Market Power and Cost Efficiencies in Banking[1]

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Abstract

A merger wave during the last 20 years has led to a decrease in the number of commercial banks from 12,343 in 1990 to 6,222 in 2012. For anti-trust and regulatory agencies, evaluating the relative importance of market power and cost efficiencies that result from a horizontal merger is important. To quantify these two effects, I develop an empirical model of banking which includes a demand model for differentiated products that allows market power effects to be calculated and a cost model that quantifies cost efficiencies from a merger. Since most of these banks operate in more than one market, incorporating the network structure of branches in the analysis is important. Cost parameters related to the network structure are estimated using moment inequality methods. Using the estimated parameters, I simulate mergers between banks of various sizes. I find that for a merger between 2 small banks (less than 500 branches), cost efficiencies play an important role in profitability. While for mergers involving a large bank (more than 500 branches) and a small bank or two large banks, the benefits accruing from market power are far more than the cost savings if there is substantial overlap in the networks of the merging banks. Although mergers involving large banks generate more market power, overall consumer welfare increases as the price effect of market power gets dominated by the consumer's preference for a larger bank.

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1 Introduction

Th removal of legal restrictions on intrastate and interstate banking was a gradual process that culminated with passage of the Riegle-Neal Act in 1994. Since then, the banking industry has undergone substantial restructuring. This gradual deregulation has led to a consolidation of banks over the last 30 years that is still ongoing. In 1990, there were 12,343 commercial banks and 2,815 savings FDIC insured banks in the United States.[3] In 2012, these numbers had fallen to 6,222 commercial banks and 1,024 savings banks. This consolidation in the banking industry has been driven primarily by mergers. As the number of banks has declined, the average size of banks, measured by deposits, has risen from 184 million dollars in 1990 to 978 million dollars in 2012. Since the banking industry is connected to all other industries and, as we have seen recently, widespread failures can lead to a financial crisis, it is important to understand the reasons behind the ongoing consolidation and its impact on the strength of competition and cost efficiencies. This paper will study these effects of a merger and also quantify its impact on consumer welfare.

Anti-trust and regulatory agencies always screen horizontal mergers for the role of market power and cost efficiencies as the possible driving forces behind the merger. For a merger between two conglomerates (firms present in more than one market), market power is often a geographically local phenomenon while cost efficiencies are realized at the firm level. In this paper I quantify and compare these two forces. Another aspect that is particular to banking industry mergers is the consumer's preference for a large network of branches. Consumers prefer large network of branches not only due to geographical convenience, but also because larger banks are deemed safer to bankruptcy risk. As a result, just looking at the price effects to evaluate a merger could leave out an important effect of merger.[4] This paper accounts for the role of price as well as the preference for large banks in the calculation of consumer welfare.

I develop a three stage empirical model of competition that captures the long-run effects of establishing a branch network and short-run effects due to price competition and capital structure. In the first stage, all banks choose their network of branches. The network decision comprises the number of branches to open and their location. In the second stage, banks choose equity capital. Equity capital is needed for three reasons: to satisfy government regulation constraints, signal safety to uninsured depositors, and acts as an alternative to deposits for funding loans. In the third stage, banks set deposit interest rates and compete in a Bertrand competition to collect deposits. Consumers demand deposit services and

[3]Almost 98% of the banks in the U.S. are FDIC insured.

[4]The 2010 Horizontal Merger Guidelines adopted UPP(Upward Pricing Pressure) as one of the ways to evaluate a merger which is based on price effects alone.

choose banks based upon their characteristics. This choice of timing distinguishes long-run decisions about network structure from short-run decisions about capital choice and pricing of deposits.

Structural estimation of the model is done in three stages. First, demand parameters are estimated using supply-side and demand-side moments jointly. Second, the cost of raising equity capital is estimated by using moments formed by the first-order condition of equity capital. Finally, the remaining cost parameters are estimated using the moment inequality method proposed in Pakes, Porter, Ho and Ishii (2011) , PPHI henceforth. To form inequalities, counterfactual policies are generated using addition and subtraction of branches in different markets. For inference, I use the PPHI method as well as the generalized moment selection approach proposed by Andrews and Soares (2011).

The presence of market power in the banking industry is well documented. Prager and Hannan (1998) find that a reduction in interest rates on local deposit accounts was associated with horizontal mergers that raised market concentration significantly. Berger, Demsetz, and Strahan (1999) use data for the 1990s and find a negative relationship between local market concentration and deposit rates. Simons and Stavins (1998) find that an increase in a local concentration measure (HHI) leads to a decrease in deposit interest rates.

On the cost side, there is a long debate about the presence of economies of scale in banking. Studies by Boyd and Graham (1998), Mester (1987), Berger, Hanweck and Humphrey (1987), and Boyd and Runkle (1993) did not find economies of scale beyond very small banks. These studies used data from the 1980s and didn't incorporate risk aspects of banking into the banking technology. More recently, Hughes, Mester, and Moon (2001), Hughes, Lang, Mester, and Moon (1996), Hughes and Mester (1998) found significant economies of scale in most banks when capital structure and endogenous risk taking were explicitly considered in the analyses of production. My paper also contributes to this stream of literature. None of these papers controlled for market power at the local geographic level while calculating economies of scale at the national level. It is possible that the change in profits/costs with size could be different if we control for local market power. Hence, the conclusions about scale economies in the existing literature may be misleading as a result of ignoring the market power effect.

The estimation results show that consumers prefer banks who offer high deposit rates, have more branches locally and nationwide, and are more capitalized. The cost parameters estimated through moment inequalities are partially identified and I get set estimates for these parameters. I allow for the cost function to differ between small (less than 500 branches) and large banks (more than 500 branches). After controlling for market power, the evidence for cost efficiencies is weak at best for smaller banks. For larger banks, the cost function is less concave than smaller banks suggesting a decrease in cost efficiencies as banks get larger. The estimated interest rate to raise equity capital for small banks is 6.03% while for larger banks the interest rate is 5.24%. This result is reasonable given that large banks are more diversified and could be perceived as being too big to fail. From an investor's point of view, this allows big banks to be considered as a safer investment.

Using the estimated parameters, I simulate mergers between different type of banks to compare the benefits that accrue from market power versus cost efficiencies. I simulate mergers in three categories: between two small banks, a small bank and a large bank and between two large banks. For mergers between two small banks cost efficiencies are found to play an important role. For a merger between a small and a large bank, the extra revenue generated by market power is much larger than the cost savings if there is substantial overlap in the networks of the merging banks. When two large banks merge the market power effect dominates the cost efficiencies effect. The reason behind these results is the decrease in the concavity of the cost function for larger banks. The mergers involving larger banks (small-large bank merger or large-large bank merger) increase consumer surplus if I account for both price effects as well as consumer's preference for large networks. Hence, the market power effect of prices is dominated by a better quality product in mergers involving large banks. Large network of branches can be assumed to be of higher quality due to two reasons. First, banking services are easier to access for large networks. Second, larger banks can be more safer to bankruptcy risk.

The rest of the paper is organized as follows. Section 2 discusses data used for the analysis. Section 3 introduces the model. In Section 4, I outline the estimation strategy. Section 5 discusses the estimation results. Section 6 contains counterfactual experiments and section 7 concludes.

2 Data

2.1 Data Sources

The data used in this paper is a cross-section of commercial banks from 2006.

Data is taken from three sources. Information on bank ownerships, location of branches and deposits is taken from Summary of Deposits at the Federal Deposit Insurance Corporation (FDIC). The variables in the FDIC data can be divided into three categories: Bank Holding Company (BHC) variables, institution (bank level) variables, and branch variables. Bank holding companies (BHC) are at the top of hierarchy, with banks in the middle level and branches are at the bottom. A bank holding company (BHC) is a company that controls one or more banks. There are also banks that are not owned by any BHC. All BHCs in the U.S. are required to register with the Board of Governors of the Federal Reserve System whereas non-BHC banks can function under the supervision of the Comptroller of the Currency or the Federal Deposit Insurance Corporation. A BHC needs a separate charter for each bank.[5] For example, Bank of America may have many bank charters and multiple branches across the country but it will have only one BHC. In this paper, the decision maker is a BHC. Some small banks are not registered as a BHC and for them the bank is the decision maker. For the rest of the paper, banks and bank holding companies (BHC) are used interchangeably.

I also use bank level data taken from the Call Reports available at Federal Reserve Bank of Chicago. Call reports contain information on interest expenses on deposits, interest revenues from loans, equity capital, total employees and wages. Using the hierarchy information in the FDIC data, the bank level data from the Call Reports is aggregated into BHC level data. The interest rate on deposits is calculated as a ratio of interest expenses to total deposits. Similarly, the interest rate on loans is calculated as a ratio of interest revenue to total loans. I use wages and employees per branch as instruments in the demand estimation.

Data on demographic information such as population and income is taken from the Bureau of Economic Analysis (BEA). Total income in a market is used to calculate the outside good in the demand estimation where consumers choose banks for deposit services. I also use market level income as a measure of market size to construct the branch density variable used in demand estimation. Market level population is used to form weighting function used in the moment inequality estimation.

2.2 Market and Data Summary

A market is defined as a Metropolitan Statistical Area (MSA). Antitrust analysis has relied on the definition of a banking market at the MSA level. Using data from the Survey of Consumer Finances, Amel and Starr-McCluer (2001) find that households obtain 90% of the checking accounts, savings accounts and certificates of deposits within the local market. Kwast, Starr-McCluer and Wolken (1997) find that over 94% of small businesses use a local depository institution.

The sample covers 353 MSAs and 4,316 firms.[6] Out of the 4,316 decision makers, 3,194

[5]Becoming a bank holding company makes it easier for the firm to raise capital than as a traditional bank. The holding company can assume debt of shareholders on a tax free basis, borrow money, acquire other banks and non-bank entities more easily, and issue stock with greater regulatory ease. The downside includes responding to additional regulatory authorities.

[6]In total there are 366 MSAs. Small MSAs that do not have any commercial banks are not considered in the analysis.

are BHCs and 1,122 are banks that are not part of a BHC. The average number of BHCs in a market is approximately 23. The smallest number of BHCs in a market (El Centro, CA) is 5, while the market with the most BHCs, Chicago-Joliet-Naperville, IL-IN-WI, has 227.

As banks get larger in size they set lower deposit interest rates. The correlation coefficient between the log of deposit interest rate and the log of the number of branches is -0.0493 (0.0012).[7] This provides some preliminary evidence that bigger banks may exercise market power by setting lower deposit interest rates.

