A Frontier Measure of U.S. Banking Competition*

Wilko Bolt, Economist
De Nederlandsche Bank, Amsterdam, The Netherlands.

David Humphrey, Professor of Finance
Florida State University, Tallahassee, FL, U.S.A.

December, 2012

Abstract
The three main measures of competition (HHI, Lerner Index, and H-Statistic) are uncorrelated for U.S. banks. We investigate why this occurs, propose a frontier measure of competition, and apply it to five major bank service lines using data only available since 2008. Fee-based banking services comprise 35% of bank revenues so assessing competition by service line is preferred to using a single measure for traditional activities extended to the entire bank. Academic-based competition measures explain only 1% of HHI variation. HHI merger/acquisition guidelines could be raised since current banking concentration seems unrelated to competition. (92 words)

Key Words: Competition, banks, frontier analysis
JEL Classification Code: L11 G21 C21

* Comments by seminar participants at the IAES 2012 Conference and DIW Berlin are acknowledged and appreciated.

Corresponding Author:
David Humphrey, Department of Finance, Florida State University, Tallahassee, FL 32306-1042 USA; +1-850-294-7896; dhumphrey@cob.fsu.edu

Wilko Bolt, Research Department, De Nederlandsche Bank, PO Box 98, 1000 AB Amsterdam, The Netherlands; +31-(0)20-524-3524; w.bolt@dnb.nl
1 Introduction.

The three standard indicators of banking competition used in empirical studies (HHI, Lerner Index, and H-Statistic) measure competition differently. Even so, the expectation would be that when the HHI suggests competition is weak, the Lerner Index and the H-Statistic could generally be counted upon to draw a similar conclusion. For the banking industry, however, these measures are essentially uncorrelated with each other and inferences regarding competition appear to be measure-specific: results obtained with any one measure need not be confirmed by either of the other two.

While regulators rely on the HHI because it has been predictive in concentrated industries, this measure shows only the potential for competitive/collusive behavior and is thus augmented with additional market/behavioral information (e.g., U.S. Department of Justice, 2010). Academics have for solid theoretical reasons favoured the Lerner Index and/or the H-Statistic which seeks to measure realized competition. Using a procedure based on efficient frontier analysis, we derive inferences of competition separately for five bank service lines which the other competition measures, except for loans and deposits, are currently unable to do. We also suggest that all the standard measures incompletely adjust for important cost differences among banks and incorporate these costs in our analysis.

A revenue weighted average of our frontier measure combining five bank service lines is significantly related to the Lerner Index and the H-Statistic ($R^2 = .16$). It is also significantly related to the HHI, but with little explanatory power ($R^2 < .01$). Indeed all three of these theoretically-based competition measures together explain only one percent of the HHI variation across banks. Thus if banking authorities wish to decide policy issues based on competition, their reliance on the HHI could usefully be augmented with an indicator that reflects competition rather than just concentration (since banking concentration seems unrelated to competition in the U.S.).

The HHI focus on market shares does not account for how they may have been achieved—through lower costs or by uncompetitive behavior, the so-called efficient struc-
ture controversy (c.f., Berger, 1995). If lower costs have been an important reason for some banks in achieving a relatively high HHI, this will overstate the apparent lack of competition. While the Lerner Index examines the spread between average price and estimated marginal cost all divided by average price, the influence of scale economy, productivity, and risk differences among banks cloud the interpretation. Observed input costs will be higher than their true value for banks with greater productivity, making productive banks appear to be more competitive than they are since their measured spread from output price will be lower. Passing on these productivity-reduced costs would lower observed output prices making the bank appear to be even more competitive. Here the influence is productivity-related, rather than due to competition. The H-Statistic faces much the same problem as it relates changes in total revenues to changes in observed input prices, holding output level constant. For both measures, observed factor prices need not reflect their true value at more productive banks. Finally, a lack of detailed price and output data limits the application of the three standard measures to traditional (albeit important) bank service lines but neglects fee-based services that generate over a third of bank revenues.

In what follows, the lack of a correlation among the HHI, Lerner Index, and H-Statistic are illustrated for U.S. banks in Section 2, a condition that holds for Europe as well. Our revenue-based competition frontier measure is explained in Section 3 as is our econometric framework. Section 4 contains our results where we assess relative competition among five bank service lines. In Section 5 we illustrate how the competition frontier differs from the three standard competition measures. Characteristics of the most and least competitive banks are outlined in Section 6 while conclusions are presented in Section 7.
2 Correlations Among the Standard Measures of Competition.

As there are over 6,500 commercial banks in the U.S., we restricted our competition analysis to those banks that had assets of $100 million or more in 2010 which accounts for over 98% of all commercial bank assets and employs close to 1.9 million workers. Indeed, banks having $100 million in assets are smaller than the average branch office at large banks ($125 million).\(^1\) Various screens were applied to eliminate shell banks, special purpose banks, banks with no loans, or no deposits, or no full time employees, etc., or that contained variables beyond five standard deviations from the mean and are clearly unrepresentative of the banking industry.\(^2\) The final sample contained 2,655 banks and the 382 institutions with more than $1 billion in assets accounted for 90% of total sampled assets. These large banks are the focus of our analysis as they have by far the greatest impact on the competitive efficiency of the U.S. banking sector.

All bank income, expense, and balance sheet data (deposits excepted) are reported at the level of the bank regardless of where it operates. This means that our competition indicators reflect the weighted average of the local and regional markets they are in. The median bank has branches in only two Metropolitan Statistical Areas (MSAs). Although the subset of billion dollar banks have a broader geographical representation, the median billion dollar bank has branches in only four MSAs and operates in only 1 state out of 50. Even at the 99th percentile, the average billion dollar bank has offices in only 26 states. While a deposit-based HHI can be computed for each MSA, all the measures in this study—including our frontier indicator—will reflect the weighted average of the separate markets they are in.

Following Hirtle (2007), a deposit-based HHI was determined for each of the 2,655 commercial banks for 2010. Lerner Indices and H-Statistics were estimated using a

---

\(^1\) The average size of all commercial banks < $100 million is only $57 million.

\(^2\) As we effectively sample the entire population of commercial banks and apply OLSQ, there is no need keep large outliers in the data set and also square them to represent other outlier observations not included in the sample.
standard translog or Fourier specification applied to quarterly bank level data over 2008-2010. These specifications and the HHI calculation are shown in the Appendix. Table 1 shows the average and 25th and 75th percentiles of all three competition measures for the 382 banks with total assets (TA) greater than $1 billion (accounting for 90% of total assets) as well as the 2,273 banks with assets between $100 million and $1 billion (accounting for 10%).

The U.S. Justice Department’s 2010 horizontal merger guideline suggest that markets with an HHI below 1,500 can be considered to be unconcentrated. The guideline also suggests that a moderately concentrated market exists when the HHI lies between 1,500 and 2,500 while a highly concentrated market has a HHI above 2,500. Based on the average HHI in Table 1 for billion dollar banks, U.S. institutions appear to operate in unconcentrated and hence apparently competitive markets. Indeed some 75% of billion dollar banks have a HHI at or below this level. In the sample of smaller banks ($N = 2,273$), 4.0% of banks are in highly concentrated markets (with an HHI $\geq 2,500$), while only 3.1% of the billion dollar banks are ($N = 382$). Using the stronger 1992 guidelines, the percent of banks in highly concentrated markets (HHI $> 1,800$) would be 16.1% and 16.0%, respectively. For the same banks, the average mark-up of price over marginal cost is 26% while the average H-Statistic is .82. As seen in the lower half of Table 1, similar average values were found for banks with $100 million to $1 billion in assets (as well as when the entire sample was used—not shown).

---insert Table 1 here---

The three competition measures in Table 1 are unrelated to one another as their $R^2$'s are effectively zero. This holds for both groups of banks in the table. Greater compe-

---

3 The median HHI is slightly smaller (at 1,271) than the average in Table 1 while the median values of the Lerner Index and H-statistic are equal to their averages for billion dollar banks. Marginal cost from the less flexible translog function yields an average Lerner Index of .31. Replacing marginal cost with average cost—which is observed rather than estimated—gives an average Lerner Index of .26.

