\phi}_{jt} = \ln Y_{jt} - \hat{\theta} \ln A_{jt} - \hat{\Gamma} X_{jt} - \hat{\gamma_t} = \hat{\gamma}_j + \hat{\epsilon}_{jt}.$$

Our asset productivity is equal to the estimated bank fixed effect plus the bank-quarter specific residual. 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 (5) 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.

[17] 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 as K, and the set of banks in each county k is denoted as L_k. Our instrument $\overline{\delta_{-j}}$ is then constructed as follows (note time subscripts t are omitted for ease of notation):

$$\overline{\delta_{-j}} = \overline{\sum_{k \in K} \frac{N_k}{N} \sum_{l \in L_{-jk}} \hat{\delta}_l},$$

Our instrument reflects the average competitiveness of each market, weighted by the average size of the market. The size of the aggregate deposit market is denoted N and the size of the deposit market in county k is denoted N_k. The term $\hat{\delta}_l$ corresponds to eq.(7). In our IV specifications, we use the variables $\overline{\delta_{-j}}$ and $\overline{\delta_{-j}}^2$ to instrument for $\ln A_{kt}$.

[18] Our finding of decreasing returns to scale depends on including bank fixed effects in our estimation. In untabulated results, when we estimate the production function without bank fixed effects, we find roughly constant returns to scale. This suggests that there are constant returns to scale in the cross section of banks, but banks face decreasing returns to scale when adjusting scale on the margin.

3 Economic Sources of Bank Value

3.1 Productivity and the Cross Section of Bank Value

We begin by examining how our productivity measures relate to a stock-market based measure of value: the market-to-book (M/B) ratio. It is worth noting up front that because we are using a market-based measure of value, our results only directly speak to private value created for shareholders, not the total social value created by banks.

We regress M/B on our estimates of deposit and asset productivity as well as time fixed effects and additional bank-level controls:

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

We use M/B as a proxy for average Q, the average market value created per dollar of book assets, not marginal Q, as it is sometimes used in the investment literature. M/B is a particularly useful measure because it provides a natural economic benchmark: under the null hypothesis that the Modigliani-Miller theorem holds, banks create no social or private value. Thus, all banks should have an M/B of one. In Section 5, we also verify that our results hold using alternative measures of bank value such as profitability and total market capitalization.

Table 4 displays the results. All specifications include time fixed effects, so our analysis is solely based on cross-sectional variation. We standardize our productivity measures so that the coefficients correspond to a one-standard deviation increase in productivity. Standard errors are clustered by bank and are computed by bootstrap to account for the fact that our productivity measures are estimated.

Column (1) documents the baseline relationship between deposit productivity and M/B. In column (2), we add controls X_{jt} to account for size and risk: lagged (log) assets; leverage; the bank's estimated equity beta; the standard deviation of its net return on interest-bearing assets; the standard deviation of its return on assets (ROA); the share of deposit liabilities; the share of loans in assets; and the share of securities in assets.[19]

[19] We control for size as a proxy for growth expectations, since larger banks will tend to grow more slowly and thus have lower M/B ratios. The remaining controls are meant to account for any correlation between our productivity measures and risk. Note that risk acts like measurement error here. It may affect the independent variables, but it should not affect M/B because it increases both cash flows and discount rates. To see this, imagine a bank with no deposits that just held a newly-issued investment grade bond with a 3% coupon trading at par. This bank would have M/B=1. If the bank instead held a newly-issued high-yield with a 10% coupon trading at par, it would also have M/B=1. Similar intuition applies for differences in loan maturity across banks. Consistent with this intuition, we find that our risk controls do not

The results show that a one-standard deviation increase in deposit productivity is associated with an increase in M/B of 0.2 to 0.8 points, an economically significant effect. The cross-sectional standard deviation of M/B is 0.69 in our sample.[20] Columns (3) and (4) show that a one-standard deviation increase in asset productivity is associated with an increase in M/B of 0.1 to 0.2 points, an effect that is also economically significant.

We next compare the relative importance of deposit and asset productivity in determining bank value by simultaneously including both deposit and asset productivity in eq. (9). 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, deposit productivity has a larger impact on M/B than asset productivity. The results in column (5) indicate that a one-standard deviation increase deposit productivity is associated with an increase of 0.2 points in M/B, whereas a one-standard deviation increase in asset productivity is associated with an increase of 0.08 points in M/B. Relative to asset productivity, the impact of deposit productivity is about twice as large in column (5), where we only include time fixed effects, and roughly seven 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.

3.2 Relationship Between Deposit and Asset Productivity

An important consideration in our above analysis is that there may be synergies between deposit gathering and lending. Synergies make it challenging to separately assign value to a bank's deposit and lending businesses. A bank may have a high value of our asset productivity measure, i.e., earn high revenues given its asset base, because in reality it is deposit productive (e.g., its deposit business allows it to write highly profitable credit lines). Conversely, a bank may have a high value of deposit productivity, i.e., raise many deposits at relatively low cost, because in reality it is asset productive (e.g,. has a good mortgage origination business that allows it to gather low-cost deposits by requiring that borrowers establish a deposit account).

To assess this possibility, we examine the relationship between our productivity measures in

affect our point estimates very much. We discuss measurement error further in Section 5 below.

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

Table 5a. Specifically we run regressions of the form

$$\hat{\phi}_{jt} = \gamma_0 + \gamma_1 \hat{\delta}_{jt} + \Gamma X_{jt} + \mu_t + \varepsilon_{jt}. \tag{10}$$

The table shows that our two productivity measures are correlated. Column (1) shows that a one-standard deviation increase in deposit productivity is associated with a 0.45 standard deviation increase in asset productivity. This is economically significant: 20% of the variation in our asset productivity measure can be explained by variation in deposit productivity. This correlation is consistent with the idea of synergies. However, it can be thought of as an upper bound on the strength of synergies, as it may be explained by factors like good management, in addition to the banking-specific synergies the theoretical literature focuses on.[21]

To understand the implications of the correlation between deposit productivity and asset productivity for our results in Table 4, we conduct a simple bounding exercise. We first residualize deposit productivity with respect to asset productivity and then run our benchmark regressions of market-to-book on residualized deposit productivity and asset productivity:

$$\left(\frac{M}{B}\right)_{jt} = \gamma_0 + \gamma_1 \hat{\delta}^*_{jt} + \gamma_2 \hat{\phi}_{jt} + \Gamma X_{jt} + \mu_t + \varepsilon_{jt}, \tag{11}$$

where $\hat{\delta}^*_{jt}$ is the residualized variation in deposit productivity for bank j and at time t and is constructed as the residual from a regression of deposit productivity on asset productivity. This exercise essentially ascribes to asset productivity any part of deposit productivity that could be due to synergies to the asset side of the balance sheet. The corresponding results are reported in columns (1) and (2) of Table 5b. The results confirm our baseline findings: even being as generous to the asset side of the balance sheet as possible, the majority of the variation in bank value appears to come from the deposit side (columns 1 and 2). The results in column (2) indicate that a one standard deviation increase in residualized deposit productivity is correlated with a 0.64 increase in market-to-book, while a one standard deviation increase in asset productivity is correlated with a 0.41 increase in market-to-book.

In contrast, if we are as generous to the liability side of the balance sheet as possible, we attribute 90% of the variation in bank value to the deposit side. Columns (3) and (4) of Table

[21] In the Appendix, we further examine sources of synergies. The ability to collect all types of deposits, except for transactions deposits, is positively correlated with asset productivity. This finding suggests that the ability to raise "sticky" short-term funding is a key source of bank synergies. We also find that deposit-productive banks offer more loan commitments and lines of credit, consistent with Kashyap, Rajan, and Stein (2002) and Gatev and Strahan (2006).

5b report the results of regressing market-to-book on deposit productivity and residualized asset productivity, which is the residual from a regression of asset productivity on deposit productivity. The results in column (4) indicate that a one standard deviation increase is deposit productivity is correlated with a 0.77 increase in market-to-book while a one standard deviation increase in residualized asset productivity is associated with a 0.086 increase in market-to-book.

It is worth noting that if synergies played a central role in bank value creation, we would not be able to assign value to one side of the balance sheet or the other. For instance, consider the synergies between deposits and credit lines emphasized by Kashyap, Rajan, and Stein (2002). Having more deposits raises the value to a bank of writing credit lines by reducing the incremental liquidity needed to meet draws on those credit lines. Conversely, having more credit lines increases the value of raising deposits because deposits allow the bank to reduce the amount of liquidity it holds to meet draws on credit lines. In this case, the incremental value generated by the union of deposits and credit lines does not "belong" to either the asset or liability side of the balance sheet. If these kinds of synergies constituted the majority of bank value, then our bounding exercise above would result in vastly different results when we attribute all synergies to the asset side of the balance sheet than when attribute all synergies to the liability side. The results of our bounding exercise suggest instead that synergies do create value but that they are not so large as to render our balance sheet decomposition uninformative.

3.3 From the Cross Section to Levels

Thus far, our results speak to the cross section of bank value. With additional assumptions, we can also make statements about levels of net income and M/B. These exercises, which we describe below, imply that for the average bank, deposit productivity makes a larger contribution to value than asset productivity.

3.3.1 Contributions to Net Income

In our framework in Section 1, 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, all else equal, are given by

$$Cost\ Savings = Deposits \times \frac{\delta^1 - \delta^0}{\alpha} \tag{12}$$

where α is the elasticity of demand for deposits. Given an assumed value for δ^0, eq. (12) can be used to calculate deposit productivity's contribution to bank cash flows for each bank in our sample. Similarly, if a bank's asset productivity increases from ϕ^0 to ϕ^1, all else equal its income increases by

$$\Delta Y = \left[exp(\phi^1) - exp(\phi^0)\right] exp(\Gamma X_j) A_j^\theta. \tag{13}$$

Given an assumed value for ϕ^0, eq. (13) can be used to calculate asset productivity's contribution to bank cash flows for each bank in our sample. We pin down ϕ^0 by assuming that for a bank earning an asset yield equal to the 5-year Treasury yield, asset productivity's contribution to value is zero. Similarly, we pin down δ^0 assuming that if a bank pays depositors a rate equal to 3-month LIBOR, deposit productivity's contribution to value is zero.[22]

Figure 1 shows the decomposition of these contributions to net income across banks. The red shaded histogram shows deposit productivity's contribution to net income changes as we vary bank deposit productivity (δ_{jt}) across its observed distribution in the data. The blue histogram shows the analogous exercise varying asset productivity across its distribution in the data. The figure shows that deposit productivity contributes more to net income, as the average of the deposit productivity distribution is to the right of the average of the asset productivity distribution.

Figure 2 ignores the structure imposed by our framework, and simply plots variation in interest income and interest expense, each 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, the accounting-based decomposition obscures the primitives that enter the bank's optimization problem and are responsible for determining a bank's value. For example, if banks that are good at raising deposits and investing optimally increase their scale and there are diminishing returns, then variation in observed (scaled) interest income and interest expense will be smaller than the underlying variation in productivity. This is exactly what we find in Figures 1 and 2.

[22] We use the 5-year Treasury yield because Begenau and Stafford (2018) and Drechsler, Savov and Schnabl (2021) suggest that the average maturity of bank assets is roughly five years. This normalization means that 18% of banks do not generate any asset side value. We use 3-month LIBOR because it is the average non-deposit unsecured funding for banks. Our normalization means that the bottom 16% of banks in terms of deposit productivity quarter do not generate any value on the deposit side. In Appendix B, we show that our results are qualitatively similar using other normalizations.

3.3.2 Contributions to Value

We next calculate the model-implied M/B ratio for each bank. In contrast to our reduced-form estimates in Table 4, which flexibly allow the payout ratio λ, discount rate k, and growth rate g to vary across banks, in this exercise, we assume that they are the same for all banks. With these assumptions, we can write a bank's market-to-book ratio as a function of its deposit and asset productivity:

$$M/B = \frac{\lambda}{k-g}\left[exp(\phi_j)exp(\Gamma X_j)A_j^{\theta} + Deposits \times \frac{\delta_j}{\alpha}\right]/A + 1.$$

As described in Appendix B, to calculate the model implied market-to-book, we estimate $\frac{\lambda}{k-g}$ in the data to be 3.46, which is consistent with the historical average payout ratio of $\lambda = 28\%$, an average cost of equity of $k = 9 - 10\%$, and an average growth rate of $g = 1 - 2\%$.

Figure 3 plots model-implied estimates of M/B for each bank against observed M/Bs. The estimates from our simple quantitative framework seem to match the observed M/B data quite well. We can also determine the share of value coming from deposits for each bank. Figure 4 shows the distribution of deposit's share of value across banks. On average, deposit productivity accounts for about twice as much value as asset productivity. The mean deposit share of bank value is 64%. However, there is significant heterogeneity across banks; for example, the majority of value comes from asset productivity for some banks.

Overall, our results show that deposit productivity is more important than asset productivity for explaining both the level of bank value and variation in value across banks.

3.4 Which Assets and Liabilities Create Value?

In this section, we disaggregate our results, asking which products and business lines are most related to bank valuations. This analysis sheds further light on the economic sources of bank value creation since certain products are most closely associated a particular theory of value creation. For instance, checking deposits are most closely associated with transaction services.

3.4.1 Decomposing Bank Productivity

We start in Table 6 by asking whether certain types of assets and deposits contribute particularly strongly to our overall productivity measures. Specifically, we compute productivity measures for different subcategories of assets and deposits the same way we construct our overall productivity measures as described in Section 2 and reported in Appendix F. These more granular 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.

Table 6 shows that the ability to raise savings deposits is particularly important for bank value, suggesting that safety provision, moreso than liquidity provision, is a key activity linked to bank value. Columns (1) and (2) of Table 6 examine the relationship between overall deposit productivity and our subcategory estimates for savings deposits, small time deposits, large time deposits, and transaction deposits.[23] As before, the productivity measures are standardized. All of the subcategory measures are positively correlated with our overall deposit productivity measure. The correlation is strongest for savings 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 0.52 standard deviation increase in total deposit productivity, though savings deposits make up only 39% of a bank's total deposits on average. In addition, we obtain similar estimates for small time deposits (which are typically insured) and large time deposits (which are typically uninsured), suggesting that our productivity estimates are not driven by differences in the quantity and pricing of insured versus uninsured deposits across banks.