There are 8,252 market-bank observations in the data. The following table provides a size distribution,

Size(# branches)	Total Banks	Average Assets(million $'s) per bank
1	1,202	129
2 − 10	2,519	343
11 − 100	527	2,165
101 − 500	51	43,600
500+	17	295,000
Total	4,316	2,175

Table 1: Size Distribution

The size distribution is skewed towards smaller banks, where size is defined by the number of branches and there are very few large banks. This suggests that larger banks may have a different incentive structure than smaller banks. Cohen and Mazzeo (2007) treat single and multi-market banks separately to assess competition among retail depository institutions in rural markets. Ramiro (2009) finds that there are significant revenue and cost differences between single and multi-market banks. Motivated by this, I distinguish between small and large banks in the construction of the cost function. The cost function in this paper depends on the total size, measured as the number of branches in the network, and concavity of this function gives us a measure of the cost efficiencies.

The cut-off of small versus large banks is chosen at 500 branches ($log(500 + 1) \approx 6.23$) using the scatter-plot in figure 1. There are 17 banks above this cut-off.[8] It is also important to separate the large banks from a policy standpoint. One of the objectives of the recent Dodd-Frank act was to immunize the economy from the failing of such large banks. Sometimes these large banks are also referred as too-big-to-fail banks.[9]

[7] P-values are reported inside the parenthesis.

[8] Although the cut-off between small and large banks is ad-hoc, there is no reason to believe that this choice can alter the qualitative results of this paper.

[9] The stated aim of the Dodd-Frank legislation is: To promote the financial stability of the United States by improving accountability and transparency in the financial system, to end "too big to fail", to protect

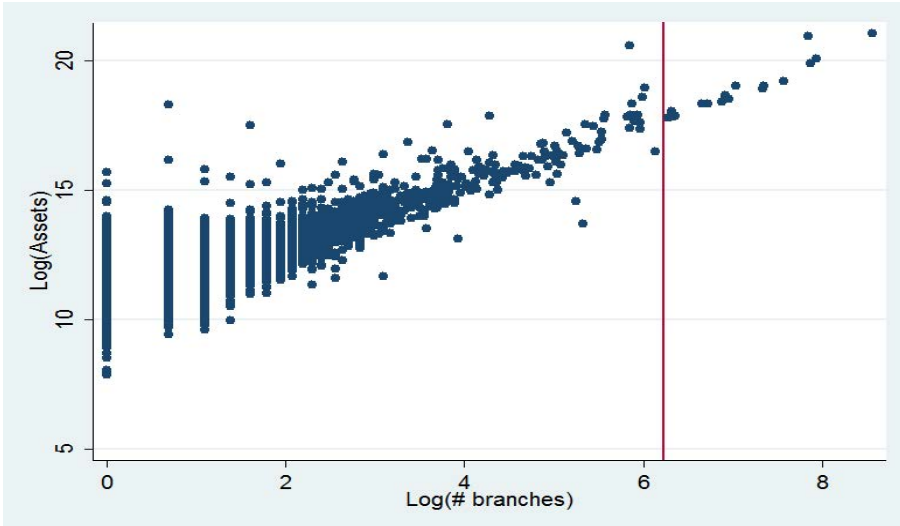

Figure 1: Scatterplot between log(Assets) and log(branches). Each data point represents a firm (bank or BHC).

Overall there are two patterns worth noting in this section. First, the data provides some preliminary evidence of market power. I take that into account by developing a model where banks competitively collect deposits. Second, there maybe a need to distinguish between small and large banks in their technology. I address this issue by distinguishing between the small and large banks in the cost function. I incorporate these insights into the model.

3 Empirical Model of Consumer Demand and Firm Choice

I develop a model of consumer behavior and firm choice. Consumers choose banks for their deposits to maximize utility. Their utility depends upon the returns on deposits, security from bank failure and convenience of availing banking services. Banks choose the network of branches, equity capital and deposit interest rate in a three-stage game to maximize profits. The model will be used to quantify market power, cost efficiencies and consumer welfare in the merger simulations. The model has local market competition as the source of market power while the cost efficiencies are at the firm-level.

the American taxpayer by ending bailouts, to protect consumers from abusive financial services practices, and for other purposes.

3.1 Consumer Demand

Consumers either save money in a bank or spend it on the outside good. Consumers save money by choosing a bank for deposit services based upon the bank's characteristics. Consumer i's utility from deposit services of bank j in market m is:

$$U_{ijm} = \theta_1 P^d_{jm} + \theta_2 d_{jm} + \theta_3 ONE_j + \theta_4 (\frac{k_j}{n_j}) + \theta_5 log(n_j + 1) + \theta_6 + \xi_{jm} + \epsilon_{ijm},$$

where P^d_{jm} is the deposit interest rate and d_{jm} is the branch density of bank j in market m. Branch density (d_{jm}) is defined as the ratio of the number of branches in a market m of bank j to total income (a measure of market size) in the market m.[10] The consumers have a preference for branch density because they incur a disutility from distance traveled for their deposit services, which was most recently shown by Ho and Ishii (2010). ONE_j is the dummy variable for one-branch banks. Business model of one branch banks and multi-branch banks could be very different with the latter's main focus on the expansion of their branch network. Therefore, I allow for them to have different effects on the consumer's utility. $(\frac{k_j}{n_j})$ is the ratio of equity capital (k_j) to the total number of bank branches (n_j). The capital-asset ratio which banks use as a signal for safety to uninsured depositors (Hughes and Mester (1998)) is proxied by $(\frac{k_j}{n_j})$.[11] I allow for the bank's size (n_j) to enter the consumer utility function logarithmically since the size distribution is highly skewed. This term captures the importance of branches outside the depositors' market as I already conditioned the utility on branch density inside the market. Consumers care about a bank's size for two reasons. First, larger banks are perceived safer as compared to smaller banks with respect to the bankruptcy risk. This perception can develop due to more diversified portfolio of a large bank or by observing government bailouts of larger banks in the past. Second, consumers who travel a lot will care more about the total number of branches of a bank.[12] When simulating a merger, this preference for total branches owned by a bank will give positive utility to the consumer. Unobserved bank-market quality is denoted by ξ_{jm} which includes characteristics like the number of service counters in a branch, quality of employees and time taken to serve a customer. Also, ξ_{jm} will measure the firm-market fixed effects that are not captured by the observed variables. Measurement error is denoted by ϵ_{ijm} which is assumed to be type-1 extreme value distributed error.

[10] Using population as a measure of market size provides similar results.

[11] If I use capital-asset ratio instead of $\frac{k_j}{n_j}$, it would make the market share equation endogenous to solving an implicit integral equation, as in equilibrium: assets=deposits+capital. This makes the level of demand of deposits a function of deposits itself in the integral equation.

[12] Since I don't have data on the number of ATM machines, total number of branches acts as a proxy for it. I am making the assumption that number of branches and number of ATMs are positively correlated.

Market share of a bank is calculated as the total deposits of a bank in a market divided by the total income in that market.[13] Suppose there are $j = 1, 2, ..., J$ banks in a market m and let the outside good be denoted by 0. Then the mean utility of a bank j in market m, δ_{jm}, can be defined as

$$\delta_{jm} = \theta_1 P^d_{jm} + \theta_2 d_{jm} + \theta_3 ONE_j + \theta_4 (\tfrac{k_j}{n_j}) + \theta_5 log(n_j + 1) + \theta_6 + \xi_{jm}.$$

Using the logit error assumption on ϵ_{ijm}, I can define the market share, s_{jm}, as

$$s_{jm} = \frac{\exp(\delta_{jm})}{1 + \sum_{k=1}^{J} \exp(\delta_{km})} ,$$

where the utility of the outside good is normalized to zero.

3.2 Supply side

Banks generate revenues from loans and incur costs on interest expenses on deposits, equity capital, labor, and physical capital expenditures. A bank's maximization problem is

$$\begin{aligned} &\max_{n_j, k_j, P^d_{jm}} \Pi_j \\ s.t. \quad &\Pi_j = L_j P^l_j - \sum_m D_m s_{jm}(\theta) P^d_{jm} - C(n_j, k_j) \\ &L_j \leq \sum_m D_m s_{jm}(\theta) + k_j \\ &G(k_j, L_j) \geq \Delta, \end{aligned}$$

where L_j are the total assets of a bank, P^l_j is the average interest rate on assets, D_m denotes total deposits in market m and $s_{jm}(\theta)$ is the market share of bank j in market m. k_j is the equity capital of a bank i.e. bank's own money at stake. The interest rate on assets, P^l_j, is allowed to be correlated with ξ_{jm}.[14] This is important as a bank with high quality (or high brand effect) is likely to offer loans with higher interest rates. The cost, $C(n_j, k_j)$, consists of two components: labor/physical capital cost and the cost of equity capital. The labor and physical cost incurred by a bank is for loan services, deposit services, advertising expenses and risk management. I assume this cost to be a function of the number of branches (n_j). Note that this cost is independent of the location of these branches. It is intuitive to think that a branch in a bigger market should have higher costs compared to one in a smaller

[13] An alternative would be to define market shares in terms of bank accounts. The data on accounts is not available by market but is at the firm-level. Dick (2002) defines market shares in terms of accounts rather than deposits by allocating the total accounts of a bank to each market. She found that results are robust to this alternative definition.

[14] In other words, for demand estimation, P^l_j is not used as an instrument.

market. Although this is true to some extent, the objective of this paper is to find scale efficiencies which are usually assumed at the firm level. These efficiencies are realized by a reduction in expenses at the firm level such as advertising expenditures or risk management expenses which are common across many markets.

The first constraint captures feasibility i.e. total loans made by a bank can be funded either by deposits or by equity capital. The second constraint is a regulation constraint. As per the guidelines of the Board of Governers of Federal Reserve Bank, all chartered banks in the U.S. should have a capital-asset ratio above a threshold.[15] In practice, all banks are well above the limit, hence this constraint never binds in the data.

Apart from the regulation constraint, there are two other roles for equity capital. First, it is a source of funding for loans as an alternative to deposits. Hence, labor cost and physical capital cost spent to collect deposits are affected by the level of equity capital. So failing to condition on equity capital can bias the cost parameters. Second, banks use equity capital as a signal of safety to uninsured depositors.[16] This is accounted for in the demand model. The role of equity capital in the cost function of a bank was first noted by Hughes and Mester (1998).

