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Bank Efficiency: Evidence from a Panel of European Banks

Summary: The goal of this paper is to investigate the efficiency of the banking systems in eight European countries over the period 1994 to 2008 by using the production frontier methodology. The paper shows that risk factors along with a size variable should be taken into account, otherwise inefficiency tends to be overstated.

Key words: Bank efficiency, Stochastic frontier, European banks.

JEL: G21, C13, C32.

Bank efficiency has been analyzed according to the economic growth by many surveys (Robert G. King and Ross Levine 1993; Riccardo Lucchetti, Luca Papi, and Alberto Zazzaro 2001; Michael Koetter and Michael Wedow 2007), which argue that a sound financial system fosters economic growth and vice versa. Lucchetti, Papi, and Zazzaro (2001) state that banks have effects on economic development if they are able to recognize the most innovative entrepreneurs and allocate their financial and real resources in the most efficient and productive way, an opinion agreeing with those of Hyman P. Minsky (1986) and Basil J. Moore (1988).

The "*major shortcoming*" of the above studies, as Koetter and Wedow (2007) point out, is that they analyze the relationship between financial development and growth using quantitative variables, such as size, liquidity, and capitalization, rather than measuring quality, understood as the efficiency of the banking sector. In particular, bank efficiency measures the performance of a bank relative to the performance of a best-practice bank. Ranking the banks this way is feasible and useful for the government policy by showing the effects of deregulation or mergers, for research purposes and for identifying the best and worst practices in order to improve managerial performance (Allen N. Berger and David B. Humphrey 1997).

The rest of the paper is organized as follows. Section 1 reports an analysis of the concept of bank efficiency. Section 2 describes the data and Section 3 describes the econometric methodological approach. Section 4 presents the results and finally, Section 5 concludes.

1. Bank Efficiency

In recent decades banks have operated in an extremely competitive environment. Consequently, in addition to the size, capitalization, liquidity and other quantitative variables, efficiency is an additional factor that banks should take into consideration. This variable has always been an "asset" for the banking system, but was not prioritised, because the circumstances differed from today's and banks were able to operate in those environments. Economic conditions have changed, affecting the way that the banking sector operates. Its structure, its performance and its function had to adapt to the conditions of the time, requiring the banks to become efficient, both because, doing so is crucial for their survival and may offer them a competitive advantage. An efficient banking sector is able to handle negative shocks and contribute to the stability of the financial system.

Banks are efficient, assuming they use the appropriate amounts of inputs and in the right proportions in order to convert them into financial products and services. It comprises a way to evaluate banking performance and separate those banks that perform well from those banks that perform poorly. In other words, it provides a numerical efficiency value and ranking of firms. As Berger and Humphrey (1997, p. 175) mentioned, it is "a sophisticated way to 'benchmark' the relative performance of the production units". The performance of each bank is measured relative to what the performance of a best-practice bank on the efficient frontier would be expected to be if it faced the same exogenous conditions as the bank being measured (Berger 2007).

There are three categories of efficiency: productive, cost and profit efficiency. The first type is related to the production of outputs given some inputs. Specifically, the production plan is assumed to be technically efficient if there is no way to produce more outputs with the same input or to produce the same output with less inputs (Carlo A. Favero and Papi 1995). If managers organize production so that the firm maximizes the amount of output produced with a given amount of inputs, then the firm is operating on its production frontier (Joseph P. Hughes and Loretta J. Mester 2008).

By contrast, cost efficiency measures the ability of a bank to minimize costs given the prices of inputs. To rephrase, this type of efficiency measures how close or far the costs of a bank are from the costs of the best practice bank, producing the same output under the same conditions. If the costs of a bank are larger than the costs of the best practice bank and the difference cannot be explained by any statistical noise, then the bank is characterized as cost inefficient.

Finally, profit efficiency measures the ability of a bank to maximize profits, given the prices of inputs and outputs. In this case it implies output maximization (cost minimization) at a given level of expenditures (output).