Columns (3) and (4) of Table 6 display the relationship between asset productivity and our asset-side subcategory measures, which are lending productivity and securities productivity.[24] Our asset productivity measure is more highly correlated with loan productivity than with securities productivity. This accords with intuition: there is more scope for banks to use their screening and monitoring technologies to generate excess returns in loan markets than in securities markets.

Finally, columns (5) and (6) link our subcategory productivity measures to banks' M/B. The results suggest that not all deposits are created equal: columns (5) and (6) suggest that the main

[23]We define deposit subcategories based on the reporting in the BHC FR Y-9C regulatory filings. In contrast, Egan et al. (2017) examines deposit demand separately for insured and uninsured deposits. The composition of a banks' deposits across subcategories is highly correlated with a bank's share of insured/uninsured deposits. For example, small-time and checking deposits are more likely to be insured while large time deposits are uninsured. Thus, by examining deposit types, we are largely stratifying by whether deposits are insured or uninsured.

[24]Interest income is only disaggregated in the Y-9C reports into interest income from loans and interest income from securities, so this is the most granular decomposition we can do on the asset side.

driver of bank value is savings deposits, with transaction deposits a distant second. In column (6), savings deposit productivity explains over three times as much variation in M/B as any other subcategory productivity measure.

Why are saving deposits so strongly correlated with value? A key part of the answer, as eq. (12) shows, is that the price elasticity of demand is negatively correlated with value. We find that demand for savings deposits is almost completely inelastic.[25] This means that a bank that is good at gathering savings deposits can gather them at very low rates. In contrast, demand for time deposits is quite elastic, so they contribute little to value; a less productive bank can always offer a time deposit rate slightly higher than the most productive bank and collect more time deposits.

These decompositions have interesting implications for mapping our results back to theory. Our results in Section 3 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, which provide limited transaction services relative to checking deposits. On the asset side, we find that loans create more value than securities.

3.4.2 Our Productivity Measures and Balance Sheet Composition

Another way to understand what products and business lines drive our productivity measures is to examine how they correlate with banks' balance sheet composition. If there is within-bank variation in subcategory productivity (i.e., a single bank has different productivity for C&I loans, CRE loans, residential mortgages, etc.), an optimizing bank will tilt its portfolio towards high-productivity subcategories. Thus, the relationship between balance sheet composition and our asset and deposit productivity measures, which aggregate over subcategories, reveals which subcategories the bank perceives to have the highest productivity.

In Table 7a, 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 while banks with higher deposit productivity do have higher leverage, the effect is tiny: a one-standard deviation increase in deposit productivity is associated with a 0.02 standard deviation increase in bank leverage. Hence, banks that are particularly good at raising deposits do not appear to lever up much more than other banks.

Table 7b displays correlations between our asset productivity measure and banks' asset compo-

[25]Demand estimates for each type of deposit are in Appendix Table A1.

sition. Columns (1)-(3) show that more productive banks tend to hold more real estate 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. Overall, we find strong evidence that our productivity measures are capturing meaningful information about bank-specific business line specialization.

4 What Drives Differences in Productivity?

What are the underlying sources of variation in our productivity measures? The industrial organization literature finds that a number of variables including technology, quality of inputs, market power, and firm structure are primary drivers of non-financial firms' productivity (Syverson, 2011). In the context of banks, explanations for differences in productivity can be categorized broadly as either being "technological" or "customer-based." 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 category includes differences in productivity due to market power, customer sophistication, or 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 category includes differences in quality of inputs, variety of products, or sophistication in price-setting or marketing strategies.

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

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 8a. We combine county-level Census data with the FDIC's Summary of Deposits to compute average demographic characteristics of the counties where a 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, increasing relationship between asset productivity and population. Banks in higher-population areas have higher asset productivity, but the relationship fades as population increases since the coefficients on the squared terms are negative. Banks in high house price areas also have higher asset productivity. 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 flexibly control for other unobservables. Specifically, we regress 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 to keep the number of independent variables manageable. The R^2 of the regression in column 2 is 25%, suggesting that demographic and geographic variation explain a significant fraction of asset productivity. Columns (3) and (4) repeat these exercises for deposit productivity with similar results. Interestingly, the age of bank branches is strongly correlated with deposit productivity, possibly reflecting that older branches have over time isolated the stickiest deposits.

These results suggest that customer-based explanations play a large role in explaining variation in our deposit productivity and asset productivity measures. However, Table 8b shows that even after controlling for MSA fixed effects and directly including demographic characteristics and market concentration variables in our regressions, our main findings continue to hold: our productivity measures are still strongly related to bank value, and deposit productivity continues to have a larger impact than asset productivity. In total, demographic and geographic variables explain about 40% of the variation in M/B, suggesting there is significant remaining variation for technological differences in productivity to explain.

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 baseline data with 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 9 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 better customer service. 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 9 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 do not find a relationship between asset productivity and CFPB complaints.

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 examine the variation in deposit and mortgage rates offered by a bank. The idea is that banks with more sophisticated rate-setting technologies will offer location-specific 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-county-by year level.[26] 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 10 shows the correlations between asset and deposit productivity and our measures of rate setting sophistication. In general, banks that set more heterogeneous deposit and mortgage rates are more deposit- and asset-productive, respectively.

Overall, the results in this section suggest that both customer-based and technological sources of variation are important in driving our productivity measures. What prevents banks from investing to decrease differences in productivity over time? As Syverson (2004b) and Hsieh and Klenow (2009) show, differences in productivity are generally large and persistent across firms, and there is no reason to think that banks are any different than other types of firms. If anything, banks may face even greater frictions that could limit the convergence of productivity over time. For example, switching costs and information frictions (i.e. relationship lending) are likely to be very important for banks relative to other types of firms, and these factors can significantly limit convergence. As

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

our results in Table 8a show, the set of customers a bank has captured through its branch network is a key driver of deposit productivity. Because these customers are sticky, it is difficult for other banks to induce them to switch, which makes it difficult for some banks to achieve the high deposit productivity enjoyed by other banks. In addition, labor market search frictions in the spirit of Eeckhout and Kircher (2018) may also affect the matching of workers to firms in a manner that limits productivity convergence. For instance, our evidence in Table 9 shows that banks could increase their deposit productivity if they improved their customer service and reduced the number of CFPB complaints filed against them. However, labor market frictions may prevent banks from finding employees who can provide better customer service.

5 Robustness

We find that banks that are more productive in raising deposits and generating asset income have higher M/B ratios, with deposit productivity accounting for twice as much of bank value as asset productivity. In this section, we show that these general findings hold under a host of alternative specifications. We explore alternative data, functional forms, and methodologies, including other measures of bank efficiency that have been commonly used in the literature. For brevity, we provide an overview of our robustness checks and findings and relegate many of the details to the Appendix.

5.1 Alternative Production Function and Demand Estimates

We first consider an alternative methodology to compute deposit and asset productivity that directly measures differences in average bank interest expense and interest income. An advantage of this alternative methodology is that both deposit and asset productivity are calculated in parallel fashion, which helps reduce concerns that our findings are driven by the specific approach used to calculate deposit and asset productivity. A drawback is that this alternative methodology does not have a structural interpretation; that is, it does not emerge from a model of optimizing banks and consumers. This means it would be more difficult for us to conduct our analysis of the level of bank value with this methodology.

We construct our alternative measure of deposit productivity based on the following regression

$$i_{jt} = \alpha \ln Dep_{jt} + \beta X_{jt} + \psi_j + \psi_t + \eta_{jt}. \quad (14)$$

Observations are at the bank-by-quarter level. The dependent variable is a bank's average net deposit interest expense (net of fees). The control variables include a bank's log deposits and the other controls in our baseline deposit demand specification (eq. 6), which are a bank's number of branches, non-interest expense, and number of employees. The idea is that we want measure a bank's average deposit interest cost conditional on the size of the bank and the quality of the services it offers. We also include bank and time fixed effects to capture bank-specific differences in interest expense (i.e. deposit productivity) and common trends across banks over time.

We estimate eq. (14) using two-stage least squares to address the concern that deposits are endogenous in the regression. We use our same set of instruments (pass-through and BLP instruments) as exogenous shifters in the size of the bank in terms of its deposits. We construct our corresponding alternative measure of deposit productivity based on the residual from eq. (14) and the bank fixed effects. Notice that a large residual from eq. (14) indicates that the bank's interest expense is higher than expected, given bank characteristics $\ln Dep_{jt}$ and X_{jt}. Thus, we multiply by -1 so that our alternative measure of deposit productivity is given by

$$\hat{\delta}_{jt}^{Alt.} = \hat{\alpha} \ln Dep_{jt} + \hat{\beta} X_{jt} + \hat{\psi}_t - i_{jt} = -\left(\hat{\psi}_j + \hat{\eta}_{jt}\right).$$

A higher measure of deposit productivity indicates that, all else equal, a bank is collecting a given amount of deposits at a lower cost.

We construct our alternative measure of asset productivity based on the analogous regression

$$\iota_{jt} = \theta \ln A_{jt} + \Gamma X_{jt} + \varphi_j + \varphi_t + \zeta_{jt}. \tag{15}$$

Observations are at the bank-by-quarter level. This specification parallels eq. (8) except that the dependent variable is a bank's average interest income net of gains/losses ($\iota_{jt} = \frac{Y_{jt}}{A_{jt}}$) rather than the log of a bank's interest income net of gains/losses $\ln Y_{jt}$. We include the same control variables as in our baseline estimates reported in Section 2.3 (eq. 8), which include bank assets, leverage, measures of risk, and other bank characteristics (e.g., number of branches). We include time fixed effects to capture common trends in bank returns. The objects of interest are the bank fixed effects φ_j and the bank and time specific residual ζ_{jt}. The bank fixed effects measure persistent differences across banks in their ability to generate risk-adjusted returns, and the residual ζ_{jt} measures within bank variation in a bank's ability to generate risk-adjusted returns over time.

We estimate eq. (15) using two-stage least squares to address the concern that assets are endogenous in the regression. We use our same instruments as exogenous shifters, the deposit productivity and characteristics of a bank's competitors, to instrument for interest-bearing assets $(\ln A_{jt})$. We construct our corresponding alternative measure of asset productivity based on the residual from eq. (15) and the bank fixed effects:

$$\hat{\phi}_{jt}^{Alt.} = \iota_{jt} - \hat{\theta} \ln A_{jt} + \hat{\Gamma} X_{jt} + \hat{\varphi}_t = \left(\hat{\varphi}_j + \hat{\zeta}_{jt}\right).$$

Here, a high measure of asset productivity indicates that a firm generates higher income from a given asset base and level of risk.

Using these alternative measures of asset and deposit productivity, we replicate our baseline results and report the corresponding results in Table 11. The results in indicate that our alternative measures of both deposit and asset productivity are positively and significantly correlated with bank value (eq. 9), but that deposit productivity explains a greater share of the the variation in bank M/B. Overall, these results suggest that our findings are not driven by the specific functional forms used to compute deposit and asset productivity.

5.2 Comparison with the Literature

Our measures of deposit and asset productivity are related to, but fundamentally distinct from, existing measures of bank efficiency such as Berger and Mester (1997)'s cost efficiency measure. In particular, our measures isolate different aspects of a bank's production function relative to existing measures. To make these differences clear, we focus on how our measure of deposit productivity relates to Berger and Mester (1997)'s measure of cost efficiency. Berger and Mester (1997) measure cost efficiency as bank costs C, conditional on output y (loans and securities), input prices w (wages, interest rate on deposits, and interest rate on non-deposit liabilities), fixed netputs z (off-balance-sheet guarantees, physical capital, and financial equity capital), and environmental variables v. Assuming that efficiency is multiplicatively separable from the rest of the cost function, as in Berger and Mester (1997), the bank's cost function can be written as

$$\ln C_j = f(w_j, y_j, z_j, v_j) + \ln u_j$$

The residual term u_j is a bank-specific inefficiency factor that measures a bank's costs relative to the best-practice level.[27] The key distinction between our measure of deposit productivity and cost efficiency is that cost efficiency is calculated conditional on the size of a bank's liabilities and the interest rate it pays on those liabilities. By controlling for both the size of a bank's liabilities and the interest rate the bank pays on its deposits and other liabilities, bank efficiency is calculated conditional on how cheaply a bank can raise a given amount of liabilities, which depends on a bank's deposit productivity. Thus, bank efficiency, by construction, does not capture differences in bank deposit productivity. Cost efficiency is effectively calculated conditional on deposit productivity. Indeed, in our simple model in Section 1, all banks would have the same cost efficiency regardless of their deposit and asset productivity. The reason is that cost efficiency is calculated conditional on a bank's cost of collecting deposits. Cost efficiency and our productivity measures are simply designed to capture different economic forces.

In practice, we might still expect deposit productivity to be correlated with bank efficiency. For instance, high deposit productivity could in part reflect good management, which could also impact cost efficiency. To help further understand how our findings relate to the previous literature, we directly follow the methodology in Berger and Mester (1997) to construct cost efficiency C with our updated bank holding company data set; the full details are in the Appendix. Figure 5 displays a binned scatter plot of deposit productivity and cost efficiency. As expected, the two are positively and significantly correlated, but the correlation is relatively low at 0.16.

5.3 Other Robustness

Alternate Functional Forms: In the Appendix, we also re-estimate our baseline deposit demand and asset production functions using other alternative functional forms and more granular data. On the deposits side, we re-estimate our baseline demand function using more granular data at the bank-by-county level. Using county level data allows us to construct deposit productivity measures that are fully purged of geography and that allow different banks to face consumers with different deposit rate elasticities. The county-level demand estimates are quantitatively similar to our baseline estimates and our main inference regarding the cross-section of value remains unchanged. Using county-level data, we also examine how the average demand elasticity a bank faces impacts the contribution of deposit productivity to value. Recall from Section 1.2 that, all else equal, de-

[27]Note that Berger and Mester's (1997) cost function also includes an additional error term $\ln \epsilon_C$ which captures measurement error and luck. For ease of exposition, we omit the error term ϵ_C in our discussion.

posit productivity is more valuable if a bank faces an inelastic demand curve. Consistent with the theoretical predictions, we also find that deposit productivity creates more value when a bank faces more inelastic demand for deposits.