I assume a parametric form for the bank cost function,

$$C(n_j, k_j) = \beta_1 n_j + \beta_2 n_j^2 + \beta_3 I(n_j > X)(n_j - X)^2 + [\beta_4^S I(n_j \leq X) + \beta_4^L I(n_j > X)]k_j + \gamma_j + \nu_{j,n_j},$$

where γ_j is the bank level cost shock unobserved to the researcher but observed by the bank when it makes it decisions. The measurement error or specification error is denoted by ν_{j,n_j}.[17] The parameter β_3 applies for large banks ($n_j > X$) only, where X is the chosen size cut-off between small and large banks. For small banks, the sign of β_2 will determine the presence or absence of cost efficiencies. For large banks, both β_2 and β_3 measure concavity of the cost function. The parameters β_4^S and β_4^L measure the interest rate paid on equity capital by small and large banks, respectively. As discussed in Section 2, small banks and large banks are distinguished in the cost function. The difference in production technologies between small and large banks will be captured by the parameter β_3. Also, any difference in the cost of external funding will be measured by β_4^S and β_4^L. Note that although the bank

[15] As per the guidelines of Board of Governors of Federal Reserve Bank, all chartered banks in US have to satisfy three constraints: (1) Tier 1 capital / Risk-adjusted assets > 6% (2) Total capital / Risk-adjusted assets > 10% (3) Tier 1 capital / Average total consolidated assets > 5% . More than 99 % of the banks are well above the threshold limits.

[16] Data shows a negative relationship between size and capital-asset ratio. Hence, there is some evidence that larger banks need to signal less about their safety than smaller banks.

[17] This error term is similar to the non-structural error term in Pakes, Porter, Ho and Ishii (2011)

will choose a network of branches, the cost function only depends on the total number of branches. The network effects are accounted for through the revenue side.

Using the demand and supply side of the model discussed above, I simulate and measure the market power and cost efficiency trade-off that will be relevant to evaluating a bank merger. Since market power is a geographically local phenomenon, it will be a function of the network of branches of the two merging banks. Market power will be measured as the difference in profits between the merged entity at new prices (deposit interest rate) and the two merging banks at pre-merger prices. The profit of the merged entity will include the joint effect of market power and consumer preferences for large networks. To understand the different forces, I need to isolate the effects to study them separately. Cost efficiencies are measured as the difference in cost expenditure between the merged entity and the two merging banks. Since cost efficiencies are realized at the firm-level the network structure is irrelevant here, only the total size of the network matters for the cost efficiency calculation. I also quantify the change in consumer welfare generated by a merger.

In equilibrium, the profit function of a bank can be simplified by substituting the feasibility constraint at equality (assets=liabilities) and using the parametric cost function,

$$\Pi_j = \sum_m D_m s_{jm}(\theta)(P_j^l - P_{jm}^d) + P_j^l k_j - \beta_1 n_j - \beta_2 n_j^2 - \beta_3 I(n_j > X)(n_j - X)^2 - [\beta_4^S I(n_j \leq X) + \beta_4^L I(n_j > X)]k_j + \gamma_j + \nu_{j,n_j}.$$

3.3 Timing of the Firm Choices

There are the three stages in the game between banks. In the first stage, banks choose the network of branches (n_j) i.e. how many branches to open and where to locate them. This decision is made simultaneously by all banks. In the second stage, banks choose their equity capital (k_j). Equity capital is chosen at the firm level. In the third stage, banks compete for deposits in a Bertrand competition within each geographic market and choose interest rates (P_{jm}^d).

4 Estimation

The model is solved and estimated using backward induction. In the first stage, demand parameters are estimated. The second stage involves estimation of the cost parameter (β_4^S and β_4^L) on equity capital. In the third stage, cost parameters related to the network structure are obtained using moment inequalities.

4.1 First Stage: Demand Estimation

Demand parameters are estimated using demand-side and supply-side moments jointly.

In the final stage of the game, bank's compete for deposits and set their deposit interest rates (prices). I assume that the competition for deposits in each market is independent of the competition in other markets. Under this assumption, the first order condition w.r.t. P^d_{jm} is

$$D_m \frac{\partial s_{jm}(\theta)}{\partial P^d_{jm}}(P^l_j - P^d_{jm}) - D_m s_{jm}(\theta) = 0 \;\; \forall m.$$

The first order condition above represents a trade-off: an increase in deposit interest rate will increase expenditure on all the existing deposits but increased deposit interest rate will also increase the market share of a bank for deposits and hence increase the revenue from loans. Using the fact that a consumer's utility has a logit error term (ϵ_{ijm}), I can write the slope of the market share function w.r.t. price as $\frac{\partial s_{jm}(\theta)}{\partial P^d_{jm}} = \theta_1 s_{jm}(1 - s_{jm})$. Substituting this into the above first order condition I get,

$$M_{jm}(\theta) \;\equiv\; \theta_1(1 - s_{jm})(P^l_j - P^d_{jm}) - 1 = 0 \;\; \forall m \tag{1}$$

This equation acts as the basis for the supply side moment. I denote this equation by $M_{jm}(\theta)$.

To derive demand side moments, I need to calculate $\xi_{jm}(\theta)$. Since a consumer's utility has a logit error, the demand shock can be solved for explicitly as

$$\xi_{jm}(\theta) = ln(s_{jm}) - ln(s_{0m})$$

where s_{0m} is the market share of the outside option.

Demand side moments are derived by finding instruments (Z_{jm}) which are un-correlated with bank-market shocks (ξ_{jm}) to consumer utility.[18] Specifically, I need instruments for prices (P^d_{jm}) and equity capital (k_j). The correlation between prices and unobserved quality (ξ_{jm}) is obvious. In the second stage, banks choose k_j as a function of ξ_{jm} and other variables, hence they may be correlated. Intuitively, a bank with higher quality, may choose lower k_j as both are substitutes in the consumer's utility. Instrumental variables used for prices are cost shifters (wages and employees per branch) and rival firm characteristics (number of rival banks in a market, number of rival branches in a market, size of rival banks). Instrumental variable used for k_j is wages since higher wages correspond to a higher cost of collecting

[18]This moment is developed in the spirit of Berry(1994), where the author finds that matching market shares to estimate demand parameters directly can lead to an endogeneity bias because price can be correlated to the unobserved quality term.

deposits, which would lead firms to choose a higher level of equity capital. Overall, Z_{jm} includes wages, employees per branch, rival firm characterstics, d_{jm}, ONE_j and $log(n_j+1)$. Hence, the estimating GMM equation is given by,

$$E\begin{bmatrix} M_{jm}(\theta) \\ Z_{jm}\xi_{jm}(\theta) \end{bmatrix} = 0$$

There are 11 moment conditions I use to estimate 6 parameters. Hence, the system is over-identified. I use two step GMM with an optimal weighting matrix to estimate the parameters.

4.2 Second Stage

In the second stage, banks choose equity capital (k_j). Assuming risk-neutrality, a bank's equity capital choice is modeled as

$$\max_{k_j} \sum_m D_m s_{jm}(\theta)(P_j^l - P_{jm}^d) + P_j^l k_j - C(n_j, k_j)$$

$$s.t. \qquad G(k_j, L_j) \geq \Delta$$

$$\theta_1(1 - s_{jm})(P_j^l - P_{jm}^d) - 1 = 0.$$

The last constraint is the FOC of Bertrand competition and appears as banks take into account the effect of equity capital choice on the deposit rates chosen in the last stage. The first constraint is the regulation constraint and almost all banks in the data easily satisfy it. Hence, I can assume an interior solution to the above maximization problem. On substituting the FOC of P_{jm}^d into profits yields,

$$\Pi_j = \sum_m D_m \frac{s_{jm}(\theta)}{\theta_1(1 - s_{jm}(\theta))} + P_j^l k_j - C(n_j, k_j).$$

I can write the FOC of k_j i.e. $\dfrac{\partial \Pi_j}{\partial k_j} = 0$ as,

$$\sum_m \frac{D_m}{\theta_1}[\frac{\frac{\partial s_{jm}}{\partial k_j}}{1 - s_{jm}} + \frac{s_{jm}\frac{\partial s_{jm}}{\partial k_j}}{(1 - s_{jm})^2}] + P_j^l - \frac{\partial C(n_j, k_j)}{\partial k_j} = 0.$$

On simplifying the FOC of k_j I get[19]

$$\sum_m \frac{D_m}{\theta_1}[\frac{\theta_4 s_{jm}}{n_j(1 - s_{jm})}] + P_j^l = \beta_4^x, \tag{2}$$

[19]The details of the calculation can be found in the appendix 8.4.

where x={S,L} corresponds to small or large banks. The first term on the left corresponds to the marginal revenue from uninsured depositors and the second term on the left is the revenue per dollar of loans generated from loans that were funded by equity capital. Parameters β_4^S and β_4^L measure the marginal cost of equity capital to small and large banks respectively. Assuming a mean zero measurement error in the above equation, parameters β_4^S and β_4^L can be estimated by taking expectation of both sides of the equation

$$\beta_4^x = E[\sum_m \frac{D_m}{\theta_1}[\frac{\theta_4 s_{jm}}{n_j(1-s_{jm})}] + P_j^l]$$

In a more general setup, the marginal cost of equity capital could be measured as a function of observed variables such as size and geographic diversification. Geographic diversification measures the risk in the loan portfolio of bank as well as the risk in collecting deposits (Aguirregabiria, Clark and Wang (2011)), hence there is an incentive for investors to look at this aspect. The number of branches a bank has is an important decision criteria for investors as larger banks can be perceived as too big to fail. To understand the relationship between the cost of equity capital, the bank's size and its diversification, I estimate these relationships using OLS regression. I measure geographic diversification by the number of markets a bank is present in.

4.3 Third Stage

The cost function parameters β_1, β_2 and β_3 are estimated in this stage. The estimates quantify how the network of branches affect the bank's fixed cost and will enter the calculation of the cost efficiencies. To this end I employ the moment inequality estimator proposed by Pakes, Porter, Ho and Ishii (2011) (henceforth PPHI).

