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Efficiency and market power in Spanish banking^{*}

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Abstract

This article explores how cost and revenue efficiency measures for Spanish banks are related to the so-called return to the dollar (RD), whose advantage over other profitability measures lies on it being a ratio—in contrast to the additive structure associated with profit. This relationship is explored by considering nonparametric procedures, a set of techniques which is more consistent with those employed to measure efficiency in the first stage of the analysis. Results show that banks' efficiency is differently related to the return to the dollar according to different circumstances. Specifically, for those firms whose revenues are lower than their costs, the relationship is positive. However, it turns to be negative for those banks with revenues above costs, suggesting that the "quiet life" might be a reality for those banks exerting market power. This finding is more apparent when decomposing efficiency into its different components (cost/revenue, technical, and allocative), since the relationship found is more obvious for allocative efficiency, both on the cost or revenue side.

Keywords: banking, efficiency, kernel smoothing, return to the dollar, nonparametric regression

JEL Classification: C14, C61, G21, L50

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1. Introduction

Over the last twenty years, the changes and challenges faced by most banking industries worldwide have prompted a remarkable interest in analyzing several industrial organization (IO) topics in banking. Indeed, as suggested by Rhoades (1997), during the past fifteen years or so there has been more IOrelated research in banking than many students of IO might expect. Perhaps some of the IO topics more profoundly examined in the banking literature relate to the structure-conduct-performance (SCP) paradigm (Bain, 1956), and the ensuing efficient-structure (ES) hypothesis (Demsetz, 1973). As reviewed by Berger *et al.* (2004), the early 1990s empirical banking studies analyzing the effects of concentration and competition were particularly concerned about whether the traditional SCP paradigm held for the U.S. banking industry. Although this literature is abundant, and despite the difficulties of summarizing results,¹ most studies found that banks in more concentrated local markets—as measured by the Herfindal-Hirschman Index (HII), or *n*-firm concentration ratio (CR*n*)—charged higher rates on loans, and payed lower rates on retail deposits (see, for instance, Berger and Hannan, 1989; Hannan, 1991).

Although most findings were consistent with the exercise of market power under the SCP hypothesis (Hannan and Berger, 1991; Neumark and Sharpe, 1992), it was not unusual to obtain weak relationships between concentration and profitability when firms' market shares were included in the regressions (Berger et al., 2004). Therefore, paralleling the making in the IO literature, some studies aimed to analyze the validity of the ES hypothesis in banking—according to which high concentration endogenously reflects the market share gains of efficient firms (see Smirlock et al., 1984). Typically, such studies controlled for measures of X-efficiency and scale efficiency, allowing concentration and market share to be functions of these efficiency measures (see, for instance, Berger, 1995). As for the SCP paradigm, the empirical evidence for the ES hypothesis was also weak.

Apart from the efficient-structure hypothesis and the structure-conduct-performance paradigm mentioned above, there is a third hypothesis, the relative market power hypothesis (Shepherd, 1982, 1986), which considers that performance disparities' are explained by efficiency along with the residual influence of market share—which controls for the influence of factors unrelated to efficiency such as market power/and or product differentiation. A special case is constituted by the so-called "quiet life" hypothesis (Berger and Hannan, 1998), which postulates a positive relationship between market power and inefficiency. As pointed out by Maudos and Fernández de Guevara (2006), only few studies such as Berger and Hannan (1998) have tested the "quiet life" hypothesis, by analyzing how market concentration—which proxies for market power—impacts on the efficiency of the financial institutions.

According to the "quiet life" hypothesis, the higher the market power, or the lower the competitive pressure, the lesser the managerial effort to maximize operating efficiency (Berger and Hannan, 1998; Maudos and Fernández de Guevara, 2006). Thus, if in addition to the higher prices and reduced output emanating from the existence of market power we find higher costs per unit of output in concentrated markets due to mismanagement, a negative relationship between market power and efficiency would

¹For a more thorough review, see the introductory article (Berger *et al.*, 2004) to the recent special issue of the *Journal* of Money, Credit, and Banking on bank concentration and competition.

emerge.

Berger and Hannan (1998) and related studies use a variety of methods for measuring market power such as concentration ratios which are simpler than the indicators based on the New Empirical Industrial Organization (NEIO). These indicators include the Lerner index (Beighley and McCall, 1975), the conjectural variation models (Shaffer, 1989, 1993), Panzar and Rosse (1987) models, and those using Tobin's qfor measuring market power (Keeley, 1990).² However, despite their higher complexity which makes them (in principle) more desirable, these indexes may face problems as to the difficulties of the Panzar-Rosse approach in distinguishing between collusion and competition for some technologies, or the biases faced by Hall methods in industries deviating from constant returns to scale (Hyde and Perloff, 1995).

Since NEIO methods are not disadvantage-free, and considering we have an attempt to fit our study within the group of pioneering studies testing the "quiet life" hypothesis in banking, our proxies for market power are affiliated to the group of "raw" measures—as opposed to some recent studies such as Maudos and Fernández de Guevara (2006). However, we consider a new, different twist by attempting to disentangle painstakingly the relationship between efficiency and profits (our measure of market power) in banking. We do not pursue this by entering a unique efficiency measure in the structural model underlying the ES hypothesis as, for instance, in Berger (1995). Instead, our aims are more comprehensive, since we consider cost, technical and allocative efficiency, along with its revenue variants. The latter is important since, as suggested by Berger and Mester (1997), cost and profit efficiency may differ—even moving in opposite directions. However, the precise linkages between both cost and revenue efficiency have not been analyzed in depth in the literature; we attempt to measure this as well.

Therefore, we propose a methodological novelty by using an alternative to the traditional means used to evaluate the validity of the "quiet life" hypothesis. Specifically, we employ nonparametric methods to explore the likely linkages between efficiency and profitability. These methods are highly appropriate when a theory is lacking to evaluate the associations between two variables. Although theories are well established in our case, the empirical evidence suggests they might be more difficult to test than one a *priori* might expect. Earlier initiatives, such as Clark (1986), considered similar issues; in particular, he argued that tests of the structure-performance paradigm yielded quantitatively small statistical significance because of the methodology employed. However, in contrast to a less restrictive nonparametric approach, his analysis was entirely confined to the parametric field, therefore disallowing looser interpretations of the relationship.

Our analysis is focused on the Spanish banking system, which offers a scenario where profound changes have taken place: important deregulations such as interest rate deregulation, partial or total removal of legal coefficients, legal homogenization of both commercial and savings banks, free entry for European Union banks—as long as they meet European Union legislation—, removal of the restrictions on the geographical expansion of savings banks, implementation of new telecommunications technologies, etc. In this reshaped industry, in which (supposedly) keener competition exists, an efficiency study is undoubtedly interesting, primarily because of the alleged inverse relationship between competition and inefficiency or,

 $^{^{2}}$ See Fernández de Guevara *et al.* (2005), or Maudos and Pérez (2003) for citations and a more comprehensive view of market power in banking.

more exactly, X-inefficiency. Accordingly, a considerable empirical effort has been devoted to analyze the competitive viability of Spanish banking firms, with varying results. However, most of these research studies have focused overwhelmingly on cost aspects, or even on a particular component of cost efficiency (technical efficiency). Yet no attempt has been made to compare cost efficiency and revenue efficiency.

The Spanish banking industry also represents an interesting scenario in which to perform the analysis since, as has occurred in most others European banking industries, the attention devoted to testing the SCP, the ES, or the relative market power hypotheses has been comparatively minor. Some of the studies which have addressed these issues for European banking are those by Goldberg and Rai (1996) or, more recently, Cetorelli (2004), Fernández de Guevara *et al.* (2005), or Maudos and Fernández de Guevara (2006), among others. In the Spanish case the evidence is even more scarce. See, for instance, the studies by Maudos (1998) or Lloyd-Williams *et al.* (1994) and, more recently, Maudos and Pérez (2003).

The study proceeds as follows. The next Section is devoted to emphasize the relevance of focusing on both cost and revenue efficiency, introducing both the method and results, along with a painstaking illustration of the relationship between cost and revenue efficiency. Section 3 aims at understanding the likely relationship between profitability and efficiency in banking. Subsection 3.2 provides results on that alleged relationship. Finally, section 4 concludes.

2. Cost and revenue efficiencies

According to the survey by Berger and Humphrey (1997), most studies analyzing the efficiency of financial institutions have confined their analyses to either technical or cost efficiency—or both. Yet recently the interest has shifted to a focus on profit efficiency; indeed, out of the 130 studies surveyed by Berger and Humphrey (1997), only nine focused on this type of inefficiency. However, as stated by Berger *et al.* (1993), these efficiencies may be much more relevant than expected. Indeed, except for the study by Miller and Noulas (1996), profit inefficiencies have been generally found to be larger than those attributable to failing to minimizing costs.

