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A Revenue-Based Frontier Measure of Banking Competition♦

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Abstract:

Measurement of banking competition using the HHI, Lerner Index, or H-statistic can give conflicting results. Borrowing from frontier analysis, we provide an alternative approach and apply it to Spain over 1992-2005. Controlling for differences in asset composition, productivity, scale economies, risk, and business cycle influences, we find no differences in competition between commercial and savings banks, between large and small institutions, but conclude that competition weakened after 2000. This appears related to strong loan demand where real loan-deposit rate spreads rose and fees were stable for activities where scale economies should have been realized.

JEL Classification: G21, D24, D40
Palabras clave: banks, competition indicators, revenue-based frontier

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1. Introduction.

Adequate banking competition benefits consumers by reducing costs, lowering prices, and improving offered services. While the reverse may occur if competition is too weak, if it is too strong banks may seek greater risks in an effort to replace profits lost by lowering prices more than costs can be reduced. Ideally, the level of competition that is "right" will be consistent with a reasonable risk-adjusted return on invested capital while meeting the needs of depositors and borrowers at something close to minimum production cost. While it is easy to state this goal, determining its operational realization is made difficult by the fact that assessing competition can differ depending on which one of the current measurement metrics is applied. Additional difficulties in assessing competition were outlined in an IMF survey noting that institutional changes in financial services require updated competition indicators and policies (Claessens, 2009). With this in mind, we illustrate an alternative approach to determining realized competition, examine separately the two main banking services, and apply our approach to Spain.

Standard indicators of banking competition frequently used in empirical studies have been: (a) the structure-conduct-performance (SCP) paradigm which focuses on the degree of banking market concentration, usually a Herfindahl-Hirschman index (HHI) of deposit/loan market concentration; (b) the Lerner Index which is a price mark-up measure as in (price – marginal cost)/price; and (c) the H-statistic which indicates the degree to which changes in funding/factor input costs are associated with changes in output price. In the SCP paradigm a concentrated market by itself is not sufficient to demonstrate a lack of competition; it must also be difficult for new firms to enter the industry if prices are "too high" relative to costs thereby generating greater than "normal" returns. The Lerner Index and the H-statistic are helpful in assessing whether price competition is strong or weak and, indirectly, whether entry may be easy or difficult. Either small differences between price and cost in the Lerner Index or when ∂ ln price/∂ ln cost is close to 1.0 in the H-statistic suggest price competition is strong whether achieved by easy entry or not.[1]

Unfortunately, reported cost and price data are typically limited to relatively aggregate loan and deposit services that generate loan-deposit rate spread revenues. This neglects non-interest income activities which, along with direct fees for payment and investment services, include revenues from loan and deposit service charges (debit/credit card fees, ATM fees, deposit account maintenance charges, loan fees, etc.). The cost of these activities used to be largely recouped in loan-deposit rate spreads but have increasingly been covered in the form of direct fees. Non-interest income is significant at European and U.S. banks and, for Spain in 2005, was 46% of loan-deposit spread revenues and 144% of securities revenues.

In practice, academic analyses have almost always applied only one of the above three indicators to assess banking competition. Competition authorities, in contrast, typically

[1] Although the dependent variable in the typical H-statistic regression concerns revenues, output level is specified in the equation so the H-statistic itself is really about how output prices (price) change in response to input prices (cost) which we illustrate as ∂ ln price/∂ ln cost.

rely on the HHI conditional on information regarding the ease of new firm entry or abuse of market power evident in a "high" Lerner Index. While there is disagreement about which of the three measures noted above may "best" reflect market competition, the expectation is that since they purport to measure the same thing they are all positively correlated. Unfortunately, this expectation is not always met. These measures are almost unrelated when compared across European countries over time and can be negatively related within the same country over time. If there was a consensus as to which of the indicators is indeed "best", this inconsistency would be mitigated but this is not the case so choice among these measures can influence the outcome.

To illustrate: with 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 concentration measure and the Lerner Index and H-statistic was, respectively, .09 and .05 (Carbó, Humphrey, Maudos, and Molyneux, 2009).[2] In addition, 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. The relationship between the HHI and these two measures was positive in only 8 and 5 countries, respectively. As shown below, similar inconsistencies apply to Spain. Since the choice of an existing banking competition measure may affect the results obtained, a different procedure where choice among these current measures is not necessary may prove useful.

A likely first-best assessment of competition would involve information on price-cost margins for separate sets of major banking services along with information on how these realized unit costs compare with minimum production costs. However, as price-cost data are typically limited to averages of loan prices and deposit/funding costs, only traditional banking services can be covered. In addition, it is not possible to compare realized production costs to likely minimum values and the default has been to compare these costs relatively--that is, to other banks or between time periods rather than to some unknown technological minimum.

In sum, a first-best assessment is not feasible but an alternative approach that relies on reported revenues rather than individual prices is possible and can be applied to both traditional loan-deposit spread activities as well as fee-based non-interest income activities. This is not a radical proposal since revenue is simply a weighted average of individual prices. Indeed, comparing individual prices for narrowly defined banking services, as has been done in European Commission (2007), can be misleading since a high price for one aspect of a service (e.g., a monthly deposit account fee) can be offset by a low price within the same general service category (e.g., no or limited payment transaction fees) so a weighted average of prices can be more informative. We assess competition in two important service areas--loan-deposit rate spread activities and fee-based activities. Securities activities, the third part of a bank, can be neglected since

[2] In this analysis, the H-statistic was multiplied by -1.0 so that a larger value of the H-statistic, the Lerner index, and the HHI would all indicate less competition.

these activities for the most part have their prices set in reasonably competitive national and international markets. These three revenue sources sum to total banking revenues.

A drawback of our proposed competition measure is that it is not predictive, as the HHI is presumed to be with respect to proposed mergers or acquisitions. Like the Lerner Index and the H-statistic, we can only measure past or current levels of relative competition. Another difference is that our procedure reflects competition over a period of time rather than annually, as the latter two measures are at times expected to do. In defense, it seems unrealistic to expect competition to vary annually and in our view significant annual variation is more likely to represent model misspecification and/or excluded variables rather than reflect actual changes in competitive behavior.

Our competition measure borrows from the cost/profit efficient frontier literature and is applied to Spain to assess banking competition over 1992-2005, between larger versus smaller banks, between commercial versus savings banks, and to determine if competition has changed before and after adoption of the euro. Importantly, characteristics of the set of most and least competitive banks are detailed and compared for two broad categories of banking services: traditional loan-deposit spread activities and non-traditional non-interest income fee-generating activities. We also determine the importance of changes in costs, productivity, and risk on unit revenues in these two classes of banking services.

In what follows, a brief summary of past analyses of Spanish banking competition is outlined in Section 2 while inconsistencies in identifying competition among the HHI, Lerner Index, and H-statistic measures are illustrated for Spain in Section 3. Our revenue-based competition measure is set out in Section 4 while Section 5 contains our empirical results and how they differ from the standard competition indicators. Characteristics of most and least competitive banks are covered in Section 6 while conclusions are presented in Section 7.

2. Past Analyses of Bank Competition in Spain.

Most studies of competition in Spain (as well as the U.S. and Europe) focus only on bank deposit and loan markets as this is where the necessary data are typically available. Some Spanish studies, however, have attempted to differentiate between traditional deposit/loan and non-traditional banking services (De Juan, 2001). These analyses suggest that deposit/loan activities experience greater competition than non-traditional fee-based services (Maudos and Fernández de Guevara, 2004; Carbó and Rodríguez, 2007). The number of new banking services expanded significantly in the 1990s offering new opportunities to exercise market power since, initially, there were few competitors (Carbó, López, Rodríguez, 2003). Differences in competition between traditional and non-traditional services have been shown to be even more significant when deposit-associated non-price competition influences (service quality, branches, ATMs) are included in the analysis (Ayuso and Martínez, 2006).

Most European banking studies define the banking market as being national in scope while in U.S. studies, with thousands of small banks over a large geographic area, the analyses have used a regional definition. In Spain, bank level data is available at both the national and regional level. Applying the HHI market concentration measure to Spanish provinces over 1986-1992, it was found to have increased from 1,400 to 1,600 (Fuentelsaz, 1996). Although rising, this level of the HHI still reflects a market with only moderate concentration.[3] A moderate level of concentration was also found over 1990-1993 where the HHI rose from 1,100 to 1,400 (Maudos, 1998). Using various stochastic estimations of bank cost efficiency, the same study found bank cost efficiency to be the main determinant of bank profitability even though market power, as represented by the HHI, also affected profitability (although less so).

Studies have also employed the Lerner index and the H-statistic to analyze competition in regional banking markets to determine the evolution of market power over 1992-2001 (Maudos and Pérez, 2003). The H-statistic rose slightly over this period--increasing from .64 to .67, indicating a slight rise in competition--while the Lerner Index increased markedly--from a mark-up of 16% to 26%, indicating a reduction in competition. Looking at regional banking markets over a longer (but overlapping) period 1986-1999, it was found that the HHI fell from 1,600 to 1,500, suggesting a slight improvement in competition, while the Lerner Index rose from 14% to 34% and the H-statistic fell from .89 to .83--both suggesting a worsening of competition (Carbó, López, and Rodríguez, 2003).