Let I_j be the information set of the bank when it chooses the network of branches (n_j). The information set I_j consists of $\{\xi_{jm}\}_{j=1,m=1}^{j=J,m=M}$, P_j^l and γ_j.[20] The first component of I_j, $\{\xi_{jm}\}_{j=1,m=1}^{j=J,m=M}$, implies that banks know their fixed brand effect in each market and that of other banks when making the network choice. This means that a bank deciding to open a branch in a market knows how it will be perceived by the consumers conditional on the other observed variables in their utility function. The second component of I_j, P_j^l, means that banks know what kind of asset portfolio they will be investing in before deciding where to open branches and how many to open. For example, a lower P_j^l means a bank is targeting a low risk-low return portfolio and knowing this it will open branches in markets with more predictable, low-return industrial activity. Another way to rationalize this assumption is to assume that banks are targeting a fixed level of returns on their assets before making

[20]The PPHI estimator allows for the possibility of the information set to remain unspecified. So, in principle there could be variables which are unobserved to the econometrician but are in I_j.

any entry decisions. The third component of I_j, is the firm level cost shock, γ_j, and it corresponds to the management practices and organization structure that are specific to a particular bank. This implies that a bank making an entry decision knows about its specific management practices.[21]

A bank maximizes its expected profits,

$$\max_{n_j} E[\Pi_j | I_j]$$

where Π_j is the firm-level profits previously specified in section 3.2. A choice of network consists of the number of branches to open and their locations across markets. A bank can choose to have 0, 1 or more branches in any market. The expectation arises because of the uncertainty in the bank's observed profit at the time decisions are made. This uncertainty arises due the randomness in the decision of the rival banks, n_{-j}. The randomness could be due to the error term, ν_{j,n_j}, or due to the presence of mixed strategies.

The profit function of a bank j is

$$\Pi_j = \sum_m D_m s_{jm}(\theta)(P_j^l - P_{jm}^d) + P_j^l k_j - \beta_1 n_j - \beta_2 n_j^2 - \beta_3 I(n_j > X)(n_j - X)^2$$
$$-[\beta_4^S I(n_j \leq X) + \beta_4^L I(n_j > X)]k_j + \gamma_j + \nu_{j,n_j} \qquad (3)$$

The location of branches affects the profits through the first term. For example, consider two banks with the same number of branches and similar in all aspects except for the location of these branches. These two banks collect different deposits in each market because the market share, s_{jm}, depends on the branch density (d_{jm}) in that particular market alongside other variables. This will lead to these two banks having different profits.

Note that the network choice parameters cannot be estimated directly using the maximum likelihood estimation. This is due to the fact that the possible network choices a bank has in the maximization problem are way too large compared to the number of choices observed in the data.[22] Hence I employ the moment inequality method to partially identify the parameters.

A necessary condition for any Nash equilibria is that the expected profits from choices observed in the data are greater than any other feasible alternate choice. This forms the basis of the moment inequality estimation method. I construct an expression for the difference in

[21] If $\{\xi_{jm}\}_{j=1,m=1}^{j=J,m=M}$ was not in the information set, to form moment inequalities I would have to simulate the expected levels of this variable from a distribution approximated from the demand estimation.

[22] I observe 4,316 firm choices in data. The possible network choices for 4,316 firms in 353 markets with maximum allowed branches in a market as 500 are: 4316×353^{500}. Hence it is almost impossible to directly estimate the parameters with such sparse information.

profits for the two policies and then take moments of this differenced profit expression to form the estimating inequalities. Using the profit function for the choice observed in the data (n_j) and some other alternate policy $(n_j^{'})$, so that $(n_j - n_j^{'} = t)$, I can difference the profits. The alternate policy, $n_j^{'}$, involves addition or subtraction of a fixed number of branches, t, from the existing network. Following is the differenced profit equation,

$$\begin{aligned} \Delta\Pi_j = \Delta Y_j(n_j, n_j^{'}, n_{-j}) - \beta_1(n_j - n_j^{'}) - \beta_2(n_j^2 - n_j^{'2}) \\ -\beta_3[I(n_j > X)(n_j - X)^2 - I(n_j^{'} > X)(n_j^{'} - X)^2] + \nu_{j,n_j,n_j^{'}}, \end{aligned} \tag{4}$$

where $\nu_{j,n_j,n_j^{'}} = \nu_{j,n_j} - \nu_{j,n_j^{'}}$ and $\Delta Y_j(n_j, n_j^{'}, n_{-j})$ is the part of the differenced profit function which doesn't contain any parameters to be estimated (because they have already been estimated in the first and second stage) :

$$\begin{aligned} \Delta Y_j(n_j, n_j^{'}, n_{-j}) = [\sum_m D_m s_{jm}(\theta)(P_j^l - P_{jm}^d) + P_j^l k_j - [\beta_4^S I(n_j \leq X) + \beta_4^L I(n_j > X)]k_j] \\ -[\sum_m D_m s_{jm}^{'}(\theta)(P_j^l - P_{jm}^{'d}) + P_j^l k_j^{'} - [\beta_4^S I(n_j^{'} \leq X) + \beta_4^L I(n_j^{'} > X)]k_j^{'}]. \end{aligned}$$

To evaluate (ΔY_j) all the endogenous variables need to be evaluated under the alternate policies: market shares $(s_{jm}^{'})$, deposit interest rates $(p_{jm}^{'d})$ and equity capital $(k_j^{'})$. Market share and deposit rates are solved as a system of equations using the first order conditions for deposit rates (see equation (1)) with the alternative network structure. Equity capital is estimated non-parameterically from the first order condition for equity capital choice (see equation (2)) using a third degree polynomial function. In the above equation, the error term, $\nu_{j,n_j,n_j^{'}}$, is attributed to measurement error or specification error.

We can simplify the differenced profit function as,

$$\Delta\Pi_j = \Delta R_j(n_j, n_j^{'}, n_{-j}) + \nu_{j,n_j,n_j^{'}},$$

where ΔR_j is defined as,

$$\begin{aligned} \Delta R_j(n_j, n_j^{'}, n_{-j}) = \Delta Y_j(n_j, n_j^{'}, n_{-j}) - \beta_1(n_j - n_j^{'}) - \beta_2(n_j^2 - n_j^{'2}) \\ -\beta_3[I(n_j > X)(n_j - X)^2 - I(n_j^{'} > X)(n_j^{'} - X)^2]. \end{aligned}$$

Using the above notation a moment function can be formulated as,

$$S(\beta) = E[h(n_j^{'}; n_j, I_j)\Delta R_j(n_j, n_j^{'}, n_{-j})]$$

where $h(n_j^{'}; n_j, I_j)$ is the weighting function defined below using instruments z_j,

$$h(n_j^{'}; n_j, I_j) = \begin{cases} g(z_j) & \text{if } n_j - n_j^{'} = t \\ 0 & \text{otherwise} \end{cases}$$

where $z_j \in I_j$ are demand shifters which are independent of cost shocks. Refer to the appendix 8.1 for the satisfaction of the sufficiency conditions for the PPHI estimator.

Essentially, I am looking for parameters that satisfy $S(\beta) \geq 0$. The dimension of the moment function is $\dim(h) \times \dim(\Delta R_j)$ i.e. I have more moment restrictions if I have more weighting functions or have more alternate policies. Since banks are interacting agents in a particular market, I make use of this by forming the sample analog of the moment by averaging over banks in a market, followed by averaging over all markets:[23]

$$s(\beta) = \frac{1}{M}\sum_m \frac{1}{J_m}\sum_{j_m} h(n_j^{'}; n_j, I_j)\Delta R_j(n_j, n_j^{'}, n_{-j}). \tag{5}$$

The following equation forms the basis for estimation

$$\hat{\boldsymbol{\beta}} = \{\beta : \beta \in \arg\min_{\beta} ||(s(\beta))_{-}||\}, \tag{6}$$

where $(\cdot)_{-} = min(\cdot, 0)$ and $\hat{\boldsymbol{\beta}}$ is the set of identified parameters. The norm used is L_1.[24] A usual concern with the set identification approach is that the identified set may potentially be so large that it is uninformative. In practice, this is taken care of by imposing a large number of moment restrictions. This is the case here.

In the objective function, there are two categories of moment conditions. The first set of moment conditions only apply to the small banks. The second set of moment conditions apply to all banks. This choice of moments is crucial for restricting the set size of β_3. The first set of moments provides identifying power only for β_1 and β_2. With β_1 and β_2 restricted by the first set of moments, the second set of moments identifies β_3. Also, this choice of moments is important as small banks may behave differently from the large banks.[25]

I use three methods to do inference: PPHI inner and outer confidence interval methods and point-wise generalized moment selection method proposed by Andrews and Soares (2011). In the literature for inference of partially identified models, a distinction is made between constructing a confidence interval for the identified set versus a confidence interval for the true parameter. The first two methods from PPHI fall in the first category in which

[23]This idea was previously used by Ishii(2007).

[24]Results with L_2 norm are almost the same.

[25]Note that this choice of moments could not be done another way i.e. one set of moments targeting large banks and second set of moments targeting all bank or small banks. This is because there are only 17 large banks and I wont have enough observations to average over.

confidence intervals are for the extreme points of the identified set. Inference using generalized moment selections lies in the second category where I can do inference point-wise. Using generalized moment selection method, I can do inference for a point outside of the estimated set also. The algorithm used for the generalized moment selection inference can be found in appendix 8.2.

A growing industrial organization literature considers partially identified models using moment inequalities for estimation. Holmes (2011) studies diffusion of Walmart using the PPHI estimator. Ishii (2008) studies the effect of ATM surcharges on competition and welfare using moment inequalities also using the PPHI estimator. Ciliberto and Tamer (2009) study an entry game among airlines using a partially identified model. Ellickson, Houghton and Timmins (2012) use moment inequality method to estimate chain economies in the retail industry.

4.4 Weighting functions and alternate policies

To decrease the size of the identified set, I use several moment restrictions. Hence, to increase the number of moment conditions in the objective function (equation (6)), I can either increase the number of weighting functions ($h(\cdot)$) or increase the number of alternate policies. For each combination of a weighting function and an alternate policy, I can form a moment inequality. The weighing functions used for estimation are:

1. Constant function
2. $I[$ Mean population of the markets bank j is present in $\geq$ population of market $m]$
3. $I[$ Mean population of the markets bank j is present in $\leq$ population of market $m]$

I use two weighting functions other than the constant function. The second weighting function in the above list, includes markets which are larger (in terms of population) than the average market the bank is present in while forming the moments. Using this weighting function includes more of the larger markets in the moment conditions. The third weighting function is just the opposite and includes markets which are smaller than the average market for a particular bank.