4 Some studies have noted that the Lerner Index is not well related to the HHI (Maudos and Fernandez de Guevara, 2004) and others have shown the same for the H-Statistic and HHI (Claessens and L. Laeven, 2004). What seems to be missing is looking at how the Lerner Index is or is not related to the H-Statistic.

5 The bivariate correlation results are the same if marginal cost from a translog cost function for
tition is indicated with lower HHI and Lerner Index values but with higher H-Statistic values (1.0 being the expected maximum). Thus a positive correlation coefficient ($r$) between the H-Statistic and either the HHI or Lerner Index means that when the H-Statistic suggests less competition the other suggests the opposite.\textsuperscript{6} Similar results have been obtained for Europe. These same three bank competition measures are almost unrelated to each other when compared across European countries over time and can be negatively related within the same country over time (Carbó, Humphrey, Maudos, and Molyneux, 2009).\textsuperscript{7} As shown below, however, there is a weak correspondence between these three measures and with our frontier competition measure – when the data are sorted into quartiles of most and least competitive banks.

2.1 Why Are the Correlations Weak?

They are weak because all three measures assess competition differently. A contributing factor could be that U.S. banking markets are not strong oligopolies. However, banking concentration in Europe is considerably greater than in the U.S. and the same three concentration measures are only weakly correlated there. Maybe if banking was as concentrated as the steel and auto industry post WWII, the relationship among the three competition measures would be stronger. This is unlikely to occur. Since 1994 no bank’s deposit market share can exceed 10% of nationwide deposits (and none did at that time). With one exception, this national limit can only be exceeded by de novo entry and/or market growth which is very slow, more costly, and much more

\textsuperscript{6}Such “reversals” occur for the H-statistic paired with the Lerner Index (for both sets of banks) and for the H-statistic with the HHI (for large banks) due to a positive $r$ value. It also occurs for the Lerner Index with the HHI (for smaller banks) due to a negative $r$ value. Out of the six competition measure pairings in Table 1 four suggest the measures are (weakly) inconsistent.

\textsuperscript{7}Using aggregate data on 14 European countries over 1995-2001 covering 1,912 banks, the $R^2$ between the Lerner Index and the H-statistic was only .06. Similarly, the $R^2$ between the HHI and the Lerner Index and H-statistic was, respectively, .09 and .05. Looking at each of the 14 countries separately over time, the relationship between the Lerner Index and the H-statistic was positive in only 8 out of 14 countries. (This was after the H-statistic was multiplied by -1.0 so higher values of all three measures indicate less competition.). The relationship between the HHI and these two measures was positive in only 8 and 5 countries, respectively.
competitive than bank expansion through merger or acquisition. An acquiring bank has to offer significantly higher deposit rates and/or lower loan rates to attract market share rather than just buy it outright.\footnote{The national deposit cap applies only to commercial banks. Two banks have each subsequently acquired a large savings and loan institution so their deposits both exceed 10%, the highest of which is 12% nationwide. There is also a 30% cap on statewide deposits of any single bank but, as state legislatures could change this cap, 20 have abolished it.} This is why 72\% of the past real growth of the 20 largest U.S. banks in 1980 was achieved through mergers and acquisitions (Rhoades, 1985). If more recent mergers were included, the figure would be considerably higher.

While the relatively unconcentrated nature of U.S. banking may help explain why the HHI is unrelated to the other two measures, it is not clear why the Lerner Index and H-Statistic are also uncorrelated. The Lerner Index reflects the spread of output price ($P_o$) to marginal cost ($MC$) by individual banks averaged over 2008-2010. In banking, output price is typically approximated by the ratio of total revenue to total assets ($TR/TA$) where total revenue is $TR = P_oQ_o$ and $Q_o = TA$ represents output quantity. As scale economies ($SCE$) are the ratio of marginal to average cost ($AC$), the Lerner Index can be simplified to $P_o - AC \cdot SCE$.\footnote{As the variation of this unit spread across banks will accord well with its percentage value if divided by $P_o$ or $AC$, in this illustration we focus on the spread alone.} In contrast, the H-Statistic is based on $TR = f(P_i, TA)$ where $P_i$ represents the price of inputs. The H-Statistic itself is the sum of partial derivatives: $\sum \partial TR/\partial P_i$. The H-Statistic reflects the change in output price to input prices since output (measured as TA or some of its components) is being held constant. Assuming that average cost reflects the weighted average of input prices and neglecting a measurement issue,\footnote{Researchers assume $P_oQ_o/TA = P_o$ and $\sum \partial TR/\partial P_i = \sum \partial P_o/\partial P_i$ even though $Q_o \neq TA$. The inequality arises because 35\% of total revenues are generated from non-interest income sources that do not have a corresponding asset value (or output indicator) in the balance sheet nor are these outputs reported elsewhere. See Bikker et al (2007) for a country study on bank competition based on the H-statistic.} these two competition measures— for comparison purposes—can be expressed as:

\begin{align*}
\text{Lerner Index} & \quad P_o - AC \cdot SCE \\
\text{H-Statistic} & \quad \partial P_o - \partial AC.
\end{align*}

In effect, the Lerner Index looks at the average level of the price-cost spread over a
sample period while the H-Statistic looks at changes in that spread and thus measure different aspects of competition. If a bank’s Lerner Index is relatively high, it may have achieved that level at an earlier time but now may behave in a more competitive manner (according to the H-Statistic) by closely aligning output prices to changes in input prices due to new firm entry, a desire for greater asset diversification, or (more likely) a downswing in the business cycle. Similarly, if the Lerner Index is relatively low (suggesting greater competition), it may now be in a position to marginally raise its price-cost spread by raising output prices more than input prices (lowering competition according to the H-Statistic). This could be due to a change in market structure, a desire to reduce asset growth, or (often) a rise in demand associated with an upswing in the business cycle. Indeed, depending on the strength of a cycle upswing/downswing, most banks may respond similarly even if they start out with different Lerner unit spreads.

3 Estimating A Competition Frontier.

The fact that U.S. regulators would view an average HHI of 1,364 in Table 1 as indicating an unconcentrated (and presumedley competitive) banking market does not mean that all major banking services are competitive. Indeed, regulators consider HHIs for local deposit markets, local and national loan markets, and examine other indicators of competition. Unfortunately, academic studies lack such detail. However, by using publicly available banking data, we provide an indicator of relative banking competition across five major service lines: consumer loans, business loans, payment activities, investment banking and other fee-based activities, and securities.\footnote{Our data source was the Federal Reserve Bank of Chicago which has up to 2010 appropriately combined the two bank Call Reports (031 for banks with domestic and foreign offices and 041 for banks with only domestic offices) to generate a consistent set of data (see http://www.chicagofed.org/webpages/banking/financial_institution_reports/commercial_bank_data.cfm).}

Our approach to measuring competition is similar to that developed independently by Boone (2008), whose aim was to determine competition based on a firm’s profits.
Here competition is determined by subtracting a firm’s variable costs from its revenues. This gives a return to fixed inputs plus extra revenues associated with the degree of relative competition. Boone shows this approach to be more robust theoretically than the price-cost margin of a Lerner Index. Our focus is on an empirical specification of a Boone-type theoretical model.

3.1 The Framework.

As publicly available information on individual banking service prices or profits are limited or do not exist, our approach relies on existing and newly available bank revenue data. A recent European report noted large cross-country differences in individual bank fees and service requirements (European Commission, 2007). As a high price on one component of a service line can be offset by a low price on a different component, looking at total service line revenues is likely more informative.