Still other analyses have looked to see how competition may have changed after a particularly important event such as the removal of restrictions on branching for Spanish savings banks in 1989 (Coello, 1994 and 1995). In this case, competition appeared to have increased in the years following deregulation but later seems to have diminished.

In sum, there are times when the various indicators of competition suggest the same result for Spain and at other times suggest a different result, either in the direction of the change in competition or in the magnitude of the change. For example, commercial banks lost market share over 1983-1991, falling from 65% down to 56%, but loan prices increased due to price coalition and coordination over the period (Jaumandreu and Lorences, 2002). This did not occur for savings banks even though their market share rose by the 9 percentage points that were lost by commercial banks. Thus the fall in commercial bank market share, which would indicate greater competition, resulted in higher rather than lower prices. Three competition measures are now presented for Spain over the same time period and sample set for a more controlled comparison to see how they have changed.

[3] The HHI is the sum of market shares squared. If there were 100 banks each having a market share of 1%, the HHI = 1^2 (100) or 100 and is a very unconcentrated market. At the other extreme, if one bank had 100% of the market, then the HHI = 100^2 (1) or 10,000. According to U.S. Department of Justice merger guidelines, an HHI value < 1,000 is classified as being unconcentrated. HHI values between 1,000 and 1,800 are moderately concentrated while HHI values > 1,800 are highly concentrated.

3. Inconsistencies Among Standard Measures of Bank Competition.

The HHI, Lerner Index, and H-statistic have all been used to assess the degree of market competition. Accordingly, one would expect them to consistently identify those banks experiencing more competition from those experiencing less of it. Table 1 presents these three measures for different aggregations of Spanish banks over 1992-2005.[4] The average HHI for all banks is 978. This is a relatively low level of market concentration and suggests that competition is likely "reasonable".[5] However, the H-statistic at .20 suggests weak competition since the relationship between changes in output and input prices is low. On average, a 10% change in input prices is associated with only a 2% change in output prices suggesting other influences on output prices are much more important than costs. This conclusion is seemingly supported by the average 25% mark-up of price over marginal total cost from the Lerner Index. This mark-up is rather large considering that marginal cost here includes funding as well as operating cost and the total cost scale economies are on the order of .95.[6]

Looking at quartiles of the largest versus smallest banks, there is a dramatic difference in market concentration as large banks have an average HHI of 2,970 versus only 97 for smaller banks. While this suggests smaller banks operate in more competitive markets while large banks do not, there is no real difference in the Lerner Index or the H-statistic suggesting no difference in competition between large and small institutions. However, although the Lerner Indices for large and small banks are equal to the average for all banks (row 1), the H-statistic for these two groups are larger (at .27 and .29) than the overall average of .20. Thus the H-statistic suggests the middle two size quartiles are less competitive than either the largest or the smallest banks.

Comparing savings with commercial banks, the HHI would suggest that savings banks operate in more competitive markets than commercial banks. This conclusion would be supported using the H-statistic, as savings banks have a higher H-statistic, but is not consistent with the Lerner Index since savings banks have a marginally higher mark-up. Contrasting these measures over time, there is little change in the HHI 6 years before the euro was implemented (1992-1997) relative to the 6 years during and after implementation (2000-2005). This holds for the average of all banks as well as savings and commercial banks averaged separately. The Lerner Index gives essentially the same result as the HHI--little change pre- or post-euro--as does the H-statistic for all banks in

[4] The HHI is computed for each bank for each 6-months and averaged for the time periods or set of banks shown in the table. The Lerner Index and H-statistic are estimated separately for the time period or set of banks shown. For example, only savings banks (row 4 in Table 1) or only commercial banks (row 5) are used in the estimation models outlined in the Appendix. The difference in procedures--6-month estimates for each bank which are then averaged or separate estimations for each row shown in the table--generate almost identical results for the Lerner Index but one difference for the H-statistic (which is noted below).

[5] For example, in the U.S. Department of Justice merger guidelines an HHI < 1,000 would represent an unconcentrated market.

[6] Funding costs essentially have no scale economies but operating costs do. If marginal operating cost were considered instead, the associated operating cost scale economies would be close to .30.

these two periods (rows 6 and 9). However, looking as savings and commercial banks separately, competition is considerably reduced for savings banks but apparently improves for commercial banks between these two periods.[7]

Table 1: Standard Competition Efficiency Measures: Spain, 1992-2005

	HHI	Lerner Index	H-Statistic
All 75 Banks	978	25%	.20
Quartile of Largest Banks	2,970	25%	.27
Quartile of Smallest Banks	97	26%	.29
Savings Banks (45)	714	27%	.25
Commercial Banks (30)	1,375	23%	.17
Pre-Euro Period 1992-1997	968	25%	.26
Savings Banks	691	27%	.43
Commercial Banks	1,384	23%	.22
Post-Euro Period 2000-2005	993	22%	.22
Savings Banks	740	23%	.21
Commercial Banks	1,373	20%	.35

Another way to contrast these three standard competition measures concerns their degree of correlation across individual banks over 14 years.[8] The R^2s between the HHI and the Lerner Index or the H-statistic across banks was, respectively, .04 and .01 over 1992-2005. That is, a conclusion of no relationship would be the conclusion here. And while there is a positive relationship between the Lerner Index and the H-statistic across banks, it is quite weak since the R^2 = .15. For these reasons, it may be useful to investigate a different way to measure banking competition.

4. A Revenue-Based Frontier Indicator of Banking Competition.

Prior to the adoption of the euro, European banks are estimated to have saved some $32 billion in operating costs over 1987 to 1999 due to the realization of scale economies as non-cash payment volume expanded combined with the technology-associated shift from

[7] The two ways of estimating the Lerner Index and H-statistic only affected the H-statistic. Estimating the H-statistic for each bank in each 6-month period and then averaging over the different time periods or sets of banks in Table 1 resulted in lower post-euro period results--showing less competition--for all banks together as well as commercial and savings banks separately. All of the other H-statistic conclusions were unchanged. An H-statistic robustness test indicating competitive equilibrium is outlined in the Appendix.

[8] This involves estimating all three measures using all banks and then evaluating the results for each bank giving 2,100 observations (14 years times 75 banks observed every 6-months). This is the second estimation method noted earlier and in the previous footnote.

paper-based to cheaper electronic payment methods plus the increased use of lower cost ATMs versus branch offices for cash acquisition (Humphrey, Willesson, Bergendahl, and Lindblom, 2006). For Spain, these changes in payments and cash delivery services are estimated to have reduced bank operating cost by 37% compared to what they otherwise would have been and saved some € 4.5 billion or 0.7% of GDP over 1992-2000 (Carbó, Humphrey, and Lopez, 2006). Over a longer time period (1987-2004), cost savings at European banks are evident from a 34% reduction in the average ratio of operating costs to asset value. For Spain, this reduction was even greater at 50% (Bolt and Humphrey, 2007).

If European and Spanish banking markets are reasonably competitive, such large unit cost reductions should be correlated over time with lower unit revenue flows from loan-deposit rate spreads and non-interest income activities. This is because banking revenues are fundamentally a function of underlying input costs and factor productivity. Indeed, differences in input costs, factor productivity, scale economies, bank risk, temporary demand variations associated with the business cycle, along with the degree of price competition in the market for banking services are the six major determinants of revenue flows among banks and over time. As detailed cost accounting and other data are not available by specific banking service category either currently or over time, statistical procedures can be used to "subtract" the influence of the first five revenue determinants from observed revenue flows across banks such that the remaining or residual differences in revenues are likely associated with differences in price competition--the sixth influence. In simple terms, this is our approach to measuring banking competition: namely, as residual revenues after accounting for costs and other influences. This approach is broader than the typical procedure used in applications of the H-statistic or the Lerner Index in that it does not require information on specific unit revenues (prices) which, for payment and other non-spread activities, is simply not available.[9]

While our procedure borrows from the efficient frontier literature to estimate a competition frontier, the framework is not very different from the theoretically-based industrial organization approach of Boone (2008A and 2008B). Specifically, Boone proposes to rely upon a firm's balance sheet to compute the difference between reported total revenues and reported total variable costs, a spread that contains total fixed cost plus extra revenues associated with the degree of price competition (along with other influences). As we are interested in revenues for particular subsets of banking services, statistical cost analysis is used to identify the associated (but unallocated) variable and fixed costs, along with other influences on revenues, leaving the effect of price competition on revenues as an average residual.