On the asset side, we consider more flexible functional form assumptions and alternative measures of risk. One potential concern with our investment income production function estimates is that our empirical specification may not be flexible enough to capture a bank's true production function. As a robustness check, we estimate the bank's investment income production function using a spline with a five knot points. We also re-estimate our bank investment income production function where we further account for differences in risk by controlling for a bank's asset composition and the Fama and French (1993) factors. We find that these alternative measures of asset productivity are positively correlated with bank value, but deposit productivity still has a larger impact on bank value.[28]

Alternative Measures of Value: In our baseline analysis, we document the relationship between M/B and productivity. In the Appendix we verify that our main findings are robust to other measures of bank value, including Tobin's q and total market capitalization.[29]

Measurement Error: Because our productivity measures 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. In the Appendix 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 that allow us to directly account for measurement error in the distributions of deposit and asset productivity. The results suggest that most of the variation in our productivity estimates is driven by true variation in productivity rather than measurement error. Overall, we find that after accounting for measurement error, deposit productivity still explains more variation in bank value than asset productivity.

[28] As an additional robustness check, we also reestimate our deposit demand and asset production functions where we control for average wages. We find that our baseline results are robust to controlling for wages and report the corresponding results in Appendix F.

[29] We also find that both deposit and asset productivity are both equally correlated with profitability, measured as return on equity (ROE).

Sub-sample Analysis: We also run several robustness checks regarding the set of banks in our sample where we exclude: the largest 5% of banks; observations from the financial crisis; nontraditional banks with business models not centered around deposit taking and lending; and observations in the year preceding or proceeding merger and acquisition activity. We report the corresponding results in the Appendix. In each subsample analysis, our results are both qualitatively and quantitatively similar to those in our baseline analysis and indicate that both asset and deposit productivity are both positively correlated with M/B but that deposit productivity has a relatively larger impact on M/B. Collectively, these results demonstrate that our findings are not driven by large money center banks, the financial crisis, M&A activity, or non-traditional banks.

6 Conclusion

What are the key determinants of bank value? In this paper, we draw upon the industrial organization literature to develop a simple empirical framework to answer this question. 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 banks' market values and that their contributions vary by bank. Of the three channels, we find that a bank's ability to produce deposits is the most important factor in explaining cross-sectional variation in bank market 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 necessarily those that provide the most transaction and liquidity services. Under plausible additional assumptions, we reach similar conclusions about the level of bank value: it is primarily driven by deposit productivity. Overall, 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.

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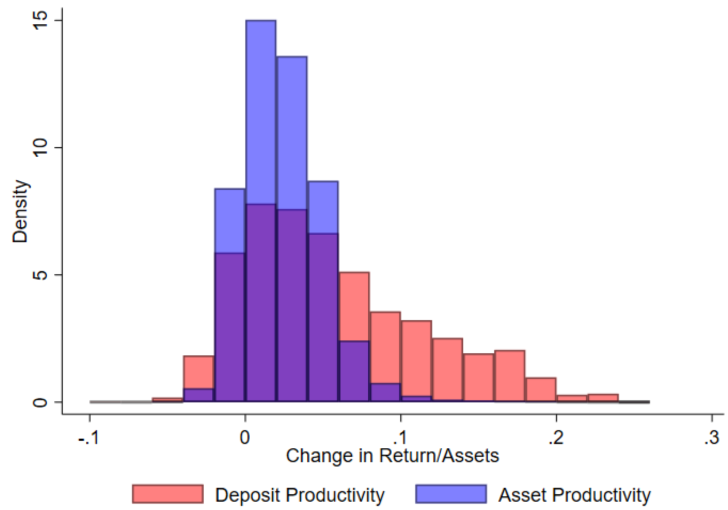
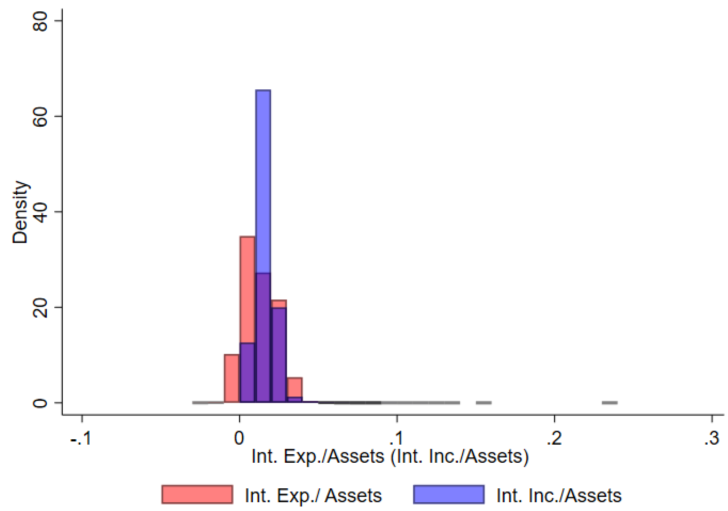
Figures

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



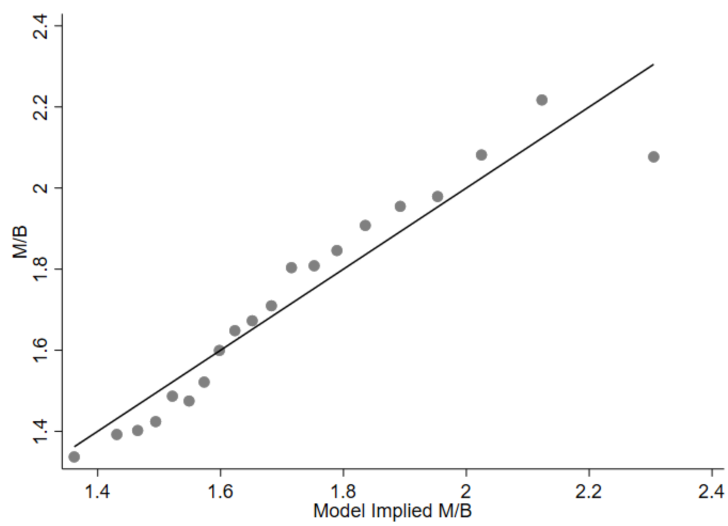
Note: Figure 1 displays the estimated distributions of asset and deposit productivity. Observations are at the bank by quarter level. The red shaded histogram plots the distribution of bank deposit productivity scaled by $\widetilde{Deposits/A}\frac{1}{\alpha}$ where $\widetilde{Deposits/A}$ denotes the median value for the banks our sample. The blue histogram displays the scaled distribution of asset productivity $\frac{\widetilde{Assets}^{\theta}}{\widetilde{Assets}}exp(\phi_{jt} + \Gamma\tilde{X_{jt}})$ where $\widetilde{Assets}$ and $\tilde{X_{jt}}$ denote the median values for the banks in our sample. As discussed in Section 3 the scaling converts deposit and asset productivity in terms of returns on assets. We normalize the level of asset productivity relative to five year Constant Maturity Treasury rates such that the set of banks earning risk adjusted returns below the five year Treasury rate have negative asset productivity. We also normalize the deposit productivity distribution relative to 3-month LIBOR. Specifically, we calculate a bank's expected deposit rate as a function of its deposit productivity by regressing a bank's deposit rate on its deposit productivity and time fixed effects. We assume those banks who's expected deposit rate, conditional on deposit productivity, is equal to 3-month LIBOR do not generate any value from their level of deposit productivity. For banks paying less than 3-month LIBOR, deposit productivity contributes positively to value. Our normalization of the deposit productivity distribution means that the bottom 16% of banks in terms of deposit productivity quarter do not generate any value on the deposit side of the bank. The deposit productivity estimates correspond to the specification reported in column (2) of Table 2. The asset productivity estimates correspond to the specification reported in column (5) of Table 3.

Figure 2: Interest Expense vs Interest Income



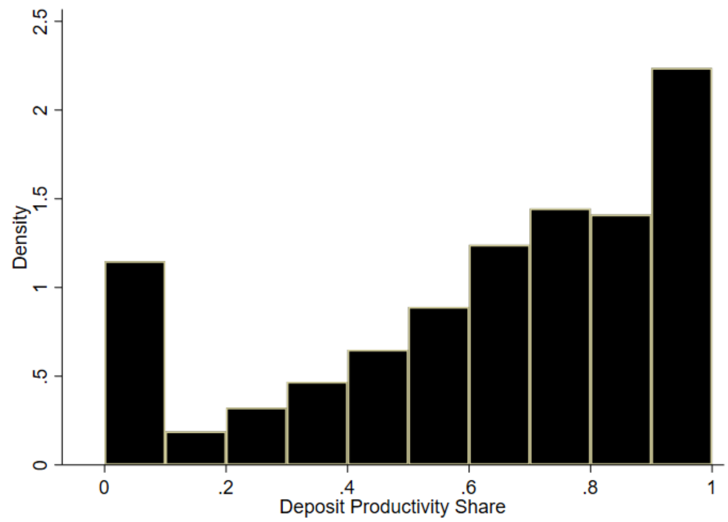
Note: Figure 2 displays the distributions of deposit interest expense and interest income. Observations are at the bank by quarter level. The red shaded histogram plots the distribution of deposit interest expense divided by assets. The blue shaded histogram plots the distribution of interest income divided by assets. Both deposit interest expense and interest income are annualized (multiplied by 4).

Figure 3: Market-to-Book



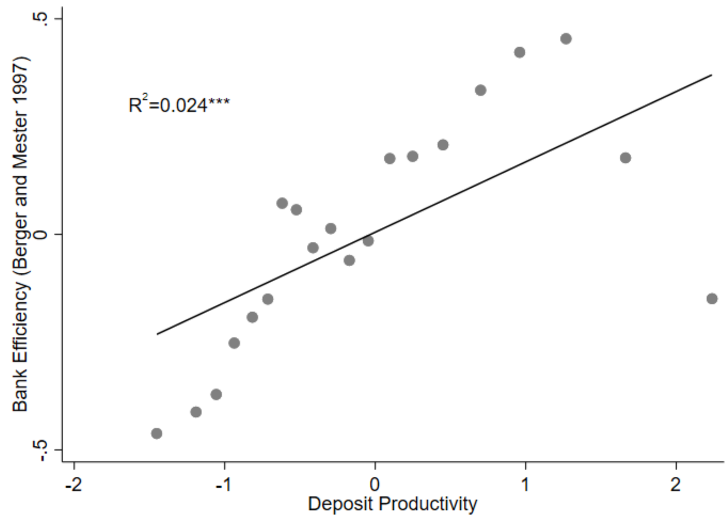
Note: Figure 3 displays a binned scatter plot of each bank's market value versus the model implied estimate. Observations are at the bank by quarter level. The binned scatter plot includes time fixed effects. We calculate the model implied market-to-book as the predicted value from the regression $M/B_{jt} = \beta_0 + \frac{\lambda}{k-g}\widehat{\varpi_{jt}} + \mu_t + \epsilon_{jt}$. The term $\widehat{\varpi_{jt}}$ measures bank excess per-period returns as a function of its deposit and asset productivity. We estimate $\widehat{\frac{\lambda}{k-g}} = 3.46$. We calculate $\widehat{\varpi_{jt}} = \left[exp(\hat{\phi}_{jt})exp(\Gamma\tilde{X}_j)\tilde{A}_j^{\theta-1} + \widetilde{Deposits}/A\frac{\hat{\delta}_{jt}}{\alpha}\right]$, where ($\sim$) denotes the median value for the banks in our sample. As discussed in Section 3 this scaling converts deposit and asset productivity in terms of returns on assets. The deposit productivity estimates ($\hat{\delta}$) correspond to the specification reported in column (2) of Table 2. The asset productivity estimates ($\hat{\phi}$) correspond to the specification reported in column (5) of Table 3.

Figure 4: Deposit Productivity Share



Note: Figure 4 displays the distribution of the share of bank value from deposits foreach bank. Observations are at the bank by quarter level. The share of bank value from deposits reflects the percentage of bank value that is generated by deposit productivity relative to asset productivity. We calculate the share of of bank value from deposits ($Deposit\,Value\,Share$) as $Deposit\,Value\,Share_{jt} = \frac{\widetilde{Deposits/A}\frac{\hat{\delta}_{jt}}{\hat{\alpha}}+\kappa_1}{\widetilde{Deposits/A}\frac{\hat{\delta}_{jt}}{\hat{\alpha}}+\kappa_1+exp(\hat{\phi}_{jt})exp(\Gamma\tilde{X}_{jt})\tilde{A}_{jt}^{\theta-1}+\kappa_2}$ As discussed in Section 3 the scaling converts deposit and asset productivity in terms of returns on assets. To construct the $Deposit\,Value\,Share$ we fix bank characteristics A, X, $Deposits/A$ at their median values (denoted by $\sim$), such that the variation in the $Deposit\,Value\,Share$ is driven by variation in deposit and asset productivity. Our measures of deposit and asset productivity reflect cross-sectional variation in deposit and asset productivity, not the levels. To calculate $Deposit\,Value\,Share$ share we need to make normalizing assumptions about the level of deposit and asset productivity (κ_1 and κ_2). We normalize the deposit productivity distribution (κ_1) relative to 3-month LIBOR such that the set of banks that offer deposit rates above 3-month LIBOR have negative deposit productivity. Specifically, we calculate a bank's expected deposit rate as a function of its deposit productivity by regressing a bank's deposit rate on its deposit productivity and time fixed effects. We assume those banks who's expected deposit rate, conditional on deposit productivity, is equal to 3-month LIBOR do not generate any value from their level of deposit productivity. For banks paying less than 3-month LIBOR, deposit productivity contributes positively to value. The term κ_2 is a normalizing constant where we normalize the level of asset productivity relative to five year Constant Maturity Treasury rates such that the set of banks earning risk adjusted returns below the five year Treasury rate have negative asset productivity. We censor those observations with negative deposit value shares at zero and those observations with deposit value shares greater than 1 at 1. The deposit and asset productivity estimates correspond to the specifications reported in columns (2) of Table 2 and (5) of Table 3.