There are also several studies that examine whether there are economies of scale and/or scope and consider them a type of efficiency measurement. Economies of scale are evident in the relationship between the average cost per unit of output and the production volume; average production costs fall output increases. By contrast, economies of scope are evident when the joint cost of producing two complementary outputs is less than the combined costs of producing the two outputs sepa-

rately. Alternatively, economies of scope exist between outputs, when the cost of producing them together in a single firm is less than the cost of producing them in different firms (Jeffrey A. Clark 1988).

There are two types of approaches that can be used to estimate the efficiency of the banks: the parametric approach and the non-parametric approach. Both approaches require the specification of a frontier, but the parametric approach involves the specification and the econometric estimation of a statistical or parametric function, whereas the non-parametric approach provides a linear frontier by enveloping the observed data points (Leigh Drake and Maximilian J. B. Hall 2003). In general, both of the approaches study a "best practice production/cost/profit frontier". A serious drawback of the non-parametric approach is that it does not allow for any error in the data and therefore assumes that the final estimates are exclusively due to inefficiencies. In other words, the non-parametric approach does not take into consideration factors that are not under the control of management, measurement errors and other random factors. In this paper we use the stochastic frontier approach, because the inefficiency term is separated from random errors unlike the non-parametric approach and also because several studies have shown that the efficiency results are larger when the non parametric approach is used.

2. Data

The data comprises of banks in eight European countries, namely Austria, Belgium, Denmark, France, Germany, Italy, Luxembourg and the United Kingdom. In particular, balance sheet and income statement data is used, which is obtained from BankScope database spanning the period 1994 to 2008.

There has been considerable controversy over the appropriate definition of bank output. There are two main alternative approaches, labeled the "intermediation approach" and the "production approach". Under the former, financial institutions are viewed as intermediates in financial markets. In other words, they collect deposits and purchase funds that are intermediated into loans and other assets. In the intermediation approach deposits are treated as inputs. By contrast, in the production approach, deposits are treated as outputs, because financial institutions are viewed as producers of services associated with individual loan and deposit accounts (Calvin W. Sealey Jr. and James T. Lindley 1977; Clark 1988). In this paper we follow the intermediation approach, positing that deposits are inputs in the production process of banks.

Consequently, to estimate bank efficiency, we use deposits, labor and fixed assets as inputs in the production process, whereas we treat total loans as outputs. Beyond just the traditional operation of producing loans, we estimate efficiency using total loans, total securities and total non-interest operating income as outputs of the production process. We compare the results with those obtained by the production function in which total loans are the only output.

Additional variables included in the production process as inputs are financial capital and total assets, which control for risk and size respectively. Table 1 reports total assets in each European country as a percentage of the sum of total assets in all countries of the sample. Financial capital is included to account for the risk of insol-

vency and differences in risk preferences (Mester 1996; Berger and Mester 1997). The probability of default depends on the composition of the bank's assets and on its ability to absorb any failed investments through financial capital (Joaquín Maudos et al. 2002). The risk of insolvency can affect efficiency estimates and is treated as an input because it provides cushion against losses and also can be used as a substitute for deposits to fund loans (Mester 1996, 1997).

Several studies have also investigated the impact of quality on efficiency. We incorporate this variable into our empirical analysis for a sub-sample of banks and countries. In this case - a lack of data - the number of observations is reduced significantly because it is difficult to find this information for a substantial number of banks. The variable used as a proxy for quality is the loan impairment charges as a proportion of average gross loans. We should mention that all data is corrected for inflation using individual production price indices as deflators.