In simple terms:

\[ \Pi = f(\text{competition, costs}), \]

where \( \Pi \) denotes profits. As profits are simply revenues - costs, profit differences across banks can be alternatively measured as the "mark-up" ratio revenue/costs and, if all explicit costs are included, an estimate of relative competition can be obtained from:

\[ \frac{\text{revenue}}{\text{costs}} - f(\text{costs}) = g(\text{competition}). \]

Here \( g(\text{competition}) \) represents the unexplained mark-up over cost and includes a normal return on equity which is not explicitly specified in the model. When a bank’s mark-up is expressed relative to the mark-up for the bank that defines the frontier, the result is an indicator of competition that excludes the normal return on equity of the frontier bank. The revenue/cost ratio is the inverse of the popular Cost Income Ratio used in the banking industry. This is the ratio of operating cost to operating revenue.
and banks with a lower input cost per unit of output revenue raised are (by definition) more profitable.\textsuperscript{12}

Our approach is similar to a Lerner Index where $(P_o - MC)/P_o = \text{competition measure}$, which is also a mark-up over costs. Nothing is lost if the Lerner Index is instead expressed as the ratio $P_o/MC$. Our approach differs in that, lacking prices, we use the ratio of revenues to cost where the denominator is average cost ($AC$) not $MC$ and the numerator and denominator are multiplied by their respective output ($Q_o$) and input ($Q_i$) quantities giving: $(P_o \times Q_o/AC \times Q_i) = \text{revenue/cost}$.\textsuperscript{13}

$AC$ is calculated from observed input prices while $MC$ is estimated from a cost function using these same prices. However, if the productivity of these inputs differ across banks then input prices will not reflect their true cost to the bank. Observed input cost will be higher for banks with greater productivity making them appear more competitive than they are as the observed spread $P_o - MC$ or $P_o - AC$ will be lower. If these lower real costs are passed on, observed output prices would be lower and a bank would appear to be even more competitive. Thus observed $MC$ or $AC$ would benefit from being adjusted for productivity before a Lerner Index is used to indicate competition since the Lerner Index itself can indicate competition as well as reflect productivity differences across banks. The H-Statistic faces much the same problem. Our frontier competition measure, however, controls for two indicators of bank productivity.

\subsection*{3.2 Model Specification.}

Our approximation to the ratio of revenues to costs is the ratio of five separate banking service revenues or revenues minus average funding costs ($REV_n$) to overall bank

\textsuperscript{12}The Cost Income Ratio = (labor + capital + other non-interest expense)/(interest revenue - interest expense + fee income). It is typically used to indicate productivity or efficiency but to do this properly the numerator and denominator would have to be adjusted, respectively, for differences in factor input and output service prices yielding a more "physical" input/output relationship (Burger and Moormann, 2008).

\textsuperscript{13}The Lerner Index gives the same ranking of bank competition whether it is defined as $(P_o - MC)/P_o$ or $(P_o - AC)/P_o$ since $MC$ is uniquely tied to $AC$ by the slope of the supply curve (or scale economies).
operating cost \((OC)\), comprised of labor, physical capital, and materials expense. We do not have an exact measure of the operating cost associated with each of the five separate banking services. However, we do specify variables to explain its overall level and variation which, in turn, influence the effect of operating cost on the five revenue streams. The three major determinants of the dependent variable \(REV_n/OC\) in equation (1) are the underlying unit operating costs of producing these banking services, the productivity of the factor inputs used in producing these services (along with other cost influences), and the existing level of market competition. We specify the first two while the unexplained portion, averaged over 6 separate two quarter cross-section/panel regressions, is maintained to reflect the average influence of competition over 2008-2010.\(^{14}\)

For both consumer and business loans the dependent variable \(REV_n/OC\) is the ratio of the spread between the average return on loans and the average funding cost \((REV)\) to operating cost \((OC)\). The spread reflects bank price setting of loan outputs and funding inputs, which are both influenced by the level of market interest rates and factor prices. For payment services, investment banking activities, and securities, observed revenues are used instead of a spread as their reliance on funding is minimal and almost all of their costs are operating expenses. Scale economies, factor productivity, indicators of output level, and risk also play a role. Specifically, the variation in the ratio \(REV_n/OC\) is explained in (1) by the following:

\[ (1) \text{Technical: } \text{standard cost function influences composed of bank output for three major services and factor prices: the value of the level of consumer (CLOAN) and business loans (BLOAN) and securities held (SEC) along with the average price of labor (PL) and an approximation to the cost of physical capital (PK)}; \]

\(^{14}\)A general issue in measuring competition is whether or not observed input costs are close to their minimum levels. If not, the revenue-cost spread may be lower than otherwise suggesting that competition is greater than it is. Differences in input productivity is one way observed costs may not reflect their actual minimums and is the reason for including two indicators of bank productivity.

\(^{15}\)Levels of loan outputs reflect bank size which affects cost economies and the ability to diversify assets which can reduce risk (Demsetz and Strahan, 1997). Logs of the levels data have only a slight trend over our 12 quarters so time-series stationarity is not an issue (and even if it was, the estimation results are dominated by the 382 or 2,273 cross-section observations). The price of labor is the ratio
(2) **Productivity and Scale:** the productivity of capital in producing/supporting deposits measured in the industry by the deposit/branch ratio \((DEP/BR)\), labor productivity as reflected in the labor/branch ratio \((L/BR)\), and a prediction of the effect of scale economies on average operating cost based on a prior estimation of how U.S. banking unit operating cost changes with the value of output produced \((PREDAC)\),\(^{16}\)

(3) **Risk:** differences in bank risk are leverage or the ratio of risk-based equity capital to assets \((CAPITAL)\) as well as the ratio of the provision for loan losses to loans \((LLR)\)^{17}; and

(4) **Market Rate/Business Cycle:** the 3-month Treasury bill rate \((RATE)\) is used to control for the base cost of funds which can influence deposit and loan rates charged, securities revenues, as well as fees and points assessed for banking services. The quarterly variation of this variable is very similar to the real GDP output gap which can affect changes in the demand for banking services (so both could not be used).

The full model contains \(n = 5\) translog equations in logs:

\[
\ln(REV_n/OC) = \alpha_0 + \sum_{i=1}^{9} \alpha_i \ln X_i + 1/2 \sum_{i=1}^{9} \sum_{j=1}^{9} \alpha_{ij} \ln X_i \ln X_j + \sum_{i=1}^{9} \sum_{k=1}^{2} \delta_{ik} \ln X_i \ln P_k \\
+ \sum_{k=1}^{2} \beta_k \ln P_k + 1/2 \sum_{k=1}^{2} \sum_{m=1}^{2} \beta_{km} \ln P_k \ln P_m + \ln \epsilon + \ln u
\]  

(1)

where:

\(n = \) revenues from consumer loans, business loans, payment activities, investment banking and other fee-based services, and securities;

\(P_k = PL, PK;\)

of salaries and benefits to the number of full-time-equivalent employees while the capital price is the ratio of premises expense to the value of premises.

\(^{16}\)Predicted bank average unit operating cost uses parameters from a translog cost function estimated with annual data over 1996-2008 but evaluated using bank values for each quarter over 2008-2010. The resulting average operating cost curve was relatively flat when arrayed against the log of total assets with scale economies at the mean of only .98 for billion dollar banks.

\(^{17}\)The loan loss ratio was measured as \((\text{value of all loans and leases} - \text{provision for losses on loan and leases})/(\text{value of loans and leases})\).
\[ X_i = \text{CLOAN, BLOAN, SEC, DEP/BR, L/BR, PREDAC, CAPITAL, LLR, RATE}; \]

and have been defined above. The composed error term \( \ln e + \ln u \) reflects normal error (+\( \ln e \)) and inefficiency (+\( \ln u \)). The five equations in (1) are estimated using quarterly data over 2008-2010, two separate quarters at a time for 6 separate cross-section/panel regressions. This permits market interest rates (+\( \text{RATE} \)) to vary across the two quarters in each regression. This variable, which also reflects the business cycle, represents the basic cost environment for banks and is especially important in setting the base cost of loans and securities. The own, squared, and interaction parameters were separately estimated for each of the four sets of explanatory variables shown above—not for all eleven variables together.\(^\text{18}\)

### 3.3 Productivity and Risk.

Our specification includes two banking productivity variables which, along with standard cost function influences (output levels and input prices) have been important in reducing cost inefficiency to low levels in both stochastic and linear programming frontier models (Carbó, Humphrey, and Lopez del Paso, 2007).\(^\text{19}\) Our capital and labor productivity measures (+\( \text{DEP/BR} \) and +\( \text{L/BR} \)) indicate inefficiency or overuse when they are "too high" relative to other banks. While other possible influences come to mind (Hicksian 'quiet life', agency, governance, contestability, or misreading expected demand and producing an inappropriate output mix), the first three reflect cost inefficiency which is already captured in the productivity variables while the last two should affect revenues. If some banking markets are more contestable than others, this potential or actual price competition should already be reflected in our revenue/cost ratio

---

\(^{18}\)Thus own, squared, and interaction terms were estimated for the five Technical or cost function variables separately from the own, squared, and interaction terms for the three Productivity and Scale variables and also separately from the two Risk variables. The Market Rate/Business Cycle variable has only an own and squared term since there is only one variable. As all the RHS variables are the same for each of the 5 equations in (1), it makes no difference if they are estimated individually or as a system of seemingly unrelated regressions.