Figure 5: Bank Efficiency vs. Deposit Productivity



Note: Figure 5 displays a binned scatter plot of bank deposit productivity vs. bank efficiency. Observations are at the bank by quarter level. Bank efficiency is calculated as per Berger and Mester (1997) as discussed in the Appendix. The deposit productivity estimates correspond to the specification reported in column (2) of Table 2.

Tables

Table 1: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Deposit Int. Expense	25,845	1.71%	1.36%	-0.46%	6.16%
Deposit Int. Expense (Net of Fees)	25,845	2.16%	1.34%	0.11%	6.53%
Non Int. Expense (Millions) 25,845	144	523	1.27	3,662	
No. Branches	25,845	120	310	1	2,024
No. Employees	25,845	3,479	10,587	54	68,396
Assets (Billions)	25,845	27.10	163	0.10	2,580
Interest-bearing Assets (Billions)	25,845	21.10	119	0.09	1,960
Interest Income (Millions)	25,845	286	1,550.	1.97	33,000
Interest Income Net of Lossees (Millions)	25,845	94.0	4,670.	0.20	96,000
Deposits (Billions)	25,845	14.5	80.2	0.01	1,370
Leverage	25,845	0.91	0.04	0.19	1.02
Beta	25,845	0.63	0.58	-0.66	2.46
Std. Dev. ROA	25,845	0.14%	0.17%	0.01%	0.91%
Std. Dev. Net Ret. on Inv. Assets	25,845	0.80%	0.90%	0.08%	5.62%
Market-to-Book	25,845	1.72	0.85	0.18	5.30
Liabilities (Relative to Total Liabilities)					
Deposits	25,845	0.83	0.12	0.00	1.00
Small Time Deposits	25,842	0.20	0.11	0.00	0.68
Large Time Deposits	25,842	0.13	0.08	0.00	0.89
Savings Deposits	23,740	0.34	0.15	0.00	0.89
Transaction Deposits	23,737	0.15	0.10	-0.30	0.81
FF+Repo	17,695	0.04	0.06	0.00	0.69
Assets (Relative to Total Assets)					
Loans	25,845	0.65	0.13	0.00	0.96
RE Loans	23740	0.46	0.16	0.00	0.90
C&I Loan	22806	0.11	0.07	0.00	0.58
Loan Commitments	25845	0.14	0.17	0.00	21.10
Securities	25845	0.22	0.12	0.00	0.94
Cash	25845	0.02	0.04	0.00	0.41
FF+Repo	17695	0.01	0.03	0.00	0.45
Deposit Productivity	25,845	0.00	1.37	-4.77	4.25
Asset Productivity	25,845	0.00	0.32	-6.84	2.17

Note: the table 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 to account for outliers: 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., and Std. Dev. of Net Return on Interest-Bearing Assets. The deposit productivity estimates correspond to the specification reported in column (2) of Table 2. The asset productivity estimates correspond to the specification reported in column (5) of Table 3. See the Appendix E for a full description of the variables.

Table 2: Deposit Demand

	(1)	(2)
Deposit Rate	12.66***	17.85***
	(1.841)	(4.318)
No. Branches (hundreds)	0.0404***	0.0426***
	(0.00931)	(0.00942)
No. Empl (thousands)	0.0267***	0.0271***
	(0.00812)	(0.00830)
Non-Int. Exp. (billions)	-0.0813	-0.102
	(0.1000)	(0.103)
Time Fixed Effects	X	X
Bank Fixed Effects	X	X
IV-1		X
IV-2		X
Observations	25,845	25,845
R-squared	0.982	0.982

Note: the table displays the results corresponding to our demand estimates (Eq. 6). The unit of observation is at the bank 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 total 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 set (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 set (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) as described in the text. We winsorize all independent variables at the 1% level 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)	(5)	(6)
$\ln A_{kt}$ (θ)	0.900***	0.901***	0.950***	0.872***	0.862***	0.951***
	(0.0169)	(0.0157)	(0.0157)	(0.0618)	(0.0610)	(0.0613)
Beta		-0.0107	-0.00933		-0.00906	-0.00935
		(0.00723)	(0.00767)		(0.00764)	(0.00812)
Beta (fwd 2 yr)			-0.0231***			-0.0231***
			(0.00801)			(0.00833)
SD ROA		-0.0653***	-0.0547***		-0.0654***	-0.0547***
		(0.00754)	(0.00697)		(0.00754)	(0.00700)
SD ROA (fwd 2 yr)			-0.0803***			-0.0804***
			(0.00686)			(0.00847)
SD Net Ret. on Inv. Assets .		0.00525	0.0147***		0.00590	0.0147***
		(0.00604)	(0.00529)		(0.00606)	(0.00529)
SD Net Ret. on Inv. Assets(fwd 2 yr)			0.0662***			0.0662***
			(0.00631)			(0.00827)
Lag Leverage		-0.983***	-0.267		-0.983***	-0.267
		(0.260)	(0.253)		(0.262)	(0.253)
No. Branches (hundreds)		-0.000380	-0.00307		0.00113	-0.00309
		(0.00926)	(0.00916)		(0.00918)	(0.00904)
No. Empl (thousands)		0.00753	0.00794*		0.00853	0.00793
		(0.00470)	(0.00476)		(0.00529)	(0.00513)
Non-Int. Exp. (billions)		-0.154***	-0.106**		-0.157***	-0.106**
		(0.0533)	(0.0475)		(0.0556)	(0.0474)
Bank F.E.	X	X	X	X	X	X
Time F.E.	X	X	X	X	X	X
IV				X	X	X
Observation	25,845	25,845	20,576	25,845	25,845	20,576
R-squared	0.975	0.976	0.980	0.975	0.976	0.980

Note: the table displays the results corresponding to our asset income production function estimates (eq. 8). The unit of observation is at the bank by quarter level. The dependent variable is the log interest income net of losses. The key independent variable of interest is log interest-bearing assets. Interest income and interest-bearing assets exclude interest income and assets from trading. We measure interest-bearing assets based on the quarterly average over the previous four quarters. Because of the potential endogeneity of interest-bearing assets, we instrument for assets in columns (4)-(6). Specifically, we instrument for assets using the weighted average of the deposit product characteristics of a bank 's competitors as described in Section 3.3. We also control for the bank's equity beta, standard deviation of return on assets (standardized), standard deviation of net return on interest-bearing assets (standardized), and leverage. We measure beta on a rolling basis using monthly equity returns over the previous 24 months with data from CRSP and Kenneth French. We measure the standard deviation of return on assets and net return on interest-bearing 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***	0.766***			0.199***	0.729***
	(0.0232)	(0.148)			(0.0341)	(0.145)
Asset Productivity			0.168***	0.114***	0.0816***	0.0959***
			(0.0539)	(0.0227)	(0.0206)	(0.0172)
Time F.E.	X	X	X	X	X	X
Other Controls		X		X		X
Observations	25,845	25,845	25,845	25,845	25,845	25,845
R-squared	0.416	0.463	0.382	0.437	0.424	0.472

Note: the table displays the estimation results corresponding to a linear regression model (Eq. 9). Observations are at the bank by quarter level. 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 the specification reported in column (2) of Table 2. The asset productivity estimates correspond to the specification reported in column (5) of Table 3. Other controls include: log assets (lagged by one year); leverage (lagged by one quarter); three-month returns (lagged by one quarter); equity beta; the standard deviation of net return interest-bearing assets (net of losses); the standard deviation of return on assets; the share of deposit liabilities; and the share of assets in loans and securities. The standard errors are reported in parentheses 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: Relationship Between Deposit and Asset Productivity

(a) Deposit vs. Asset Productivity

	(1)	(2)
Deposit Productivity	0.453*	0.382
	(0.253)	(0.347)
Time F.E.	X	X
Other Controls		X
Observations	25,845	25,845
R-squared	0.200	0.271

(b) Bank Market-to-Book and Bank Productivity

	(1)	(2)	(3)	(4)
Residualized Deposit Productivity	0.174***	0.638***		
	(0.0408)	(0.144)		
Asset Productivity	0.168***	0.412**		
	(0.0539)	(0.188)		
Deposit Productivity			0.236***	0.772***
			(0.0232)	(0.146)
Residualized Asset Productivity			0.0730***	0.0858***
			(0.0185)	(0.0142)
Time F.E.	X	X	X	X
Other Controls		X		X
Observations	25,845	25,845	25,845	25,845
R-squared	0.424	0.472	0.424	0.472

Note: Panel (a) displays the relationship between deposit productivity and asset productivity (Eq. 10). Observations are at the bank by quarter level. All independent and dependent variables are standardized. The dependent variable is asset productivity as measured using the production function estimates reported in column (5) of Table 3. We measure deposit productivity using the demand estimates reported in column (2) of Table 2.

Panel (b) displays the relationship between bank market-to-book and bank productivity (Eq. 11). The dependent variable is the bank's market-to-book ratio. The independent variables deposit productivity, asset productivity, residualized deposit productivity, and residualized asset productivity are standardized. Residualized deposit productivity is constructed from the residual of the regression of deposit productivity on asset productivity, such that the variable residualized deposit productivity is the variation in deposit productivity that is orthogonal to variation in asset productivity. Residualized asset productivity is constructed from the residual of the regression of asset productivity on deposit productivity, such that the variable residualized asset productivity is the variation in asset productivity that is orthogonal to variation in deposit productivity. Other controls in both panels include: log assets (lagged by one year); leverage (lagged by one quarter); three-month returns (lagged by one quarter); equity beta; the standard deviation of net return interest-bearing assets (net of losses); the standard deviation of return on assets; the share of deposit liabilities; and the share of assets in loans and securities. The standard errors in both panels are reported in parentheses 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: Deposit and Asset Productivity Subcategories

Dep. Var	Deposit Productivity		Asset Productivity		Market to Book	
	(1)	(2)	(3)	(4)	(5)	(6)
Deposit Prod.:						
Savings	0.523***	0.386***			0.258***	0.432***
	(0.0297)	(0.0564)			(0.0434)	(0.0692)
Small Time	0.0912***	0.0517**			-0.223***	-0.162***
	(0.0265)	(0.0254)			(0.0404)	(0.0484)
Large Time	0.154***	0.122***			0.0343	0.0925***
	(0.0248)	(0.0219)			(0.0416)	(0.0359)
Transaction	0.292***	0.241***			0.0738**	0.137***
	(0.0227)	(0.0361)			(0.0357)	(0.0382)
Asset Prod.:						
Loans			0.747***	0.666***	0.0905***	0.0843***
			(0.0580)	(0.0652)	(0.0173)	(0.0133)
Securities			0.186***	0.141***	0.0344**	0.0321**
			(0.0584)	(0.0257)	(0.0145)	(0.0133)
Time F.E.	X	X	X	X	X	X
Other Controls		X		X		X
Observations	21,809	21,809	17,700	17,700	16,133	16,133
R-squared	0.979	0.982	0.780	0.863	0.459	0.491

Note: the table displays the relationship between our more refined measures of productivity, overall productivity, and market-to-book. Observations are at the bank by quarter level. Overall deposit productivity is the dependent variable columns (1) and (2) and is standardized. We measure overall deposit productivity using the demand estimates reported in column (2) of Table 2. Overall asset productivity is the dependent variable columns (3) and (4) and is standardized. We measure overall asset productivity using the production function estimates reported in column (5) 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 A1. We measure asset productivity for loans and savings deposits using the corresponding production function estimates reported in Table A2. These subcategory measures of deposit and asset productivity are standardized. Other controls include: log assets (lagged by one year); leverage (lagged by one quarter); three-month returns (lagged by one quarter); equity beta; the standard deviation of net return interest-bearing assets (net of losses); the standard deviation of return on assets; the share of deposit liabilities; and the share of assets in loans and securities. The standard errors are reported in parentheses 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: Productivity vs. Composition of Assets and Liabilities

(a) Composition of Liabilities and Deposit Productivity

Dep. Var	Leverage (1)	Deposits/Liabilities (2)	Small Time/Liabilities (3)	Large Time/Liabilities (4)	Savings/Liabilities (5)	Trans./Liabilities (6)	FF+Repo/Liabilities (7)
Deposit Prod.	0.0238	1.818***	-0.302*	0.181	1.350***	0.396**	-0.316
	(0.0159)	(0.323)	(0.164)	(0.130)	(0.253)	(0.162)	(0.239)
Time F.E.	X	X	X	X	X	X	X
Other Controls	X	X	X	X	X	X	X
Observations	25,845	25,845	25,842	25,842	23,740	23,737	17,695
R-squared	0.970	0.533	0.375	0.159	0.375	0.215	0.142

(b) Composition of Assets and Asset Productivity

Dep. Var	RE Loans/Assets (1)	C&I Loan/Assets (2)	Loan Commit./Assets (3)	Securities/Assets (4)	Cash/Assets (5)	FF+Repo/Assets (6)
Asset Prod.	0.103***	0.00339	0.0342*	-0.169***	-0.141***	-0.126**
	(0.0255)	(0.0237)	(0.0205)	(0.0293)	(0.0383)	(0.0625)
Time F.E.	X	X	X	X	X	X
Other Controls	X	X	X	X	X	X
Observations	23,740	22,806	25,845	25,845	25,845	17,695
R-squared	0.318	0.048	0.130	0.094	0.206	0.100

Note: panels (a) and (b) display the relationship between a bank's productivity and its liability and asset structure. Observations in both panels are at the bank by quarter level. In panel (a), we regress bank leverage and the composition of its deposits on deposit productivity. We measure deposit productivity using the demand estimates reported in column (2) of Table 2. In panel (b), we regress the composition of a bank's assets on asset productivity. We measure asset productivity using the estimates reported in column (5) of Table 3. Other controls include: log assets (lagged by one year); leverage (lagged by one quarter); three-month returns (lagged by one quarter); equity beta; the standard deviation of net return interest-bearing assets (net of losses); and the standard deviation of return on assets. The standard errors are reported in parentheses 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 8: Demographic Characteristics