In our approach, if the variation in cost, productivity, scale, risk, and demand variation over the business cycle explains most of the variation in revenues then, in a manner similar to where the H-statistic (∂ ln price/∂ ln cost) is close to 1.0, we would conclude

[9] The limited availability of pricing data is why the Lerner Index and the H-statistic use computed average loan and deposit rates along with factor prices and deposit/funding average or (statistically estimated) marginal costs.

that competition is strong. Here the R^2 of the H-statistic equation would be high and the (average) unexplained variation would be small, just as it would be in our approach.

4.1 A Revenue-Based Frontier Model.

There are at least four ways to determine a competition frontier. The approach used here is the composed error Distribution Free Approach or DFA (Berger, 1993).[10] This approach assumes that averaging each bank's residuals from the relationship estimated in (1) and (2) across separate annual cross-section regressions (containing two 6-month observations on each bank) reduces normally distributed error to minimal levels leaving only the average effect of competition on bank revenues relative to a single (or set of) frontier bank(s) having the lowest averaged revenue residual.

In applying frontier analysis to the measurement of competition, it is maintained that the most important determinants of loan-deposit spread revenues and non-interest income revenues are the underlying unit operating costs of producing these services, the productivity of the factor inputs used to produce these services, the scale of bank operations, the level of bank risk, the variation in demand over the business cycle, and the degree of price competition. Two unit revenue functions are specified. One is the ratio of revenues from the loan-deposit rate spread times the value of deposits (*SPREAD*) to production or operating cost (*SPREAD/OC*).[11] A second function reflects the ratio of non-interest income (*NII*) to operating cost (*OC*) and reflects how income from priced services (payment transaction fees, debit/credit card fees, ATM fees, deposit account maintenance charges, loan fees, compensating balance requirements, loan commitment fees, etc., as well as certain trading income) varies with production costs (*NII/OC*). These two revenue sources, along with revenue from securities operations (which are excluded since these rates of return are set in competitive national and international markets), sum to total bank revenues.

The variation of each dependent variable is a function of bank asset composition of loans (*LOAN*) and securities (*SEC*), factor input costs composed of the average price of labor (*PL*) and implied cost of physical capital (*PK*) which reflects cost function influences. Factor productivity is assessed using a labor/branch ratio (*L/BR*) and a deposit/branch

[10] An alternative Stochastic Frontier Approach typically assumes a half-normal distribution for inefficiencies (or in our case competition inefficiencies) in order to separate unknown inefficiencies from normally distributed error in a panel regression. Two other approaches concern Data Envelopment Analysis (DEA) and Free Disposal Hull. These are linear programming approaches that assume error is zero but have the advantage that no functional form is imposed to fit the data.

[11] Operating cost rather than total cost is the basis for our two unit revenue dependent variables. Although the average deposit/funding interest cost varies across banks, the vast majority of this variation is due to different funding compositions as specific funding rates are quite similar across banks and over time. This suggests that the focus should be on revenues relative to operating expenses rather than total costs. Funding costs, of course, are directly reflected in the loan-deposit *SPREAD* variable.

ratio (*DEP/BR*). A bank's productivity rises when less labor is used per branch office and/or when each branch on average generates/supports a greater value of deposits.[12]

Scale economies are associated with processing greater payment volumes and having a larger network of ATMs and branch offices. Scale estimates for Spain (Bolt and Humphrey, 2007) are used to devise an index of unit payment costs (*PC*) and an index of unit ATM/branch service delivery costs (*ATMBRC*).[13] The variation in bank revenues due to risk is reflected in each bank's equity capital/asset ratio (*CAPITAL*), its loan loss ratio (*LLR*), and an indicator of funding or liquidity risk reflected in the ratio of deposits to loans (*DEP/LOAN*).[14] Finally, temporary business cycle and macroeconomic effects on loan demand and deposit supply are reflected in the level of regional GDP in Spain (*GDPR*), the growth of bank assets relative to the general level of regional economic activity (*TA/GDPR*), and the national 3-month interest rate (*INTRATE3*). In summary, our two equation translog functional form model in logs is:

$$\ln(SPREAD/OC) = \theta_0 + \sum_{i=1}^{12}\theta_i \ln X_i + 1/2\sum_{i=1}^{11}\sum_{j=1}^{11}\theta_{ij} \ln X_i \ln X_j + \sum_{i=1}^{11}\sum_{k=1}^{2}\psi_{ik} \qquad (1)$$

$$\ln X_i \ln P_k + \sum_{k=1}^{2}\phi_k \ln P_k + 1/2\sum_{k=1}^{2}\sum_{m=1}^{2}\phi_{km} \ln P_k \ln P_m + \ln e_{SPREAD} + \ln u_{SPREAD}$$

$$\ln(NII/OC) = \alpha_0 + \sum_{i=1}^{12}\alpha_i \ln X_i + 1/2\sum_{i=1}^{11}\sum_{j=1}^{11}\alpha_{ij} \ln X_i \ln X_j + \sum_{i=1}^{11}\sum_{k=1}^{2}\delta_{ik} \qquad (2)$$

$$\ln X_i \ln P_k + \sum_{k=1}^{2}\beta_k \ln P_k + 1/2\sum_{k=1}^{2}\sum_{m=1}^{2}\beta_{km} \ln P_k \ln P_m + \ln e_{NII} + \ln u_{NII}$$

where:

$X_{i,j}$ = *LOAN, SEC, L/BR, DEP/BR, PC, ATMBRC, CAPITAL, LLR, DEP/LOAN, GDPR, TA/GDPR, INTRATE3;*

[12] The labor/branch ratio is similar to a labor/capital ratio while the deposit/branch ratio is equivalent to an output/capital ratio. While banks also make and monitor loans, the vast majority of production cost is associated with deposits.

[13] Bank-specific payment volume data are not available for any European country except Norway. However, over the last 20 years in Spain (1987-2006), the R^2 between the value of aggregate bank deposits and the number of aggregate country-level non-cash transactions (check, debit and credit card, paper and electronic giro transactions) was .92. Consequently, the value of each bank's deposits was used to approximate the unknown non-cash payment volume for each bank in the payment cost index *PC*. Bank-specific information does exist for the number of ATMs and branches for Spain and the service delivery cost index *ATMBRC* is a weighted average of unit cost indices of the realized scale economies of these two networks for each bank.

[14] The loan loss ratio is expressed as (loan value - losses)/loan value since logs of all variables are used in the estimating equations. A simple ratio of losses to loan value can be negative or positive depending on recoveries recorded in periods after losses were first recorded. The *DEP/LOAN* variable reflects funding stability (and hence liquidity and funding risk) since deposits are the most stable form of funding for loans (as opposed to short-term market or inter-bank borrowings).

$P_{i,j}$ = *PL, PK,* and have been defined above.[15]

Equations (1) and (2) are related in that banks may choose to increase revenues over time (in response to higher costs or weak competition) by altering their loan-deposit rate spread (raising loan rates and/or lowering deposit rates) or they can instead increase revenues by instituting or raising the fees they charge on various banking services (affecting NII). Since errors in explaining the variation of revenues from the loan-deposit rate spread in (1) may be correlated with errors in explaining the variation of non-interest revenues in (2), these two revenue equations are estimated jointly in a seemingly unrelated regressions (SUR) framework.[16]

4.2 A Competition Frontier.

In a composed error framework, the regression relationship (2) can for illustration be truncated and re-expressed simply as:

$$\ln(NII/OC) = f(\ln \text{Cost}, \ln \text{Productivity}) + \ln e + \ln u \qquad (3)$$

The total residual (ln e + ln u) reflects the unexplained portion of the revenue dependent variable remaining after cost and productivity influences have been accounted for. Here ln e represents the value of random error while the maintained hypothesis is that ln u represents the effect of price competition on revenues. The DFA concept relies on the assumption that ln e will average to a value close to zero when the total residual in (3) is averaged across a number of separate cross-section estimations leaving the average of ln u_i to reflect the average effect of competition (ln $\bar{u}_i$).

The i^{th} bank (or set of banks) with the lowest average residual (ln $\bar{u}_{min}$) is also the bank where the variation in underlying cost, productivity, and risk explains the greatest amount of the variation in revenues and hence the smallest variation in revenues attributed to price competition.[17] 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 by their dispersion from this frontier:

$$CE_i = exp\,(\ln \bar{u}_i - \ln \bar{u}_{min}) - 1 = (\bar{u}_i / \bar{u}_{min}) - 1 \qquad (4)$$

[15] Each variable has an own and squared term but the interaction terms are limited to 12 in each equation (versus a possible 78). This trades-off a minor improvement in fit for less multicollinearity which reduces our ability to gauge significance of the RHS variables. Interaction terms are specified within the cost group (*LOAN, SEC,PL,PK*), productivity group (*L/BR, DEP/BR*), scale group (*PC, ATMBRC*), risk group (*CAPITAL, LLR, DEP/LOAN*), and business cycle group (*GDPR, TA/GDPR, INTRATE3*) but not between groups. The exception is the 3-month interest rate (*INTRATE3*) which only has an own term. This variable is at times the same for all banks even though it is observed over the two 6-month periods that comprise each annual cross-section estimation (hence the 12 own terms but 11 squared terms shown in the summations).