This section measures both sides of inefficiency, i.e., cost and revenue. Only few studies such as those by Färe *et al.* (2004), Devaney and Weber (2002) and Maudos and Pastor (2003) have used the nonparametric techniques presented in Färe and Grosskopf (2004) to measure profit efficiency. If the analysis were confined to revenue efficiency, the evidence is virtually nonexistent—at least in banking studies.³ Our analysis differs from previous work also in terms of how the results by each type of efficiency (cost, revenue) are compared; we focus on the *entire* distribution of efficiency scores, rather than only summary statistics like correlation coefficients.

This type of inefficiency is important for several reasons. Among them, we must recall that banks attempt not only to offer products and services at the minimum cost—i.e., to be *cost* efficient—but also to maximize the revenues they generate—i.e., to be *revenue* efficient. Together, both attempts imply *profit*

³However, the number of studies analyzing bank profit efficiency using econometric techniques is substantial. See Färe *et al.* (2004) for a review. In the case of the Spanish banking industry, only the studies by Lozano-Vivas (1997) and Maudos and Pastor (2003) have focused on profit efficiency, using parametric and nonparametric techniques, respectively, although with aims different from those pursued in our paper.

efficiency. By omitting the revenue side, we provide a partial view of bank performance and probably a misleading view too.

The (scarce) empirical evidence has reinforced the higher quantitative relevance of the revenue side (revenue inefficiency) relative to cost inefficiency, suggesting significant inefficiencies on the revenue side, either due to a wrong output mix—given output prices—or the establishment of an inadequate price policy. In addition, as suggested by Berger and Mester (1997), and contrary to what one might a priori expect, profit efficiency and cost efficiency are not always positively correlated.

2.1. Method: measuring efficiency

Efficiency may be measured via a variety of methods. They fall under the broad categories of parametric and nonparametric methods. Several monographs present painstaking descriptions of the available methods (see, for instance, Fried *et al.*, 1993). However, most recent monographs lean either towards parametric (see Lovell and Kumbhakar, 2000) or nonparametric methods (see Färe and Grosskopf, 2004). Findings showing that results may differ greatly between parametric or nonparametric techniques might have deterred publication of new monographs presenting both approaches.

In addition to this, the evolution of parametric and nonparametric techniques has not been entirely equal. Up to the early nineties, both groups of techniques went through relevant progress, yet newer proposals have leaned towards the nonparametric field. Cazals *et al.* (2002) present a nonparametric estimator which is more robust to extreme values than DEA (Data Envelopment Analysis) or FDH (Free Disposable Hull), Aragon *et al.* (2005) present a nonparametric estimator of the efficient frontier based on conditional quantiles of an appropriate distribution associated with the production process. Martins-Filho and Yao (2006) also propose a nonparametric model of frontiers which envelops the data and is also more robust to extreme values than previous methods.⁴

However, prices do enter the analysis using any of these new methods, and some of them carry difficulties in handling multiple outputs and multiple inputs. Yet in banking the availability of prices, and the multiple-input/multiple-output nature of the banking firms suggests previous nonparametric methods (such as DEA and FDH) may be more advisable—at least until further progress is made in the aforementioned new fields of research.

Therefore, the set of activity analysis techniques presented and revised in Färe and Grosskopf (2004) is our reference for measuring efficiency. Let $\boldsymbol{x} = (x_1, \ldots, x_N) \in \mathbb{R}^N_+$ be the input quantities, with associated prices $\boldsymbol{\omega} = (\omega_1, \ldots, \omega_N) \in \mathbb{R}^N_+$, and $\boldsymbol{y} = (y_1, \ldots, y_M) \in \mathbb{R}^M_+$ be the output quantities, with associated prices $\boldsymbol{p} = (p_1, \ldots, p_M) \in \mathbb{R}^M_+$. Accordingly, total costs and total revenues will be defined as $\boldsymbol{\omega} \boldsymbol{x} = \sum_{n=1}^N \omega_n x_n$ and $\boldsymbol{p} \boldsymbol{y} = \sum_{m=1}^M p_m y_m$, respectively. It is important to note that we are assuming both input and output quantities are divisible and, more importantly, both the costs and revenues they generate, respectively, are divisible as well. This is a critical issue in banking, since information disaggregated enough is not always available.

Technology is defined as

⁴Some recent initiatives have also focused on the econometrics area; however, as suggested by Dorfman and Koop (2005), "the distinction between advances in econometric methods and advances in efficiency measurement is not a clear one".

$$\mathcal{T} = \{ (\boldsymbol{x}, \boldsymbol{y}) : \boldsymbol{x} \text{ can produce } \boldsymbol{y} \},$$
(1)

and input requirement and output sets are defined as

$$\mathcal{L}(\boldsymbol{y}) = \{ \boldsymbol{x} : (\boldsymbol{x}, \boldsymbol{y}) \in \mathcal{T} \}, \boldsymbol{y} \in \mathbb{R}^M_+,$$
(2)

and

$$\mathcal{P}(\boldsymbol{x}) = \{ \boldsymbol{y} : (\boldsymbol{x}, \boldsymbol{y}) \in \mathcal{T} \}, \ \boldsymbol{x} \in \mathbb{R}^N_+,$$
(3)

respectively.

If \boldsymbol{x}_s^* and \boldsymbol{y}_s^* are the optimal input and output vectors for firm $s, s = 1, \ldots, S$, respectively, cost and revenue efficiency indexes will be defined as $CE_s = \boldsymbol{\omega}_s' \boldsymbol{x}_s^* / \boldsymbol{\omega}_s' \boldsymbol{x}_s$ and $RE_s = \boldsymbol{p}_s' \boldsymbol{y}_s / \boldsymbol{p}_s' \boldsymbol{y}_s^*$. The indexes will be bounded by unity from above and below for cost efficiency and revenue efficiency, respectively, namely, in either case efficient firms will be those with efficiency scores equal to one—or 100, if results were expressed as percentages. However, so as to ease comparison of results, we invert revenue efficiency indexes.

Optimal values are found by solving linear programming problem. For cost efficiency, the linear programming problem (where \mathbf{X} and \mathbf{Y} are observed data) for each *s* firm is as follows:

$$\begin{split} \min_{\boldsymbol{\lambda}, \boldsymbol{x}_{s}^{*}} & \boldsymbol{\omega}_{s}^{\prime} \boldsymbol{x}_{s}^{*} \\ \text{s.t.} & -\boldsymbol{y}_{s} + \mathbf{Y} \boldsymbol{\lambda} \geq \boldsymbol{0}, \\ & \boldsymbol{x}_{s}^{*} - \mathbf{X} \boldsymbol{\lambda} \geq \boldsymbol{0}, \\ & \boldsymbol{1} \boldsymbol{\lambda} = \boldsymbol{1}, \\ & \boldsymbol{\lambda} \geq \boldsymbol{0}. \end{split}$$
(4)

whereas maximal revenues will be obtained by solving the following linear programming problem:

$$\begin{aligned} \max_{\boldsymbol{\lambda}, \boldsymbol{y}_{s}^{*}} & \boldsymbol{p}_{s}^{\prime} \boldsymbol{y}_{s}^{*} \\ \text{s.t.} & -\boldsymbol{y}_{s}^{*} + \mathbf{Y} \boldsymbol{\lambda} \geq \boldsymbol{0}, \\ & \boldsymbol{x}_{s} - \mathbf{X} \boldsymbol{\lambda} \geq \boldsymbol{0}, \\ & \boldsymbol{1} \boldsymbol{\lambda} = \boldsymbol{1}, \\ & \boldsymbol{\lambda} \geq \boldsymbol{0}. \end{aligned}$$
(5)

2.2. Data, inputs, and outputs

Data are provided by the Spanish Confederation of Savings Banks (Confederación Española de Cajas de Ahorro, CECA) and the Spanish Association of Commercial Banks (Asociación Española de Banca, AEB) for years 1992 through 2003. This is the only public information available for Spanish commercial and savings banks at the individual firm level. Although the Bank of Spain provides some further disaggregated information for different balance sheet categories, it is available only for aggregated data—i.e., commercial banks and/or savings banks considered altogether. Data come from each firm's balance sheet and profit

and loss account. The overwhelming majority of firms making up the industry are considered in the study. Only those banks for which either missing or unreliable information (zero employees, etc.) were excluded from the study.