Table 1 Total Assets as a Percentage Over the EU-8

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Austria	1.28	1.52	1.40	1.84	1.83	2.00	2.11	2.27	2.53	2.75	2.97	2.08	1.91	1.94	2.63
Belgium	3.08	3.10	3.06	2.53	1.97	1.36	1.55	1.63	1.66	1.54	1.53	1.25	1.11	1.07	1.17
Denmark	0.30	0.64	0.89	0.96	1.60	1.88	1.94	1.61	1.48	2.02	1.85	2.87	2.95	3.14	4.03
France	6.84	7.53	7.53	6.72	7.35	8.38	7.25	9.07	8.95	9.89	9.46	7.85	6.35	6.86	7.44
Germany	68.21	68.80	68.23	74.95	74.49	74.22	78.39	76.33	74.17	73.58	73.83	53.88	46.48	45.73	48.40
Italy	9.60	7.79	7.58	7.89	7.81	7.08	2.91	3.10	1.46	0.82	0.81	21.01	22.55	21.98	22.11
Luxembourg	3.96	3.67	3.35	3.33	2.35	2.66	2.77	2.86	2.47	2.37	2.42	2.43	2.28	2.67	2.67
UK	6.73	6.96	7.97	1.77	2.60	2.42	3.07	3.14	7.28	7.04	7.12	8.64	16.37	16.61	11.55
EU-8	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Notes: EU-8 stands for the eight European countries of the sample.

Source: BankScope database.

The model was developed by Timothy J. Coelli (1996) and in the empirical analysis the estimation is carried out using Frontier 4.1 software (Coelli 1996; Coelli, Rao D. S. Prasada, and George E. Battese 1998). Banks with incomplete data are not included in the sample, since the program does not tolerate missing values (Coelli, Prasada, and Battese 1998). Finally, the software Frontier assisted the empirical analysis.

3. The Econometric Approach

The goal of an efficient bank is to maximize its product given a number of inputs. To estimate efficiency we use the stochastic production function, which was initially proposed by Dennis J. Aigner, Knox C. A. Lovell, and Peter Schmidt (1977) and Wim Meeusen and Julien van Den Broeck (1977). The production function shows the relationship between inputs and outputs (Claudia Girardone, Philip Molyneux, and Edward P. M. Gardener 2004) and measures the output of the i-th bank relative to the output that could have been produced by a fully efficient bank using the same vector of inputs (Coelli, Prasada, and Battese 1998). The production function can

also be interpreted as the frontier of the production alternatives, which extracts the maximum levels of output from adopted inputs. Hence, it indicates the success (or failure) with which the inputs are used, also showing if there is any nonproductive use of resources (Drake and Hall 2003; Ali Awdeh and Chawki El Moussawi 2009). The general form of the production function yields:

$$y_i = \alpha + \beta * x_i + e_i \quad (1)$$

where y_i is the logarithm of the maximum output obtained from x_i, x_i is a vector of logarithms of inputs i, β is the parameter vector to be estimated and e_i is the error term. It is important to mention that the error term is a two-component error term, which can be written as:

$$e_i = v_i - u_i \quad (2)$$

where v_i is a measurement error and other random factors and u_i is the inefficiency component. More precisely, v_i is a two-sided error term, representing statistical noise, factors beyond management's control, measurement errors and approximation errors associated with the choice of the functional form and is assumed to be independently and identically distributed. u_i measures technical inefficiency and is a non-negative random variable that is distributed independently of v_i and ensures that all observations lie on or beneath the stochastic production frontier. Also, v_i is assumed to be normally distributed with mean zero and variance σ^2_v and u_i is assumed to be distributed as half normal with mean μ and variance σ^2_u. We also observe that u_i is subtracted from v_i because the production frontier represents maximum output.