[16] Homogeneity of degree 1.0 in input prices is not imposed. A doubling of input prices need not double revenues (but would double costs in a cost function).

[17] In the context of an H-statistic, this would be the bank with an H-statistic closest to 1.0.

As the term u_i is multiplicative to the dependent variable in an unlogged equation (3), the ratio $(NII/OC)_i$ equals R (Cost, Productivity)$_i$ u_i. Thus the ratio $\bar{u}_i / \bar{u}_{min}$ is an estimate of the ratio *NII/OC* for the i^{th} bank, for a given level of underlying cost, service productivity, and risk, to the value of the ratio $(NII/OC)_{min}$ for the bank facing the greatest price competition and having the same underlying cost, service productivity, and risk.[18]

If $CE_i = .25$, then $\bar{u}_i$ is 25% larger than $\bar{u}_{min}$ so the unexplained portion of the revenue dependent variable in (3) is 25% larger than its minimum value at another bank. 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.[19]

A limitation is that CE only indicates the relative level of competition: it can not determine the absolute level of competition even for the most competitive bank. Consequently, it is important to examine the fit of the estimating equation since, if the R^2 is high (e.g., .80 or above), the difference in relative competition measured by CE may not be very economically significant since the residuals $\bar{u}_i$ and $\bar{u}_{min}$ would themselves be absolutely small (regardless of their percent difference).[20]

5. Banking Competition in Spain.

5.1 Competition Efficiency by Bank Type, Size, and Time Period.[21]

Separate cross-section SUR estimations of (1) and (2) were made for each of the 14 years over 1992-2005. Each annual estimation includes two 6-month observations on 45 savings and 30 commercial banks that were in continuous operation over the period.[22]

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[18] The ratio $\bar{u}_i / \bar{u}_{min}$ = [$(NII/OC)_i$/R (Cost, Productivity)$_i$]/[$(NII/OC)_{min}$/R (Cost, Productivity)$_{min}$] and when evaluated at the same mean level of underlying cost and service productivity, the predicted values of R (Cost, Productivity)$_i$ and R (Cost, Productivity)$_{min}$ are equal as both are at the same point on the estimated unit revenue curve, leaving the ratio $(NII/OC)_i/(NII/OC)_{min}$.

[19] The cost efficiency literature reports efficiency (EFF) and inefficiency (INEFF) values. If efficiency is 80% (EFF = .80), then inefficiency is INEFF = (1 - .80)/.80 = .25 or 25%. In (4), CE reflects the relative weakness of competition in restraining revenues and is equivalent to INEFF which reflects relative weakness of cost efficiency.

[20] This qualification is not well-understood in the frontier literature. Absolute differences in residuals need to be considered along with their relative size, so goodness of fit should be an additional consideration (Carbó, Humphrey, and Lopez, 2007).

[21] A similar model was applied to aggregate country-level data on 11 European countries, finding very little difference in competition efficiency across countries (Bolt and Humphrey, 2009). The Spanish sample concerns individual banks and is a much larger and richer data set.

[22] The data set includes all savings banks, all but the very smallest commercial banks (which were excluded due to missing data), and no cooperative banks (who also had missing data). Banks that merged or were acquired during the period were treated as being merged/acquired for the entire period via backward aggregation. For example, if bank 1 merged with or was acquired by bank 2 in 2001, the data for both

These banks accounted for 93% of deposits and 94% of banking assets in Spain in 2005. Residuals from these cross-section estimations were then averaged for each bank separately and (4) was used to obtain the competition efficiency (CE) measures shown in Table 2.

Looking at all 75 banks over the entire 1992-2005 period, the average unit revenue dispersion of banks from the competition frontier was 40% for the loan-deposit rate spread (CE_{SPREAD}) but only 11% for non-interest income activities (CE_{NII}). As a lower CE value indicates a smaller average dispersion of revenues associated with price competition, SPREAD activities appear to have experienced less price competition than NII fee-based activities over the 14-year period. That is, a smaller variance in residual unit revenues is equated with a smaller dispersion of price competition effects on revenues once other plausible influences have been accounted for.

Table 2: Competition Efficiency in Spain: 1992-2005

	CE_{SPREAD}	CE_{NII}
Single Frontier Over 1992-2005:		
All 75 Banks	.40	.11
Quartile of Largest Banks	.38	.10
Quartile of Smallest Banks	.34	.11
Savings Banks (45)	.42	.10
Commercial Banks (30)	.38	.11
Separate Frontier For Each Period:		
Pre-Euro Period 1992-1997	.21	.13
Savings Banks	.23	.13
Commercial Banks	.17	.13
Post-Euro Period 2000-2005	1.40	.22
Savings Banks	1.42	.21
Commercial Banks	1.37	.24

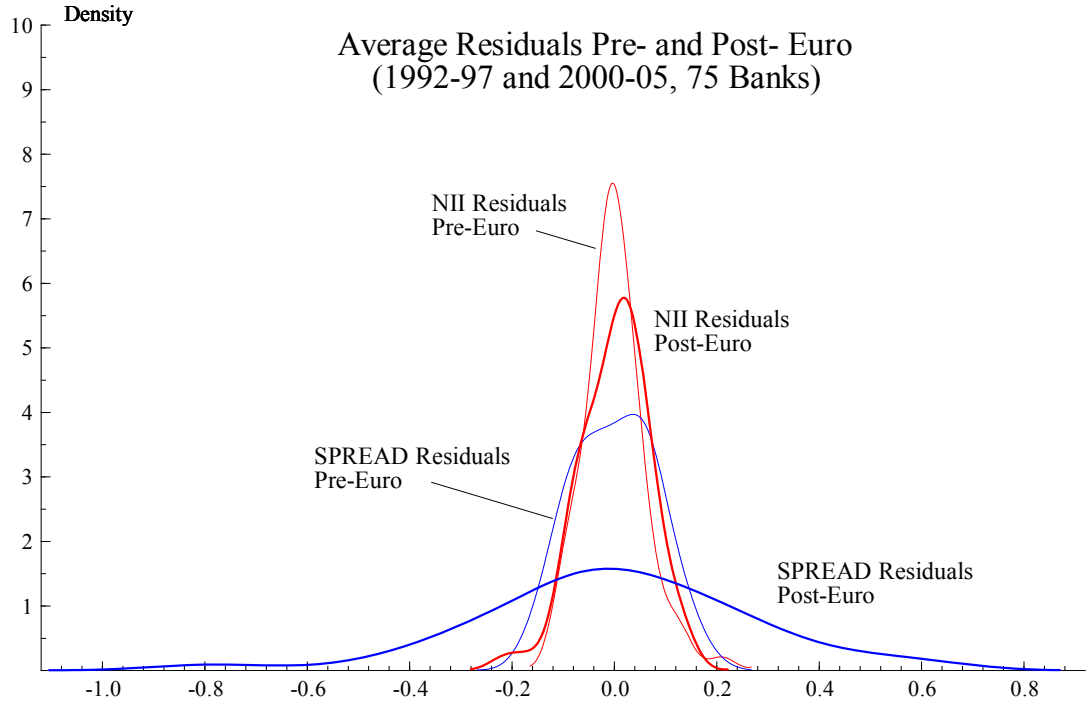
When all banks are separated into asset size quartiles, banks with the largest assets are about equally competitive with those with the smallest assets in each of the two activities separately. While there is little difference in competitive efficiency by bank size within a given activity, SPREAD activities remain less competitive than fee-based NII activities. The same results apply when savings banks are separated from commercial banks. In sum, there is little difference in competition efficiency between banks by size or type of

banks are aggregated backward in time to 1992. Thus bank 1 is reflected in the data for bank 2 for the entire 1992-2005 period. This yields a balanced panel which does not neglect merged/acquired banks.

institution for either SPREAD or NII activities separately but there is a consistent difference between the two activities with SPREAD activities experiencing less price competition.

Comparing competitive efficiency over time, the 14-year time frame was split into pre- and post-euro periods and separate frontiers were estimated for each period. Both sets of activities appear to have worsened in the second period. In the pre-euro period (1992-1997), CE values were relatively low--21% for SPREAD and 13% for NII activities--indicating stronger price competition compared to the average for the entire period. In the post-euro period (2000-2005), however, CE values are markedly higher--rising by a factor of six for SPREAD activities and almost doubling for NII activities--suggesting less price competition. Importantly, this deterioration was experienced for both savings and commercial banks to about the same degree in each activity.

Figure 1: Distributions of Averaged Residuals Pre- and Post-Euro.