Specifying inputs and, especially, outputs, is often a controversial issue in banking. On the input side, our choice is standard and stands with most previous literature. We consider three inputs, namely, labor (x_1) , capital (x_2) and purchased funds (x_3) . See Table 1 for specific definitions and summary statistics for year 2003. We can calculate prices for each input category since information on the costs they generate is also available—i.e., labor expenses, amortizations and other noninterest expenses, and financial costs, respectively. Modeling the output side entails some added difficulties. There exist three basic approaches to define bank output, namely, the asset, user cost, and value-added approach (Berger and Humphrey, 1992). Most studies fall under the first category, basically due to data limitations. Many others have considered an "enlarged" version of the asset approach, considering not only that asset categories yielding revenues are to be considered outputs, but also that transaction deposits are also an output, since they may be considered a proxy for the provision of payment and safekeeping services provided by each bank. However, there is no available disaggregation for deposits, which severely restrains our choice.

Taking into account the rationale presented above, we consider banks to provide four outputs: loans (y_1) , fixed-income securities (y_2) , other securities (y_3) , and nontraditional output (y_4) . Specific descriptions for each of them, along with descriptive statistics, are provided in Table 1. Our choice is also conditional on the available information on the revenues attributable to each output category. Following Rogers (1998), we have also considered a further category, namely, nontraditional output, based on Rogers' findings which pointed out that disregarding the new activities in which most banks engage (basically activities that provide financial services and generate fee income) leads to biased efficiency estimates for both cost, revenue, and profit efficiency.⁵

2.3. Results

Results are displayed in Table 2, for cost efficiency, and Table 3, for revenue efficiency. Technical and allocative efficiencies are also reported, for both input and output orientations (see tables 4, 5, 6 and 7). We provide a variety of summary statistics to achieve better insights on the peculiar distributions of efficiencies. We find marked differences not only for each type of efficiency but also for the different types of firms and their sizes. We also find differences over time.

Mean <u>cost</u> efficiency has been declining from 0.843 in 1992 to 0.698 by 1999 for all banking firms, reviving to reach 0.760 by 2003. Commercial banks were the best performers; they departed from 0.912, bottomed at 0.749 by 1999, but ended up with efficiency levels as of 1992. A similar pattern is found for savings banks, yet their efficiency is substantially lower. Savings banks also bottomed earlier, declining from 0.774 to 0.625 in 1998, reaching 0.683 by the end of the sample period. Weighted values are higher in all instances, yet the inflection by the end of the nineties is mirrored. In this case, the inflection occurs earlier, suggesting that large firms could be leading in an industry characterized by rapid change.

⁵See also the relevant discussion on the "decline" of traditional banking (Edwards and Mishkin, 1995).

Results differ substantially on the <u>revenue</u> side. Although optimal revenues were measured so as to provide revenue efficiency scores bounded from <u>below</u>, results have been inverted (divided by 1) so as to ease comparison with cost efficiency. An inflection point is found again, yet it occurs later, between years 2001 and 2002. Therefore, the declining cost efficiency was partly offset by the revenue side, since the decline for the latter occurred slightly later. There is a seamless link between our results and previous findings for the Spanish banking sector. The reversal in the increasing cost efficiency found in Tortosa-Ausina (2002) by the middle nineties is mirrored here, and the declining trend is found to continue.

Therefore, despite the intense regulatory initiatives, inefficiency not only persists but also increases over time. In addition, although all banking firms face the same regulation, and they can perform the same operations,⁶ cost efficiency differences, on average, are not fading away. However, savings banks regain ground on the revenue side, ending up better off than commercial banks. Thus one might tentatively conclude that some firms are focussing on more expensive ranges of products and services, probably innovating more financially and, therefore, evaluating their performance considering only the cost side provides just a partial, biased view. However, the results in our study must be valued with care, since the number of firms differs for each period. Under these circumstances, declining average efficiency means only that, on average, banks are performing worse against each period's benchmark. However, the benchmark (the frontier) might be shifting—i.e., there could exist simultaneously technological progress and efficiency regress.

The decomposition of cost and revenue efficiency into their technical and allocative components is quite revealing, since the sources of inefficiency are identified. Technical efficiency, both on the input and output sides (Table 4 and Table 5, respectively), is quite impressive, reaching *mean* values close to 100% in some cases. Firms' performances are much closer than in the cost and revenues cases, as revealed by much lower standard deviations. Allocative efficiency, on the other hand, presents more instability, since it does not differ a great deal from technical efficiency at the beginning of the sample period, yet ends up being, on average, much lower. Therefore, when prices do not enter the analysis one faces an industry where most firms are close to the efficient frontier. However, when they are included, discrepancies are remarkable, driving efficiency downwards.

Tables 2–7 contain also additional summary statistics on efficiency scores. Yet their informativeness is overshadowed by what more comprehensive, graphical based, indicators such as boxplots reveal. Boxplots are displayed in Figure 1 for all types of efficiency studied. In each of the subfigures the vertical axis represents the variable's scale—which, in the case of efficiency scores, is bounded between 0 and 1. The box represents the interquartile range (IQR), containing the 50% midrange values of efficiency. A small interquartile range is shown by a relatively short box, indicating a tighter concentration of the efficiencies'

⁶The Spanish banking system is made up of private commercial banks, savings banks, and credit co-operatives. For regulatory reasons, they have traditionally specialized in different lines of business. Today, they face exactly the same operational regulation, which allows them to undertake the same activities. The only regulatory differences they face arise from their ownership type, as commercial banks are privately owned, savings banks are foundations, and credit co-operatives are mutually owned. This difference is subtle, as savings banks are allowed to acquire commercial banks, but the opposite does not hold, as the former are a mix of privately- and publicly-owned companies. In contrast, due to this ownership type, savings banks have substantial difficulties in gaining equity. In fact, 50% of their profits has to be dedicated to increasing reserves. However, the three types of firms are still influenced by their historical specializations, although over the last few years firms' product mixes have varied greatly. See Crespf *et al.* (2004) for deeper insights on the peculiar ownership type of Spanish savings banks.

mid-values. The horizontal line inside the box is the median. The location of this line relative to the top and bottom of the box conveys graphical information on the symmetry of the distribution; if the median centrally located, the distribution is asymmetrical. The whiskers, also called adjacent values, define the natural bounds of the distributions (the mean $\pm 1.5IQR$), while the crosses represent outliers which lie outside the natural bounds. The whiskers define the expected range of observations, indicating also how far outliers are from the natural limits of the distribution.

Considering the banking industry as a whole, Figure 1(a) indicates that discrepancies are important on the cost side, and they increase over time. The increasing tendency is paralleled in the revenue side. However, as revealed by the shape of the boxes, as well as the position of the whiskers and the outliers, there exists a great variety of firm behavior. These trends are not entirely coincidental when analyzing the trends for each type of firm—Figure 1(b) and Figure 1(c). Differences among commercial banks increase rapidly, especially on the revenue side; on the other hand, savings banks' behavior is much more homogeneous, although differences seem also to be growing.

What has not been examined elsewhere are the precise links between cost and revenue efficiency. As suggested in Section 2, recent changes in the Spanish banking industry have reshaped many firms' strategies, especially those of savings banks, which can now choose less regulation-conditioned product mixes. Therefore, firms leaning toward more cost-intensive products and services could be very cost inefficient yet, on the other side, be revenue efficient. These ideas have been exploited by Berger and Mester (1997), Dietsch and Weill (2000) or, in an application to the Spanish banking system, Maudos and Pastor (2003), and comparisons are usually based on correlation coefficients. In our specific setting, correlation coefficients between cost and revenue efficiency generally support the view of increasing differences over time—see Table 8. We argue here that these statistics carry meaningful information, yet not as much as, for instance, bivariate density functions.

These are estimated by means of kernel smoothing. Details are provided in Appendix A and elsewhere (see, for instance, Silverman, 1986). Results are shown in figures 2, 3 and 4 for all banking firms, commercial banks, and savings banks, respectively. We confine the analysis to both cost and revenue efficiency, so as not to strain the very limits of space. The upper panels in each figure contain perspective plots, whereas the lower panels display contour plots. In each figure probability mass shows how firms' relative positions vary according to whether we consider cost or revenue efficiency. Thus, if probability mass were totally located along the 45-degree line, cost and revenue efficiency would be the same for each and every firm—their relative positions do not vary, and the revenue analysis would not add anything new. On the other hand, if it were distributed along a hypothetical negatively-sloped diagonal (135-degree), cost and revenue efficiency would be at stark contrast for most firms. Hence, for those firms at the upper-left end of each contour plot, revenue efficiency would be much higher than cost efficiency, whereas for those firms at the lower-right end of each figure, the opposite would hold. In this extreme case, the hypotheses stated in Section 2 would be totally validated.

Results can be explored from multiple angles. Neither of the extreme views holds—i.e., although each firm's cost and revenue efficiency scores are not entirely coincidental, they do not completely move in opposite directions. However, the probability mass abandoning the 45-degree line following a clockwise

twist suggests that the most cost inefficient firms offset their poor behavior via revenue efficiencies above average. This is observed, with some exceptions, regardless of the type of firm considered (commercial banks, savings banks), and the time span (1992–1995, 1996–1999, or 2000–2003). Regarding the selection of periods, we have taken into account those years in which the effects of deregulation were still apparent (1992–1995), e.g., many savings banks were deeply involved in mergers, and those others renowned by the surge in economic activity (1996–1999, and 2000–2003).