The specification of the functional form used in this paper is the translog production function, which is a generalization of the Cobb – Douglas form with the advantage of more flexibility form than the latter. Another common specification, which, besides the translog form, is widely used in the literature is the Fourier-flexible form. There is considerable controversy over which of the two forms is a better approximation. Several studies (Patrick H. McAllister and Douglas McManus 1993; Karlyn Mitchell and Nur M. Onvural 1996) argue the Fourier-flexible form is a better approximation because it is more flexible, adding Fourier-trigonometric terms to the model and is a global approximation. Other studies find there is little difference in results obtained by the Fourier-flexible and translog form. In this paper, the translog form is used because the Fourier-flexible form requires many variables, sacrificing too many degrees of freedom. Specifically, the stochastic production function takes the form:

$$\ln y_i = \beta_0 + \sum_{i=1}^{3} \beta_i \ln x_i + \frac{1}{2} \sum_{i=1}^{3} \sum_{i-1}^{3} \beta_{ij} \ln x_i \ln x_j + e_i \quad (3)$$

where y_i is the bank output as measured by total loans, xi represents the inputs used - deposits, employees and fixed capital - and β are the parameters of the stochastic production function, estimated using the maximum likelihood approach. Further-

more, the second order parameters of the production function must be symmetric that is $\beta_{ij} = \beta_{ji}$, for all i, j.

The above model is differentiated in the following way when either financial capital or total assets are added:

$$\ln y_i = \beta_0 + \sum_{i=1}^{3} \beta_i \ln x_i + \frac{1}{2} \sum_{i=1}^{3} \sum_{i=1}^{3} \beta_{ij} \ln x_i \ln x_j + \varphi_s \ln S + \frac{1}{2} \varphi_{ss} \ln S \ln S + \sum_{j=1}^{3} \varphi_{sj} \ln S \ln x_j + e_i \tag{4}$$

where S is either the financial capital or total assets. When both of these variables are used, the model is as follows:

$$\ln y_i = \beta_0 + \sum_{i=1}^{3} \beta_i \ln x_i + \frac{1}{2} \sum_{i=1}^{3} \sum_{i=1}^{3} \beta_{ij} \ln x_i \ln x_j + k_k \ln K + \frac{1}{2} k_{kk} \ln K \ln K + \sum_{j=1}^{3} k_{kj} \ln K \ln x_j + \tau_\tau \ln TA + \frac{1}{2} \tau_{tt} \ln TA \ln TA + \sum_{j=1}^{3} \tau_{tj} \ln TA \ln x_j + \rho_{k\tau} \ln K \ln TA + e_i \tag{5}$$

where K is the financial capital and TA is total assets.

4. Empirical Analysis

Concerning the first part of the analysis, the estimation of bank efficiency, results are reported in Table 2 through Table 9. The first four tables report the average efficiency of each country, which is estimated by the production function that uses total loans as the only output of the banking system. The last four tables show the efficiency measures, which are estimated using total loans, total securities and non-interest operating income as outputs.

Table 2 provides the efficiency estimates derived from the production function that does not include either risk or size variables. As can be seen, Germany, Denmark and Austria seem to have the most efficient banking system among the particular group of countries whereas France, Luxembourg and the United Kingdom perform poorly.

The ranking is fairly similar when financial capital is included in the estimation of efficiency (Table 3). Germany, Denmark and Austria still emerge as the most efficient countries, while Luxembourg and France stand at the opposite side. In some countries, efficiency levels are increased in the case that financial capital is taken into account in the production function. This means that risk preferences are important factor and inefficiency seems overstated when they are not included in the specification of the production function. This result is in accordance with the findings of Berger and Mester (1997), Yener Altunbas et al. (2000) and Girardone, Molyneux, and Gardener (2004).

Table 4 reports the efficiency estimates derived from a production function where total assets are used as a size variable. Total assets as a factor alter the results

of efficiency but it is not obvious in what manner. For instance, Germany has the largest percentage of total assets over the group of the eight European countries and is among the most efficient banking systems. By contrast, Denmark also belongs to the most efficient countries even though total assets as a percentage over the total assets of the EU-8 is small. Overall, total assets when used as a size variable improve the results compared to those derived from the standard production function, but they do not alter the ranking of the banking systems. Denmark, Germany, Austria and Italy remain the countries with the most efficient banking systems.