The reason for this reduction in competitive efficiency is directly related to the marked change in the distribution of the averaged residuals between the pre- and post-euro periods shown in Figure 1. The distribution of residuals, in turn, is directly related to the ability of equations (1) and (2) to explain the variation in unit revenue in the two periods. While the average R^2 for the two sets of six separate yearly cross-section regressions for fee-based activities rose somewhat (from .62 pre-euro to .71 post-euro), the average for

spread activities fell from .76 to .54 indicating a reduction in explanatory power in the post-euro period.[23]

As seen in Figure 1, there is a slight expansion in the range of averaged residual values for the post-euro period for NII fee-based activities.[24] The rise in dispersion accounts for the doubling of CE values for NII activities in the post-euro period even though the change in the range in Figure 1 seems rather small. This illustrates the sensitivity of CE values to what appear to be small changes in minimum values of averaged residuals. Thus not too much should be read into the magnitude of the CE changes. The main point is that price competition appears to have worsened and that spread activities appear to have worsened more than fee-based activities.

The conclusion that price competition deteriorated in the post-euro period conflicts with two standard indicators of competition. The average HHI only rose by 3% over its pre-euro value of 968 while the average Lerner Index fell by 3 percentage points in Table 1. While either of these results suggest little change in competition, the H-statistic fell for savings banks (falling from .43 to .21) while it rose for commercial banks (from .22 to .35) suggesting worsening competition for the former and improvement for the latter.[25]

5.2 Why Do Standard and CE Competition Measures Give Different Results?

As shown in Section 3, the HHI, Lerner Index, and H-statistic can differ in identifying most and least competitive banks for Spain. The HHI, for example, only suggests the possibility of a lack of price competition leading to a larger mark-up of price over cost when market concentration is "high" while the Lerner Index is a direct measure of the mark-up itself. In contrast, the H-statistic is concerned with how strongly changes in costs are reflected in output prices. The presumption is that if ∂ ln price/∂ ln cost is close to 1.0, then competition induces firms to reflect increases or decreases in input costs directly in the output prices being charged. In such a regression, the residual--the unexplained variation in output price--would be small and the percent difference across residuals would also likely be small. This result suggests that our CE measure has more in common with the H-statistic than the Lerner Index or the HHI and that the main difference is the use of additional independent variables to hold constant revenue changes that are not directly related to price competition but rather reflect other influences.

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[23] For fee-based activities in the post-euro period, the yearly R^2s ranged from .63 to .76 but was .76 to .38 for spread activities, with the lowest values occurring during 2003-2005.

[24] These residual values are estimated separately and averaged separately in the pre- as well as the post-euro periods as separate frontiers apply to each period.

[25] Estimating an H-statistic for all banks and averaging the results for these separate time periods suggests that both savings and commercial banks experienced weaker competition in the post-euro period (.15 and .11, respectively, versus .34 and .17 pre-euro). This result is consistent with the competition efficiency measure of Table 2.

Some examples may make this distinction clearer. If either the Lerner Index or the H-statistic are not adjusted for differences in factor productivity or ATM/branch network economies of scale across banks and over time, the observed factor prices (the average cost of labor and physical capital) will not be an accurate representation of their "true" cost. That is, observed factor prices will be higher than their true value at banks with greater productivity and need not reflect the full benefit from scale economies. With stable output prices, this would generate a lower Lerner Index suggesting greater competition when in fact competition is not different between more and less productive banks but productivity is. What if more productive and scale efficient banks pass on some (not all) of this cost reduction to users by lowering their output prices? These banks will look to be even more competitive because their observed mark-up is even lower when, if input prices could be properly adjusted, the mark-up need not have changed much even if output prices have been reduced. These same problems arise with the H-statistic since it is based on the sum of partial derivatives measuring the change in output prices with respect to changes in input prices and the input and output prices can be mis-measured.[26]

By the same token, a higher Lerner Index or lower H-statistic can be due to absorbing greater risk. Banks that take on more risky consumer and business loans usually charge somewhat higher loan rates (or direct fees) so a higher Lerner Index or a weaker correlation between output and input prices due to risk differences does not reflect a reduced intensity of price competition.[27] As well, given two banks with the same Lerner Index or H-statistic, the one with the higher productivity or greater scale economies can generate greater revenues and profits than the other (ceteris paribus). As output per unit of input is larger when productivity is higher or unit operating costs are lower due to scale benefits, more can be produced at the same output and input prices suggesting that neither measure may be a good indicator of profits.

From this perspective, our competitive efficiency measure CE is more like a "corrected" Lerner Index or an expanded H-statistic--corrected or expanded for differences in productivity, scale, risk, and temporary business cycle effects that are, in our view, outside of the effects one normally associates with the behavior of closely matching output price and service levels associated with the low cost market supplier.[28] In sum, there are a number of reasons why a Lerner Index or H-statistic can differ across banks and not all of them are associated with more or less price competition. These adjustments are what our CE measure proposes to do. Since opinions may differ on just what

[26] The regression used to derive the H-statistic includes the level of output so if revenues are the dependent variable the partial derivatives reflect the relation between output and input prices.

[27] Of course, if competition authorities are only concerned with the mark-up of price over cost and how this spread is viewed by consumers, then the Lerner Index is a reasonable approach even if the level of the mark-up is associated with influences not directly associated with price competition, narrowly defined.

[28] Maudos and Fernández de Guevara (2004) identified reductions in operating cost and credit risk as important reasons for the decline in the loan-deposit interest margin over 1993-2000 as well as an increased emphasis in obtaining fee-based revenues to offset a lower mark-up.

influences may bias the measurement of competition, this can be accommodated in the decision on what to include/exclude in the CE frontier model.

5.3 Identifying Why Competition Appears Weaker in the Post-Euro Period.

As shown in Table 2, there seems to be no important difference in competition between large and small banks in Spain nor between savings and commercial banks. However, competition appears weaker in the post-euro period compared to the earlier period, especially for traditional loan-deposit spread activities. Researchers assessing competition using a Lerner Index would point to a rise in the index to conclude that competition worsened. That is, a higher index would itself be the reason competition worsened.[29] With the H-statistic, a lower value would indicate that price changes are less closely related to underlying cost changes suggesting that other influences on prices are stronger, implying that competition based on cost changes is weaker.[30]

An inference similar to the H-statistic applies to the post-euro competition efficiency results in Table 2. That is, after controlling for changes in unit revenues from costs, productivity, scale economies, risk, and business cycle influences, unit revenues rose suggesting that the dispersion of price competition among banks expanded (c.f., Figure 1) reflecting less price competition. An alternative interpretation would be that some important influence on revenue or cost has not been included in the model. Given the lack of detailed cost accounting and revenue data by bank service line, such an alternative interpretation can not be dismissed and our results require a deeper explanation of why competition may have been reduced in the post-euro period.

Looking at the raw data, the pre-euro difference between the average price of loans (11.7%) and deposits (6.1%) was 5.6 percentage points. Post-euro, the loan and deposit rates both fell (to 6.9% for loans and 4.5% for deposits) and the difference was only 2.4 percentage points. The change in rate spreads pre- to post-euro is -3.2 percentage points, close to the -3 percentage point reduction in the Lerner Index of Table 1 which was estimated for the entire bank. Over the same period the 3-month market interest rate fell from an average 9.2% pre-euro to 3.5% post-euro, a reduction of -5.7 percentage points.

As average loan and deposit rates largely mirror changes in market rates over time, the reduction in the loan-deposit rate spread and the Lerner Index is not surprising but a conclusion that the reduction in these spreads necessarily indicates an improvement in competition would be misleading. Using the average 3-month market rate as an interest cost index, it would be 1.00 pre-euro (from 9.2%/9.2%) but falls to .38 post-euro (from 3.5%/9.2%). Deflating the average nominal loan-deposit rate spreads gives a "real" spread of .056/1.00 = .056 pre-euro and .024/.38 = .063 post-euro. This suggests--but does not prove--that the real spread may have increased by perhaps 13%, rising from .056

[29] As shown in Table 1, however, the Lerner Index did not rise but instead fell by 3 percentage points in the post-euro period.

[30] The H-statistic in Table 1 only fell for savings banks (suggesting weaker competition) while it rose for commercial banks (suggesting the reverse).

to .063. One reason why the real spread may have increased, even as the nominal spread fell, is the fact that there was a 147% rise in loan demand between the two periods.[31] Indeed, loan growth was so large that it far outstripped the growth of deposits, evident by the fall in the ratio of deposits to loans from 1.28 pre-euro to .95 post-euro. In such an environment it would not be surprising to find that some (many) banks adjusted their loan/deposit pricing behavior to raise real margins, reducing competition, and generating greater dispersion of CE values from the competition frontier.