The alternate choice of network used to form moments deviates from the choice in the data only marginally so that the estimated bounds can be tighter. When the alternative policy used ($n_j^{'}$) only differs marginally from the actual policy (n_j), we are closer to the trade-off the banks may have faced when making the entry decision. For example, a bank with 100 branches in the data is more likely to have considered the possibility of opening

95 or 105 branches, rather than 50 or 200 branches. Also, since profits are calculated by summing over markets, I don't add up the estimation error in demand parameters in the calculation of $\Delta R(\cdot)$ in equation (5) if I change the policy in the data only marginally. Alternate choice of the network of branches has to involve either adding new branches or removing existing branches. Otherwise, if I just change the location of existing branches in the data to form an alternate policy without addition/subtraction of branches, the terms involving parameters to be estimated will vanish (see equation (4)). Policies that involve adding branches help to bound the marginal cost from below. Similarly, policies that involve subtracting branches bound the marginal cost from above. Hence, using these two kind of alternate policies jointly gives us tighter bounds for the cost parameters. In principle, any alternative policy will satisfy the inequalities since they correspond to the necessary condition of the Nash equilibrium.

I have to decide which markets to add/subtract branches, for construction of the alternate policies. For the moments involving all banks, I add/subtract branches only in the markets where the banks have the largest presence. In the data, large urban areas see more growth in branching while in the smaller cities the number of branches has been almost stagnant.[26] This fact suggests that banks are more interested in their choices regarding large markets. So, I create alternate policies that affect larger markets which usually are the markets where a bank has a large presence. For the moments involving small banks only, I add/subtract branches in markets where the banks have largest presence as well as in markets where the banks have least presence. This captures the fact that some of the small banks only target a small region and are in the growing phase. This is reasonable given the skewed size distribution in the data.

The alternate policies used in the moment conditions that involve all banks are,

1. Adding 1 branch in a market where the bank has its largest presence.
2. Subtracting 1 branch in a market where the bank has its largest presence.
3. Adding 1 branch each in the 5 markets where the bank has its largest presence.
4. Subtracting 1 branch each in the 5 markets where the bank has its largest presence.
5. Adding 1 branch each in the 10 markets where the bank has its largest presence.
6. Subtracting 1 branch each in the 10 markets where the bank has its largest presence.

The alternate policies used in the moment conditions that involve small banks only are,

[26] Refer to FDIC 2006 FYI bulletin for details.

1. Adding 1 branch in a market where the bank has its largest presence.
2. Subtracting 1 branch in a market where the bank has its largest presence.
3. Adding 1 branch each in the 2 markets where the bank has its largest presence.
4. Subtracting 1 branch each in the 2 markets where the bank has its largest presence.
5. Adding 1 branch each in the 2 markets where the bank has its least presence.
6. Subtracting 1 branch each in the 2 markets where the bank has its least presence.
7. Adding 1 branch each in the 10 markets where the bank has its largest presence.
8. Subtracting 1 branch each in the 10 markets where the bank has its largest presence.

Some small banks go out of business with alternate policies involving subtraction of branches. Profits of these banks are equated to zero under alternate policies.

5 Results

This section is divided in two parts. The first part contains results from the demand estimation. These results show the presence of market power and consumer's preference for a large network of branches. The second part contains results from estimation of the cost function. The parameter on equity capital will measure the cost of external funding. Remaining parameters in the cost function will measure the magnitude of cost efficiencies.

5.1 Demand Parameters

Demand parameters are estimated from 353 markets using demand and supply side moments jointly. The estimated parameters are reported in table 2. The parameter on the deposit rate, θ_1, is 24.1617 suggesting that consumers prefer high deposit rates.[27] The parameter on the branch density variable, θ_2, is 22.2884 implying a preference for the distance traveled by depositors. It strengthens the finding of Ho and Ishii (2010) that consumers incur a disutility from distance traveled for their deposit services. The value of -0.5817 on θ_3 indicates consumers aversion towards 1-branch banks for their deposit services. This supports the fact that the 1-branch banks are not after deposits and their business model may be different. This is inline with the finding in Dunne, Kumar and Roberts (2012), where

[27] All the variables in demand estimation are scaled to be of the same order for numerical stability. Hence the magnitudes of the parameters doesn't have any direct meaning.

the authors find that 1-branch bank's main source of revenue is the non-interest income. The parameter on the capital-size ratio, θ_4, is estimated to be 2.3054 suggesting that consumers prefer banks which are more capitalized. One possible reason for this parameter to be just significant could be that part of the population (insured depositors) don't care too much about the safety of their deposits. The parameter on size, θ_5, is 0.1561 and significant suggesting that consumers favor banks with more branches, although their branches may be outside of the market. Depositors have an incentive to look for signals about the safety of their deposits and we account for it by including size of the bank and the capital-size ratio which acts as a proxy for capital-asset ratio. Standard errors reported are heteroscedasticity robust standard errors.

		Demand and supply jointly (with IV)		Demand and supply jointly (without IV)	
Variables	Parameter	Value	Std. Error	Value	Std. Error
Price	θ_1	24.1617	0.1220	24.1317	0.1282
Branch Density	θ_2	22.2884	0.5789	22.26371	0.5871
1-Branch Dummy	θ_3	-0.5817	0.0518	-0.5894	0.0519
Capital-Size Ratio	θ_4	2.3054	2.1016	1.5037	1.0280
# Branches	θ_5	0.1561	0.0087	0.1577	0.0086
Constant	θ_6	-6.6241	0.0280	-6.6283	0.0279

Table 2: Logit Demand Estimation

Demand elasticities w.r.t. size are also calculated. For small banks, the average elasticity is 0.36 while for large banks, the average elasticity is 1.11. This large difference in elasticities shows consumer's preference for large network of branches. However, the average interest rate elasticity is almost the same for small and large banks at 0.38 and 0.34 respectively. These numbers are close to the price elasticities estimated by Dick (2008) for all banks using MSA level data from 1993-1999 (0.30).

I perform three modifications to the base case as a robustness check. First, I estimate the model with both demand and supply moments jointly but without any instrumental variables for price and equity capital. Second, I estimate the demand parameters with demand-side moments only and with instrumental variables. Third, I estimate the demand parameters with demand-side moments only but without any instrumental variables.[28] I find that using instrumental variables changes the value of the parameter on the capital-size ratio variable to some extent, and using the supply side moments is crucial for identification of the parameter

[28]Refer to the appendix 8.3 for the second and third case.

on price (θ_1). This suggests that the correlation between unobserved quality and price is weak. Overall, using supply side moments and instrumental variables doesn't provide any significant difference in the magnitudes of demand estimates.

Banks exercise market power by reducing their deposit interest rate. Since consumers have a preference for a large network of branches, banks with large size exercise more market power by lowering the deposit interest rate (hence reducing their interest expenses). Hence, market power increases with size.

5.2 Cost Function Parameters

There are two stages of the cost function estimation. First, the parameter on equity capital (β_4^S and β_4^L) is estimated. Second, the parameters on the quadratic spline function of network size (β_1, β_2 and β_3) in the cost function are estimated using the moment inequality estimation. The moment inequality method would use all parameters estimated in the previous stages.

Table 3 contains the estimates of β_1, β_2 and β_3. The negative sign on β_2 implies the presence of cost efficiencies for small banks (less than 500 branches). For larger banks (more than 500 branches), the parameter β_3 is added into the cost function. The positive sign on β_3 implies that cost efficiencies are smaller in magnitude for larger banks because concavity for larger banks is inferred by the sum: $\beta_2 + \beta_3$. As banks grow in size, cost efficiencies can come from a reduction in risk management expenses and advertising expenditures because these expenses don't grow proportionally such as an expense for a advertisement on TV or newspaper doesn't grow with size.

The estimates imply that the physical capital and labor cost of setting up the first branch is between 6.3780 million dollars and 6.6472 million dollars ($\beta_1 + \beta_2$). For the second branch this cost drops by 9.8 thousand dollars to 12.8 thousand dollars ($2\beta_2$). For each new branch, up to the size of 500 branches this cost declines by a factor proportional to β_2. The decline in the marginal cost due to concavity is not big for banks in the very lower tail of the size distribution, e.g. a bank with 10 branches will get a reduction of 2% in the marginal cost for the next branch it adds. The cost savings become significant with somewhat larger banks, e.g. a bank with 100 branches will get a reduction of 15% in the marginal cost for an extra branch. Once I cross the barrier of 500 branches, concavity in the cost function is reduced. At the lower end of β_3, with a value of 0.0012, the large banks still have concavity in their cost function. At the upper end of β_3, with a value of 0.0121 the cost function for large banks becomes convex with no cost efficiencies.

The inference results are also listed in table 3. The confidence intervals constructed using the PPHI outer method and the moment selection method are similar qualitatively, while the inner method of PPHI produces somewhat tighter confidence intervals. Although the estimated set suggests the presence of cost efficiencies, some of the confidence intervals for β_2 and β_3 contain zero implying that the evidence for cost efficiencies is not very strong in the data. The main qualitative difference between this paper and earlier studies on cost efficiencies in banking is that I have an explicit demand-side which allows me to account for market power and consumers' preference for size of the branch network. The existing literature on banking scale economies has conflicting findings. Stiroh (2000) used 1991-1997 data to find that the largest bank holding companies have stronger cost efficiencies than the smaller ones. Boyd and Graham (1998) examined the effects of mergers and found evidence of cost efficiency gains for only the smallest banks. The gains disappeared quickly with increases in size and were negative for larger banks. Hughes, Mester, and Moon (2001), Hughes, Lang, Mester, and Moon (1996), Hughes and Mester (1998) find strong cost efficiencies for all banks and the largest banks have slightly more cost efficiencies than rest of the banks. None of the above mentioned papers controlled for market power at the local geographic level while calculating cost efficiencies at the national level. These papers measure cost efficiencies as the percentage change in profits/costs with unit change in size (measured by assets). It is possible that the change in profits/costs with size could be due to the lowered interest expenses on deposits (market power). This could be the reason why some of the above studies find strong evidence of cost efficiencies. But once I control for market power, the evidence of cost efficiencies becomes weak at best. Hence, the existing findings in the literature may be misleading by ignoring the market power effect.[29]

	Parameter Values		95 % Confidence Interval		
	Lower Bound	Upper Bound	Inner C.I.	Outer C.I.	Moment Selection
β_1	6.3844	6.6521	[4.4868 8.4056]	[3.5815 8.6557]	[6.2676 10.490]
β_2	-0.0064	-0.0049	[-0.0073 -0.0017]	[-0.0103 0.0024]	[-0.0066 0.0102]
β_3	0.0012	0.0121	[-0.0204 0.0196]	[-0.0182 0.0355]	[-0.0137 0.0237]

Table 3: Cost Function Estimation(in million dollars)

The parameters on the equity capital are in the Table 4. This parameter measures the interest rate on the funds generated from investors. Large banks pay an interest rate of 5.24% while the smaller banks have to pay a higher rate of 6.03%.[30] These results support

[29]A similar argument can be constructed for ignoring consumers' preference for size of a bank by the earlier papers.