The entries in Table 5 report the efficiency estimates obtained by the translog production function that includes both risk and size variables. The group of four most efficient banking systems Germany, Denmark, Austria and Italy remains the same whereas Luxembourg is the least efficient country. The estimations of Table 5 are improved in most of the years compared to those in Table 2 that are obtained by the standard production function.

Table 2 Efficiency Estimates

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Austria	0.9302	0.5274	0.5106	0.6423	0.9272	0.7456	0.7732	0.7338	0.7848	0.7164	0.7232	0.6840	0.6140	0.5893	0.5952
Belgium	0.4251	0.6168	0.3859	0.3442	0.4278	0.5075	0.4804	0.4492	0.4200	0.3904	0.3319	0.5084	0.5331	0.5627	0.4430
Denmark	0.7502	0.8808	0.9999	0.6108	0.9999	0.5167	0.9973	0.9985	0.9999	0.5322	0.9999	0.9984	0.9987	0.9989	0.9999
France	0.4657	0.4950	0.4685	0.4368	0.4223	0.4600	0.4758	0.4622	0.4269	0.4712	0.5124	0.5386	0.4528	0.4935	0.5244
Germany	0.9153	0.7619	0.7599	0.6934	0.6835	0.6756	0.6835	0.6531	0.6549	0.6470	0.6421	0.6580	0.6549	0.6515	0.6316
Italy	0.9245	0.9981	0.9176	0.9056	0.9098	0.6163	0.6101	0.5290	0.4352	0.4228	0.4829	0.5750	0.5931	0.5932	0.6052
Luxembourg	0.3257	0.4104	0.5080	0.4554	0.3905	0.3444	0.3354	0.3434	0.3263	0.3295	0.3007	0.4038	0.3438	0.2950	0.2882
UK	0.5181	0.5498	0.5534	0.5177	0.4624	0.4816	0.3679	0.4500	0.3672	0.3961	0.3493	0.4012	0.3010	0.3941	0.4580

Notes: Loans are the outputs of the banking system and inputs refer to total deposits, fixed assets and employees. Standard production function estimates.

Source: Authors' calculations.

Table 3 Efficiency Estimates (Including Financial Capital)

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Austria	0.7613	0.6456	0.4995	0.6478	0.7992	0.7301	0.9358	0.9992	0.8002	0.7503	0.9262	0.6847	0.6174	0.6019	0.5996
Belgium	0.4976	0.5783	0.4498	0.4465	0.5033	0.5400	0.8970	0.5794	0.4351	0.4540	0.4509	0.5536	0.5123	0.4860	0.7141
Denmark	0.7976	0.9367	0.8094	0.7513	0.7111	0.9979	0.7674	0.7750	0.6674	0.7061	0.7522	0.7609	0.7679	0.7677	0.7807
France	0.4649	0.4746	0.4855	0.4705	0.4019	0.4730	0.4884	0.4740	0.5107	0.5121	0.5237	0.5675	0.4432	0.5235	0.5784
Germany	0.6917	0.6855	0.6924	0.6739	0.6853	0.6890	0.6840	0.6673	0.6629	0.6518	0.6510	0.6563	0.6626	0.6604	0.6395
Italy	0.9471	0.9449	0.9373	0.9240	0.6927	0.5583	0.6256	0.5184	0.5862	0.5524	0.4440	0.5907	0.6056	0.6118	0.5952
Luxembourg	0.3310	0.4187	0.4893	0.4759	0.3849	0.3381	0.3103	0.3601	0.4190	0.3677	0.3541	0.3995	0.3779	0.3727	0.4604
UK	0.5932	0.7603	0.5124	0.3491	0.4492	0.4984	0.3803	0.5110	0.3842	0.4216	0.4896	0.3945	0.4431	0.4570	0.5119

Notes: Loans are the outputs of the banking system and inputs refer to total deposits, fixed assets and employees. Production function estimates with risk variable.