A deeper scrutiny of results suggests that, should we take the banking industry as a whole, a tendency for revenue efficiency to beat cost efficiency is observed, since the probability mass shifts clockwise. This trend is common for all three subperiods (1992–1995, 1996–1999, and 2000–2003). However, over time, the probability is increasingly spreading out, coinciding with the epoch in which firms have been more profitable (1996–2003). We also observe that cost inefficiency increases, but the trend is not mirrored on the revenue side. Therefore, it seems that the higher revenues might have contributed more to increased profitability than lowering costs, since cost and revenue efficiency have moved in opposite directions. Yet the different type of firms have not behaved the same, since commercial banks' pattern (Figure 3) follows an abrupt evolution, whereas savings banks' (Figure 4) is milder.

Therefore, the results obtained so far provide a deeper understanding of the relationship between the different types of efficiencies. Although the analysis has been fairly confined to the comparison of cost and revenue efficiency, the same could be done for their technical and allocative components, or even to compare cost efficiency with technical efficiency and so forth. An analysis as such enriches our conclusions on the precise links between the different concepts being measured. Therefore, we can respond more properly to the question as to whether financial institutions are equally cost and revenue efficiency—or, as considered in other studies, profit efficiency.

3. Bank efficiency and return to the dollar

Deregulation introduced in European banking markets is intended to pursue—amongst other attempts the goal of increasing efficiency in the provision of financial services by increasing competition. However, previous literature has not found a clear and steady improvement over time. Yet in our case, considering the whole sample (both commercial banks and savings banks), profitability, measured by Georgescu-Roegen's (1951) notion of "return to the dollar", defined as the ratio of revenues and costs, increased sharply in the past few years. See Figure 5, which provides information on the relationship between banks' revenues and costs both with and without accounting for firms' size (Figure 5.a and Figure 5.b, respectively). These contrasting trends need further investigation, the theoretical underpinnings were briefly presented in the introduction.

According to these diverging trends, entirely based on averages, one might roughly conclude either that the ES hypothesis does not hold or, for instance, that we are facing a concentrated industry in which market power exists and firms are earning monopoly rents at the expense of consumers' welfare. Indeed, some recent studies have found that market power exists in Spanish banking (Maudos and Pérez, 2003; Salas and Saurina, 2003), and even in European banking (Fernández de Guevara *et al.*, 2005). Previous evidence shared these views (e.g., Neven and Röller, 1999), although findings also differed from country to country (Molyneux *et al.*, 1994). Therefore, the empirical evidence resembles that obtained by Berger and Hannan (1998), whose findings suggested that in more concentrated markets efficiency of banks worsens, since the absence of competitive pressures results in lessened effort by managers to minimize costs. Managers can simply enjoy a "quiet life", translating higher inefficiencies into higher prices.

Therefore, based on these views, which show that increasing profits and decreasing (or stagnant) efficiency are occurring simultaneously, one could infer that inefficient firms might be translating their higher costs into higher profits and still earn abnormal returns. These views would be in contrast to what Berger (1995) found for the U.S. banking industry, were X-efficiency was associated with higher profits. As suggested in the introduction, we explore the relationship assuming a rather loose approach, postulating no a priori relationship between both return to the dollar and efficiency.

3.1. Method: nonparametric and spline smoothing regression

A mere cursory look at the empirical literature in most fields of economics reveals that a majority of applications use simple parametric approaches such as ordinary least squares (OLS) regression or two-stage least squares accompanied by simple descriptive statistics (DiNardo and Tobias, 2001). This approach resembles classical statistics, which is heavily based on parametric models—for example, observations are often regarded as a random sample from an underlying Gaussian distribution with an unknown mean and variance to be estimated from data. (Parametric) regression has possibly been the most popular data-based technique for understanding the way two variables are related, especially for those cases falling into the "cause and effect" class. Yet these techniques have often been employed in an *ad hoc* way, without taking much account of the underlying mechanism of the relationship being modeled.

This type of linear model represents valid alternatives in most cases. Yet sometimes their choice only entails a fair preliminary approach and can sometimes be very restrictive, leading to departures from reality. Indeed, in econometrics, the assumption of statistical adequacy, or correct model specification has often constituted an important concern, and functional forms misspecified may lead to invalid tests for the hypotheses under discussion. Although there are circumstances in which transformations and/or quadratic terms can be used to handle nonlinearities, it should be kept in mind that their use can require a good deal of expertise and time. Therefore, it remains an open question as to why more flexible methods—such as nonparametric regression—are still far from overused by economists, despite the recent (and not so recent) advances in this field by the statistics and econometrics literatures (DiNardo and Tobias, 2001).

Nonparametric regression allows us to understand how some variable of interest, in our case the efficiency (Y or, in our particular setting, EFF) of any particular decision unit, is affected by variations in some other variable X. The utmost advantage of this type of technique—compared to parametric methods such as linear or polynomial regression—is its absence of a priori assumptions concerning the particular functional form on the link between Y and X.

As mentioned above, despite their advantages, the techniques being weighed up remain far from overused by economists. Whereas one may find some applications of kernel regression, spline smoothing approaches are scarcer (see, for instance, Bao and Wan, 2004). Despite their current, and growing, popularity among statisticians, their generalized use in economics is still yet to come. However, several studies have been already devoted to compare a variety of nonparametric techniques one may consider, claiming for their advantages when applied to economics problems (see, for instance Engel and Kneip, 1996).

Some monographs cover the topic of nonparametric and spline smoothing regression; see, for instance, Härdle (1990), Härdle and Linton (1994), Härdle *et al.* (2004), Pagan and Ullah (1999), or Ruppert *et al.* (2003). However, although many different methods have been proposed to construct nonparametric estimates of a smooth regression function, the attention devoted to the different smoothing methods has not been great. Among them, the kernel, k-nearest neighbor (k - NN), orthogonal series and spline estimators have received far more attention than some others such as recursive techniques, the regressogram, convolution smoothing, median smoothing, split linear fits or empirical regression which notwithstanding represent satisfactory choices in some specific cases (see Härdle, 1990).

A comparison among the three most popular and easy-to-implement methods, namely, the kernel, the k-nearest neighbor, and the (cubic) spline smoothers, is performed in Härdle (1990), both in theoretical and empirical terms.

The underpinnings of nonparametric regression methods are as follows. For a particular data set $\{(X_s, Y_s)\}_{s=1}^S$, we are interested in estimating the mean response curve m:

$$Y_s = m(X_s) + \varepsilon_s, \ s = 1, \dots, S.$$
(6)

It is often difficult to ascertain the particular nature of $m(\bullet)$, i.e., it is difficult to know whether the relationship is linear, quadratic, growing in X, etc. In such cases, nonparametric regression advantages turn out to be especially relevant. The basic idea consists of obtaining the conditional average of Y on a particular value for X (such as, e.g., X_s), by defining an interval in a neighborhood of the evaluation point x and computing a weighted average for those values of Y corresponding to the observations inside the interval. Therefore, it is a local averaging procedure in which the local average is calculated from observations in a small neighborhood of x. The procedure could therefore be defined as:

$$\widehat{m}(x) = s^{-1} \sum_{s=1}^{n} W_{Ss}(x) Y_s, \tag{7}$$

where $\{W_{Ss}(x)\}_{s=1}^{S}$ is the sequence of weights depending on the whole $\{X_s\}_{s=1}^{S}$ vector, which meets several properties (see Härdle, 1990). It is feasible to define the sequence of weights by picking a *kernel* function which tunes the size and shape of the weights in the vicinity of x. Therefore, considering the kernel estimator devised by Rosenblatt (1956) and Parzen (1962), \hat{f}_h , which estimates the marginal density of X, the sequence would be defined as:

$$W_{Ss}(x) = K_h(x - X_s)/\widehat{f}_h(x), \tag{8}$$

where

$$\widehat{f}_h(x) = S^{-1} \sum_{s=1}^{S} K_h(x - X_s),$$
(9)

and

$$K_h(u) = h^{-1} K(u/h)$$
(10)

Nadaraya (1964) and Watson (1964) proposed the so-called Nadaraya-Watson estimator to estimate (8):

$$\widehat{m}_{h} = \frac{\sum_{s=1}^{S} K_{h}(x - X_{s})Y_{s}}{\sum_{s=1}^{S} K_{h}(x - X_{s})}$$
(11)

Yet there is another popular kernel regression estimator, namely, the Gasser-Müller estimator—due to Gasser and Müller (1979)—which has some technical advantages over the Nadaraya-Watson estimator. However, under most circumstances, there is no clear preference between the two kernel-regression methods. Since in most cases the choice of bandwidth has quite an effect, larger than that attributable to the choice of estimator, and that some advances in bandwidth estimation have been developed considering the Gasser-Müller estimator, this will be our choice.