[30]Accounting for the error in demand parameters estimated in the first stage changes the parameters very

the fact that the larger banks are at an advantage when it comes to external funding. The attractiveness of large banks to investors could be attributed to the fact that either their portfolio is more diversified or their size signals safety.[31] A similar result was found by Shull and Hanweck (2001), where they find that the top 10 largest banks paid less for funds than smaller banks.

Variable	Parameter	Value	Std. Error
Equity Capital(Small banks)	β_4^S	0.0603	0.0250
Equity Capital(Large banks)	β_4^L	0.0524	0.0082

Table 4: Cost Function Estimation: Equity Capital Parameters

Using the parameters, I do some preliminary analysis to distinguish between diversification and size motives behind the difference in the cost of equity capital. I measure diversification by the number of markets a bank is present in and I measure size by number of branches. I run OLS regressions with the log of size and log of the number of markets a bank is present in as the independent variables. Table 5 contains all the results. The dependent variable is the log of the marginal cost in all three regressions which is calculated from equation (2). Specification (1) contains log of the size as the only independent variable. Specification (2) contains log of the number of markets a bank is present in as the independent variable. Specification (3) has both of them as the independent variable. In specification 3, which is the most general one, increase in size decreases the interest rate on cost of funds. This shows some evidence of investors preferring to invest in larger banks over the diversification incentive.

Variable	Parameter(Std. Error)		
	(1)	(2)	(3)
log(Size)	-0.0375(0.0038)	-	-0.0564(0.0059)
log(# Markets)	-	-0.04022(0.0087)	0.0559(0.0133)

Table 5: Cost Function Estimation: Parameters for variable marginal cost of equity capital.

Overall, the demand and cost estimates suggest that both market power at the geographic

marginally.

[31] To answer this question, one has to incorporate risk into the bank's profit function. By incorporating risk I mean that bank's care about both mean profits and the variance of profits so that portfolio diversification can be endogenized. I leave this topic for future research.

market level and a weak evidence of cost efficiencies at the firm level are present as banks increase in size. To assess the relative importance of these two effects I simulate mergers between two banks in the next section.

6 Industry Analysis and Counterfactual Experiments

6.1 Industry Analysis

The banking industry is one of the important industries in the U.S. with total assets of approximately $11.7 trillion in 2006. For decades, commercial banks had been geographically constrained by the McFadden Act of 1927 that prohibited them from operating across state lines. Additionally, state laws often restricted banks ability to branch across county lines and in many states prohibited branch banking entirely. The states deregulated their banking laws at different times. Some deregulated as early as 1970 whereas others were deregulated only when the Riegle-Neal Act was passed in 1994. The after effects of Riegle-Neal Act on market structure are significant. This gradual deregulation has led to a consolidation of banks over the last 30 years and is still ongoing. In 1990, there were 12,343 commercial banks and 2,815 savings banks that were FDIC insured. In 2006, the number of commercial banks was reduced to 7,402 while savings banks were reduced to 1,279. Since the financial crisis started in 2007, the drop in the number of banks is also due to bank failures and the forced mergers of failing institutions with healthy ones, as well as regular mergers between healthy banks.[32] In 2012, these numbers were reduced to 6,222 commercial banks and 1,024 savings banks. Figure 2 shows the number of regular mergers (excluding corporate re-organization mergers and failing bank mergers) from 2000-2010.[33]

Before the financial crisis in 2007, there were more than 100 regular mergers per year. After 2007, the number of regular mergers drops but still there are more than 50 mergers per year. The presence of so many mergers, suggests the need to study them in depth and understand the driving forces behind these mergers and its effects on consumers.

[32] A regular merger is defined as a merger between two banks which are owned by separate bank holding companies and neither of the banks is a failing institution.

[33] All bank mergers must be approved by one of the three federal bank regulators: Office of the Comptroller of the Currency(OCC), Federal Deposit Insurance Corporation(FDIC) or Board of Governors of the Federal Reserve System(FRB). Over the years OCC and FRB have published lesser details about the mergers making it difficult to distinguish between regular mergers and corporate re-organization mergers. The histogram is based on the numbers from FDIC alone.

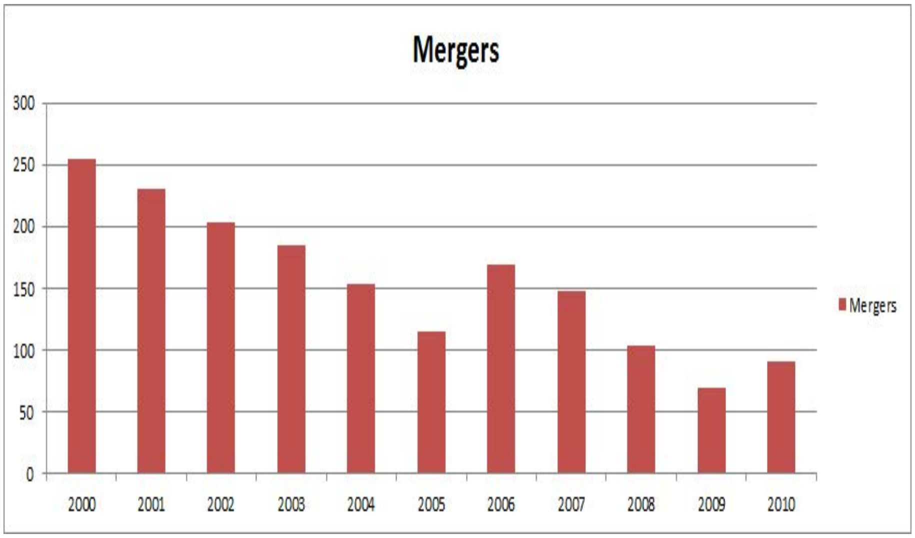

Figure 2: Mergers between 2000 and 2010 in the US banking industry. Corporate re-organization mergers and failing bank mergers are excluded.

6.2 Merger Simulations

I use the estimated parameters to simulate some actual mergers between banks that occurred in 2006 or later. For the set identified parameters, I use the mid-point of the set for the following merger simulations.[34] The objective of this exercise is to quantify the effects of market power, cost efficiencies and equity capital on the profitability of a merger. I also calculate the change in consumer welfare due to the decrease in deposit rates and increase in network size because of the merger.

In the following experiments, revenues from loans are split in two categories: loans funded through deposits ($\sum_m D_m s_{jm}(\theta)(P^l_j - P^d_{jm})$) and loans funded through equity capital ($P^l_j k_j$). Costs are also split in two categories: operating costs ($\beta_1 n_j + \beta_2 n_j^2 + \beta_3 I(n_j > X)(n_j - X)^2$) and cost of raising equity capital ($\beta^S_4 k_j$ or $\beta^L_4 k_j$). The numbers in the tables below are the difference between the merged entity with joint profit maximization and consolidated numbers of the two banks with pre-merger values.

There are two demand-side effects due to a merger. First, consumers get a better quality product as they prefer larger network of branches (demand synergies). Second, consumers get a lower interest rate on deposits as firms re-optimize deposit rates. I attribute this second effect to market power. To isolate market power, I have to separate these two effects so that I can measure the effect of price alone. I explain my calculation of market power using a simple example. Say, bank 1 and bank 2 merge into a bank 12. Each bank's network and

[34] I am currently working on robustness to this choice of mid-point of the parameter set. I plan to uniformly sample the parameter set and run the counterfactual experiments for each parameter.

deposit rate are denoted by n_i and p_i respectively, where i = 1, 2 or 12. The merged bank's network, n_{12}, is the combined network of bank 1 and bank 2, while the deposit rate, p_{12}, is obtained by re-optimizing prices with the combined network of branches. Let the loan revenues funded through deposits for bank i be denoted by $r(p_i, n_i)$[35]. I can measure the combined effect of demand synergies and market power by

$$E_1 \equiv r(p_{12}, n_{12}) - r(p_1, n_1) - r(p_2, n_2). \tag{7}$$

E_1 measures the combined effect because consumer's utility depends on both prices and total size of the network. To measure the demand synergies component of the total effect, I assume a hypothetical scenario. I assume that both the merging banks, 1 and 2, are present in the economy with each bank having all characteristics of the merged bank except the deposit rate. In this setup, both the merging banks re-optimize prices.[36] Let this price be denoted by p. This setup will measure the effect of the network on profits without any price effects coming from the reduction of competition. Note that in this hypothetical scenario there is no reduction in the number of players in a market. I quantify demand synergies by measuring

$$E_2 \equiv r(p, n_{12}) - r(p_1, n_1) - r(p_2, n_2), \tag{8}$$

where $r(p, n_{12})$ is the revenue of one of the merging banks with the combined network. Finally, to calculate the market power effect, I subtract the equation (8) from the equation (7) ($E_1 - E_2$). Using this approach, there is no market power effect in the markets where the merging banks do not overlap. This is inline with the fact that market power is a local geographic phenomenon. A similar calculation is done for consumer surplus to isolate the market power from the combined effect.

The cost efficiency in a merger between two banks with n_1 and n_2 branches is quantified by,

$$\begin{aligned} CE(n_1, n_2) \equiv {} & [\beta_1(n_1 + n_2) + \beta_2(n_1 + n_2)^2 + \beta_3 I((n_1 + n_2) > X)((n_1 + n_2) - X)^2] \\ & -[\beta_1 n_1 + \beta_2 n_1^2 + \beta_3 I(n_1 > X)(n_1 - X)^2] - [\beta_1 n_2 + \beta_2 n_2^2 + \beta_3 I(n_2 > X)(n_2 - X)^2]. \end{aligned} \tag{9}$$

The first term in $CE(n_1, n_2)$ is the operating cost of the merged entity, the second and

[35] In the real calculation there are other variables also, but to simplify the exposition I omit them in this example.

[36] Note that both the merging banks will choose the same price.

third terms are operating costs of the two merging banks. The concavity in the quadratic function generates cost savings for the merged bank. Similarly, cost savings from equity capital (say for a merger between two large banks) are measured by,

$$E_3 \equiv \beta_4^L k_{12} - \beta_4^L k_1 - \beta_4^L k_2, \tag{10}$$

where k_{12} is the equity capital corresponding to the merged bank. It is important to note that the choice of mid-point for the cost parameters will only affect the measurement of cost savings, the quantification of market power and demand synergies is immune to this choice.