(a) Productivity and Demographic Characteristics

Dep. Var.	Asset Productivity		Deposit Productivity	
	(1)	(2)	(3)	(4)
ln(Population)	0.222***	0.170***	0.593***	0.354***
	(0.0441)	(0.0166)	(0.0562)	(0.00900)
ln(Population)^2	-0.0642***	-0.0164**	-0.119***	-0.0384***
	(0.0176)	(0.00764)	(0.0246)	(0.00415)
ln(Wage)	-0.104*	-0.0148	-0.164**	0.00242
	(0.0599)	(0.0217)	(0.0754)	(0.0119)
ln(Wage)^2	-0.0562*	-0.0358***	0.0251	0.00816**
	(0.0289)	(0.00643)	(0.0238)	(0.00346)
ln(Branch Age)	0.0656**	-0.0619***	0.381***	0.133***
	(0.0315)	(0.00830)	(0.0376)	(0.00453)
ln(House Prices)	0.165***	0.113***	0.105	0.0217***
	(0.0520)	(0.0144)	(0.0669)	(0.00781)
HMDA HHI	0.134***	0.0795***		
	(0.0283)	(0.0120)		
Deposit HHI			0.176***	0.0762***
			(0.0342)	(0.00508)
Time F.E.	X	X	X	X
MSA F.E.		X		X
Observations	23,066	23,066	23,066	23,066
R-squared	0.050	0.255	0.329	0.775

(b) Controlling for Geography

Dep. Var.	Market-to-Book	
	(1)	(2)
Deposit Productivity	0.355***	0.753***
	(0.0352)	(0.135)
Asset Productivity	0.0902***	0.0863***
	(0.0158)	(0.0163)
Time F.E.	X	X
MSA F.E.	X	X
Demographic Controls	X	X
Other Controls		X
Observations	23,066	23,066
R-squared	0.604	0.628

Note: In Panel (a) we show how deposit and asset productivity correlate with the geographic characteristics of areas where banks operate. In Panel (b), we replicate our baseline set of results controlling for fixed effects for each MSA a bank operates in. Observations in both tables are at the bank by quarter level. We measure deposit and asset productivity using the estimates reported in columns (2) of Table 2 and (5) of Table 3. Other controls include: log assets (lagged by one year); leverage (lagged by one quarter); three-month returns (lagged by one quarter); equity beta; the standard deviation of net return interest-bearing assets (net of losses); the standard deviation of return on assets; the share of deposit liabilities; and the share of assets in loans and securities. 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 9: Productivity and Quality

	Deposit Productivity		Asset Productivity	
	(1)	(2)	(3)	(4)
CFPB Complaints	-0.273**	-0.0560**	0.126	0.126
	(0.110)	(0.0225)	(0.173)	(0.0770)
Time F.E.	X	X	X	X
Other Controls		X		X
Observations	222	222	222	222
R-squared	0.099	0.947	0.041	0.615

Note: The table displays the relationship between productivity and the quality of services a bank offers. Observations are at the bank by quarter level. The dependent variable in columns (1) and (2) is deposit productivity and the dependent variable columns (3) and (4) is asset productivity. We measure deposit and asset productivity using the estimates reported in columns (2) of Table 2 and (5) of Table 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: log assets (lagged by one year); leverage (lagged by one quarter); three-month returns (lagged by one quarter); equity beta; the standard deviation of net return interest-bearing assets (net of losses); the standard deviation of return on assets; the share of deposit liabilities; and the share of assets in loans and securities. 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 10: Productivity and Rate Setting Technology

Dep. Var	Deposit Productivity		Asset Productivity	
	(1)	(2)	(3)	(4)
Variation in Deposit Rates (σ_{CD})	0.238***	0.0175**		
	(0.0359)	(0.00812)		
Variation in Mortgage Rates (σ_{MTG})			0.126**	-0.0110
			(0.0604)	(0.0319)
Time F.E.	X	X	X	X
Other Controls		X		X
Observations	3,037	3,037	1,252	1,252
R-squared	0.058	0.947	0.017	0.212

Note: the table displays the relationship between productivity and the variation in rates set by banks. Each column corresponds to a separate linear regression. Observations in each column are at the bank by quarter level. The dependent variable in columns (1)-(2) is deposit productivity as measured using the demand estimates reported in column (2) of Table 2. The dependent variable in columns (3)-(4) is asset productivity as measured using the production function estimates reported in column (5) 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. Other controls include: log assets (lagged by one year); leverage (lagged by one quarter); three-month returns (lagged by one quarter); equity beta; the standard deviation of net return interest-bearing assets (net of losses); the standard deviation of return on assets; the share of deposit liabilities; and the share of assets in loans and securities. 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 11: Alternative Productivity Estimates

	(1)	(2)	(3)	(4)	(5)	(6)
Deposit Productivity	0.245***	0.685***			0.172***	0.629***
	(0.0236)	(0.127)			(0.0356)	(0.118)
Asset Productivity			0.220***	0.186***	0.107***	0.152***
			(0.0346)	(0.0410)	(0.0245)	(0.0361)
Time F.E.	X	X	X	X	X	X
Other Controls		X		X		X
Observations	25,845	25,845	25,845	25,845	25,845	25,845
R-squared	0.422	0.468	0.409	0.446	0.430	0.482

Note: the table displays the results corresponding to the regression of bank market-to-book on bank deposit and asset productivity. Observations are at the bank by quarter level. The dependent variable is bank market-to-book. We construct deposit productivity as the residual and bank fixed effect from the regression of a bank's average net interest expense (net of fees) on log bank deposits and a vector of control variables. Similarly, we construct asset productivity as the residual and bank fixed effect from the regression of a bank's average net interest income (net of losses) on log interest-bearing assets and a vector of control variables that capture bank risk. Both deposit and asset productivity are standardized. Other controls include: log assets (lagged by one year); leverage (lagged by one quarter); three-month returns (lagged by one quarter); equity beta; the standard deviation of net return interest-bearing assets (net of losses); the standard deviation of return on assets; the share of deposit liabilities; and the share of assets in loans and securities. The standard errors are reported in parentheses 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.

Online Appendix

A. Details on Deposit Instruments

We construct two sets of instruments to instrument for deposit rates in our deposit demand regressions (6). Our first set of instruments is based on the bank-specific pass-through of 3-month LIBOR into deposit rates and consists of a single instrumental variable. The idea for the instrument comes from Villas-Boas (2007). To construct the instrument, we estimate a bank-specific pass-through regression of deposit rates on 3-Month LIBOR. To construct the instrument, for each bank in our sample, we estimate the regression:

$$i_{jt} = \alpha_j + \rho_j LIBOR_{t-1} + \varepsilon_{jt}.$$

We then construct the instrument as the predicted value

$$Z_{jt}^{PT} = \widehat{\alpha_j} + \widehat{\rho_j} LIBOR_{t-1}.$$

For the instrument to be valid, it needs to satisfy the relevance and exogeneity conditions. The relevance condition requires that the predicted value Z_{jt}^{PT} be correlated with the bank's average deposit rate. The F-statistic in our first stage regression is over 1,000, indicating that the instrument is highly relevant. In addition, Dreschler, Schnabl, and Savov (DSS, 2017) further support the relevance of our instrument by documenting that interest rate pass-through is heterogeneous and persistent across banks, which is the key feature we need for the instrument to relevant. The exogeneity condition requires that Z_{jt}^{PT} is orthogonal to the bank-quarter specific demand shocks ξ_{jt}. This assumption will be satisfied as long as the bank's average pass-through rate ρ_j, interacted with changes in aggregate rates ($LIBOR_{t-1}$), is orthogonal to the demand shock bank j experiences at time t. In order to violate the exogeneity condition, it would have to be the case that bank-specific time-varying demand shocks are correlated with the average pass-through rate interacted with changes in aggregate rates. In other words, the exogeneity condition would not be violated if the average pass-through rate were correlated with demand shocks per se; it would only be violated if the average pass-through rate interacted with aggregate changes in rates were correlated with demand shocks. The story would have to be that pass-through is related to consumer characteristics and the demand of different consumers for deposits changes differently when the short rate changes. DSS suggests that pass through is about market power (i.e., the supply side), not consumer characteristics (the demand side), which provides additional support for the validity of the instrument.

Our second set of instruments consist of the traditional Berry, Levinsohn, and Pakes (1995)-style instrument set. Following BLP (1995) we define our instrument as the simple average of a bank's competitors' characteristics, where the characteristics we examine are the number of branches, number of employees, non-interest expenditures, and fees. To construct our instruments, we first take the unweighted average of a bank's competitors' characteristics at the county l by quarter level, $Z_{jlt}^{BLP} = (\overline{Branches_{-jlt}}, \overline{Employees_{-jlt}}, \overline{Non-Int.Exp_{-jlt}}, \overline{Fees_{-jlt}})$. Given the county-level averages Z_{jlt}^{BLP}, we then form our instrument at the bank- by-quarter level by taking the weighted average of Z_{jlt}^{BLP} across all counties a bank operates in to form Z_{jt}^{BLP}, where we weight by the size of the county in terms of the total amount of deposits across all banks. Because of potential nonlinearities in how banks set deposit rates as a function of their competitors' characteristics, we also include the corresponding quadratic terms ($Z_{jlt}^{BLP(2)}$) in our instrument set.

The relevance condition for our BLP instruments requires that the instruments are correlated with a bank's deposit rates. The intuition behind the BLP instruments is that, when setting its deposit rate, a bank must factor in the characteristics of its competitors. A bank that faces stronger competitors, in terms of a greater number of branches, lower fees, etc., will likely find it optimal to offer higher deposit rates. Consistent with this intuition, we find that our BLP instruments are relevant (F-statistic: 71). Second, we need the instruments to be exogenous. This means a bank's competitors' characteristics (number of branches, number of employees, non-interest expenditures, and fees) must be uncorrelated with the bank's quarter-specific demand shock. The endogeneity threat would be that a bank's competitors respond to the bank's own quarter-specific demand shock by updating its branches, employees, non-interest expenditure or fees. Here we use branches, employees, non-interest expenditure, and fees because these bank characteristics tend to be sticky in the short run. In other words, these variables are unlikely to be the margin of adjustment when responding to a competitor's demand shock. In contrast, we do not include a competitor's interest rate in our instrument set, because interest rates are often updated on a weekly or daily basis and it would be easy and highly plausible for a bank to adjust its deposit rates in response to a competitor's demand shock.

B. Calculating Model Implied Market-to-Book

As discussed in Section 1, our two productivity measures directly affect bank cash flows. For example, if a bank's ability to collect deposits 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

$$Cost\, Savings = Deposits \times \frac{\Delta\delta}{\alpha} \tag{16}$$

where α is the elasticity of demand for deposits. Similarly, if a bank's ability to invest assets and make loans increases from ϕ^0 to ϕ^1, its returns increase by

$$\Delta Y = \left[exp(\phi^1) - exp(\phi^0)\right] exp(\Gamma X_j) A_j^\theta. \tag{17}$$

Variation in a bank's ability to collect and invest deposits translates directly into bank value. Assuming a fixed payout ratio λ, discount rate k, and growth rate g, and keeping size fixed, we can write a bank's market-to-book as a function of its deposit and asset productivity plus some constant C.

$$\begin{aligned} \frac{M}{B} &= \frac{\lambda}{k-g}\left[\frac{exp(\phi_j)exp(\Gamma X_j)A_j^\theta + Deposits \times \frac{\delta_j}{\alpha}}{A}\right] + C \qquad (18) \\ &= \frac{\lambda}{k-g}\varpi_j + C \end{aligned}$$

where the term ϖ_j measures the variation in bank profitability attributable to variation in asset and deposit productivity. We use the model estimates of $\hat{\phi}$ and $\hat{\delta}$ to calculate the model implied market-to-book. Specifically, we calculate the term $\widehat{\varpi_j} = \left[exp(\hat{\phi}_j)exp(\Gamma\tilde{X}_j)\frac{\tilde{A}_j^\theta}{\tilde{A}} + \frac{\widetilde{Deposits}}{A} \times \frac{\hat{\delta}_j}{\alpha}\right]$ for each bank, keeping size fixed, where ($\sim$) denotes the median value for the banks in our sample. We then regress a bank's market-to-book on the term $\widehat{\varpi_j}$ and time fixed effects in order to recover an estimate of $\widehat{\frac{\lambda}{k-g}}$. We estimate a positive and statistically significant coefficient (p<0.01) of $\widehat{\frac{\lambda}{k-g}} = 3.46$. Assuming a fixed payout ratio of $\lambda = 28\%$ based on historical averages, the estimate of $\widehat{\frac{\lambda}{k-g}}$ implies an $k-g$ value of 8%, which is consistent with an average cost of equity of 9-10% (King, 2009) and an average growth rate of 1-2%. Hence, the estimates from our simple quantitative framework seem to match the observed M/B data quite well.

We can also use the estimates to help pin down the levels of bank productivity. A bank with zero deposit and asset productivity would have a market-to-book of 1, which implies the constant C should be equal to one in the above eq. (18). For robustness, we use this restriction to help pin down the level of deposit productivity. As described in Section 3, much of our baseline analysis speak to the cross section of bank value. With additional normalizing assumptions, we can make statements about the level of bank value. It is straightforward to to normalize our asset productivity measures based on the risk free return. We normalize the level of asset productivity by assuming that for a bank earning an asset yield equal to the 5-year Treasury yield, asset productivity's contribution to value is zero. For banks earning more than the 5-year Treasury yield, asset productivity's contribution is positive. Here, as a robustness check, we normalize the level of deposit productivity such that $C = 1$ in the eq (18). Specifically, we add the constant κ to deposit productivity δ_j for each bank in the above regression such that we estimate $\hat{C} = 1,$ as of 2015. This implies that a bank with zero deposit and asset productivity has a predicted value market-to-book of 1. We report the corresponding normalized distribution of deposit and asset productivity in Figure A1. The figure indicates that the liability side of the balance sheet accounts for the bulk of the level and variation in bank value.