Source: Authors' calculations.

Table 4 Efficiency Estimates (Including Total Assets)

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Austria	0.7726	0.6654	0.5554	0.7458	0.7293	0.7028	0.7033	0.6989	0.7020	0.6843	0.6617	0.6646	0.6763	0.6281	0.6317
Belgium	0.4984	0.4819	0.4627	0.4042	0.4879	0.6400	0.9064	0.4439	0.3912	0.5072	0.4312	0.4311	0.6322	0.5943	0.8920
Denmark	0.7853	0.7575	0.7829	0.7442	0.6859	0.9459	0.7030	0.7598	0.7254	0.7148	0.7655	0.7746	0.7595	0.7731	0.8098
France	0.4736	0.4987	0.4898	0.5202	0.4913	0.5566	0.5541	0.5172	0.5254	0.4946	0.5702	0.4940	0.5068	0.5525	0.6190
Germany	0.7365	0.7336	0.7367	0.7295	0.7430	0.7452	0.7375	0.7133	0.7102	0.6991	0.6926	0.6935	0.6878	0.6821	0.6696
Italy	0.8233	0.8068	0.8239	0.7252	0.7015	0.6958	0.6373	0.6108	0.5292	0.6457	0.6261	0.6796	0.6995	0.7215	0.7314
Luxembourg	0.3683	0.4014	0.4944	0.4350	0.3501	0.3483	0.3197	0.3953	0.3640	0.4149	0.3693	0.3947	0.3581	0.4119	0.3499
UK	0.7801	0.6070	0.5419	0.6071	0.5051	0.4360	0.4045	0.4549	0.4663	0.4928	0.4879	0.4278	0.4563	0.5048	0.5159

Notes: Loans are the outputs of the banking system and inputs refer to total deposits, fixed assets and employees. Production function estimates with size variable.

Source: Authors' calculations.

Table 5 Efficiency Estimates (Including Financial Capital and Total Assets)

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Austria	0.9584	0.6688	0.6310	0.7303	0.7431	0.7530	0.7469	0.7217	0.7292	0.6934	0.9379	0.6943	0.6393	0.6344	0.6799
Belgium	0.6468	0.5481	0.4481	0.4746	0.5310	0.6425	0.6137	0.6426	0.5528	0.5052	0.5089	0.4862	0.5532	0.5476	0.0560
Denmark	0.8478	0.8314	0.8374	0.8029	0.7496	0.9598	0.7782	0.7633	0.7542	0.7435	0.7952	0.7959	0.7858	0.9186	0.8118
France	0.4916	0.5434	0.5080	0.5280	0.5077	0.5312	0.5314	0.5284	0.5739	0.5789	0.5924	0.5413	0.5362	0.5958	0.6190
Germany	0.7450	0.7415	0.7441	0.7385	0.7513	0.7521	0.7403	0.7181	0.7149	0.7014	0.6960	0.6938	0.6941	0.6868	0.6732
Italy	0.8577	0.7495	0.8075	0.7179	0.7314	0.6837	0.6594	0.5300	0.5700	0.4877	0.6313	0.6737	0.7119	0.7315	0.7292
Luxembourg	0.3646	0.4123	0.4075	0.3633	0.3779	0.3202	0.3531	0.3600	0.4392	0.3832	0.4034	0.4402	0.4303	0.4569	0.3731
UK	0.7024	0.5839	0.5644	0.6040	0.5345	0.5192	0.4722	0.5717	0.5097	0.5341	0.5623	0.4898	0.4577	0.5074	0.5256

Notes: Loans are the outputs of the banking system and inputs refer to total deposits, fixed assets and employees. Production function estimates with quality and size variables.

Source: Authors' calculations.

Bank efficiency is estimated, as mentioned, using two different dimensions of output. In the first case, represented by Tables 2 to 5, total output is considered to be total loans only, whereas in the second case, total output consists of total loans, total securities and non-interest operating income. Tables 6 to 9 report the efficiency results obtained by the production function which considers loans, securities and non-interest operating income as output.