The Gasser-Müller estimator can be represented as a convolution of the data with the kernel function:

$$\hat{m}_{GM}(x) = \frac{1}{h} \sum_{s=1}^{S} \int_{s_s}^{s_{s+1}} K\left(\frac{x-u}{h}\right) du Y_s$$
(12)

Additionally, the choice of kernel K consists of several alternatives. For simplicity, we chose the Gaussian kernel, whose expression follows:

$$K(u) = (2\pi)^{-1/2} \exp(-u^2/2).$$
(13)

However, nonparametric regression is comparatively more noticeably influenced by the choice of bandwidth, window width or smoothing parameter, for which a relevant literature exists. We have considered the family of locally adaptive kernel regression estimators considered in Herrmann (1997), or Brockmann et al. (1993). These methods provide a vector of bandwidths instead of a single bandwidth, bearing in mind that data structures might vary a great deal for different (X, Y) combinations.

Apart from the popular kernel smoothing method considered above, we have also considered penalized smoothing splines, not only because of their growing popularity among statisticians, but especially due to their seamless link with semiparametric approaches to regression. An excellent comparison of smoothing splines, k-nearest neighbor (k-NN) and kernel estimators is provided by Jennen-Steinmetz and Gasser (1988). Accordingly, several studies such as Bao and Wan (2004) have considered this alternative, considering that, as suggested above, in some circumstances the underlying theories are not capable of conveying sufficient information to enable a correct and successful specification of parametric models.

As suggested by Jennen-Steinmetz and Gasser (1988), out of the three best-known estimators of the nonparametric regression problem—smoothing splines, k-nearest neighbor estimator, and kernel estimatorsthe large body of theoretical results regarding asymptotic properties of these estimators has so far not solved the problem as to which method is always best and, if not, under which circumstances each method is preferable. Therefore, we consider both kernel estimators and spline smoothing. Several comparative studies exist such as Jennen-Steinmetz and Gasser (1988) and, in an application to Engel curves estimation, see Engel and Kneip (1996).

Specifically, in this paper we consider the *penalized* (or *p*-splines) variant to smoothing splines (see Ruppert and Carroll, 2000), whose novelty is that a penalty is introduced so as to adapt for possible spatial heterogeneity in the regression function. Similarly to kernel regression, we assume m in Equation (6) to be a smooth function equal to the conditional mean of y_s given x_s , which is estimated using a regression spline model:

$$\widehat{m}(x;\beta) = \beta_0 + \beta_1 x + \ldots + \beta_p x^p + \sum_{k=1}^K \beta_{p+k} (x - \kappa_k)_+^p.$$
(14)

Splines are essentially piecewise polynomials whose different polynomial segments are tied together at a series of knots in a way that insures certain continuity properties (Bao and Wan, 2004). In Equation (14) the knots are represented by $\kappa_1, \kappa_2, \ldots, \kappa_K$, whereas $p \ge 1$ is an integer, $\beta = (\beta_0, \ldots, \beta_p, \beta_{p+1}, \ldots, \beta_{p+K})^{\top}$, with β_p the coefficient of the p^{th} knot, is a vector of regression coefficients, and $(u)_+^p = u^p I(u \ge 0)$. Since the number of knots determines whether the fit may be too rough, or too smooth (too many knots yield quite a rough fit), it may be relevant to constrain their influence. Penalized spline regression provides means for doing so, hoping to result into a less variable fit.

Equation (14) represents a spline model of general degree (i.e., a p^{th} -degree spline) in which, using truncated power functions, the basis is:

$$1, x, \ldots, x^p, (x - \kappa_1)^p_+, \ldots, (x - \kappa_k)^p_+$$

which is known as the truncated power basis of degree p. When p is odd, a set of basis functions spanning the space of p^{th} -degree polynomials with knots at $\kappa_1, \ldots, \kappa_K$ is

$$1, x, \ldots, x^p, |x - \kappa_1|^p, \ldots, |x - \kappa_k|^p.$$

Smoothing splines have a natural representation in terms of this type of functions, sometimes called radial basis functions (Ruppert *et al.*, 2003). Specifically, we consider the cubic smoothing spline:

$$\widehat{m}(x;\boldsymbol{\beta}) = \beta_0 + \beta_1 x + \sum_{k=1}^{K} \beta_{1k} |x - \kappa_k|^3$$
(15)

where $\hat{\beta}_0, \hat{\beta}_1$ and $\hat{\beta}_{11}, \ldots, \hat{\beta}_{1K}$ minimize

$$||\mathbf{y} - \mathbf{X}_0 \boldsymbol{\beta}_0 - \mathbf{X}_1 \boldsymbol{\beta}_1||^2 + \lambda^3 \boldsymbol{\beta}_1^\top \mathbf{K} \boldsymbol{\beta}_1$$
(16)

subject to

$$\mathbf{X}_0^\top \boldsymbol{\beta}_1 = \mathbf{0},\tag{17}$$

where $\beta_0 \equiv [\beta_0, \beta_1]^{\top}, \beta_1 = [\beta_{11}, \dots, \beta_{1K}]^{\top}, \mathbf{X}_0 = [1, x_i]_{1 \le i \le n}$, and:

$$\mathbf{X}_1 = \left[|x_i - \kappa_k|^3 \right], \ \mathbf{K} = \left[|\kappa_k - \kappa_{k'}|^3 \right]$$

This is accomplished by specifying a knot sequence $\kappa_1, \ldots, \kappa_K$ using the basis functions $1, x, |x - \kappa_1|^3, \ldots, |x - \kappa_K|^3$ (Ruppert *et al.*, 2003). We have followed Ruppert *et al.* (2003) regarding the choice of smoothing parameter and knots' position.

3.2. Results: on the causality between efficiency and return to the dollar

The results above could suggest that most firms have faced difficulties in managing their resources in recent years—at least when compared with their most successful peers. Yet simultaneously, profitability, as measured by the revenue-to-cost ratio, or the return to the dollar concept (Georgescu-Roegen, 1951) has been increasing at a great pace. If we also recall that when including prices higher inefficiencies are found, together with the existence of market power found in recent studies on the Spanish banking system, it seems we are facing some elements which must be "triangulated"—i.e., the variability of return to the dollar, efficiency (in all its components), and the existence of market power.

The links between our profitability measure and the variety of efficiency concepts considered here are explored in figures 6–11. Figures 6–8 display nonparametric kernel regression curves with bandwidths estimated using local adaptive methods (see Brockmann *et al.*, 1993; Herrmann, 1997) for all cost, technical, and allocative efficiency. Figures 9–11 explore the same topic using spline smoothing (see Ruppert *et al.*, 2003) and for all three types of efficiencies as well. All estimations have been performed for the entire 1992–2003 period. Each figure contains three panels: banking firms, commercial banks, and savings banks.

When considering the relationship between return to the dollar and cost or revenue efficiency estimated via kernel regression (Figure 6), the difficulties of fitting a linear model are blatant due to the apparent nonlinearity of the relationship. Should all banking firms be considered, both panels in Figure 6.a (for cost and revenue efficiency) show a U-inverted functional form, driven mostly by commercial banks behavior as shown by Figure 6.b. For those firms facing difficulties (firms whose costs are higher than revenues, RD < 1), the relationship is found to be **positive**. However, an inflection point is observed in the vicinity of 1 < RD < 1.2, for both commercial banks and banking firms as a whole, and the nonparametric regression line turns negative almost until the very end. The trend is similar for both types of efficiency, although some specificities exist for each case, namely, whereas cost efficiency shows a milder trend for firms with positive returns, revenue efficiency displays a more marked inverted-U shape; besides, for low values of RD the shape of the curve is mostly determined by some outliers.

The panorama is slightly different for savings banks (see Figure 6.c), since for all these firms revenues

are higher than costs.⁷ In addition, their homogeneity explains their comparatively similar performance their efficiencies' range shrinks notably compared to that of commercial banks'. For cost efficiency, the trend closely resembles that found for commercial banks, yet for revenue efficiency no clear pattern emerges.

Estimation under spline methods for cost and revenue efficiency appears in figures 9.a–9.c for banking firms, commercial banks, and savings banks, respectively. Akin to what considered above, the left panel in each figure reflects the relationship for cost efficiency, whereas the right panel reflects it for revenue efficiency. The relationships closely resemble those found above. Specifically, the inverted-U functional form is found for banking firms as a whole, especially for revenue efficiency, and the trend is mainly driven by commercial banks. In addition, we also provide standard error bands—in particular, pointwise ± 2 std. error bands—which provide a more precise view of the probability mass supporting the sign of the relationship. They clearly suggest that, in the case of savings banks, the trends are not only milder but, in the case of revenue efficiency, the relationship is positive; however, the wide standard error bands do not provide statistical support to this claim.