We also note that if we were to normalize asset productivity relative to other benchmark yields, such as the A or AAA corporate bond yield, that would shift our distribution of asset productivity further to the left in Figure A1. This is because, if we benchmark a bank's investment income to a yield that is higher than the corresponding Treasury rate, such as the A or AAA corporate bond yield, banks will appear less productive on the asset side. By benchmarking bank investment income to Treasury rates, we are being relatively generous to the asset side of the bank. Despite being generous to the asset side of the bank, we still find that liability side of a bank contributes more to the level of bank value than the asset side.

C. Calculating Bank Efficiency

We construct bank cost efficiency following Berger and Mester (1997). Berger and Mester (1997) write bank cost efficiency as

$$C_{jt} = C(w_{jt}, y_{jt,} z_{jt,} v_{t,} u_{cj}, \epsilon_{ctj}),$$

where j indexes the bank, t indexes time, C_{jt} measures variable costs, w_{jt} is a vector of input prices, y_{jt} is a vector of variable outputs, z_{jt} is a vector of fixed netputs, v_{jt} is a vector of market factors, u_{cj} is a bank's cost inefficiency factor, and ϵ_{cjt} is a random error term. Note that we assume that the bank efficiency factor u_{cj} is persistent over time. This is consistent with the distribution-free approach in Berger (1993). Under the assumption that the inefficiency and random terms are multiplicatively separable, Berger and Mester (1997) write the cost function as:

$$\ln C_{jt} = f(w_{jt}, y_{jt}, z_{jt}, v_{jt}). \tag{19}$$

We estimate an empirical analog of eq. (19) using the distribution free approach and flexibly estimating the function $f(w_{jt}, y_{jt}, z_{jt}, v_{jt})$.

We define the variables as per Berger and Mester (1997). Output (y) consists of loans (y_1) and securities (y_2). Input (z) consists of off-balance-sheet guarantees (z_1), physical capital (z_2), and financial equity capital (z_3). Input prices (w) consist of the price of non-core deposits (w_1), core deposits (w_2), and the price of labor (w_3). There is one slight difference between our variable definitions and the variable definitions in Berger and Mester (1997). Berger and Mester (1997) treat consumer loans and business loans as separate outputs. However, because holding companies do not have to report disaggregated lending data in their FR Y-9C filings, we cannot differentiate between consumer loans and business loans and treat them as a single output.

We use flexibly estimate the function $f(\cdot)$ using the same functional forms and scaling used in Berger and Mester (1997). In particular, we estimate eq. (1) using the following specification

$$
\begin{aligned}
ln\left(\frac{C_{jt}}{w_{3jt}z_{3jt}}\right) =& \sum_{i=1}^{2}\beta_i \ln\left(\frac{w_{ijt}}{w_{3jt}}\right) + \frac{1}{2}\sum_{i=1}^{2}\sum_{k=1}^{2}\beta_{ik}\ln\left(\frac{w_{ijt}}{w_{3jt}}\right) + \sum_{l=1}^{2}\ln\left(\frac{y_{ljt}}{z_{3jt}}\right) \\
&+ \frac{1}{2}\sum_{l=1}^{2}\sum_{m=1}^{2}\gamma_{lm}\ln\left(\frac{y_{ljt}}{z_{3jt}}\right)\ln\left(\frac{y_{mjt}}{z_{3jt}}\right) + \sum_{r=1}^{2}\delta_r \ln\left(\frac{z_{rjt}}{z_{3jt}}\right) \\
&+ \frac{1}{2}\sum_{r=1}^{2}\sum_{s=1}^{2}\delta_{rs}\ln\left(\frac{z_{rjt}}{z_{3jt}}\right)\ln\left(\frac{z_{sjt}}{z_{3jt}}\right) \\
&+ \sum_{i=1}^{2}\sum_{l=1}^{2}\eta_{il}\ln\left(\frac{w_{ijt}}{z_{3jt}}\right)\ln\left(\frac{y_{ljt}}{z_{3jt}}\right) + \sum_{i=1}^{2}\sum_{r=1}^{2}\rho_{il}\ln\left(\frac{w_{ijt}}{z_{3jt}}\right)\ln\left(\frac{z_{rjt}}{z_{3jt}}\right) \\
&\sum_{l=1}^{2}\sum_{r=1}^{2}\tau_{lr}\ln\left(\frac{y_{ljt}}{z_{3jt}}\right)\ln\left(\frac{z_{rjt}}{z_{3jt}}\right) + \sum_{n=1}^{6}\left[\phi_n\cos(x_{njt}) + \omega_n\sin(x_{jnt})\right] \\
&+ \sum_{n=1}^{6}\sum_{q=n}^{6}\left[\phi_{nq}\cos(x_{njt}+x_{qjt}) + \omega_{nq}\sin(x_{jnt}+x_{qjt})\right] \\
&+ \sum_{q=n}^{6}\left[\phi_{nnn}\cos(x_{njt}+x_{njt}+x_{njt}) + \omega_{nnn}\sin(x_{njt}+x_{njt}+x_{njt})\right] \\
&+ \mu_j + \mu_t + \epsilon_{jt}.
\end{aligned}
\tag{20}
$$

where observations are at the bank j by quarter t level. The dependent variable is the bank's cost in terms of interest expense and wages. For each control variable $\left\{\ln\left(\frac{w_{1jt}}{w_{3jt}}\right), \ln\left(\frac{w_{2jt}}{w_{3jt}}\right), \ln\left(\frac{y_{1jt}}{z_{3jt}}\right), \ln\left(\frac{y_{2jt}}{z_{3jt}}\right), \ln\left(\frac{z_{1jt}}{z_{3jt}}\right), \ln\left(\frac{z_{2jt}}{z_{3jt}}\right)\right\}$, we define the normalized variable $x_1, x_2, \ldots, x_6$ such that each of the x_i is in the interval [0,2π] following the method in Berger and Mester (1997). Our empirical specification is nearly identical to Berger and Mester (1997) except we include time fixed effects (μ_t) to capture environmental changes and include bank dummy variables (μ_j) to capture the persistent differences in cost efficiencies across banks $\ln u_{cj}$. Using bank dummy variables follows the distribution-free methodology suggested in Berger (1993). Due to computational issues at the time, Berger (1993) was unable to directly estimate bank fixed effects; however, with the benefit of additional computing power, we are able to directly estimate bank fixed effects and can thus extend Berger (1993)'s findings. Our methodology is also consist with the methodology in Berger and Mester (1997), where efficiency is calculated based on the average bank-level residual. Including bank fixed effects nests the specification in Berger and Mester (1997) and also helps reduce potential endogeneity concerns. We estimate eq. (20) using ordinary least squares, and the estimated bank dummy variables (u_j) correspond to bank cost efficiency $\ln u_{cj}$.

D. 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 of productivity will overstate the true variance of productivity.[30] 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.

We examine a bank's average deposit and asset productivity in our sample using the estimated bank fixed effect in eqs. (6) and (8). We shrink the estimated distribution of fixed effects by the factor λ. 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 from 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 0.908), 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 A2. Figure A2 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 Figures 1 and A2.

[30]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 productivity is then equal to the true variance of deposit 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 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.

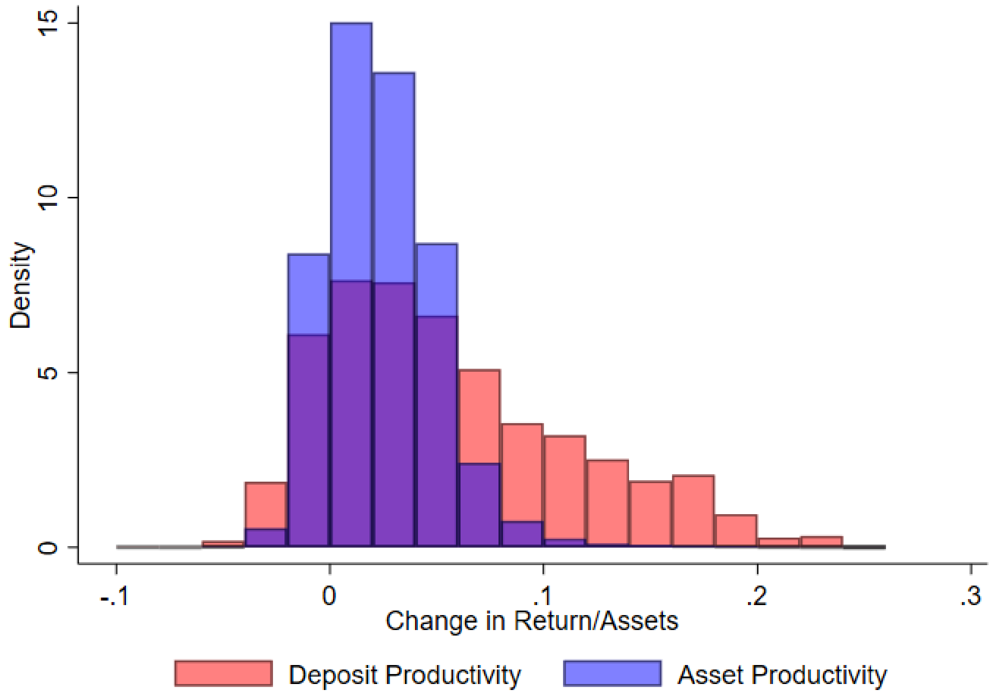
E. Data Appendix

Data Appendix

Variable	Description	Data Set
Deposit Int. Exp.	Quarterly interest expense on deposits divided by deposits and multiplied by 4.	FR Y-9C
Net Deposit Int. Exp	Quarterly interest expense on deposits minus service charges on deposit accounts in domestic offices divided by deposits and multiplied by 4.	FR Y-9C
Non Int. Expense	Quarterly non-interest expense.	FR Y-9C
No. Branches	Number of bank branches.	FDIC SOD
No. Employees	Number of full-time employees.	FR Y-9C
Assets	All bank assets	FR Y-9C
Interest-bearing Assets	Cash, securities, fed funds, and loans/leases, excluding trading assets.	FR Y-9C
Interest Income	Quarterly interest income multiplied by 4.	FR Y-9C
Interest Income Net of Losses	Quarterly interest income minus loan loss provisions, losses (gains) on loan sales, losses (gains) on held-to-maturity securities, losses (gains) on available-for-sale securities, and interest income on trading asset.	FR Y-9C
Deposits (Billions)	Total deposits.	FR Y-9C
Leverage	Book value debt divided by the book value of assets.	FR Y-9C
Market-to-Book	Market capitalization divided by book value of equity.	CRSP and FR Y-9C
Small Time Deposits	Time deposits of less than $100,000.	FR Y-9C
Large Time Deposits	Time deposits of $100,000 or more.	FR Y-9C
Savings Deposits	Money market deposit accounts and savings accounts.	FR Y-9C
Transaction Deposits	Non-interest bearing deposits and interest bearing demand deposits, NOW, ATS, and other transaction deposits.	FR Y-9C
FF+Repo	Fed funds purchased and securities sold under agreements to repurchase.	FR Y-9C
Loans	Total loans.	FR Y-9C
RE Loans	Total real estate loans.	FR Y-9C
C&I Loan	Total commercial and industrial loans.	FR Y-9C
Loan Commitments	Unused commitments (as per Kashyap et al. 2002).	FR Y-9C
Securities	Total securities holdings.	FR Y-9C
Cash	Total cash holdings.	FR Y-9C
FF+Repo	Federal funds sold and securities purchased under agreements to resell.	FR Y-9C

F. Appendix Figures and Tables

Figure A1: Value Creation: Asset Productivity vs. Deposit Productivity (Alternative Normalizations)



Note: the figure displays the distributions estimates of asset and deposit productivity with alternative level normalizations. Observations are at the bank by quarter level. The red shaded histogram plots the distribution of bank deposit productivity scaled by $\widetilde{Deposits/A}\frac{1}{\alpha}$ where $\widetilde{Deposits/A}$ denotes the median value for the banks our sample. The blue histogram displays the scaled distribution of asset productivity $\frac{\widetilde{Assets}^{\theta}}{Assets}exp(\phi_{jt} + \Gamma\tilde{X_{jt}})$ where $\widetilde{Assets}$ and $\tilde{X_{jt}}$ denote the median values for the banks in our sample. As discussed in Section 3.3 the scaling converts deposit and asset productivity in terms of returns on assets. We normalize the level of asset productivity relative to five year Constant Maturity Treasury rates such that the set of banks earning risk adjusted returns below the five year treasury rate have negative asset productivity. We normalize the level of deposit productivity as described in Section B such that a bank with zero deposit and asset productivity has a predicted market-to-book ratio of 1. The deposit productivity estimates correspond to the specification reported in column (2) of Table 2. The asset productivity estimates correspond to the specification reported in column (5) of Table 3.

Figure A2: Value Creation: Asset Productivity vs. Deposit Productivity (Measurement Error Adjusted)

Note: Figure A2 displays the distributions of our empirical Bayes estimates of asset and deposit productivity as discussed in Appendix D. We "shrink" the estimated distribution of asset and deposit productivity to account for measurement error. Observations are at the bank by quarter level. The red shaded histogram plots our empirical Bayes estimates of bank deposit productivity scaled by $\widetilde{Deposits/A}\frac{1}{\alpha}$ where $\widetilde{Deposits/A}$ denotes the median value for the banks our sample. The blue histogram displays the scaled distribution of our empirical Bayes estimates of asset productivity $\frac{\widetilde{Assets}^{\theta}}{\widetilde{Assets}} exp(\phi_{jt} + \Gamma \tilde{X_{jt}})$ where $\widetilde{Assets}$ and $\tilde{X_{jt}}$ denote the median values for the banks in our sample. As discussed in Section 3.3 the scaling converts deposit and asset productivity in terms of returns on assets. We normalize the level of asset productivity relative to five year Constant Maturity Treasury rates such that the 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 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 (2) of Table 2. The asset productivity estimates correspond to the specification reported in column (5) of Table 3.