The efficiency estimates of the standard production function using total output as mentioned above appear in Table 6. Comparing the results with those in Table 2, in which the estimates are derived by the standard production function where total outputs are loans, it is obvious that efficiency is generally improved when total loans, securities and non-interest operating income is defined as the output of the production process.

The same improvement is observed when Table 7 is compared to Table 3, which includes efficiency measurements obtained by the production function considers financial capital as a risk variable. Also in the case of total assets, which are used as proxy for size, an increase in efficiency estimates is reported in Table 8 compared

to the estimates shown by Table 4. Similar conclusions are derived by the comparison between Tables 9 and 5, reporting the efficiency estimates obtained by the model that controls for risk and size factors. The efficiency of the banking systems is higher when loans, securities and non-interest operating income are considered as the total outputs.

As far as the second sample of data is concerned, which accounts for quality factors, the results from the estimation of efficiency are reported in Tables 10 and 11. More specifically, the entries in Table 10 report the efficiency estimates obtained by the standard production function, whereas Table 11 reports the results of the model that controls for quality. It is obvious that the observations in Table 11 are higher than those reported in Table 10. These results are similar to the findings of Altunbas et al. (2000) and Girardone, Molyneux, and Gardener (2004) and show that inefficiency is reduced when quality factors are taken into account compared with when they are not.

Table 6 Efficiency Estimates

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Austria	0.9964	0.6514	0.6389	0.7961	0.9994	0.9494	0.9526	0.9508	0.9436	0.9503	0.9527	0.7792	0.8189	0.7395	0.7048
Belgium	0.6754	0.7003	0.6712	0.6835	0.6231	0.9299	0.9983	0.5893	0.5744	0.5642	0.6027	0.5859	0.5552	0.4980	0.5829
Denmark	0.8618	0.9999	0.8763	0.9188	0.9999	0.9990	0.9984	0.9997	0.9999	0.9327	0.9999	0.9993	0.9992	0.9993	0.9999
France	0.6591	0.6812	0.6201	0.6127	0.9974	0.9988	0.6735	0.5913	0.5764	0.5601	0.5380	0.5694	0.5938	0.6963	0.6463
Germany	0.9431	0.9417	0.9993	0.9440	0.9995	0.9991	0.9994	0.8399	0.8527	0.8187	0.8394	0.8057	0.8037	0.8077	0.8062
Italy	0.9450	0.9455	0.9993	0.9356	0.7700	0.8722	0.9991	0.6715	0.5379	0.6010	0.6480	0.7680	0.7654	0.7425	0.7297
Luxembourg	0.5064	0.5279	0.6110	0.9973	0.7238	0.6081	0.5301	0.5369	0.5638	0.9958	0.4158	0.9989	0.9933	0.9972	0.8635
UK	0.6387	0.4757	0.9933	0.5043	0.5158	0.4430	0.4159	0.4360	0.4422	0.4602	0.4497	0.4134	0.3838	0.4690	0.4365

Notes: Loan, total securities and ton non-interest operating incomes are the outputs of the banking system and inputs refer to total deposits, fixed assets and employees. Standard production function estimates.

Source: Authors' calculations.

Table 7 Efficiency Estimates (Including Financial Capital)