While the competition efficiency measure for fee-based activities in Table 2 also suggests weaker competition in the post-euro period, the change here is considerably smaller than for spread activities. Recent merchant complaints of high bank credit and debit card fees have some validity since the existence of strong scale economies associated with rapidly growing volumes of electronic non-cash payment transactions should have reduced these payment fees if competition in the post-euro period was strong.[32]

While the post-euro period is seemingly less competitive for both spread and fee-based activities in Spain, should antitrust authorities or banking regulators be concerned? Our answer is yes if prices of fee-based activities do not reasonably fall as underlying costs are reduced due to realized scale economies. The answer would also be yes if the apparent strong demand for loans in the post-euro period, which seemingly increased the real loan-deposit rate spread, is unlikely to be reversed when the supply of deposits outstrips the demand for loans in the future. This could be assessed by determining how real spreads have responded in the past with large (and long-term) fluctuations in loan demand. In sum, the whole process of identifying potentially less competitive banking services over time would be more informative if more data were publicly available on revenues by major type of loan and non-interest income service category. Statistical analysis could then be used to estimate the associated production cost, in effect relating changes in revenues to changes in costs and other influences on revenues in a more detailed manner than is now possible.

5.4 Frontier Choice: Range or Observations Close to the Density of the Data?

As noted in equation (4), the competition efficiency frontier is defined by the bank with the lowest average residual. If this minimum value is close to the density of the data (i.e., where the frequency distribution of average residuals does not have long tails), then any truncation of extreme values of residuals before averaging will have little effect on the frequency distribution of CE values. As seen in Figure 2, however, the distribution of

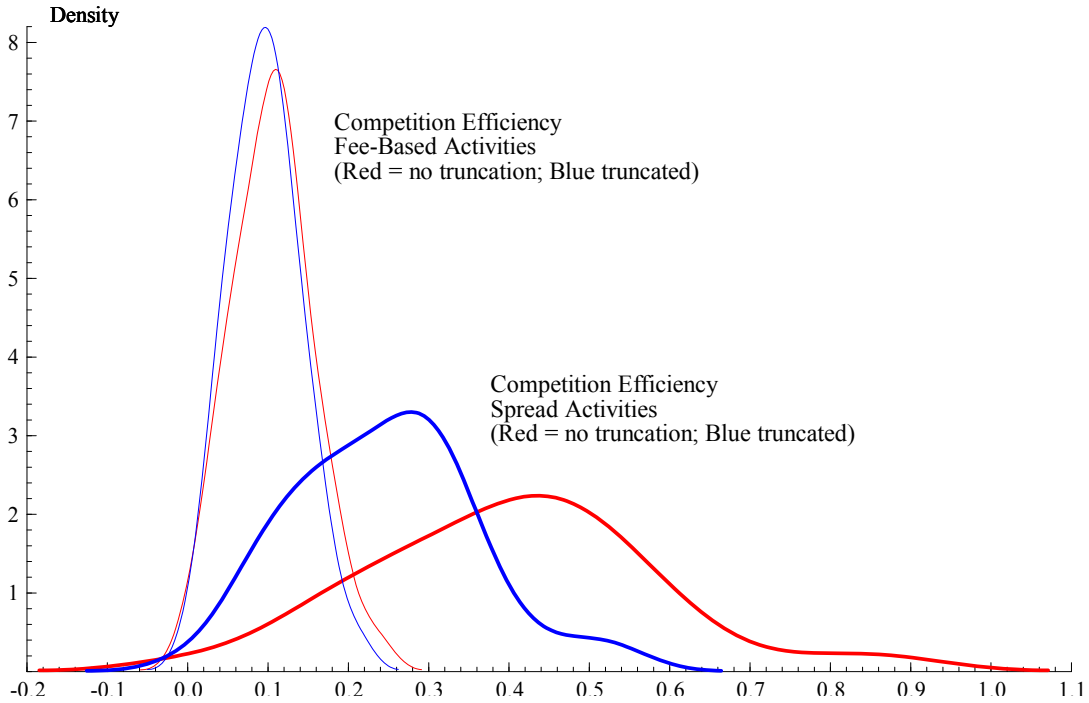
[31] Deflating the nominal deposit/loan rate spread by the cost-of-living index (COL), rather than an index of the market interest rate, is not appropriate. Banks buy deposits and sell loans at interest rates: they do not buy housing, food, clothing, etc., that comprises the COL indicator of consumer purchasing power.

[32] While merchant payment fees that do not reflect realized bank scale benefits is the main merchant complaint, an additional concern is the perception that merchants' sales are unlikely to be larger from accepting cards when the vast majority of merchants already accept them. That is, the real beneficiary of bank card use is (if it ever really was) no longer merchant sales but rather the card user who is effectively subsidized since they do not pay the full cost of their card use that generates bank revenues.

competition efficiency values for spread activities for all banks over 1992-2005 (thick red line) has long tails and contains some extreme values that are not representative of the density of the data.

The influence of extreme residual values prior to averaging on the frequency distribution of CE values is illustrated by truncating 4% of the highest and lowest of the 2,100 residuals obtained from the 14 sets of annual cross-section estimations of (1) and (2).[33] The un-truncated CE values for spread and fee-based activities in Figure 2 are in red while the truncated values are in blue.

Figure 2: Distributions of Competition Efficiency (CE) Values With and Without Truncation of Residuals: 1992-2005.



With no truncation, the mean competition efficiency value over 1992-2005 is .40 for spread activities and .11 for fee-based activities (shown earlier in Table 1). After truncation, the mean CE value for spread activities falls to .24 (a 40% reduction) while for fee-based activities the CE value falls from .11 only to .10.[34] Truncating extreme

[33] The 2,100 residuals for spread activities were ranked lowest to highest, as were the 2,100 residuals for fee-based activities. Truncation involved setting 83 of the lowest residual values equal to the 84th lowest residual and setting 83 of the highest residual values equal to the 2,016th highest residual. The sample size is still 2,100 but the frontier is now closer to the density of the data in Figure 2 since the range has been reduced.

[34] Truncated CE values for fee-based activities are all one percentage point lower for the largest banks, smallest banks, savings banks, and commercial banks compared to CE values shown in Table 1 while truncated CE values for spread activities are 13 to 16 percentage points lower.

values of residuals has little effect on the ranking of which banks are more versus less competitive since the R^2 between truncated and un-truncated spread CE values is .91 while it is .99 for fee-based values.

Finally, there is only a minor change in the R^2 between un-truncated spread and fee-based CE values which rose from .03 to .06 when the data was truncated. This indicates that there is little relationship between banks that are competitive in either spread or fee-based activities and truncation--which is common when the DFA frontier is applied to cost and profit functions--appears to have little effect on our competition efficiency conclusions. While truncation reduces the CE values, it has little effect on the ranking. Indeed, the main results of Table 1 still hold: spread activities experience less competition than fee-based activities, there is no real difference in competition between large and small banks, almost no difference in competition between savings and commercial banks, and competition is weaker in the post-euro period (mostly for spread as opposed to fee-based activities).

6 Characteristics of Most and Least Competitive Banks.

6.1 How Do Most and Least Competitive Banks Differ?

What aspects of a bank are associated with being more or less competitive than the average institution? Table 3A contrasts the most competitive CE quartile of banks with institutions in the least competitive quartile for spread activities. Using a 15% difference as the cutoff to identify the largest differences, the quartile of most competitive banks experienced 17% lower loan-deposit spread revenues relative to operating cost, held 23% more assets, and received 31% fewer profits before taxes as a ratio to asset value (ROA).

More directly, competitive banks received a 4% lower average loan rate and paid an 11% higher average deposit rate (so the loan-deposit rate spread at competitive banks was 20% lower). All of these differences would be expected to be associated with greater price competition even after accounting for cost, productivity, scale, and risk differences.[35]

As competitive banks were larger, they employed 14% more workers overall. Although the average employee received essentially the same average wage plus benefits as did workers at the set of least competitive banks, competitive banks employed 10% more workers per office. This higher labor cost per branch was more than offset by the fact that each office generated 44% more deposits, indicating greater labor/capital productivity in producing/supporting deposits. Finally, their loan losses as a percent of loans were 27% lower.

[35] It is also interesting to see what the less important differences were. Competitive CE banks generated about the same level of total revenues relative to operating cost (masking differences in spread vs. fee-based activities), experienced minor differences in their share of loans to assets or deposits to loans, experienced only slightly higher asset growth, held about the same level of capital to assets, and were in regions with slightly higher GDP.