Recent findings on the Spanish banking sector help to explain the patterns found above. In particular, the existence of market power found in Maudos and Pérez (2003) or Fernández de Guevara *et al.* (2005) suggests prices might play quite a role. So as to disentangle this, we perform the regression analysis for the technical and allocative components of cost and revenue efficiency.

As revealed in figures 7.a–7.c and 8.a–8.c, for kernel regression, the patterns found for cost and revenue efficiency are mostly driven by their allocative components. The trend is apparent for any type of firm. Spline smoothing regression does also confirm these findings (see figures 10.a–10.c and 8.a–8.c). In the case of technical efficiency, the sign of the relationship is mostly **positive** regardless of the type of firm under analysis; these trend exists for both kernel regression (figures 7.a, 7.b and 7.c) and spline smoothing (figures 10.a, 10.b and 10.c). However, the trends are not entirely coincidental for commercial banks and savings banks.

Allocative efficiency is the main source for the inverted-U relationship found for cost and revenue efficiency. As suggested in figures 8.a–8.c and 11.a–11.c for kernel regression and spline smoothing, respectively, the shape is clearly U-inverted for commercial banks and mostly negative for savings banks—yet there are no savings banks for which costs overcome revenues.

4. Concluding remarks

This article has analyzed cost and revenue efficiency for Spanish financial institutions, focusing both on the precise links between the two concepts along with their likely relationship with bank profitability. The analysis has been performed using a fully consistent approach in which nonparametric techniques are employed not only for measuring bank efficiency but also in the second stage of the analysis, in which a deeper understanding of the relationship between efficiency and profits is investigated.

The first part of the study is entirely devoted to efficiency measurement, for which we employ activity

 $^{^7\}mathrm{Some}$ of the reasons explaining this have been put forward in section 1.

analysis techniques. Specifically, we used Data Envelopment Analysis to measure both cost <u>and</u> revenue efficiency; this is important since the revenue side has been largely ignored by many bank efficiency studies, yet it has been proved to be as relevant as the cost side as a source of inefficiencies. Our results suggest it is important to consider both sides of inefficiency. Not only is its magnitude found to be substantial for every side of the analysis; but also, we find that despite the fact that both commercial banks and savings banks do not show remarkable discrepancies when attempting to maximize revenues, the same does not hold when assessing their efforts to minimize costs—for which savings banks are found to face greater difficulties. Factoring in the time variable is also appropriate since, over time, dissimilarities between cost and revenue increase, especially for commercial banks. However, results are difficult to summarize, since for all the types of firm under analysis, the efficiency studied, and the period considered play a non-negligible role.

The second part of the analysis leans towards the likely connections between efficiency and profitability, using the Georgescu-Roegen's (1951) return-to-the-dollar concept as a byword for profits. Although previous initiatives had already debated the topic, their results were far from being conclusive—much on the contrary. We argue that reasons for this may be related to the way in which the (likely) affiliation between the two variables was approached. Specifically, we advocate for a more unrestricted, nonparametric, procedure, in which the linkage is not postulated to be either positive or negative throughout all the profits' range. Seeking for a rather comprehensive approach, a variety of nonparametric regression estimators are used, reaching thought-provoking conclusions. In particular, an inverted *U*-shape is found for both cost and revenue efficiency, especially for commercial banks, suggesting that the least profitable firms have higher incentives to enhance efficiency than the most profitable firms in the industry. Therefore, one might conclude that managers might face higher difficulties when attempting to run their firms in "good" times than in "bad" times.

The analysis steps further by assessing how the different components of inefficiency—technical and allocative—are linked to the return to the dollar concept, using the same techniques. The analysis for technical efficiency, which sets prices aside, reveals also interesting trends: in this case, a positive relation-ship is found; on the other hand, when prices enter the analysis—allocative efficiency—we find that the relationship is either inverted U-shaped or even negative, which is the case for savings banks. Therefore, the simultaneous existence of high allocative inefficiency and high return to the dollar calls for explanations which could be related to the existence of market power in Spanish banking encountered in recent studies on the Spanish banking sector.

A. Bivariate density estimation

As suggested by Wand and Jones (1995), although scatterplots are the most widely used means of graphically displaying bivariate data sets, they are not free from disadvantages⁸ from which kernel density estimates are exempt. However, although univariate kernel density estimation has received considerable

 $^{^{8}}$ For instance, "the eye is drawn to the peripheries of the data cloud, while structure in the main body of the data will tend to be obscured by the high density points".

attention in the literature, the same does not hold for the bivariate case, which may be partly explained by the difficulties in viewing high dimensional density functions.

The bivariate case constitutes a junction between the univariate and higher-dimensional multivariate cases. Some old difficulties estimating bivariate density functions deal with bandwidth choice, although there have been some important improvements recently.

For a bivariate sample $\mathbf{X}_1, \ldots, \mathbf{X}_n$, the kernel density estimate is defined by:

$$\widehat{f}(\boldsymbol{x}; \mathbf{H}) = n^{-1} \sum_{i=1}^{n} K_{\mathbf{H}}(\boldsymbol{x} - \mathbf{X}_{i})$$
(18)

where $\boldsymbol{x} = (x_1, x_2)^{\top}$, $\mathbf{X}_i = (X_{s1}, X_{s2})^{\top}$, $s = 1, \dots, S$. In our case, $\boldsymbol{x} = (x_1, x_2)^{\top} = (CE, RE)^{\top}$, $\mathbf{X}_s = (CE_s, RE_s)^{\top}$, where CE and RE stand for cost and revenue efficiency, respectively.⁹ K is a bivariate kernel function satisfying $\int K(\boldsymbol{x})d\boldsymbol{x} = 1$ and \mathbf{H} is a symmetric positive definite 2×2 matrix called bandwidth matrix.

The first decision in kernel density estimation regards the choice of kernel. Our computations are based on one of the most popular choices, i.e., the standard bivariate normal density:

$$K(\boldsymbol{x}) = (2\pi)^{-1} \exp\left(-\frac{1}{2}\boldsymbol{x}^{\top}\boldsymbol{x}\right)$$
(19)

However, the relevance of the kernel's choice is overshadowed by the choice of bandwidth matrix. In this case, the innovations' pace has just resumed. Previous work (Wand and Jones, 1994) demonstrated that it was impossible to derive an explicit expression for the plug-in estimator—one of the most up-to-date ones—of **H** for general multivariate kernel density estimators and, consequently, efforts were reallocated towards searching on diagonal bandwidth matrices for bivariate density estimation. However, Duong and Hazelton (2003) have developed further this stem of research by focusing on plug-in methods for selecting a <u>full</u> bandwidth matrix for bivariate kernel density estimation, which can give markedly better performance for some types of densities—and it turns out to be our case. All details on the selection procedure are discussed in Duong and Hazelton (2003).

 $^{^{9}}$ In order not to strain too much the limits of space, comparisons were confined to cost and revenue efficiency only.

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Variable	Variable name	Definition	Mean	Std. dev.
Outputs				
y_1	Loans [‡]	All forms of loans	$10,\!218,\!555.16$	21,432,079.11
y_2	Fixed-income securities [‡]	Fixed-income securities	2,090,161.71	$6,\!650,\!321.65$
y_3	Other securities [‡]	Other securities and participating interests	$802,\!539.46$	$3,\!210,\!842.41$
y_4	Nontraditional output	Noninterest income (net)	$87,\!626.85$	$215,\!877.86$
Output prices				
p_1	Loan rates	Loan revenues/ y_1	0.041	0.010
p_2	Fixed-income securities' rates	Revenues from fixed-income securities/ y_2	0.080	0.214
p_3	Other securities' rates	Revenues from other securities/ y_3	0.094	0.182
Inputs				
x_1	$Labor^{\ddagger}$	Number of employees	2,505	4,827.83
x_2	Capital [‡]	Physical capital	$185,\!679.47$	$364,\!581.79$
x_3	Purchased funds [‡]	All deposit categories	$12,\!446,\!063.86$	28,729,959.75
Input prices				
ω_1	Wages & salaries	Labor expenses/ x_1	51.287	10.627
ω_2	Price of physical capital	$(Amortizations+other noninterest expenses)/x_2$	0.987	1.994
ω_3	Price of purchased funds	Financial costs/ x_3	0.019	0.009

 Table 1: Definition of the relevant variables, 2003

[‡]In thousands of euros.