\(^{19}\)Berger and Mester (1997) and Frei, Harker, and Hunter (2000) have also shown productivity influences to be a primary determinant of previously unexplained bank cost inefficiency. Other influences (e.g., balance sheet variables) turn out to have almost no impact.
dependent variables while output mix is captured in the Technical or cost function variables. Barriers to new bank entry are quite low in the U.S. and credit unions (because their profits are not taxed) typically pay marginally higher deposit rates and charge less for consumer loans.

One example of $L/BR$ productivity differences across banks occurs when branches are over staffed. Detailed studies of branch operations identify a daily peak load for teller window transactions and back office processing. Some banks are more adept than others in obtaining part-time (rather than full time) workers to staff the peak load. Another example would be sharing a branch manager when branches are close together (Sherman and Ladino, 1995) or operating in-store or supermarket branches where the staffing level is about half that of a stand-alone office (Radecki, Wenninger, and Orlow, 1996). The capital cost of an in-store branch is also only about one-fifth of a conventional branch and is reflected indirectly in the approximation to the price of capital ($PK$).\textsuperscript{20}

In addition, in-store branches and stand-alone branches located in higher per capita income areas (suburban versus central city or rural) generate more deposits per office, raising the deposit/branch ratio ($DEP/BR$) as well as generating a greater demand for other banking services. As deposits are typically the cheapest and most stable source of bank funding, a higher deposit/branch ratio can support a larger loan-deposit rate spread. Importantly, branch locations in high income areas are limited and in-store branch contracts with supermarket chains are exclusive within states or metropolitan areas so these productivity/cost differences can be relatively persistent.

Just as productivity is used to adjust observed input prices to reflect better underlying bank costs and their effect on profits, risk variables are specified in (1) to control for differences in bank revenues associated with holding riskier assets. However, the relation between bank risk and competition is complex. Keeley (1990) provided a theoretical framework and empirical evidence that deregulation of the banking sector

\textsuperscript{20}A better measure would be the number of in-store versus traditional branches a bank has but this information is not available.
in the U.S. in the 1970s and 1980s had increased competition and led to a reduction in monopoly rents. Given this reduction in "charter value", the bank owners—or managers acting on their behalf—had an increased incentive to take on extra risk, given the guaranteed funds available to them because of deposit insurance. These riskier policies included granting loans for riskier projects (reducing loan quality), or lowering capital levels, or both, which increased the probability of higher ratios of non-performing loans and bank defaults. Ultimately, the extra risk that banks took on as a result of this agency problem caused a dramatic increase in bank failures during the 1980s (Allen and Gale, 2004).

In contrast, Boyd and De Nicoló (2005) proposed a different view. Within their model, less competition among banks results in higher interest rates on business loans which can raise borrower credit risk. The rise in firm default risk in turn leads to increased bank non-performing loans and greater probability of bank failure. They thus predict a positive relationship between banking market concentration and bank risk-taking (see Boyd, De Nicoló, and Jalal, 2006, for an empirical underpinning).

Known risks require banks to hold a larger ratio of risk-based capital to assets (CAPITAL) and also hold a larger provision for loan losses (LLR), which are our two specified risk variables. Currently unknown risks are difficult to adjust for as they are typically incurred in the upswing of the business cycle and only become known and adjusted for in the downswing. In the upswing, unknown risks can expand bank revenues and potentially influence competition results based on our frontier CE measure (as well as the Lerner Index and H-Statistic). This suggests that a business cycle indicator may mitigate this local identification problem.

Our model has used the 3-month Treasury bill rate (RATE) to capture changes in the base cost of bank funding over two quarters for our six separate cross-section estimations. Originally, a measure of the real GDP output gap was also specified to control for the business cycle effect on loan demand and a possible risk-associated change in bank revenues. Like the Treasury bill rate, the output gap is a constant for
each quarter. Including both variables in (1), however, was not possible as they were highly collinear so the Treasury bill rate reflects both the base cost of bank funding as well as the output gap business cycle indicator. In addition, as our time period is 2008 to 2010, previously unknown asset risks accumulated earlier should have been recognized and affect our specified risk variables (especially \( LLR \)). Thus it is unlikely that much unknown risk remains during our time period to affect our competition measure.

3.4 A Competition Efficiency Frontier.

In estimating the competition frontier, we use the composed error Distribution Free Approach (DFA) in Berger (1993). Two other frontier approaches exist: linear programming Data Envelopment Analysis (DEA) and a composed error Stochastic Frontier Approach (SFA). While any one of these frontier approaches could be used, we feel that the DFA has the fewest limitations.\(^{21}\)

With DEA there is no need to specify a functional form which can affect the placement of the frontier. However, random error is assumed to be zero (so hypotheses can not generally be tested) and the more influences (constraints) considered in the analysis, the lower will be the dispersion from the frontier even when—in a regression framework—the added influences (variables) may be insignificant. The difficulty with SFA is the assumption that inefficiency follows a half-normal distribution with most banks located on or close to the estimated frontier, an assumption not supported when no restriction is placed on the inefficiency distribution (c.f., Bauer, 1990; Berger, 1993).\(^{22}\) Unlike SFA or DEA, the DFA model requires panel data and assumes averaging each bank’s residuals across separate cross-section regressions reduces normally distributed error to minimal levels leaving only average inefficiency (or the average

---

21 A similar approach was earlier applied to national level (not bank level) European data but was only able to distinguish between two aggregate service lines: traditional loans versus all fee-based activities (Bolt and Humphrey, 2010).

22 Using a Gamma distribution for inefficiencies mitigates this problem but also makes it more difficult to distinguish random error from inefficiency in a composed error framework.
effect of competition on revenues). In previous cost efficiency analyses the DFA and SFA approaches have yielded similar levels and rankings of inefficiencies for most—but not all—banks (Bauer, Berger, Ferrier, and Humphrey, 1998).

In a composed error framework, equation (1) can for illustration be expressed as

\[
\ln(\frac{REV_n}{OC}) = R(\ln X_i, \ln X_j, \ln P_k) + \ln e + \ln u. \tag{2}
\]

The total residual \((\ln e + \ln u)\) reflects the unexplained portion of the revenue-operating cost dependent variable remaining after cost, productivity, and other influences have been accounted for. Here \(\ln e\) represents the value of random error while our maintained hypothesis is that \(\ln u\) represents the effect of competition on revenues. As noted, the DFA concept assumes that \(\ln e\) will average to a value close to zero while the average of \(\ln u\) will reflect the average effect of competition (\(\ln \bar{u}\)). DeYoung (1997) has suggested that 6 separate cross-section estimations may be needed for random error in the composed error term to achieve an average value close to zero. Our composed error terms are averaged over up to 6 cross-section estimations of two quarters each.\(^{23}\) In all cases, the averaging process reduced the standard deviation of the distribution of our competition indicator \((CE_i)\).