Table A1: Refined Demand Estimates: Demand for Deposits by Type of Deposit

	Deposit Type			
	Savings	Small Time	Large Time	Transaction
	(1)	(2)	(3)	(4)
Deposit Rate	-19.65*	61.76***	54.91***	-2.579
	(11.50)	(17.50)	(15.44)	(11.63)
No. Branches (hundreds)	0.0799***	0.109***	0.0155	0.0139
	(0.0207)	(0.0381)	(0.0202)	(0.0140)
No. Empl (thousands)	0.00788	0.0253	0.0474***	0.0372***
	(0.0102)	(0.0186)	(0.0128)	(0.0105)
Non-Int. Exp. (billions)	-0.171	-0.900***	-0.565***	0.0737
	(0.156)	(0.313)	(0.217)	(0.0910)
Time Fixed Effects	X	X	X	X
Bank Fixed Effects	X	X	X	X
IV	X	X	X	X
Observations	23,719	23,955	24,011	21,809
R-squared	0.970	0.874	0.869	0.941

Note: Table A1 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 set (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) as described in the text. 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 A2: Refined Function Estimates: Bank Production Function by Asset Type

	Asset Type	
	Loans	Securities
	(1)	(2)
$\ln(\text{Loans}_{kt})$ (θ_L)	0.869***	
	(0.0228)	
$\ln(\text{Securities}_{kt})$ (θ_S)		0.962***
		(0.0155)
Beta	-0.0288***	0.00604
	(0.0100)	(0.0103)
SD ROA	-0.0570***	-0.0152**
	(0.00909)	(0.00680)
SD Net Ret. on Inv. Assets .	-0.0181	0.0130
	(0.0114)	(0.00898)
No. Branches (hundreds)	-0.00335	0.00384
	(0.00880)	(0.00710)
No. Empl (thousands)	0.0181**	0.000522
	(0.00841)	(0.00358)
Non-Int. Exp. (billions)	-0.289**	-0.00723
	(0.114)	(0.0510)
Bank F.E.	X	X
Time F.E.	X	X
Observations	17,878	18,893
R-squared	0.968	0.975

Table A2 reports our asset production function estimates for loans and securities. The unit of observation is at the bank by quarter level over the period 1994-2015. The dependent variable in column (1) (column 2) is log loan (securities) interest income earned by the bank. The key independent variable of interest in column (1) (column 2) is log bank loans (securities) where we calculate loans (securities) based on the quarterly average over the past year. We also control for the bank's equity beta, standard deviation of return on assets (standardized), standard deviation of net return on interest-bearing assets, and leverage. We measure beta on a rolling basis using monthly equity returns over the previous 24 months with data provided by CRSP and Kenneth French. We measure the standard deviation of return on assets and net return on interest-bearing 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 A3: Relationship Between Deposit and Asset Productivity

(a) Deposit vs. Asset Productivity

Dep. Var	Asset Productivity		Loan Productivity		Sec. Productivity	
	(1)	(2)	(3)	(4)	(5)	(6)
Deposit Productivity	0.453*	0.382	0.260**	0.378*	0.202**	0.105
	(0.253)	(0.347)	(0.130)	(0.427)	(0.0786)	(0.217)
Time F.E.	X	X	X	X	X	X
Other Controls		X		X		X
Observations	25,845	25,845	17,878	17,878	18,893	18,893
R-squared	0.200	0.271	0.067	0.129	0.038	0.071

(b) Deposit vs. Asset Productivity - Subcategory Measures

Dep. Var	Asset Productivity		Loan Productivity		Sec. Productivity	
	(1)	(2)	(3)	(4)	(5)	(6)
Deposit Prod.:						
Savings	0.250*	0.326***	0.124	0.439***	0.141**	0.112
	(0.147)	(0.101)	(0.105)	(0.151)	(0.0643)	(0.0902)
Small Time	0.130**	0.0818*	0.196**	0.237***	0.0847*	0.0821*
	(0.0510)	(0.0479)	(0.0775)	(0.0724)	(0.0446)	(0.0434)
Large Time	0.158**	0.125**	0.0715	0.0842	0.0589	0.0518
	(0.0693)	(0.0582)	(0.0678)	(0.0658)	(0.0450)	(0.0482)
Transaction	-0.0143	0.0447	-0.0658	0.0700	-0.0636	-0.0443
	(0.0879)	(0.0871)	(0.0644)	(0.0973)	(0.0584)	(0.0646)
Time F.E.	X	X	X	X	X	X
Other Controls		X		X		X
Observations	21,809	21,809	16,297	16,297	16,711	16,711
R-squared	0.216	0.266	0.093	0.139	0.045	0.079

Note: Tables A3a and A3b display the relationship between deposit productivity and asset productivity (Eq. 10). Observations are at the bank by quarter level. Each column corresponds to a separate linear regression. All independent and dependent variables are standardized. The dependent variable in columns (1)-(2) is overall productivity as measured using the production function estimates reported in column (5) 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 A2. The dependent variable in columns (5)-(6) is securities productivity as measured using the production function estimates reported in column (2) of Table A2. The key independent variable of interest is deposit productivity. We measure overall deposit productivity using the demand estimates reported in column (2) of Table 2 and deposit productivity for each type of deposit using the demand estimates reported in Table A1. Other controls include: log assets (lagged by one year); leverage (lagged by one quarter); three-month returns (lagged by one quarter); equity beta; the standard deviation of net return interest-bearing assets (net of losses); the standard deviation of return on assets; the share of deposit liabilities; and the share of assets in loans and securities. The standard errors are reported in parentheses 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 A4: Productivity vs. Composition of Assets and Liabilities

(a) Composition of Assets and Deposit Productivity

Dep. Var	RE Loans / Assets (1)	C&I Loan / Assets (2)	Loan Commit. / Assets (3)	Securities / Assets (4)	Cash / Assets (5)	FF+Repo / Assets (6)
Deposit Prod.	0.180	0.717***	0.251*	-0.0149	-0.140	-0.686**
	(0.155)	(0.157)	(0.142)	(0.207)	(0.138)	(0.317)
Time F.E.	X	X	X	X	X	X
Other Controls	X	X	X	X	X	X
Observations	23,740	22,806	25,845	25,845	25,845	17,695
R-squared	0.312	0.089	0.134	0.072	0.192	0.125

(b) Composition of Liabilities and Asset Productivity

Dep. Var	Leverage (1)	Deposits / Liabilities (2)	Small Time / Liabilities (3)	Large Time / Liabilities (4)	Savings / Liabilities (5)	Trans. / Liabilities (6)	FF+Repo / Liabilities (7)
Asset Prod.	-0.0102**	-0.0104	0.0124	0.0881***	-0.0120	-0.0830***	-0.00663
	(0.00483)	(0.0445)	(0.0183)	(0.0234)	(0.0292)	(0.0306)	(0.0286)
Time F.E.	X	X	X	X	X	X	X
Other Controls	X	X	X	X	X	X	X
Observations	25,845	25,845	25,842	25,842	23,740	23,737	17,695
R-squared	0.970	0.275	0.368	0.163	0.231	0.208	0.134

Note: Table A4 (a) and (b) display the relationship between productivity and a bank's liability and asset structure. Observations in both panels are at the bank by quarter level. In panel (a), we regress the composition of a bank's assets on deposit productivity. We measure deposit productivity using the demand estimates reported in column (2) of Table 2. In panel (b) we regress bank leverage and the composition of its deposits on asset productivity. We measure asset productivity using the estimates reported in column (5) of Table 3. Other controls include: log assets (lagged by one year); leverage (lagged by one quarter); three-month returns (lagged by one quarter); equity beta; the standard deviation of net return interest-bearing assets (net of losses); and the standard deviation of return on assets. The standard errors are reported in parentheses 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 A5: Alternative Demand Estimates

(a) County Level Demand Estimates

	(1)	(2)	(3)
Deposit Rate	20.33	18.19**	21.02***
	(13.59)	(8.213)	(5.196)
Deposit Rate × Avg. Weekly Wage			11.78***
			(1.644)
Deposit Rate × Pct College			-10.87***
			(1.447)
Deposit Rate × Pct Over 65			6.013***
			(1.375)
No. of Branches (County Level)		1.257***	1.256***
		(0.0272)	(0.00400)
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	0.128***	0.147***	0.369***	0.0178
	(0.0219)	(0.0184)	(0.0567)	(0.0239)
Asset Productivity	0.0751**	0.0533**		
	(0.0357)	(0.0221)		
Time F.E.	X	X	X	X
Other Controls		X		X
Observations	3,005	3,005	3,005	3,005
R-squared	0.435	0.488	0.130	0.196

Table A5: Alternative Demand Estimates (Continued)

	(1)	(2)
Deposit Productivity	0.106***	0.0703***
	(0.0243)	(0.0214)
Deposit Productivity $\times$ Deposit Rate Sensitivity	-0.0409***	-0.0343***
	(0.00771)	(0.00678)
Deposit Rate Sensitivity	-0.00717	-0.00719
	(0.00904)	(0.00860)
Asset Productivity	0.0840**	0.0507**
	(0.0381)	(0.0226)
Time F.E.	X	X
Other Controls		X
Observations	3,000	3,000
R-squared	0.431	0.487

(c) Market to Book and Average Elasticity of Demand

Note: We report our demand estimates (Eq. 6) in Table A5a 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 2002-2012. 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 A5b, we replicate our baseline set of results using our alternative measure of deposit productivity. The asset productivity estimates correspond to the specification reported in column (5) of Table 3. We construct county by firm by year measures of deposit productivity using our county level demand estimates reported in column (1) of Table A5a. Let $\hat{\delta}_{jlt}$ denote the estimated deposit productivity of firm j in county l at time t where $\hat{\delta}_{jlt} = \ln N_{lt} s_{jlt} - \hat{\alpha} i_{jt} - \hat{\mu}_{lt}$. 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 $\delta_{jt} = \ln\left(\sum_{k \in K} N_{kt} exp(\delta_{kjt})\right)$ where we denote the set of counties bank j operates as K.

Table A5c 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 A5a. Observations in Tables A5b and A5c are at the bank by year level over the period 2002-2012. Other controls include: log assets (lagged by one year); leverage (lagged by one quarter); three-month returns (lagged by one quarter); equity beta; the standard deviation of net return interest-bearing assets (net of losses); the standard deviation of return on assets; the share of deposit liabilities; and the share of assets in loans and securities. 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: Alternative Production Function Estimates

	(1)	(2)
$\ln A_{kt}$ (θ)	0.965***	0.983***
	(0.0307)	(0.0492)
θ_1	-0.0334	
	(0.0391)	
θ_2	-0.0155	
	(0.0430)	
θ_3	0.0170	
	(0.0385)	
θ_4	-0.190***	
	(0.0376)	
Beta	-0.0138**	
	(0.00718)	
Beta (fwd 2 yr)		0.00682
		(0.00460)
SD ROA	-0.0633***	
	(0.00746)	
SD ROA (fwd 2 yr)		-0.0234***
		(0.00511)
SD Ret. on Loans and Sec.	0.00177	
	(0.00608)	
SD Ret. on Loans and Sec. (fwd 2 yr)		0.0577***
		(0.00657)
SMB (fwd 2 yr)		-0.000567
		(0.00212)
HML (fwd 2 yr)		-0.00129
		(0.00201)
$Securities_{t-4}/Assets_{t-4}$		-0.142
		(0.0968)
$Loans_{t-4}/Assets_{t-4}$		0.287**
		(0.115)
Bank F.E.	X	X
Time F.E.	X	X
Other Controls	X	X
Observations	25,845	17,716
R-squared	0.976	0.995

Note: Table A6 displays our alternative production function estimates. The unit of observation is at the bank by quarter level. The dependent variable in columns (1) and (2) is the logged value of interest income earned by the bank. The dependent variable in column (3) is log interest income net of realized gains/losses on loans/securities. 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 as described in Section 5. In column (2) and (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 column (2), we also control for the other Fama French Factors, HML and SMB, and asset composition. We measure betas on a rolling basis using monthly equity returns over the previous 24 months with data provided by CRSP and Kenneth French. We measure the standard deviation of return on assets and standard deviation of net return on interest-bearing assets on a rolling basis using quarterly income statement/balance sheet data over the previous eight quarters. Other controls include lag leverage, non-interest expense, number of employees, and number of branches. Standard errors are clustered at the bank level and are reported in parentheses. *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

Table A7: Alternative Asset Production Fuction Estimates

(a) Alternative Production Function Estimates - Spline

Dep. Var.	Market-to-Book		Asset Productivity	
	(1)	(2)	(3)	(4)
Deposit Productivity	0.215***	0.501***	0.345***	0.454
	(0.0247)	(0.165)	(0.0864)	(0.425)
Asset Productivity	0.0624***	0.0863***		
	(0.0214)	(0.0154)		
Time F.E.	X	X	X	X
Other Controls		X		X
Observations	25,845	25,845	25,845	25,845
R-squared	0.421	0.474	0.116	0.227

(b) Alternative Production Function Estimates - Asset Composition

Dep. Var.	Market-to-Book		Asset Productivity	
	(1)	(2)	(3)	(4)
Deposit Productivity	0.262***	0.835***	-0.0803	0.324
	(0.0454)	(0.171)	(0.368)	(0.589)
Asset Productivity	0.0675	0.0659**		
	(0.0449)	(0.0321)		
Time F.E.	X	X	X	X
Other Controls		X		X
Observations	17,716	17,716	17,716	17,716
R-squared	0.430	0.480	0.010	0.089

Note: In Tables A7a and A7b we replicate our baseline set of results using our alternative measures of asset productivity (Table A6). To construct the measure of asset productivity reported In Table A7a, we estimate the bank's asset income production function using a spline with five knot points as discussed in Section 5. To construct the measure of asset productivity reported In Table A7b, 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 (2) of Table 2. Observations in Tables A7a and A7b are at the bank by quarter level. Other controls include: log assets (lagged by one year); leverage (lagged by one quarter); three-month returns (lagged by one quarter); equity beta; the standard deviation of net return interest-bearing assets (net of losses); the standard deviation of return on assets; the share of deposit liabilities; and the share of assets in loans and securities. The standard errors are reported in parentheses 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 A8: Alternative Measures of Value