While simulating the mergers, I need to make a choice for the loan rate and the unobserved bank-market quality (ξ_{jm}) of the merged entity. I choose the maximum loan-rate and maximum ξ_{jm} of the two banks for the merged entity.[37] Using the maximum value for unobserved quality is roughly equivalent to using the unobserved quality of the larger bank. Since the larger bank is usually the acquiring bank, it is reasonable to assume that the brand-market fixed effects of the merged entity are that of the acquiring bank.

I simulate two mergers in each of the following three categories: small bank and small bank, small bank and large bank, large bank and large bank. From 2006 onwards, there have been more than 50 regular mergers every year. In many of these mergers, the acquired bank had less than 5 branches. For simulating the mergers involving small banks (less than 500 branches), I chose the ones where the bank size was not too small (more than 30 branches) so that the change in magnitudes for important variables is significant. For simulating mergers between two large banks(more than 500 branches), I pick one regular merger (Regions Bank and Amsouth Bank) and one failing bank merger (Wells Fargo and Wachovia). When Wachovia bank was collapsing in the financial crisis, it was forced by FDIC to sell itself.

There are some common elements in each merger simulation. The network of branches of the two banks are merged exogenously and after that the merged entity chooses new equity capital and deposit interest rates.[38] For the merged bank, the deposit rate in each market decreases and market share increases compared to the individual banks. This drives up the gains from revenue sources in a merger. Equity capital of the merged bank is strongly correlated with size, hence the merged bank has a higher equity capital than each of the merging banks.

[37]Results are very stable even if I pick minimum loan rate.

[38]Note that other banks are not allowed to re-optimize their network choice in response to the merger. This is not feasible in the current setup as I have not solved for the bank's policy function.

6.3 Mergers between two small banks

The first merger simulation in this category is between Prosperity Bank,TX (75 branches in 6 markets) and State Bank,TX (37 branches in 5 markets) which occurred in 2007. The two banks overlap in 4 markets. Prosperity bank is headquartered in El Campto, TX and State Bank was headquartered in La Grange, TX. Due to the merger, total revenues increased by 30.1 million dollars, most of which is contributed by equity capital. The merged bank generates extra 8.8 million dollars in revenue from deposits, of which only 1.45 million is attributed to market power. This shows that there are strong demand synergies (preference for large networks) compared to the market power effect. There are significant cost efficiencies leading to a savings of 20.8 million dollars and most of it comes from reduction in operating expenses. Cost efficiencies seem to be playing a more important role in this merger compared to market power. Overall, consumer surplus decreases by a small amount indicating that that the utility from a better quality product (bigger size of the merged entity) is not offset by the decreased deposit rates due to market power. The loss in consumer surplus due to market power is -0.22 basis points. In this setup, consumer surplus is the utility, in interest rate terms, that the consumer receives.

	$ Change(million dollars)	% Change
Change in Revenues		
From deposits(Combined effect)	8.88	4.60%
From deposits(Market Power effect)	1.45	
From Equity	21.20	11.10%
Change in Total Revenues	30.08	7.90%
Change in Cost		
From Operating Cost	-31.60	-4.60%
From Equity	10.80	6.10%
Change in Total Costs	-20.80	-2.40%
Change in Total Profits	50.90	10.5%
Change in Total Consumer Surplus	-0.098	-0.09%
CS loss due to Market Power	-0.22	

Table 6: Merger Simulation : Prosperity Bank,TX (75 branches in 6 markets) and State Bank,TX (37 branches 5 markets).

The second merger in this category is between First Tennessee Bank (232 branches in 24 markets) and Sterling Bank (41 branches in 3 markets) that occurred in 2006. First Tennessee Bank is headquartered in Memphis, TN and Sterling Bank was headquartered in Houston, TX. There is only 1 overlapping market among the merging banks. The merged entity is able to generate an extra 52.9 million dollars through offering a better quality product and charging lower deposit rates. Since there is only one overlapping market out of the total 26 markets the merged firm is present in, there is almost no market power effect here. There is extra revenue generated through equity capital as well (39.6 million dollars) but that is almost offset by the extra cost (36.3 million dollars) incurred to raise that much equity. Operating costs drop by 108 million dollars due to cost efficiencies resulting from the merger. In this simulation, cost efficiencies seem to be an important driver of the merger. Overall, consumers benefit from this merger as the depositors of the smaller bank get an big increase in the quality of the product because of the added network of a bigger bank. The loss in consumer surplus due to market power is -0.03 basis points. Note that this magnitude is much smaller than the first merger in this category. This happens because less overlap in markets reduces the market power effect.

	$ Change(million dollars)	% Change
Change in Revenues		
From deposits(Combined effect)	52.90	5.3%
From deposits(Market Power effect)	0.0022	
From Equity	39.60	8.3%
Change in Total Revenues	92.50	6.3%
Change in Cost		
From Operating Cost	-108	-7.4%
From Equity	36.30	7.2%
Change in Total Costs	-71.70	-3.7%
Change in Total Profits	164	32.7%
Change in Total Consumer Surplus	0.094	0.03%
CS loss due to Market Power	-0.03	

Table 7: Merger Simulation : First Tennessee Bank (232 branches in 24 markets) and Sterling Bank (41 branches in 3 markets) .

Overall, in mergers between two small banks cost efficiencies play a more important role. The consumer welfare either drops or increases by a small amount. This happens because the banks in these mergers are small and consumers don't benefit too much from the demand synergies. Note that since prices are chosen in the last stage of the game, cost savings are never passed on to the consumers.

6.4 Mergers between a small bank and a large bank

The first merger in this category is between PNC bank (837 branches in 23 markets) and Mercantile-Safe Deposit and Trust Company (195 branches in 7 markets) that occurred in 2007. PNC bank is headquartered in Pittsburgh, PA and Mercantile-Safe Deposit and

Trust Company was headquartered in Baltimore, MD. These banks overlap in 3 markets. As a result of the merger, revenues from deposits increase by 54.8% which translates into 835 million dollars. Out of the 835 million dollars, only 27.4 million dollars can be attributed to market power. This implies presence of strong demand synergies. Revenue from equity comes around to be 500 million dollars which is largely offset by the cost of raising equity, 440 million dollars. Cost savings due to merger synergies are 22.6 % which in dollar terms are 738 million dollars. Total revenues increase by 1.3 billion dollars (33.2 %) whereas total costs decrease by 298 million dollars (5.1%) only. In this simulation, I can clearly see cost efficiencies dominating market power as a possible driving force for merger. This happens because there are very few overlapping markets. Consumer surplus increases by 6.67 basis points indicating that the effect of increased market power is dominated by a better quality product (larger bank). The loss in consumer surplus due to market power is -0.31 basis points. Note that the loss in consumer surplus here is larger than both the small-small mergers, but is still offset by demand synergies.

	$ Change(million dollars)	% Change
Change in Revenues		
From deposits(Combined effect)	835	54.8%
From deposits(Market Power effect)	27.4	
From Equity	500	20.1%
Change in Total Revenues	1,335	33.2%
Change in Cost		
From Operating Cost	-738	-22.6%
From Equity	440	17.3%
Change in Total Costs	-298	-5.1%
Change in Total Profits	1,633	90.6%
Change in Consumer Surplus	6.67	1.92 %
CS loss due to Market Power	-0.31	

Table 8: Merger Simulation : PNC Bank (837 branches in 23 markets) and Mercantile-Safe Deposit and Trust Company (195 branches in 7 markets).

The second merger in this category is between Wells Fargo Bank (2,613 branches in 127 markets) and Greater Bay Bank (41 branches in 5 markets) that occurred in 2008. Wells Fargo Bank is headquartered in San Francisco, CA and Greater Bay Bank was headquartered in Palo Alto, CA. Before the merger, Wells Fargo was present in all the 5 markets where Greater Bay Bank was located. The revenue from loans funded by deposits increases by 1.01 billion dollars (11.6 %). Out of these 1.01 billion dollars, 339 million dollars can be attributed to market power. The revenues from loans funded by equity is almost balanced by the cost incurred to raise that equity. Operating costs decline by 62 million dollars (-0.8 %) which is really small as compared to the gains from market power. Overall the total revenues go up by 1.26 billion dollars while total costs also rise by 170.80 million dollars. Hence, the profitability of this merger is driven by market power more. The large market power effects are present due to a lot of overlapping markets between the two merging banks. The total consumer surplus goes up suggesting that the effect of decreased interest rates is more than offset by a better quality product (larger bank). This happens because the utility of consumers of Greater Bay Bank increases a lot as the network size increases from 41 to 2,654 due to the merger. The loss in consumer surplus due to market power alone is -1.3 basis points. Note that this consumer surplus loss is larger than the loss in both small-small bank mergers.

Overall, the loss in consumer surplus due to market power is more compared to the small-small bank mergers. But the change in total consumer surplus is larger compared to the small-small bank mergers. Hence, I can conclude that although market power increases when large banks are merging, demand synergies increase at a greater rate. The cost efficiencies seems to be driving the mergers when there is not a lot of overlap between merging banks. When a large bank is involved in a merger, banks are practically breaking even in terms of equity capital. This happens because of two reasons. First, equity capital is costlier than deposits so banks with large network of branches don't want to raise more equity to fund loans. Second, large banks have strong brand effects and don't need to signal safety to depositors through capital reserves.

	$ Change(million dollars)	% Change
Change in Revenues		
From deposits(Combined effect)	1,010	11.6%
From deposits(Market Power effect)	339	
From Equity	247	1.9%
Change in Total Revenues	1,257	5.8%
Change in Cost		
From Operating Cost	-62.20	-0.8%
From Equity	233	1.9%
Change in Total Costs	170.8	0.8%
Change in Total Profits	1,086	96.9%
Change in Total Consumer Surplus	16.13	1.04%
CS loss due to Market Power	-1.30	

Table 9: Merger Simulation : Wells Fargo Bank (2,613 branches in 127 markets) and Greater Bay Bank (41 branches in 5 markets).

6.5 Mergers between two large banks

The first merger in this category is between Regions Bank (971 branches in 89 markets) and Amsouth Bank (561 branches in 44 markets) that occurred in 2006. They overlap in 36 markets. Both Regions Bank and Amsouth Bank are headquartered in Birmingham, AL. The revenue from loans funded by deposits increased by 3.8 billion dollars (158%) while operating costs decreased only by 648 million dollars (15%). Out of the 3.8 billion dollars increase in revenue, 1.26 billion dollars can be attributed to market power. This is largely driven by a big overlap of markets. Like the previous merger simulations, the change in revenue and cost from equity capital roughly balance each other. Overall, total revenues increase by 5 billion dollars while total costs increase by 853 million dollars. At this point, the concavity in the cost function has been diminished by a significant amount. Clearly, the major driver behind this merger is market power. The total consumer surplus increases by 4.25 basis points suggesting that the effect of decreased interest rates is more than offset by a better quality product (larger bank). The loss in consumer surplus due to market power is -13.2 basis points which is larger compared to any of the mergers in last two categories.