The bank with the lowest average residual \((\ln \bar{u}_{\min})\) is also the bank where the variation in underlying cost and productivity explains the greatest amount of the variation in revenues relative to operating costs, reflecting the strongest effect of market discipline on the revenue/cost ratio through competition. This minimum value defines the competition frontier and the relative competition efficiency \((CE_i)\) of all the other \(i\) banks in the sample is determined in (3) by their dispersion from this frontier:

\[^{23}\text{If (1) was estimated using 12 separate cross-sections of one quarter each, market rates (which also reflect the business cycle) would be a constant in each equation. At the other extreme, if (1) was estimated as a single panel including all 12 quarters together, the dispersion of the unaveraged residuals naturally rises and markedly increases the size of the computed \(CE\) measures. Even so, this does not have much effect on the ranking of which of the five services would be deemed most or least competitive.}\]
\[ CE_i = \exp(\ln \bar{u}_i - \ln \bar{u}_{\min}) - 1 = (\bar{u}_i / \bar{u}_{\min}) - 1 \quad (3) \]

In an unlogged version of (2), \( u_i \) is multiplicative to \((REV_n/OC)_i\) since it is expressed as \((REV_n/OC)_i = R(X, P)_i u_i\). As a result, the ratio \( \bar{u}_i / \bar{u}_{\min} \) is an estimate of the ratio of \((REV_n/OC)_i\) for the \( i^{th} \) bank to the value of \((REV_n/OC)_{\min}\) for the bank facing the greatest competition when both experience the same underlying cost and service productivity.\(^{24}\) For example, if \( CE_i = 2.0 \), then \( \bar{u}_i \) is two times larger than \( \bar{u}_{\min} \) so the unexplained portion of \((REV_n/OC)_i\) is two times larger than \((REV_n/OC)_{\min}\). This difference reflects the unspecified influence of competition. Thus the larger is \( CE_i \), the weaker is the ability of market competition to restrain revenues so \( CE \) is equivalent to inefficiency in a cost frontier.

An apparent limitation of (3) is that it only indicates the relative level of competition: it can not determine the absolute level of competition. This is useful, however, since the unexplained residual includes an unknown but valid mark-up over costs (return on equity/investment) and the relative nature of \( CE_i \) reflects differences in this mark-up across banks assumed to reflect the strength of competition. It is also important to examine the fit of the estimating equation since, if the \( R^2 \) is high, the difference in relative competition measured by \( CE \) may not be very economically significant since the residuals \( \bar{u}_n \) and \( \bar{u}_{\min} \) would themselves be absolutely small.

The bank or banks that define the competition efficiency frontier are those where the specified cost, productivity, and risk variables in (1) explain the greatest portion—not necessarily all—of the variation in the revenue/cost ratio dependent variable. A frontier bank’s residual \( \bar{u}_i \) is also the minimum \( \bar{u}_{\min} \) so its \( CE_i \) value is 0.0 in (3). The average of \( CE_i \) values reported below depends on the dispersion of all bank residuals from this minimum and this dispersion (as well as the minimum) is

\(^{24}\)The ratio \( \bar{u}_i / \bar{u}_{\min} \) equals \(((REV_n/OC)_i/R(X, P)_i)/((REV_n/OC)_{\min}/R(X, P)_{\min})\) and when evaluated at the same level of underlying cost and service productivity, the predicted values of revenue \( R(X, P)_i \) and \( R(X, P)_{\min} \) are equal as both are at the same point on the estimated revenue curve, leaving the ratio \((REV_n/OC)_i/(REV_n/OC)_{\min}\).
typically smaller—indicating greater relative competition—when the $R^2$ in (1) is high. However, as $CE$ is a percentage measure and all residuals may not fall proportionally as $R^2$ rises, there need not be a one-to-one relationship between $CE$ and $R^2$. For this reason it is useful to also report the absolute value of the average residual as a ratio to the mean of the dependent variable $|\bar{u}_i/(REV_n/OC)_i|$ (where the denominator is constant). This is an alternative way to illustrate the importance of cost, productivity, and other influences in explaining the variation in the revenue/cost ratio. A low ratio implies strong competition. Frontier efficiency studies typically just look at their efficiency/inefficiency results and do not also consider how the fit of their underlying regressions can affect their interpretation.\textsuperscript{25}

### 4 Assessing Relative Competition.

The relative competition of U.S. banks across five major service lines is reported in Table 2. One service line is deemed more competitive than another when its competition efficiency measure ($CE$) is lower, the $R^2$ is higher (reflecting the extent to which cost, productivity, and other influences successfully explain the variation in the revenue/cost ratio), and the absolute value of the ratio of the average residual to the mean of the dependent variable $|\bar{u}_i/(REV_n/OC)_i|$ is lower. We interpret our $CE$ values as averages of the effect of competition for different banking services over time rather than being constant.

In terms of interbank competition, business loans and security activities have the lowest $CE$ values indicating that they are closest to their efficient frontier. Business loans—which include commercial and industrial loans and leases along with real estate, agricultural, construction, and foreign loans—also had the highest average adjusted $R^2$ (.92-.97) over the six regressions while securities had the second or third highest (.85-.89) for both banking groups. This suggests that 3\% and 15\% of the variation

\textsuperscript{25}For example, if the $R^2$ in (1) is .90 then only 10\% of the variation in the revenue/cost ratio is unexplained by cost and productivity influences and one would conclude that uncompetitive behavior plays a small role even if the computed value of $CE$ seems quite large.
in business loan and security revenue/cost ratios, respectively for billion dollar banks (8% and 11% for smaller banks), was not explained by cost and productivity influences. Finally, these two service lines had the lowest ratio of their average residual to the mean of the dependent variable showing again that costs are by far the main determinant of the revenue/cost ratio (rather than uncompetitive behavior). Business loans were more competitive than we expected, perhaps because commercial paper and other non-bank funding instruments are strong substitutes that reduce the $CE$ dispersion among banks. In contrast, security operations were expected to be competitive as most of their costs and revenues are determined by market interest rates.\footnote{If we had used logs of the ratio of consumer and business loans to total assets, the average $CE$ values for consumer and business loans would be considerably larger with a far lower $R^2$ for the estimating equations. The other $CE$ values in Table 2 are little affected. As noted in an earlier footnote, we use a levels specification for these variables as we wish to control for bank size which is related to cost economies and asset diversification.}

---insert Table 2 here---

Payment activities are less competitive. Their revenue is from deposit service charges, card interchange fees, ATM fees, and sale of checks. Importantly, it does not (but should) include income from minimum balance requirements that are used to help recoup bank payment expenses. This income is not separately reported but is reflected as part of the computed spread for consumer and business loans.\footnote{Bank income statements only show "total interest and fee income on loans" and do not breakout interest from fee income overall or by consumer/business loan type.} Given recent regulatory concern with altering interest rates on credit card balances, legislation reducing debit card fees, returned check charges, and bank deposit overdraft fees, it is not surprising that payment activities appear to be the second least competitive banking service. Unless offset by new fees and/or higher monthly deposit account charges, this service line should appear more competitive in the future.

Consumer loans cover credit card, revolving, installment, and student loans and appear to be much less competitive than business loans.\footnote{Consumer loans have a high $R^2$ so the $CE$ value may overstate the apparent lack of competition.} One reason may be that consumers typically do not shop around for the best rates as large business borrowers...
do and, since they borrow smaller amounts, they have less bargaining power. Also, many consumer loan charges— from interest rates to points for money to other fees—are not well understood by consumers as noted by Lusardi (2008) and others. Hence the current regulatory emphasis on informing consumers of the overall cost of their borrowing.  

It is not surprising that investment banking and other fee-based activities would be the least competitive of the five service lines in Table 2. 30 This line combines many specialized activities—securitization, underwriting, securities brokerage, insurance, venture capital—where service availability and reputation likely play a more important role than cost. 31 The net effect of restrictions included in the recent Dodd-Frank banking legislation (along with the Volcker rule limiting risky proprietary trading by banks with insured deposits) should make this service line less risky and also less profitable going forward.

Are banks that are competitive in one service line competitive in other lines as well? No, there is almost no relationship. The strongest positive relationship occurs for CE values between business loans and securities with an $R^2$ of only .19 while all other positive relationships have an $R^2$ of .01 or less. The strongest negative relationship is between securities and payment services at .02 with all other values being smaller. 32 As banks appear to differ considerably in their degree of competition across the five service lines, it can be misleading to infer the overall level of competition using measures that typically apply to deposit/loan activities like the HHI (which typically focuses on deposit market concentration) or the Lerner Index which usually derives its estimated

\[\frac{|u_i|}{(REV_n/OC)_i}\] 20
marginal cost from loan and security outputs and computes its spread from the average return on assets.