						-							
		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	Unweighted mean	0.843	0.822	0.814	0.802	0.817	0.734	0.714	0.698	0.733	0.760	0.722	0.760
	Weighted mean	0.928	0.930	0.929	0.904	0.906	0.872	0.845	0.876	0.898	0.910	0.867	0.884
	Std.Dev.	0.113	0.138	0.133	0.138	0.134	0.170	0.181	0.205	0.181	0.164	0.181	0.172
Banking firms	Median	0.839	0.821	0.777	0.775	0.802	0.695	0.682	0.669	0.691	0.753	0.684	0.749
	Kurtosis	-1.032	-0.463	-1.421	-1.067	-1.339	-1.103	-1.137	-1.234	-1.196	-1.156	-1.136	-1.230
	Skewness	-0.058	-0.375	0.225	0.012	0.076	0.306	0.229	0.193	0.236	0.101	0.258	0.010
	# observations	106	104	102	108	105	108	104	100	94	86	94	86
	Unweighted mean	0.912	0.894	0.887	0.874	0.889	0.803	0.795	0.749	0.806	0.816	0.777	0.849
	Weighted mean	0.966	0.967	0.974	0.956	0.954	0.920	0.910	0.936	0.965	0.960	0.939	0.960
	Std.Dev.	0.090	0.126	0.123	0.128	0.116	0.167	0.173	0.225	0.190	0.171	0.203	0.174
Commercial	Median	0.924	0.924	0.928	0.892	0.926	0.792	0.798	0.737	0.846	0.797	0.759	0.902
banks	Kurtosis	-0.332	1.411	-1.069	0.045	-0.580	-1.264	-1.261	-1.338	-1.460	-1.369	-1.442	-0.673
	Skewness	-0.693	-1.362	-0.665	-0.865	-0.750	-0.135	-0.225	-0.236	-0.306	-0.297	-0.216	-0.870
	# observations	53	53	52	58	56	58	54	51	47	41	48	40
	Unweighted mean	0.774	0.747	0.739	0.719	0.735	0.653	0.625	0.644	0.659	0.710	0.665	0.683
	Weighted mean	0.861	0.861	0.847	0.809	0.819	0.785	0.733	0.772	0.786	0.835	0.776	0.794
	Std.Dev.	0.090	0.109	0.096	0.097	0.101	0.137	0.144	0.170	0.138	0.142	0.136	0.128
Savings	Median	0.760	0.737	0.714	0.710	0.719	0.619	0.593	0.601	0.647	0.694	0.646	0.660
banks	Kurtosis	0.101	1.430	1.376	0.669	0.957	-0.060	-0.414	-0.684	-0.299	-0.564	-0.356	-0.204
	Skewness	0.452	-0.134	1.160	0.556	1.013	0.758	0.585	0.553	0.420	0.274	0.430	0.256
	# observations	53	51	50	50	49	50	50	49	47	45	46	46

Table 2: Cost efficiency, 1992–2003

Table 3: Revenue efficiency, 1992–2003

		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	Unweighted mean	0.864	0.835	0.866	0.827	0.863	0.827	0.810	0.799	0.751	0.759	0.767	0.791
	Weighted mean	0.930	0.919	0.936	0.916	0.923	0.886	0.858	0.828	0.869	0.863	0.852	0.879
	Std.Dev.	0.124	0.141	0.105	0.178	0.114	0.142	0.184	0.166	0.157	0.185	0.182	0.181
Banking firms	Median	0.873	0.850	0.873	0.867	0.867	0.847	0.863	0.808	0.764	0.800	0.800	0.828
	Kurtosis	8.829	2.251	3.033	4.204	12.059	4.438	2.975	5.394	0.839	2.123	2.082	3.754
	Skewness	-2.321	-1.399	-1.400	-2.028	-2.668	-1.671	-1.754	-1.861	-0.617	-1.415	-1.363	-1.670
	# observations	106	104	102	108	105	108	104	100	94	86	94	86
	Unweighted mean	0.885	0.843	0.875	0.810	0.871	0.829	0.798	0.793	0.756	0.722	0.745	0.760
	Weighted mean	0.951	0.930	0.953	0.921	0.935	0.878	0.843	0.812	0.900	0.867	0.856	0.889
	Std.Dev.	0.165	0.176	0.134	0.228	0.145	0.169	0.229	0.222	0.198	0.252	0.244	0.248
Commercial	Median	0.937	0.904	0.901	0.898	0.901	0.860	0.892	0.844	0.776	0.800	0.804	0.821
banks	Kurtosis	5.939	1.189	1.560	1.458	8.739	3.548	0.998	2.160	-0.109	-0.457	-0.229	0.608
	Skewness	-2.368	-1.366	-1.405	-1.533	-2.606	-1.653	-1.348	-1.530	-0.592	-0.822	-0.873	-1.053
	# observations	53	53	52	58	56	58	54	51	47	41	48	40
	Unweighted mean	0.843	0.827	0.856	0.847	0.853	0.825	0.823	0.806	0.746	0.792	0.791	0.818
	Weighted mean	0.898	0.900	0.907	0.908	0.905	0.899	0.883	0.854	0.825	0.856	0.846	0.866
	Std.Dev.	0.051	0.094	0.062	0.090	0.062	0.102	0.119	0.074	0.102	0.079	0.074	0.084
Savings	Median	0.836	0.840	0.857	0.852	0.851	0.833	0.852	0.793	0.751	0.800	0.798	0.828
banks	Kurtosis	3.325	3.319	7.281	8.366	4.117	2.413	8.355	0.421	0.942	0.599	1.409	2.111
	Skewness	0.209	-1.356	-1.355	-2.191	-0.490	-1.262	-2.570	0.966	-0.733	0.287	-0.654	-1.134
	# observations	53	51	50	50	49	50	50	49	47	45	46	46

		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	Unweighted mean	0.940	0.918	0.952	0.928	0.948	0.936	0.950	0.970	0.961	0.970	0.957	0.953
Banking firms	Std.Dev.	0.049	0.080	0.045	0.067	0.045	0.074	0.069	0.033	0.047	0.036	0.061	0.069
	Median	0.934	0.917	0.952	0.926	0.946	0.947	0.967	0.977	0.973	0.987	0.979	0.978
	Kurtosis	-1.447	1.537	0.290	2.771	-1.450	6.804	8.605	0.283	2.609	1.000	7.998	4.489
	Skewness	-0.027	-1.171	-0.628	-1.235	-0.133	-2.121	-2.536	-0.911	-1.509	-1.214	-2.489	-2.130
	# observations	106	104	102	108	105	108	104	100	94	86	94	86
	Unweighted mean	0.969	0.949	0.976	0.951	0.971	0.962	0.971	0.983	0.977	0.982	0.970	0.962
	Std.Dev.	0.041	0.078	0.037	0.064	0.037	0.046	0.054	0.024	0.042	0.028	0.057	0.080
Commercial	Median	1.000	0.998	1.000	0.982	0.998	0.992	1.000	1.000	1.000	1.000	1.000	1.000
banks	Kurtosis	-0.235	4.220	0.834	2.859	-0.276	-0.730	10.608	-0.489	9.261	2.775	6.508	4.007
	Skewness	-1.041	-1.984	-1.434	-1.547	-0.990	-0.836	-3.029	-1.030	-2.759	-1.711	-2.559	-2.263
	# observations	53	53	52	58	56	58	54	51	47	41	48	40
	Unweighted mean	0.911	0.887	0.927	0.902	0.920	0.906	0.928	0.956	0.944	0.959	0.943	0.945
	Std.Dev.	0.037	0.070	0.038	0.061	0.038	0.087	0.076	0.036	0.046	0.039	0.063	0.058
Savings	Median	0.902	0.895	0.921	0.904	0.917	0.922	0.942	0.961	0.949	0.968	0.956	0.955
banks	Kurtosis	0.077	2.239	3.158	5.671	-0.245	4.542	7.973	-0.158	1.462	0.246	10.271	7.144
	Skewness	0.759	-1.160	-0.630	-1.659	0.776	-1.906	-2.391	-0.546	-1.002	-0.863	-2.695	-2.231
	# observations	53	51	50	50	49	50	50	49	47	45	46	46