Table 3A: Banks With Most and Least Competitive Spread Activities: 1992-2005

	Spread: Most Competitive	Spread: Least Competitive	(Most-Least)/Least	
SPREADOC	1.18	1.42	-0.17	*
NIIOC	0.29	0.28	0.04	
TROC	3.50	3.41	0.03	
TA	9,363,939	7,593,641	0.23	*
PFTBTAXTA	0.009	0.013	-0.31	*
LOANTA	0.68	0.73	-0.07	
DEPLOAN	1.17	1.09	0.07	
ASSETGR	0.084	0.079	0.06	
PLOAN	0.087	0.091	-0.04	
PDEP	0.051	0.046	0.11	
PLOANMPDEP	0.036	0.045	-0.20	*
LBR	6.5	5.9	0.10	
DEPBR	20,138	13,989	0.44	*
CAPITAL	0.062	0.063	-0.02	
PL	42.9	42.2	0.02	
L	2,140	1,884	0.14	
BR	413	314	0.32	*
ATM	532	307	0.73	*
ATMBR	0.96	1.04	-0.08	
GDPR	55,607,100	49,831,100	0.12	
LOSS/LOAN	-0.0051	-0.0070	-0.27	*
HHI	720	618	0.17	*
LERNER	0.202	0.296	-0.32	*
H-STATISTIC	0.218	0.168	0.30	*

The 31% lower profits for competitive banks are associated with a 17% higher HHI,[36] a 32% lower Lerner Index, and a 30% higher H-statistic. The latter two results are consistent with greater competition and thus consistent with how the frontier competition efficiency measure has distinguished between most and least competitive banks in spread activities. In contrast, if the HHI was used to distinguish between quartiles of most and least competitive banks, the set of most competitive banks would have an average HHI of 87 (rather than 720 in Table 3A) and the least competitive an HHI of 3,051 (rather than 618 in the table). Distinguishing between most and least competitive banks using only a Lerner Index would give a mark-up of 17% (most competitive) versus 33% (least competitive) which is not too different from the 20% to 30% range in Table 3A using the frontier model. The equivalent range for the H-statistic is .32 (most competitive) versus .06 (least competitive) compared to .22 versus .17 in Table 3A. Clearly, the frontier CE measure is identifying some of the same banks as being most and least competitive as would be identified using the Lerner Index or H-statistic (much less so for the HHI).

A comparison of most with least competitive banks in non-interest income (fee-based) activities is shown in Table 3B and suggests that competitive banks have lower profits,

[36] A lower, not higher, HHI would have been expected.

are smaller, employ slightly more workers per office, pay about the same annual average wage, and support the same level of deposits per office. In contrast to spread activities, the HHI is lower for competitive banks (as would be expected). As well, the Lerner Index shows a lower mark-up and the H-statistic a higher value for the set of most competitive banks identified using the frontier model.

Table 3B: Banks With Most and Least Competitive Fee-Based Activities: 1992-2005

	NII Most Competitive	NII Least Competitive	(Most-Least)/Least	
NIIOC	0.26	0.31	-0.16	*
SPREADOC	1.26	1.41	-0.11	
TROC	3.19	3.65	-0.13	
TA	9,404,467	14,624,000	-0.36	*
PFTBTAXTA	0.011	0.013	-0.15	*
LOANTA	0.68	0.71	-0.04	
DEPLOAN	1.17	1.11	0.05	
ASSETGR	0.074	0.078	-0.05	
PLOAN	0.086	0.094	-0.09	
PDEP	0.047	0.050	-0.06	
PLOANMPDEP	0.040	0.044	-0.09	
LBR	6.3	6.1	0.03	
DEPBR	16,079	15,531	0.04	
CAPITAL	0.061	0.063	-0.03	
PL	42.9	42.5	0.01	
L	2,234	2,823	-0.21	*
BR	382	391	-0.02	
ATM	470	401	0.17	*
ATMBR	1.09	1.01	0.08	
GDPR	51,340,500	54,742,300	-0.06	
LOSS/LOAN	-0.0056	-0.0066	-0.15	*
HHI	721	1,015	-0.29	*
LERNER	0.222	0.285	-0.22	*
H-STATISTIC	0.217	0.175	0.24	*

So what do these comparisons tell us? First, that the quartile of most competitive banks in spread activities using the CE indicator receive lower profits, pay higher deposit rates, generate more deposits per branch office, and (because they are larger) likely realize greater scale economies from their ATM/branch networks and in their payment activities. Second, although these banks also have a lower average Lerner Index and higher H-statistic, they are not always the same banks that would be identified as most or least competitive using only either one of these two standard measures to judge their competitive position. As both the Lerner Index and the H-statistic effectively only indicate the spread or correlation between output and input prices, if these two measures were adjusted to account for differences in factor productivity, scale economies, and risk, their correspondence with the CE measure and with each other would likely become stronger and more consistent.

How might a CE measure assist regulatory authorities? Basically by emphasizing the usefulness, where possible, of digging deeper into why mark-ups at certain banks seem to be consistently higher than at other banks or why output prices are not strongly correlated with input prices in an industry over time. This requires a more informed understanding of bank pricing practices and industry dynamics than academics typically have but that regulatory authorities often possess or have the resources to develop. It also suggests that reporting requirements could, at a minimum, be expanded to include more detailed information about revenues and cost accounting allocations by major bank service areas. In addition, the industry should be encouraged to price its services on a per transaction basis rather than in the form of fixed fees unrelated to volume (even though current revenues raised may cover the underlying costs). This would allow bank management to determine better the profitability of the various services it offers and users to match better the costs they incur with the benefits they receive. The main problem is that assessing competition is much more nuanced than relying on simple univariate measures, the worst of which for banking is likely the HHI.

6.2 Cost, Productivity, Scale, and Risk Effects on Unit Revenues.

Elasticities illustrating how our five sets of variables have affected unit revenues in equations (1) and (2) are shown in Table 4. The elasticities were computed from a panel estimation containing each year over the entire period.[37] Looking at the effect of cost function influences on unit revenues from spread activities, it is clear that the most important effects are from a rise in loans (increasing spread revenues as a total) or a fall in the price of labor (lowering OC and raising the ratio SPREAD/OC). The effects from securities or the price of physical capital, although significant, have a much smaller impact. The same holds for unit revenues from fee-based activities.

Regarding productivity, a fall in the number of workers per office would (if this was the only change) be expected to reduce costs, as would a rise in deposits generated per office, and both would be expected to show up as a rise in unit revenues. This indeed occurs for fee-based activities since a -1% reduction in the labor/branch ratio is associated with a -1%(-.67) = .67% rise in fee-based unit revenues while a 1% rise in the deposit/branch ratio gives a 1%(.64) = .64% rise in unit revenues. However, just the reverse occurs for spread activities. A possible reason is seen in Table 3A. Here a higher labor/branch ratio for competitive banks (6.5) is associated with a lower spread to operating cost ratio (1.18) compared to the least competitive banks (1.42) with a lower labor/branch ratio (5.9). This 10% larger number of workers per office at competitive banks also occurs with a 44% higher level of deposits per branch (€ 20,138 versus € 13,989). While this would appear to reduce the labor cost per euro of deposits, competitive banks receive a lower average loan rate and pay a higher deposit rate so the net effect of greater deposit productivity is associated with a lower spread. One way or the other, it is clear that productivity effects working through labor and deposits per branch office significantly affect unit revenues.

[37] Computing elasticities for each year could be done but we are interested in average effects rather than generalizing from 14 sets of annual results.

Table 4: Elasticities of Cost, Productivity, Scale, Risk, and Business Cycle Effects on Unit Revenues: 1992-2005

Unit Revenues:	ln *SPREAD/OC*	ln *NNI/OC*
Cost Function Effects		
Loans	1.31**	-.13**
Securities	.01	.05*
Labor Price	-.29**	-.72**
Capital Price	-.07**	-.05**
Productivity Effects		
Labor/Branch	.15*	-.67**
Deposit/Branch	-.17**	.64**
Scale Economy Effects		
ATM/Branch Scale	-.05	.06
Payment Scale	-.09	.06°
Risk Effects		
Capital/TA	.28**	-.01
Deposit/Loan	2.53**	-.54**
(Loan-Loss)/Loan	-7.37**	-3.14**
Business Cycle Effects		
Regional GDP	-1.19**	.08
Asset/Regional GDP	-1.24**	.10*
3-Month Interest Rate	.05	.39**

** (*) (°) Indicates a p-value < .01 (<.05) (<.10).

Although strong scale economies are associated with ATM and branch networks along with payment processing, these economies are not significantly associated with unit revenues from spread activities and only marginally affect unit revenues of fee-based activities (and then in an unexpected direction).[38] There are likely two reasons for this result. First, as these economies are size-related, re-estimating the model without loans or securities (which are also size-related) resulted in significant network and payment elasticities for fee-based activities (.08° and -.09**, respectively) but were still insignificant for spread activities. However, only when the elasticity is negative will lower unit costs from scale effects raise unit revenues and this only occurs for payment scale effects for fee-based activities.

[38] The significant parameter (.06°) is positive so a reduction in unit cost due to scale economies reduces unit revenues rather than just reducing operating cost and raising unit revenues.

Second, loan and deposit rates as well as pricing of transaction, safekeeping, cash access, and other services are only weakly associated with usage (e.g., per deposit/withdrawal or per payment transaction). Rather, fixed fees per account or per month or low deposit interest rates are the norm. Consequently, although unit cost can fall with scale economies, total operating cost can rise faster than revenues with higher usage of services.[39] This also applies to spread activities since deposit rates paid and loan rates received are not directly tied to the size of a bank's ATM or branch network. Even so, there appears to be an indirect connection since in Table 3A competitive banks are on average larger (realizing greater scale benefits) but also pay a higher deposit rate than less competitive banks which would lower the spread.