—insert Figure 1 here—

Frequency distributions of $CE$ values for the five service lines, relative to their separate efficient frontiers (at 0.0), are shown in Figure 1 for billion dollar banks. They are not half-normal distributions like those imposed when implementing a Stochastic Frontier Approach to frontier estimation. These gamma distributions have a more normal shape but differ in their dispersion. The means of the distributions are determined from the X-axis and were reported in Table 2. Business loans account for 44% of total bank revenues and the standard deviation is by far the smallest. It was reached after averaging residuals across 6 sets of regressions (of two quarters each). Security activities comprise 13% of revenues and also have a low standard deviation. Here the minimum standard deviation occurred when averaging across just 2 sets of residuals with a mean of 1.7 reported in Table 2. Payments and consumer loans account for 11% and 8% of bank revenues, respectively, and have more dispersion. The lowest standard deviation for payments occurred when averaged across all 6 sets of residuals but only 5 was needed for consumer loans. The dispersion of the $CE$ frequency distribution for investment banking and other activities is by far the largest. The lowest standard deviation occurred when residuals were averaged over all 6 regressions. Averaging more than 6 times was not possible as there were only six regressions. Overall, it appears that $CE$ estimates for security activities contain little random error as the

\[\text{33} \text{Reporting frontier efficiency results when the standard deviation is lowest was suggested in DeYounge (1997). We have six sets of residuals from regressions using data for 2008 Q1-Q2, 2008 Q3-Q4, 2009 Q1-Q2, ..., 2010 Q3-Q4. The first set of residuals was from using 2008 Q1-Q2 data alone and was not averaged with any other residuals before CE values and their standard deviations were computed. In a second case, residuals from 2008 Q1-Q2 and 2008 Q3-Q4 were averaged before CE values were computed. A third case averaged residuals using data from 2008 Q1-Q2, 2008 Q3-Q4, and 2009 Q1-Q2, and so on for 6 sets of CE and standard deviation values.}\]

\[\text{34} \text{Only for securities, which needed to be averaged only twice, was there an important difference in bank CE rankings compared to averaging six times. All other CE values thus reflect averaging over six sets of residuals. Even though the standard deviation was marginally higher when averaging six times (versus four or five in a few cases), this had almost no effect on the ranking of banks by their CE value.}\]
lowest standard deviation was found after averaging only two sets of residuals. Given the large dispersion in Figure 1 for investment banking and related activities, our results here are likely the weakest and are viewed with caution. The dispersion likely reflects a lack of separate labor cost and productivity data pertaining specifically to the skilled labor employed in these activities and thus likely overstates actual differences in relative competition.

5 Comparing Measures of Competition.

Competition efficiency is measured by service line across banks. It is not meant to be a summary indicator of competition for the whole bank. Bank service lines are quite different and aggregating them in some fashion is like aggregating multiple outputs produced by different production functions at a single firm. Even so, some may wish to see how similar or different the CE measure is compared to the same banks’ HHI, Lerner Index, or H-Statistic. One way to do this is to compute a revenue share weighted average of the five CE values we have estimated for each bank. In the top half of Table 3 billion dollar banks are ranked by their revenue weighted average CE value and compared with the same bank’s average for the three other competition indicators (which are usually said to apply to the whole bank). The results are divided into quartiles generally separating most competitive from least competitive banks.

The weighted average CE measure more than doubles between the most and least competitive quartiles of banks but changes in the other three competition measures are more subdued. Higher weighted average CE values suggest less competition which is consistent with the higher HHI for the same banks, a higher Lerner Index, and a falling H-Statistic as shown. Thus all four measures indicate reduced competition.

\[ \text{REVSHCE}_i = \sum_j \omega_{ij} CE_{ij} \]

\[ \omega_{ij} = \frac{\text{REV}_{ij}}{\sum_j \text{REV}_{ij}}. \]

---insert Table 3 here---
as we move from the most to the least competitive quartile of banks. Even though there is a general correspondence between all four competition measures in the top half of Table 3, this consistency does not always roll over to individual banks. As seen in Table 1, there is almost no correlation between the three standard competition measures at the individual bank level. Although the revenue weighted average \( CE \) is significantly related to the corresponding HHI for the same bank (at the 90% level), the \( R^2 \) is less than .01. Greater significance and a higher correlation is obtained when \( CE \) is regressed on both the Lerner Index and the H-Statistic \( (R^2 = .16) \) suggesting that \( CE \) reflects elements of both of these theoretically-based competition measures.

What if the ranking of banks from most to least competitive were performed using the other three competition measures separately? This question is answered in the lower half of Table 3. Ranking banks from most to least competitive using only the HHI would raise it from 789 (unconcentrated) to 2,107 (moderately concentrated). Using the Lerner Index to rank banks from most to least competitive would raise it from 13% to 39% while using the H-Statistic would result in a fall (showing less competition) from .90 to .73.

One reason for the difference between the top and bottom halves of Table 3 is that the three standard competition measures are more narrow in their competition assessment than is the average \( CE \) measure which includes more cost influences and more service lines. The \( CE \) covers both traditional banking services (consumer and business loans) along with two fee-based services (payments and investment banking activities) and securities while the HHI, Lerner Index, and H-Statistic focus on consumer and business loan-deposit concentration, loan-deposit rate spreads, and changes in average asset revenue to cost, respectively.

While U.S. competition authorities can use the HHI to focus on local market concentration, this is not possible with the other measures as the necessary data are not available. However, as the median commercial bank operates in two MSAs and only one state, viewing competition at the bank level represents an alternative way to assess
competition, especially since the HHI represents only a potential for an uncompetitive outcome. Since the four competition measures shown in Table 3 measure different aspects of competition, it can be useful to look to the three theoretically-based measures for a "second opinion" to conclusions authorities may reach when relying on the HHI. A second opinion, which reflects past behavior, may also be useful when considering especially large mergers or acquisitions. Today’s 2010 HHI horizontal merger guidelines are less strict (identifying 3.1% of billion dollar banks as being highly concentrated) compared to those developed in 1992 (which would have identified 16% today as being highly concentrated) so concentration criteria has evolved over time.

6 Characteristics of Most and Least Competitive Banks by Service Line.

Billion dollar banks are divided into most and least competitive quartiles based on the rank order of their CE values for a given service line. As the CE values for a given bank can differ across the five service lines shown in Table 4, it may be in the most competitive quartile for one service line but in another quartile for a different service. For consumer loans and payment activities, the set of most competitive banks are on average somewhat smaller in terms of asset size in row 2 ($10 and $7 billion, respectively) than are the corresponding set of least competitive banks (with average assets of $17 and $19 billion). For security operations the reverse holds and asset size of the most competitive banks ($25 billion) exceeds that of least competitive banks ($18 billion). For business loans, asset size is not very different between most ($26 billion) and least ($31 billion) competitive banks while for investment banking and related activities they are the same (at $8 billion, after rounding).

—insert Table 4 here—
Although bank size differs between most and least competitive banks depending on the service line examined, the least competitive banks are on average always more profitable as measured by ROA or the ratio of net income to assets (row 3). Indeed, for business loans, the least competitive banks are seemingly four times more profitable with all but securities being at least twice as profitable. Recall that $CE$ values used for these rankings reflect bank service line revenues after controlling for cost, productivity, and risk differences. Could some of the profit differences seen in Table 4 be due to unrealized differences in risk?

We are only able to control for risk using each bank’s risk-based capital/asset ratio and the ratio of a bank’s provision for loan and lease losses to the value of loans and leases (row 6). Averaged over our three-year time period, this loan loss ratio is quite similar between most and least competitive banks. Could there be other risks that have not been provisioned for or captured in risk-based capital that generate higher profits for one set of banks rather than another? Yes, but given that the recent financial crisis started in 2007, one would expect that unrecognized risk incurred prior to 2007 would have been made obvious and found its way into capital levels and/or loan loss provisions during 2008-2010. As we see little difference in loan loss provisions between most and least competitive banks in Table 4, the likelihood of still unrecognized risk markedly influencing the profitability differences seen row 3 is not strong.

An additional difference in Table 4 is that, except for payment activities, the set of most competitive banks have from 8% to 20% fewer employees per banking office. While this could be due in part of differences in branching strategy and in a few cases having been located in a unit banking state before 1997, it can also suggest more careful attention to branch and back office staffing to achieve lower costs. The deposit/branch ratio is also a productivity indicator but only for payment activities does it suggest greater productivity for the most competitive banks.
7 Summary and Conclusions.