	$ Change(million dollars)	% Change
Change in Revenues		
From deposits(Combined effect)	3,794	158.0%
From deposits(Market Power effect)	1,260	
From Equity	1,451	44.7%
Change in Total Revenues	5,054	92.8%
Change in Cost		
From Operating Cost	-648	-15.0%
From Equity	1,501	37.9%
Change in Total Costs	853	10.3%
Change in Total Profits	4,201	92.8%
Change in Total Consumer Surplus	4.25	0.34%
CS loss due to Market Power	-13.20	

Table 10: Merger Simulation : Regions Bank (971 branches in 89 markets) and Amsouth Bank (561 branches in 44 markets).

The second merger in this category is between Wells Fargo Bank (2,613 branches in 127 markets) and Wachovia bank (2,795 branches 105 markets) which occurred in 2008. The merging banks overlap in only 8 markets. Wachovia bank was headquartered in Charlotte, North Carolina and Wells Fargo Bank is headquartered in San Francisco, CA. This merger took place during the financial crisis and it was a FDIC forced merger. The difference in

	$ Change(million dollars)	% Change
Change in Revenues		
From deposits(Combined effect)	4,130	24.9%
From deposits(Market Power effect)	222	
From Equity	6,828	24.5%
Change in Total Revenues	10,958	24.7%
Change in Cost		
From Operating Cost	11,856	72.8%
From Equity	7,415	28.3%
Change in Total Costs	19,271	45.4%
Change in Total Profits	-8,313	-24.7%
Change in Total Consumer Surplus	22.41	0.82%
CS loss due to market power	-0.80	

Table 11: Merger Simulation : Wells Fargo Bank(2,613 branches) and Wachovia bank(2,795 branches).

total revenues from this merger is 10.9 billion dollars while an extra total cost of 19.2 billion dollars needs to be incurred. This shows that the merger was not profitable under normal scenarios. Total consumer surplus went up by 22.4 basis points. This particular simulation exercise also acts as a robustness check for our parameters.

The driving force behind merger between two large banks is mostly market power. Also, the reason why cost efficiencies are not large in this category of mergers is because the parameter β_3 is important and decreases the concavity in the cost function. Also, consumer welfare goes up in the merger between two large banks due to consumer's preference for a larger network of branches.

7 Conclusion

This paper quantifies the degree of market power and cost efficiencies for U.S. banks. This paper develops a model of consumer behavior and firm choice where market power is a geographically local phenomenon whereas cost efficiencies are realized at the firm level. I develop a three-stage empirical model in which consumers choose banks for deposit services and banks choose the network of branches, equity capital and deposit rates. To estimate the cost parameters related to the network choice, I use moment inequality methods.

Demand estimates suggest that consumers prefer large, more capitalized banks and that market power increases with size. After controlling for market power, the evidence for cost efficiencies is weak for smaller banks (less than 500 branches), and it declines as banks get larger (more than 500 branches). This is a contribution to the existing literature which doesn't control for market power and size effects in calculating cost efficiencies in the US banking industry. I also find that smaller banks are at an disadvantage when it comes to borrowing money from external sources (raising equity capital).

Using the estimated parameters, I simulate mergers in three categories: between two small banks, a small bank and a large bank and between two large banks. For mergers between two small banks, cost efficiencies play an important role. For a merger between a small and a large bank, the extra revenue generated by market power is larger than the cost savings when there is a lot of overlap in the markets of merging banks. And for merger between two large banks, market power effect dominates the cost efficiencies effect. Consumer surplus always goes up in the mergers involving large banks. This happens because the market power effect is dominated by the consumer's preference for large network of branches. Hence, just looking at the market power or cost efficiency is not sufficient for approving/declining a merger. The fact that consumers have a better product at disposal should be taken into account.

8 Appendix

8.1 Sufficiency conditions for PPHI estimator

To use the PPHI estimator, the weighting function and errors should satisfy two sufficiency conditions.

Condition 1: $E[\sum_j \sum_{n_j^{'}} h(n_j^{'}; n_j, I_j)\nu_{j,n_j,n_j^{'}}] \geq 0$
Condition 2: $E[\sum_j \sum_{n_j^{'}} h(n_j^{'}; n_j, I_j)\Delta\gamma_{j,n_j,n_j^{'}}] \leq 0$

Using the information that $E[\nu_{j,n_j,n_j^{'}}|I_j] = 0$ and since I_j doesn't contain any information about rivals condition 1 is trivially satisfied.

Condition 2 is also trivially satisfied as $\Delta\gamma_{j,n_j,n_j^{'}}$ equals zero. In my model, the structural error γ_j is fixed before the network choice.

8.2 Inference using Generalized Moment Selection

Following steps are used in sequence to calculate the confidence sets,

1. Form a 3-dimensional grid of points in $(\beta_1, \beta_2, \beta_3)$ space which extends well beyond the identified set.[39]

[39]The grid is constructed so that the null hypothesis is rejected at the end points of the grid. In other words, the end points of the grid are such that they are not in the confidence interval.

2. At each grid point β_g, evaluate the objective function: $Q(\beta_g) = ||(\hat{D_M}^{-1/2} s(\beta_g))_-||$, where $\hat{D_M}$ is a diagonal matrix with variance of moments on its diagonal.

3. At each grid point a critical value is calculated through simulation, $c_\alpha(\beta_g)$.

4. If $Q(\beta_g) \leq c_\alpha(\beta_g)$, then β_g is in confidence set.

The calculation of critical value is the most important step in the above method. To compute the critical value, an approximation to the distribution of objective function under the null is simulated. The distribution of the sample moments in the expression of objective function are simulated by a normal with mean zero and variance calculated using the data across markets. Next, of all the simulated moments under the null, only the nearly binding moments at each β_g enter the expression for simulating the objective function. A moment k is defined to be nearly binding if $\sqrt{M}E(s_k(\beta_g))/\hat{\sigma}(s_k(\beta_g)) < \sqrt{2ln(ln(M))}$, where the expectation operator is replaced by its sample analog and M is the total number of markets.

8.3 Robustness for demand estimates

The demand estimates in the paper are calculated using both demand and supply side moments. The table below has estimates with only demand side moments. This acts as a robustness check for the baseline results used in the paper.

		Demand moments only (with IV)		Demand moments only (without IV)	
Variables	Parameter	Value	Std. Error	Value	Std. Error
Price	θ_1	42.2818	25.5104	38.2860	5.2018
Branch Density	θ_2	22.3717	0.5920	22.2994	0.5869
1-Branch Dummy	θ_3	-0.5763	0.0521	-0.5763	0.0521
Capital-Size Ratio	θ_4	1.5304	2.3211	1.4429	1.0357
# Branches	θ_5	0.1605	0.0106	0.1604	0.0087
Constant	θ_6	-6.9207	0.4182	-6.8580	0.0888

Table 12: Logit Demand Estimation : With demand moments only

8.4 First order condition of equity capital

Here is the simplifying algebra of the first order condition of the equity capital (k_j). Assume that j is a small bank.

$$\frac{\partial \Pi_j}{\partial k_j} = 0$$

$$\sum_m \frac{D_m}{\theta_1}[\frac{\frac{\partial s_{jm}}{\partial k_j}}{1-s_{jm}} + \frac{s_{jm}\frac{\partial s_{jm}}{\partial k_j}}{(1-s_{jm})^2}] + P_j^l - \frac{\partial C(n_j,k_j)}{\partial k_j} = 0$$

$$\sum_m \frac{D_m}{\theta_1}[\frac{\frac{\partial s_{jm}}{\partial k_j}}{1-s_{jm}} + \frac{s_{jm}\frac{\partial s_{jm}}{\partial k_j}}{(1-s_{jm})^2}] + P_j^l - \beta_4^S = 0$$

$$H_j + P_j^l - \beta_4^S = 0$$

where $H_j = \sum_m \frac{D_m}{\theta_1}[\frac{\frac{\partial s_{jm}}{\partial k_j}}{1-s_{jm}} + \frac{s_{jm}\frac{\partial s_{jm}}{\partial k_j}}{(1-s_{jm})^2}] + P_j^l$.

Using the logit error assumption in the utility of the consumer I can simplify $\frac{\partial s_{jm}}{\partial k_j}$,

$$\frac{\partial s_{jm}}{\partial k_j} = \frac{\partial s_{jm}}{\partial (k_j/n_j)}\frac{\partial (k_j/n_j)}{\partial k_j} = \frac{\theta_4 s_{jm}(1-s_{jm})}{n_j}.$$

Note that n_j is treated as constant in the above equation, because in the second stage when the banks are choosing k_j, bank size (n_j) has already been decided in the first stage. Hence I have,

$$H_j = \sum_m \frac{D_m}{\theta_1}[\frac{\frac{\partial s_{jm}}{\partial k_j}}{1-s_{jm}} + \frac{s_{jm}\frac{\partial s_{jm}}{\partial k_j}}{(1-s_{jm})^2}] + P_j^l$$

$$H_j = \sum_m \frac{D_m}{\theta_1}[\frac{\theta_4 s_{jm}(1-s_{jm})}{n_j(1-s_{jm})} + \frac{\theta_4 s_{jm}^2(1-s_{jm})}{n_j(1-s_{jm})^2}] + P_j^l$$

$$H_j = \sum_m \frac{D_m}{\theta_1}[\frac{\theta_4 s_{jm}(1-s_{jm})}{n_j(1-s_{jm})} + \frac{\theta_4 s_{jm}^2(1-s_{jm})}{n_j(1-s_{jm})^2}] + P_j^l$$

$$H_j = \sum_m \frac{D_m}{\theta_1}[\frac{\theta_4 s_{jm}}{n_j(1-s_{jm})}] + P_j^l$$

Substituting the value of H_j in the FOC I get,

$$\sum_m \frac{D_m}{\theta_1}[\frac{\theta_4 s_{jm}}{n_j(1-s_{jm})}] + P_j^l = \beta_4^S.$$

The above equation forms the basis for estimation of β_4^S. A similar calculation can be done for large banks as well.

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