 Table 4: Input technical efficiency, 1992–2003

 Table 5: Output technical efficiency, 1992–2003

		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	Unweighted mean	0.941	0.923	0.954	0.932	0.949	0.940	0.953	0.971	0.962	0.971	0.960	0.957
	Std.Dev.	0.049	0.074	0.043	0.061	0.044	0.067	0.064	0.032	0.046	0.036	0.054	0.059
Banking firms	Median	0.935	0.919	0.953	0.928	0.947	0.951	0.968	0.977	0.974	0.987	0.980	0.979
	Kurtosis	-1.169	1.126	-0.320	1.186	-1.456	5.764	8.159	0.278	2.758	1.355	5.255	3.066
	Skewness	-0.137	-1.042	-0.497	-0.869	-0.147	-1.937	-2.456	-0.911	-1.530	-1.286	-2.095	-1.830
	# observations	106	104	102	108	105	108	104	100	94	86	94	86
	Unweighted mean	0.969	0.954	0.977	0.954	0.972	0.964	0.973	0.984	0.978	0.983	0.973	0.966
	Std.Dev.	0.044	0.067	0.036	0.059	0.036	0.044	0.051	0.023	0.040	0.027	0.052	0.068
Commercial	Median	1.000	0.998	1.000	0.983	0.998	0.992	1.000	1.000	1.000	1.000	1.000	1.000
banks	Kurtosis	1.888	2.782	0.931	2.074	-0.370	-0.719	10.106	-0.464	9.517	3.006	7.046	3.392
	Skewness	-1.447	-1.689	-1.446	-1.395	-0.987	-0.836	-2.961	-1.033	-2.777	-1.767	-2.595	-2.140
	# observations	53	53	52	58	56	58	54	51	47	41	48	40
	Unweighted mean	0.913	0.891	0.929	0.908	0.922	0.913	0.932	0.957	0.946	0.960	0.947	0.948
	Std.Dev.	0.037	0.068	0.036	0.053	0.038	0.078	0.070	0.035	0.046	0.039	0.053	0.050
Savings	Median	0.904	0.898	0.922	0.909	0.917	0.926	0.944	0.961	0.950	0.968	0.957	0.955
banks	Kurtosis	0.062	2.083	1.964	3.190	-0.304	4.035	7.790	-0.180	1.680	0.622	6.005	4.303
	Skewness	0.767	-1.131	-0.278	-1.001	0.744	-1.777	-2.333	-0.538	-1.046	-0.954	-2.022	-1.733
	# observations	53	51	50	50	49	50	50	49	47	45	46	46

		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	Unweighted mean	0.894	0.889	0.852	0.860	0.858	0.779	0.746	0.715	0.758	0.780	0.751	0.793
	Std.Dev.	0.083	0.087	0.110	0.100	0.107	0.142	0.158	0.196	0.163	0.150	0.164	0.147
Banking firms	Median	0.904	0.893	0.830	0.859	0.845	0.752	0.713	0.702	0.723	0.776	0.734	0.771
	Kurtosis	-0.401	-0.676	-1.264	-0.944	-1.166	-1.115	-1.083	-1.204	-1.100	-1.099	-1.015	-1.164
	Skewness	-0.481	-0.358	0.033	-0.096	-0.099	0.290	0.254	0.126	0.208	0.080	0.157	0.010
	# observations	106	104	102	108	105	108	104	100	94	86	94	86
	Unweighted mean	0.940	0.938	0.906	0.915	0.912	0.831	0.816	0.759	0.821	0.828	0.798	0.877
	Std.Dev.	0.067	0.073	0.106	0.087	0.095	0.148	0.157	0.219	0.176	0.160	0.189	0.138
Commercial	Median	0.949	0.957	0.953	0.931	0.942	0.829	0.816	0.745	0.867	0.814	0.816	0.920
banks	Kurtosis	3.788	1.565	-0.704	0.383	-0.155	-1.212	-1.051	-1.303	-1.240	-1.274	-1.232	-0.719
	Skewness	-1.517	-1.383	-0.820	-0.927	-0.899	-0.248	-0.316	-0.290	-0.386	-0.350	-0.354	-0.810
	# observations	53	53	52	58	56	58	54	51	47	41	48	40
	Unweighted mean	0.848	0.838	0.796	0.795	0.797	0.718	0.670	0.670	0.694	0.737	0.702	0.720
	Std.Dev.	0.071	0.069	0.082	0.072	0.084	0.108	0.120	0.158	0.121	0.127	0.117	0.112
Savings banks	Median	0.841	0.836	0.794	0.789	0.795	0.691	0.643	0.628	0.696	0.735	0.697	0.712
	Kurtosis	-0.468	0.668	0.600	0.344	0.143	0.000	-0.192	-0.715	-0.116	-0.411	-0.159	-0.213
	Skewness	-0.076	-0.018	0.591	0.239	0.514	0.721	0.631	0.485	0.405	0.251	0.391	0.213
	# observations	53	51	50	50	49	50	50	49	47	45	46	46

 Table 6: Input allocative efficiency, 1992–2003

 Table 7: Output allocative efficiency, 1992–2003

		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	Unweighted mean	0.919	0.904	0.908	0.885	0.910	0.880	0.849	0.823	0.779	0.781	0.798	0.826
	Std.Dev.	0.116	0.127	0.098	0.174	0.111	0.134	0.178	0.164	0.149	0.185	0.177	0.179
Banking firms	Median	0.941	0.938	0.928	0.946	0.937	0.912	0.903	0.851	0.805	0.820	0.834	0.869
	Kurtosis	18.191	6.970	6.718	6.451	17.055	9.041	4.801	6.925	1.951	2.768	3.511	5.033
	Skewness	-3.937	-2.596	-2.448	-2.570	-3.677	-2.665	-2.238	-2.295	-1.031	-1.697	-1.817	-2.127
	# observations	106	104	102	108	105	108	104	100	94	86	94	86
	Unweighted mean	0.913	0.882	0.895	0.844	0.896	0.861	0.819	0.806	0.772	0.734	0.764	0.785
	Std.Dev.	0.159	0.166	0.128	0.221	0.145	0.172	0.227	0.222	0.195	0.253	0.239	0.247
Commercial	Median	0.968	0.960	0.944	0.947	0.938	0.927	0.910	0.872	0.819	0.813	0.824	0.868
banks	Kurtosis	9.100	2.600	2.636	2.225	9.486	4.445	1.471	2.454	0.253	-0.398	0.189	0.897
	Skewness	-2.989	-1.811	-1.767	-1.737	-2.874	-1.997	-1.526	-1.658	-0.795	-0.906	-1.071	-1.273
	# observations	53	53	52	58	56	58	54	51	47	41	48	40
	Unweighted mean	0.924	0.927	0.921	0.932	0.925	0.901	0.881	0.841	0.786	0.824	0.834	0.862
	Std.Dev.	0.041	0.061	0.047	0.069	0.048	0.061	0.094	0.059	0.082	0.063	0.052	0.071
Savings	Median	0.928	0.936	0.923	0.945	0.933	0.909	0.899	0.831	0.800	0.824	0.837	0.869
banks	Kurtosis	6.065	23.611	18.303	27.534	9.167	9.210	20.677	0.572	1.200	0.435	0.450	8.909
	Skewness	-2.066	-4.145	-3.313	-4.763	-2.366	-2.622	-4.168	0.824	-0.864	0.581	0.019	-2.298
	# observations	53	51	50	50	49	50	50	49	47	45	46	46

Table 8: Spearman	n correlation coeffic	cients betwe	een cost and revenue	efficiency, 19	992-2003
-	Firms	Period	Correlation coefficient	=	
-		1992 - 1995	0.621	_	
	Banking firms	1996 - 1999	0.550		
		2000 - 2003	0.464		
-		1992 - 1995	0.588	_	
	Commercial banks	1996 - 1999	0.467		
		2000 - 2003	0.464		
		1992 - 1995	0.682	-	
	Savings banks	1996 - 1999	0.750		
-		2000 - 2003	0.584	_	

All coefficients significant at 1% level.





Figure 2: Joint densities for cost and revenue efficiency, banking firms (perspective and contour plots)



Densities estimated nonparametrically by means of Gaussian kernel. Bandwidth matrices (2×2) chosen according to Duong and Hazelton (2003).

Figure 3: Joint densities for cost and revenue efficiency, commercial banks (perspective and contour plots)



Densities estimated nonparametrically by means of Gaussian kernel. Bandwidth matrices (2×2) chosen according to Duong and Hazelton (2003).

Figure 4: Joint densities for cost and revenue efficiency, savings banks (perspective and contour plots)



Densities estimated nonparametrically by means of Gaussian kernel. Bandwidth matrices (2×2) chosen according to Duong and Hazelton (2003).



Figure 5: Evolution of revenues as a percentage of costs (RD), 1992–2003

(b) Weighted



Figure 6: Cost efficiency, revenue efficiency, and return to the dollar, nonparametric regression (1992–2003)

Kernel regression smoothing with local plug-in bandwidth.





(c) Savings banks

Kernel regression smoothing with local plug-in bandwidth.





(c) Savings banks

Kernel regression smoothing with local plug-in bandwidth.

Figure 9: Cost efficiency, revenue efficiency, and return to the dollar, spline smoothing regression (1992–2003)





Figure 10: Technical efficiency and return to the dollar, spline smoothing regression (1992–2003)



Figure 11: Allocative efficiency and return to the dollar, spline smoothing regression (1992–2003)

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