Regulators rely on the HHI because it has been predictive in concentrated industries while academics have solid theoretical reasons for favouring the Lerner Index or the H-Statistic. The three standard competition measures focus on traditional bank loan and deposit activities, while neglecting increasingly important fee-based services, and incompletely adjust for input productivity differences among banks. We suggest a new way to assess relative competition based on efficient frontier analysis which includes the previously excluded cost influences and incorporates fee-based activities. Unlike the standard measures of competition, our approach uses available revenue data to separately cover traditional banking services (consumer and business loans) along with securities and two fee-based services (payments and investment banking activities) while the HHI, Lerner Index, and H-Statistic—due to limited data—have focused on traditional banking activities alone.

Bank retail fee and service pricing revenues are essentially determined by the level of underlying costs and market interest rates, the productivity of banks in producing their services, and the degree of market competition which may permit revenues to exceed a normal return on invested capital or equity. The current banking literature effectively ties revenues (or price or profits) to a single measure of competition as in revenues = f(competition measure) and maintains that the remaining portion of revenue is due to cost, productivity, and other "non-competition-related" influences. The competition frontier reverses this approach and instead specifies that revenues = f(costs, productivity, other "non-competition-related" influences) and maintains that the unexplained portion of revenues reflects the influence of competition on returns. Our competition efficiency measure (CE) is thus obtained by statistically "removing" the specified cost, productivity, scale, and risk effects from bank revenues which essentially leaves the effect of competition. The degree of relative competition among banks is then determined by their dispersion from a competition frontier (defined by the most competitive bank or banks).
For 382 large banks with assets greater than $1 billion (accounting for 90% of sampled bank assets), the ranking of banking activities by their degree of relative competition (most competitive first) is: business loans, security operations, payment activities, consumer loans, and finally investment banking and related services. With one exception, the same competition ranking is found for the 2,273 other banks in the sample (accounting for the remaining 10% of assets). Dividing banks into most and least competitive quartiles, the set of most competitive banks are somewhat smaller in terms of asset size for consumer loans and payment activities, are larger for security operations, but differ little for business loans and investment banking activities compared to a corresponding set of least competitive banks. However, the least competitive banks are always more profitable, tend to have more employees per banking office, but experience a similar level of loan losses. The three areas where competition efficiency appears weakest—payment activities, consumer loans, and investment banking services—have been and continue to be areas of recent regulatory interest.

There have been many studies of banking competition and almost all have used just one of the three standard measures: HHI, Lerner Index, or H-Statistic. Although each measure is presumed to measure competition, they do it differently. This would not be an issue if these three measures were closely correlated across banks. We show that these measures are essentially uncorrelated with each other across banks. While our frontier competition measure is significantly related to all three measures across banks, regressing the HHI on any or all three of the theoretically-based measures explains only one percent of the variation. Similar but slightly stronger results apply in Europe.

U.S. competition authorities use the HHI to focus on local (MSA) and regional market concentration. The Lerner Index, H-Statistic, and our frontier $CE$ measure are determined at the bank level where 92% of our sampled banks operate in only 1 to 5 MSAs. Indeed, half of the billion dollar banks operate in only 4 MSAs and/or within 1 state so our focus is on a regional rather than a national market. Such a bank-level analysis can serve as a useful "second opinion" regarding competition issues
which currently relies on the HHI. A second opinion can be helpful since the HHI, at least for the banking industry, does not seem to indicate what most would agree reflects the result of competitive or uncompetitive behavior. These results would support a higher HHI value to define a highly concentrated bank or local market.
8 Bibliography


ational Research, 98: 243-249.


Appendix

Constructing the HHI.

Using all 7,821 banks in the FDIC’s *Summary of Deposits* report for June, 2010, a deposit-based HHI was computed for each of the 956 separate MSA and non-MSA counties in the U.S. Following Hirtle (2007), a deposit share weighted sum of these 956 geographic HHIs was then computed for each bank with over $100 million in assets in the fourth quarter of 2010 that operated and had deposits in these MSA and non-MSA counties. The HHIs were then matched with the 2,655 banks in our final sample yielding the set of deposit-based HHIs used here. The very largest banks have foreign offices but the *Summary of Deposits* only has information on domestic U.S. bank branch deposits and so our calculated HHIs apply only to domestic U.S. market concentration.\(^\text{36}\)

Estimation of the Lerner Index.

The Fourier functional form used to estimate marginal cost for the Lerner Index is:

\(^{36}\text{Summary of Deposits}^\text{ data are only available once a year in June. We chose to use the HHI for 2010 since, for a few of the very largest banks, their deposit market concentration would be somewhat higher due a recent merger/acquisition. For billion dollar banks, the } R^2 \text{ between HHI values computed for 2010 (the year we used) and 2009 and 2008 are .85 and .87, respectively. Between 2008 and 2009 it was .94. Even so, only 2 banks out of 382 flip consecutive places for consecutive years when all banks are ranked by their asset value. Using any or all of the years would not have altered our results.}\)
\[
\ln TC = \alpha_0 + \sum_{i=1}^{3} \alpha_i \ln Q_i + 1/2 \sum_{i=1}^{3} \alpha_{i,i} (\ln Q_i)^2 \\
+ 1/2 \sum_{i \neq j}^{3} \alpha_{i,j} (\ln Q_i \ln Q_j) + \sum_{i=1}^{3} \sum_{k=1}^{3} \delta_{i,k} (\ln Q_i \ln P_k) + \sum_{k=1}^{3} \beta_k \ln P_k \\
+ 1/2 \sum_{k=1}^{3} \sum_{m=1}^{3} \beta_{k,m} (\ln P_k \ln P_m) + \theta_1 \ln LLR + 1/2 \theta_2 \ln (LLR)^2 + \theta_3 \ln T + 1/2 \theta_4 \ln (T)^2 \\
+ \sum_{i=1}^{3} (\tau_{1i} \sin(\ln Q_i^*) + \tau_{2i} \sin(2\ln Q_i^*) + \tau_{3i} \sin(3\ln Q_i^*)) \\
+ \sum_{i=1}^{3} (\tau_{4i} \cos(\ln Q_i^*) + \tau_{5i} \cos(2\ln Q_i^*) + \tau_{6i} \cos(3\ln Q_i^*)) \\
+ \sum_{i \neq j}^{3} (\tau_{7i} \sin(\ln Q_i^* + \ln Q_j^*) + \tau_{8i} \cos(\ln Q_i^* + \ln Q_j^*)) \\
S_k = \beta_k + \sum_{m=1}^{3} \beta_{k,m} \ln P_k + \sum_{i=1}^{3} \delta_{i,k} \ln Q_i
\]

(A1)

\(S_k = \beta_k + \sum_{m=1}^{3} \beta_{k,m} \ln P_k + \sum_{i=1}^{3} \delta_{i,k} \ln Q_i
\) (A2)

where:

\(TC\) = total operating and interest expenses;\(^{37}\)

\(Q_{i,j}\) \(i,j\) = value of the three output variables \(CLOAN, BLOAN,\) and \(SEC\) shown in the text;

\(P_{k,m}\) \(k,m\) = three input prices composed of the average interest rate paid for all domestic and foreign deposits and liability funding \((PF)\), the annual average expense per full-time equivalent worker \((PL)\), and an approximation to the cost of physical capital \((PK)\, defined in the text);

\(T\) = a quarterly time indicator variable used to reflect time-related technical change; and

\(S_k\) = the cost shares for the funding and labor inputs (the share for the physical

\(^{37}\)Off balance sheet items basically reflect contingent liabilities and incur close to zero cost—just a few highly paid employees out of hundreds or thousands. For this reason they are excluded from the cost function. Including them would add almost nothing to total cost but would bias the estimate of marginal cost since output value at effectively zero cost would be added to the cost function.
capital input is deleted to avoid singularity).