With respect to risk, a bank is usually considered less risky if it has a higher capital-asset ratio, a higher ratio of deposits to loans (for greater funding stability/liquidity), and lower loan losses.[40] For spread activities, only the loan loss variable would seem to have the expected sign since lower losses (a higher value of the variable) is associated with a lower spread. While all three variables have the expected signs for fee-based activities, the purpose of including risk was to help explain why the spread might be higher. It seems that only loan losses have the expected effect here.

Finally, business cycle effects have a significant effect on unit revenues. Regions of Spain with higher levels of GDP and where asset growth outpaces regional GDP growth would be where demand for loans (and the supply of deposits) would be relatively greater and both of these variables are associated with a smaller unit revenues. However, if the level of loans and securities are removed from the model, all three business cycle effects for spread activities are positive and significant suggesting that more rapid growth and higher interest rates are associated with higher spreads and unit revenues. Since apparent multicollinearity affects the interpretation of business cycle effects, this influence perhaps is best neglected. Indeed, some may prefer to exclude temporary business cycle effects in determining competition efficiency since they could view this effect as a partial indicator of competition and would not want to hold its effects constant in the analysis.

7. Conclusions.

The three main indicators of banking market competition in empirical analyses have been the HHI, Lerner Index, and H-statistic. Unfortunately, conclusions regarding competition among individual banks, between savings and commercial banks, or over time can differ depending of which of these measures are chosen to indicate competitive behavior. Some inconsistencies occur for Spain (Table 1 in the paper) and within and across 14 European countries (Carbó, Humphrey, Maudos, and Molyneux, 2009). While a number of academic studies have shown that the HHI can give results that differ from either the

[39] If deposit rates were directly tied to deposit service usage (which can occur for use of a foreign ATM) and all payment transactions were directly priced, then changes in the volume of use would "automatically" raise revenues to cover the higher operating costs associated with expanded usage.

[40] As noted earlier, our loan loss variable is (loan value - losses)/loan value since logs are used in the estimating equations. Thus lower losses are associated with a higher ratio.

Lerner Index or from the H-statistic, rarely has the next step been taken to contrast the latter two measures against each other or, indeed, to question how accurate either measure may be in practice. Historically, competition studies typically choose one indicator, compute or estimate its value, and opine on how competition has (or has not) apparently been affected.

Our approach to measuring price competition borrows from frontier cost and profit function analysis but is closer in concept to the H-statistic approach than to the other two methods. The approach is quite flexible and allows one to specify what influences on unit revenues are not directly or only weakly associated with competition. When these influences are statistically "subtracted" from banks' unit revenues, the average unexplained residual is assumed to reflect unspecified price competition. We interpret price competition narrowly as market pressure to match competitors' prices (resulting in low dispersion across banks from a frontier) and, at the same time, to produce services at close to minimum cost. Thus to determine competitive efficiency we seek to estimate unit revenues after accounting for differences across banks in their asset composition, factor input prices, labor and capital productivity, realized scale economies, and risk. More controversially, we also account for some business cycle effects which we view as temporary impacts on price competition as our goal is to assess relative competition among banks as an average.

Conceptually, our approach would be similar to computing a Lerner Index or an H-statistic and adjusting the resulting values for the list of influences enumerated above. For example, both of these standard measures make no allowance for differences in productivity among banks so the input prices used to estimate the mark-up (Lerner Index) or correlation of input prices with output prices will not reflect the true underlying cost. The same holds for output prices not adjusted for differences in risk. It also applies to differences in operating cost not reflected in factor prices which occurs among different sized institutions when scale economies are important and differences in wages across regions which are the result of cost of living differences and not competition.

Using our revenue-based frontier approach, we found no important difference in competition between large and small banks in Spain nor between savings and commercial banks. However, dividing our 1992-2005 time span into pre- and post-euro periods, banking competition appears to have been reduced for both traditional loan-deposit spread and non-traditional fee-based activities. For spread activities, the "real" spread seems to have increased even as it fell in nominal terms. This is likely associated with the 147% rise in loan demand between the two periods and the fact that loan growth far outstripped the growth of deposits, resulting in a 26% reduction in the ratio of deposits to loans. For fee-based activities, bank credit and debit card fees paid by merchants have been stable even as costs likely fell due to strong scale economies realized from expanding electronic payment volumes.

Should antitrust authorities or banking regulators be concerned? Yes, if prices of fee-based activities do not reasonably fall as underlying costs are reduced since this implies a lack of competition. And yes if the strong loan demand in the post-euro period did

indeed result in higher real loan-deposit rate spreads which may not be reversed when the supply of deposits outstrips the demand for loans in the future. The important message we take away from this exercise is that identifying changes in banking competition, as well as their likely source, would be more accurate if data on revenues by major type of loan and non-interest income service category were available. The costs are amenable to statistical allocation. Greater transparency would both benefit banks who would have a better idea of where their profits are indeed generated, improving internal resource allocation, while justifying better to users the prices they pay for banking services.

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Appendix:

Measurement of HHI, Lerner Index, and H-statistic for Spain.

Unlike some countries, information on the regional distribution of loans or deposits is not publicly available for Spain but the regional distribution of the number of branch offices by bank does exist. Consequently, it has been common to approximate a Herfindahl-Hirschman index of market concentration for Spain as the sum of the squared market shares of branch offices for each bank operating in each of its 52 regions (provinces). For banks operating in more than one region, the HHI is the weighted average of the HHI of the bank in those regions, using the regional distribution of bank branches as a weighting factor.[41]

The Lerner index is computed as the ratio (price of total assets - marginal costs of total assets)/price of total assets. The price of total assets for each bank is defined as the ratio bank revenue/total assets. Marginal costs are typically estimated using a translog cost function with total costs (*TC*) as the dependent variable:

$$\ln TC = \alpha_0 + \alpha_1 \ln TA + .5\alpha_3 (\ln TA)^2 + \sum_{i=1}^{3} \beta_i \ln P_i + .5 \sum_{i=1}^{3} \sum_{j=1}^{3} \beta_{ij} \ln P_i \ln P_j + \sum_{i=1}^{3} \delta_i \ln TA \ln P_i + \upsilon_1 T + \upsilon_2 .5(T)^2 + \upsilon_3 T \ln TA + \sum_{i=1}^{3} \lambda_i T \ln P_i$$

where:
TA = total assets, the value of all bank "output";
P_i = the input prices of deposit funding, labor, and physical capital; and
T = technical change indexed by time.
Parameter symmetry and linear homogeneity of input prices are imposed in joint estimation of the cost function with two cost share equations (funding and labor).

The H-statistic is represented by $\sum_{k=1}^{3} \partial \ln TR / \partial \ln P_k$ estimated from the following translog functional form with total revenues (*TR*) as the dependent variable:

$$\ln TR = \alpha_0 + \sum_{i=1}^{4} \alpha_i \ln X_i + .5 \sum_{i=1}^{4} \sum_{j=1}^{4} \alpha_{ij} \ln X_i \ln X_j + \sum_{k=1}^{3} \beta_k \ln P_k + .5 \sum_{k=1}^{3} \sum_{m=1}^{3} \beta_{ij} \ln P_k \ln P_m + \sum_{i=1}^{4} \sum_{k=1}^{3} \delta_{ik} \ln X_i \ln P_k + \upsilon_1 T + \upsilon_2 (T)^2 + \sum_{i=1}^{4} \upsilon_i T \ln X_i + \sum_{k=1}^{3} \lambda_k T \ln P_k$$

where:
X_i = *TA*, reflecting the level of banking "output"; *EQUITYTA*, the ratio of equity capital (*EQUITY*) to *TA* to reflect bank risk; *LOANTA*, the ratio of the value of loans (*LOAN*) to *TA*; and *DEPTL*, the ratio of the value of deposits (*DEP*) to total liabilities (*TL*). The last

[41] Although the size of bank offices can vary markedly across countries, the size variation within a country is quite similar. For example, approximately 85% of banking offices in Spain observed each six months over 1992-2005 employed between 5 to 7 workers. While larger branches exist, they focus on loan processing and monitoring and provide a broad range of business services in addition to basic consumer transaction, savings, and cash acquisition services.

two variables account for differences in asset and liability composition across banks.
P_i and T have been defined above. Parameter symmetry is imposed in estimation. However, unlike a cost function, linear homogeneity of input prices is not imposed as a doubling of input prices need not double total revenues. Our specification is typical of the majority of empirical estimates of the H-statistic. H-statistic results are considered to be consistent with long-run competitive equilibrium (c.f., Bikker, Spierdijk, and Finnie, 2006) if input prices are not significantly related to the return on assets (*ROA*). Replacing the dependent variable ln *TR* with ln *ROA* defined as (profits before losses)/(total assets) or (total revenue - total cost)/(total assets) and re-estimating the model, the null hypothesis of the joint significance of input prices with ROA was not rejected.

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