(a) Tobin's q

	(1)	(2)	(3)	(4)	(5)	(6)
Deposit Productivity	0.242***	0.766***			0.226***	0.742***
	(0.0276)	(0.155)			(0.0320)	(0.153)
Asset Productivity			0.134**	0.0822***	0.0362	0.0637***
			(0.0591)	(0.0222)	(0.0293)	(0.0187)
Time F.E.	X	X	X	X	X	X
Other Controls		X		X		X
Observations	25,845	25,845	25,845	25,845	25,845	25,845
R-squared	0.432	0.489	0.394	0.466	0.433	0.492

(b) Return on Equity

	(1)	(2)	(3)	(4)	(5)	(6)
Deposit Productivity	0.186***	0.526**			0.0269	0.375**
	(0.0176)	(0.120)			(0.0995)	(0.164)
Asset Productivity			0.363***	0.403***	0.351***	0.394***
			(0.0351)	(0.0420)	(0.0389)	(0.0406)
Time F.E.	X	X	X	X	X	X
Other Controls		X		X		X
Observations	25,845	25,845	25,845	25,845	25,845	25,845
R-squared	0.290	0.360	0.388	0.467	0.389	0.473

(c) ln(Market Cap)

	(1)	(2)	(3)	(4)	(5)	(6)
Deposit Productivity	1.721***	0.682***			1.672***	0.632***
	(0.0769)	(0.158)			(0.0830)	(0.147)
Asset Productivity			0.834*	0.145***	0.108	0.130***
			(0.438)	(0.0203)	(0.0706)	(0.0165)
Time F.E.	X	X	X	X	X	X
Other Controls		X		X		X
Observations	25,845	25,845	25,845	25,845	25,845	25,845
R-squared	0.871	0.948	0.240	0.946	0.873	0.951

Note: In Tables A8a, A8b and A8c, we replicate our baseline set of results from eq. (9) using alternative measures of bank value and return. Observation in each panel are at the bank by quarter level. The dependent variable in Table A8a is Tobin's q, the dependent variable in Table A8b is the bank's return on equity (ROE), and the dependent variable in Table A8c is ln(Market Cap). We calculate Tobin's q as equity market capitalization plus book value of liabilities divided by its book value of assets. Tobin's q, ROE, and ln(Market Cap) are standardized. We winsorize Tobin's q and ROE at the 2% level to account for outliers. This changes the range of quarterly ROE from [-38% to 14%] to be [-5% to 6%] and changes the range of Tobins q from [0.93 to 8.31] to [0.94 to 1.24]. The key independent variables of interest are deposit and asset productivity. Both deposit and asset productivity are standardized. The deposit productivity estimates correspond to the specification reported in column (2) of Table 2. The asset productivity estimates correspond to the specification reported in column (5) of Table 3. Other controls include: log assets (lagged by one year); leverage (lagged by one quarter); three-month returns (lagged by one quarter); equity beta; the standard deviation of net return interest-bearing assets (net of losses); the standard deviation of return on assets; the share of deposit liabilities; and the share of assets in loans and securities. The standard errors are reported in parentheses 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 A9: Measurement Error - Instrumental Variables

Dep. Var.	Market-to-Book		Asset Productivity	
	(1)	(2)	(3)	(4)
Deposit Productivity	0.161***	0.802***	0.478***	0.592**
	(0.0301)	(0.131)	(0.0268)	(0.231)
Asset Productivity	0.105***	0.126***		
	(0.0306)	(0.0193)		
Time F.E.	X	X	X	X
Other Controls		X		X
IV	X	X	X	X
Observations	16,133	16,133	21,809	21,809
R-squared	0.424	0.477	0.197	0.255

Note: In Table A9, we replicate our baseline set of results using instrumental variables to address potential measurement error issues. Observations are at the bank by quarter level. Specifically, we instrument for deposit productivity using the subcategory deposit productivity measures that we construct from the estimates reported in Table A1. Similarly, we instrument for asset productivity using the subcategory asset productivity that we construct from the estimates reported in Table A2. We measure deposit and asset productivity using the estimates reported in columns (2) of Table 2 and (5) of Table 3. Other controls include: log assets (lagged by one year); leverage (lagged by one quarter); three-month returns (lagged by one quarter); equity beta; the standard deviation of net return interest-bearing assets (net of losses); the standard deviation of return on assets; the share of deposit liabilities; and the share of assets in loans and securities. 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 A10: Subsample Analysis

(a) Subsample Analysis - Excluding the Largest Banks

Dep. Var.	Market-to-Book		Asset Productivity	
	(1)	(2)	(3)	(4)
Dep. Prod.	0.220***	1.018***	0.452*	1.439***
	(0.0344)	(0.173)	(0.245)	(0.344)
Asset Prod.	0.0891***	0.0823***		
	(0.0222)	(0.0151)		
Time F.E.	X	X	X	X
Controls		X		X
Obs.	24,064	24,064	24,064	24,064
R-squared	0.428	0.475	0.163	0.246

(b) Subsample Analysis - Excluding the Financial Crisis

Dep. Var.	Market-to-Book		Asset Productivity	
	(1)	(2)	(3)	(4)
Dep. Prod.	0.207***	0.738***	0.476*	0.388
	(0.0357)	(0.150)	(0.252)	(0.350)
Asset Prod.	0.0869***	0.112***		
	(0.0264)	(0.0241)		
Time F.E.	X	X	X	X
Controls		X		X
Obs.	23,484	23,484	23,484	23,484
R-squared	0.403	0.449	0.269	0.375

(c) Subsample Analysis - Traditional Banks

Dep. Var.	Market-to-Book		Asset Productivity	
	(1)	(2)	(3)	(4)
Dep. Prod.	0.181***	0.816***	0.508**	0.882***
	(0.0396)	(0.176)	(0.246)	(0.317)
Asset Prod.	0.122***	0.121***		
	(0.0146)	(0.0148)		
Time F.E.	X	X	X	X
Controls		X		X
Obs.	23,142	23,142	23,142	23,142
R-squared	0.461	0.533	0.237	0.280

(d) Subsample Analysis - Excluding Mergers

Dep. Var.	Market-to-Book		Asset Productivity	
	(1)	(2)	(3)	(4)
Dep. Prod.	0.198***	0.769***	0.421*	0.118
	(0.0332)	(0.165)	(0.255)	(0.360)
Asset Prod.	0.0614**	0.0891***		
	(0.0239)	(0.0174)		
Time F.E.	X	X	X	X
Controls		X		X
Obs.	17,010	17,010	17,010	17,010
R-squared	0.426	0.482	0.170	0.247

Note: In Tables A10a, A10b, A10c and A10d we replicate our baseline set of results using different subsets of the data. Observations in each panel are at the bank by quarter level. In Table A10a, 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 A10a, 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 A10c 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. In Table A10d we replicate our baseline set of results where we drop observations within a two-year period surrounding any merger or acquisition activity where the merger increased the size of the bank by more than 10%. We measure deposit and asset productivity using the estimates reported in columns (2) of Table 2 and (5) of Table 3. Other controls include: log assets (lagged by one year); leverage (lagged by one quarter); three-month returns (lagged by one quarter); equity beta; the standard deviation of net return interest-bearing assets (net of losses); the standard deviation of return on assets; the share of deposit liabilities; and the share of assets in loans and securities. The standard errors are reported in parentheses 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 A11: Alternative Deposit Demand Estimates - Extended Data Set

	(1)	(2)	(3)	(4)
Deposit Rate	13.66***	8.943**	49.40***	11.06**
	(1.721)	(4.363)	(14.43)	(4.464)
No. Branches (hundreds)	0.0366***	0.0345***	0.0518***	0.0351***
	(0.0109)	(0.0111)	(0.0128)	(0.0111)
No. Empl (thousands)	0.0330***	0.0328***	0.0353***	0.0329***
	(0.00955)	(0.00949)	(0.0104)	(0.00948)
Non-Int. Exp. (billions)	-0.163	-0.148	-0.270**	-0.151
	(0.117)	(0.117)	(0.133)	(0.116)
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	32,518	32,518
R-squared	0.976	0.976	0.970	0.976

Note: We report our demand estimates (Eq. 6) in Table A11. 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 26,153 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. We define the market for deposits at the aggregate 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 set (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 set (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) as described in the text. We winsorize all independent variables at the 1% level 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 A12: Alternative Productivity Estimates: Controlling for Wages

	(1)	(2)	(3)	(4)	(5)	(6)
Deposit Productivity	0.235***	0.750***			0.198***	0.703***
	(0.0232)	(0.144)			(0.0318)	(0.142)
Asset Productivity			0.169***	0.124***	0.0749***	0.102***
			(0.0498)	(0.0249)	(0.0218)	(0.0187)
Time F.E.	X	X	X	X	X	X
Other Controls		X		X		X
Observations	24,988	24,988	24,988	24,988	24,988	24,988
R-squared	0.418	0.469	0.384	0.446	0.424	0.478

Note: the table displays the results corresponding to the regression of bank market-to-book on deposit and asset productivity. The unit of observation is at the bank by quarter level. 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. When constructing deposit and asset productivity we include wages as an additional control variable. Other controls include: log assets (lagged by one year); leverage (lagged by one quarter); three-month returns (lagged by one quarter); equity beta; the standard deviation of net return interest-bearing assets (net of losses); the standard deviation of return on assets; the share of deposit liabilities; and the share of assets in loans and securities. The standard errors are reported in parentheses 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 A13: First Stage - Deposit Demand

	(1)	(2)	(3)
Pass-through Instrument (IV-1):			
Predicted Pass-through	0.76***		0.74***
	(0.043)		(0.042)
BLP Instruments (IV-2):			
$\overline{Fees}_{comp}$		-6.92***	-5.87***
		(1.69)	(1.48)
$\overline{Fees}^2_{comp}$		1,418***	1,197***
		(476)	(420)
$\overline{Employees}_{comp}$		0.000042	0.000034
		(0.000036)	(0.000032)
$\overline{Employees}^2_{comp}$		6.5e-08	1.7e-08
		(2.5e-07)	(2.2e-07)
$\overline{Non-Interest\,Expense}_{comp}$		-0.00020**	-0.00014*
		(0.000080)	(0.000072)
$\overline{Non-Interest\,Expense}^2_{comp}$		6.6e-06***	3.7e-06*
		(2.3e-06)	(2.0e-06)
$\overline{Branches}_{comp}$		3.2e-06	0.000038
		(0.00015)	(0.00012)
$\overline{Branches}^2_{comp}$		-5.3e-06	-5.2e-06
		(4.7e-06)	(3.7e-06)
Time F.E.	X	X	X
Bank F.E.	X	X	X
Other Controls	X	X	X
Observations	25,845	25,845	25,845
R-squared	0.944	0.937	0.945
F-Stat (of IVs)	4,146	71	515

Note: Table A13 displays the first stage estimates corresponding to our deposit demand specifications. The unit of observation is at the bank by quarter level. The dependent variable is the bank's average deposit rate net of deposit fees and is measured as the bank's total quarterly deposit interest expense net of fees (scaled by 4) divided by the bank's level of deposits. 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 set of instruments (IV-2) as the average of the product characteristics offered by a bank's competitors in the previous quarter (branches (in hundreds), employees (in thousands), non-interest expense (in billions), 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. Other controls correspond to the other controls included in our demand specifications and include the number of branches a bank operates, number of employees, non-interest expense. We winsorize all independent variables at the 1% level 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 A14: First Stage - Bank Production Function (Asset Income)

	(1)	(2)	(3)
Instruments:			
$\overline{DepositProductivity}_{comp}$	-0.0163	-0.0179	-0.0249
	(0.0171)	(0.0163)	(0.0171)
$\overline{DepositProductivity}^2_{comp}$	-0.0209***	-0.0205***	-0.0189***
	(0.00731)	(0.00680)	(0.00673)
$\overline{Fees}_{comp}$	-532.7***	-485.1***	-429.5**
	(188.2)	(178.3)	(191.3)
$\overline{Fees}^2_{comp}$	107,618**	97,408**	83,472
	(52,680)	(49,461)	(52,189)
$\overline{Employees}_{comp}$	0.00268	0.00273	0.00321
	(0.00341)	(0.00324)	(0.00321)
$\overline{Employees}^2_{comp}$	-7.44e-06	-8.21e-06	-6.05e-06
	(2.35e-05)	(2.22e-05)	(2.32e-05)
$\overline{Non-Interest\,Expense}_{comp}$	0.00544	0.00272	-0.00146
	(0.00821)	(0.00754)	(0.00739)
$\overline{Non-Interest\,Expense}^2_{comp}$	-9.28e-05	-2.45e-05	3.87e-05
	(0.000230)	(0.000214)	(0.000220)
$\overline{Branches}_{comp}$	-0.00616	-0.00760	-0.00434
	(0.0167)	(0.0156)	(0.0161)
$\overline{Branches}^2_{comp}$	-2.50e-05	6.29e-05	2.76e-06
	(0.000516)	(0.000481)	(0.000509)
Controls (1)		X	X
Controls (2)			X
Time F.E.	X	X	X
Bank F.E.	X	X	X
Observations	25,845	25,845	20,576
R-squared	0.980	0.982	0.983
F-Stat (of IVs)	98	94	76

Note: the table displays the first stage estimates corresponding to our deposit demand specifications. The unit of observation is at the bank by quarter level. The dependent variable is log investable assets. We construct our instrument as the using the weighted average deposit productivity of bank 's competitors ($\overline{DepositProductivity}_{comp}$). For ease of interpretation we standardized the variable $\overline{DepositProductivity}_{comp}$. We winsorize all independent variables at the 1% level to help control for outliers in the sample. Controls (1) include: equity beta, SD of ROA, SD of net return on investable assets, non-interest expenditures, number of employees, and number of branches. We measure beta on a rolling basis using monthly equity returns over the previous 24 months with data from CRSP and Kenneth French. We measure the standard deviation of return on assets and income on a rolling basis using quarterly income statement/balance sheet data over the previous eight quarters. Controls (2) include the forward measures of equity beta, SD of net return on investable assets, and SD of ROA, that are calculated on a rolling basis over the proceeding two years. Standard errors are clustered by bank and are reported in parentheses. The symbols *,**, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.