The Fourier form adds sin and cos terms to a translog cost function. As our main concern is to allow for greater flexibility in the local identification of scale effects (which reflects the difference between marginal and average cost), the sin and cos terms are applied to the output ($Q$) measure but not also to the input prices. Additional terms are $\ln Q_i = \ln Q_i \cdot YQ_i + ZQ_i$, $YQ_i = (0.8 \cdot 2\pi)/(\max \ln Q_i - \min \ln Q_i)$, $ZQ_i = 0.2\pi - \min \ln Q_i \cdot YQ_i$, and $\pi = 3.141593...$, so that $\ln Q^*$ is essentially expressed in radians.\(^{38}\) The Fourier form is a globally flexible approximation since the respective sin and cos terms are mutually orthogonal over the $[0,2\pi]$ interval. The Fourier function (A1) is estimated jointly with the cost shares (A2).\(^{39}\) Parameter symmetry and input price homogeneity of degree 1.0 were imposed in estimation. Marginal cost is $MC = (\sum_{i=1}^{3} \partial \ln TC/\partial \ln Q_i) \cdot AC$ where $AC$ is the ratio of total cost to total assets ($TC/TA$) and reflects overall average cost under the assumption that the scale economy measure $(\sum_{i=1}^{3} \partial \ln TC/\partial \ln Q_i)$ applies to the whole bank. The Lerner Index $= (P - MC)/P$ where $P = TR/TA$.\(^{40}\)

**Estimation of the H-Statistic.**

The H-Statistic was derived from a translog type function:

\(^{38}\)See Mitchell and Onvural (1996) and Berger and Mester (1997).

\(^{39}\)The parameters in the share equations are the same as those in the translog portion of the Fourier equation.

\(^{40}\)With an $R^2$ of .95 for the translog and .97 for the Fourier form, it is very unlikely that adding the funding expense of equity capital (difficult to determine) to $PF$ or specifying a variable cost function (where the value of equity replaces the price of capital) would meaningfully alter the marginal cost estimated for the Lerner Index.
\[
\ln TR = \alpha_0 + \sum_{i=1}^{5} \alpha_i \ln X_i + .5 \sum_{i=1}^{5} \sum_{j=1}^{5} \alpha_{ij} \ln X_i \ln X_j \\
+ \sum_{k=1}^{3} \beta_k \ln P_k + .5 \sum_{k=1}^{3} \sum_{m=1}^{3} \beta_{ij} \ln P_k \ln P_m \\
+ \sum_{i=1}^{5} \sum_{k=1}^{3} \delta_{ik} \ln X_i \ln P_k + v_1 T + v_2(T)^2 \\
+ \sum_{i=1}^{5} v_i T \ln X_i + \sum_{k=1}^{3} \lambda_k T \ln P_k 
\]

(A3)

where:

\( TR = \) total revenue;

\( X_i = \) value of the three output variables \( CLOAN, BLOAN, \) and \( SEC \) plus a loan loss risk measure \((LLR\ defined\ in\ the\ text)\) and the ratio of total domestic plus foreign deposits to total liabilities–a liability composition measure \((DEPTL)\);

\( P_k = \) the same three input prices noted above; and

\( T = \) the same quarterly time indicator variable noted above.

Parameter symmetry is imposed in estimation. Linear homogeneity of input prices is not imposed as a doubling of input prices need not double revenues. The H-Statistic equals: \( HSTAT = \sum_{i=1}^{3} \partial \ln TR / \partial \ln P_k \).

\(^{41}\)The fit of the equation was high at \( R^2 = .98.\)
## Tables

Table 1: Competition Measure Statistics and Correlation for U.S. Banks

<table>
<thead>
<tr>
<th></th>
<th>Banks with TA &gt; $1B</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>25th Percentile</td>
<td>75th Percentile</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HHI</td>
<td>1.364</td>
<td>1.043</td>
<td>1.537</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lerner Index</td>
<td>.26</td>
<td>.20</td>
<td>.33</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H-Statistic</td>
<td>.82</td>
<td>.78</td>
<td>.87</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>r</td>
<td>R^2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HHI with Lerner Index</td>
<td>.03</td>
<td>.001</td>
<td></td>
<td></td>
<td></td>
<td>(90% of TA)</td>
</tr>
<tr>
<td>HHI with H-Statistic</td>
<td>.02</td>
<td>.0001</td>
<td></td>
<td></td>
<td></td>
<td>382</td>
</tr>
<tr>
<td>Lerner with H-Statistic</td>
<td>.04</td>
<td>.001</td>
<td></td>
<td></td>
<td></td>
<td>2,273</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Banks with $100M &lt; TA &lt; $1B</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>25th Percentile</td>
<td>75th Percentile</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HHI</td>
<td>1.132</td>
<td>624</td>
<td>1.513</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lerner Index</td>
<td>.22</td>
<td>.16</td>
<td>.29</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H-Statistic</td>
<td>.89</td>
<td>.86</td>
<td>.92</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>r</td>
<td>R^2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HHI with Lerner Index</td>
<td>-.04</td>
<td>.002</td>
<td></td>
<td></td>
<td></td>
<td>(10% of TA)</td>
</tr>
<tr>
<td>HHI with H-Statistic</td>
<td>-.07</td>
<td>.005</td>
<td></td>
<td></td>
<td></td>
<td>2,273</td>
</tr>
<tr>
<td>Lerner with H-Statistic</td>
<td>.08</td>
<td>.006</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2: Competition Efficiency Across Five Banking Service Lines

<table>
<thead>
<tr>
<th>Service Line</th>
<th>Banks with TA &gt; $1B</th>
<th>Banks with $100M &lt; TA &lt; $1B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average CE</td>
<td>$R^2$</td>
</tr>
<tr>
<td>Consumer Loans</td>
<td>5.2</td>
<td>.89</td>
</tr>
<tr>
<td>Business Loans</td>
<td>1.2</td>
<td>.97</td>
</tr>
<tr>
<td>Payment Activities</td>
<td>4.8</td>
<td>.67</td>
</tr>
<tr>
<td>Investment Banking &amp; Other</td>
<td>7.7</td>
<td>.34</td>
</tr>
<tr>
<td>Securities</td>
<td>1.7</td>
<td>.85</td>
</tr>
</tbody>
</table>

Note: All CE values shown have been averaged over six sets of residuals, except Securities (averaged over two).

Table 3: Comparison of Competition Measures for Billion Dollar Banks

<table>
<thead>
<tr>
<th>Banks Ranked by Revenue Weighted Average CE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average CE</td>
</tr>
<tr>
<td>Most Competitive</td>
</tr>
<tr>
<td>2nd Quartile</td>
</tr>
<tr>
<td>3rd Quartile</td>
</tr>
<tr>
<td>Least Competitive</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Separate Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>HHI</td>
</tr>
<tr>
<td>Most Competitive</td>
</tr>
<tr>
<td>2nd Quartile</td>
</tr>
<tr>
<td>3rd Quartile</td>
</tr>
<tr>
<td>Least Competitive</td>
</tr>
</tbody>
</table>
Table 4: Characteristics of Most and Least Competitive Billion Dollar Banks by Service Line

<table>
<thead>
<tr>
<th></th>
<th>Most Competitive Quartile</th>
<th></th>
<th></th>
<th></th>
<th>Least Competitive Quartile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Consumer Loans</td>
<td>Business Loans</td>
<td>Payments</td>
<td>Investment Banking</td>
<td>Securities</td>
</tr>
<tr>
<td>1. Service Line $CE$</td>
<td>2.7</td>
<td>0.7</td>
<td>2.0</td>
<td>2.9</td>
<td>1.6</td>
</tr>
<tr>
<td>2. Total Assets ($B)</td>
<td>10 B</td>
<td>26 B</td>
<td>7 B</td>
<td>8 B</td>
<td>25 B</td>
</tr>
<tr>
<td>3. Net Income/Assets</td>
<td>.21%</td>
<td>.14%</td>
<td>.19%</td>
<td>.17%</td>
<td>.31%</td>
</tr>
<tr>
<td>4. Labor/Branch</td>
<td>24</td>
<td>26</td>
<td>25</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>5. Deposit/Branch ($B)</td>
<td>133M</td>
<td>139M</td>
<td>205M</td>
<td>97M</td>
<td>120M</td>
</tr>
<tr>
<td>6. Loan Losses/Assets</td>
<td>.51%</td>
<td>.48%</td>
<td>.52%</td>
<td>.49%</td>
<td>.44%</td>
</tr>
</tbody>
</table>
Figures

Figure 1: CE Frequency Distributions for Five Bank Service Lines (Billion Dollar Banks)