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Austria	0.7627	0.7076	0.6136	0.7987	0.9527	0.9990	0.9994	0.9992	0.9495	0.9530	0.9992	0.9537	0.7992	0.7639	0.7201
Belgium	0.7029	0.7082	0.6620	0.6759	0.5924	0.9498	0.7265	0.6431	0.5766	0.5986	0.5605	0.7046	0.6728	0.5728	0.7418
Denmark	0.8868	0.8374	0.9124	0.9980	0.9801	0.8296	0.9990	0.8185	0.8129	0.8056	0.8273	0.8056	0.8264	0.8471	0.7629
France	0.6306	0.6439	0.4855	0.6197	0.6053	0.6978	0.6467	0.5993	0.5748	0.5616	0.5893	0.5931	0.6253	0.7210	0.9984
Germany	0.8087	0.7881	0.8087	0.8112	0.8020	0.8144	0.8199	0.8237	0.8190	0.8097	0.8156	0.8123	0.8063	0.8073	0.8034
Italy	0.9647	0.9636	0.9373	0.9468	0.7377	0.6909	0.7765	0.6578	0.6312	0.7329	0.6335	0.7760	0.7783	0.7423	0.7352
Luxembourg	0.6152	0.5711	0.4893	0.8962	0.6237	0.5568	0.5226	0.5109	0.5452	0.5716	0.4764	0.4582	0.4646	0.4316	0.5051
UK	0.6712	0.5494	0.5124	0.7590	0.5744	0.4997	0.4609	0.5102	0.5672	0.5618	0.5587	0.4773	0.4955	0.4786	0.5341

Notes: Loan, total securities and ton non-interest operating incomes are the outputs of the banking system and inputs refer to total deposits, fixed assets and employees. Production function estimates with risk variable.

Source: Authors' calculations.

Table 8 Efficiency Estimates (Including Total Assets)

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Austria	0.8011	0.7704	0.7339	0.8609	0.8580	0.8037	0.8326	0.8419	0.8274	0.8707	0.8456	0.8396	0.8260	0.8133	0.7585
Belgium	0.7391	0.7979	0.7845	0.7603	0.6907	0.9657	0.7636	0.6756	0.5355	0.6207	0.5541	0.6364	0.6536	0.5247	0.7609
Denmark	0.8848	0.8520	0.8724	0.8781	0.8722	0.8701	0.8775	0.8606	0.8511	0.8683	0.8644	0.8646	0.9036	0.8997	0.8581
France	0.6196	0.6357	0.6107	0.6549	0.6722	0.6699	0.6581	0.6573	0.6866	0.6863	0.6855	0.7018	0.7128	0.7309	0.7600
Germany	0.8741	0.8717	0.8729	0.8688	0.8682	0.8754	0.8755	0.8644	0.8666	0.8680	0.8546	0.8565	0.8559	0.8433	0.8371
Italy	0.9016	0.8929	0.8420	0.8216	0.8579	0.8584	0.8369	0.8072	0.7900	0.8083	0.7990	0.8806	0.8927	0.8784	0.8749
Luxembourg	0.4711	0.4653	0.5027	0.5089	0.5181	0.5464	0.5077	0.5382	0.5900	0.5320	0.4985	0.5703	0.5623	0.5576	0.5407
UK	0.7991	0.7091	0.6385	0.7395	0.5674	0.5873	0.5127	0.5696	0.6411	0.6238	0.6471	0.5395	0.5768	0.5392	0.6182

Notes: Loan, total securities and ton non-interest operating incomes are the outputs of the banking system and inputs refer to total deposits, fixed assets and employees. Production function estimates with size variable.

Source: Authors' calculations.

Table 9 Efficiency Estimates (Including Financial Capital and Total Assets)

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Austria	0.8336	0.7745	0.7667	0.8678	0.8677	0.8716	0.8585	0.8576	0.8365	0.8562	0.8489	0.8429	0.8370	0.8170	0.7705
Belgium	0.7611	0.8202	0.8133	0.7729	0.7217	0.9742	0.8130	0.7324	0.6216	0.6638	0.5263	0.7278	0.6259	0.6285	0.2662
Denmark	0.8894	0.8785	0.8732	0.8867	0.8918	0.9830	0.9105	0.8760	0.8724	0.9847	0.8945	0.8874	0.8934	0.9145	0.8953
France	0.6222	0.6051	0.6273	0.6446	0.6949	0.6955	0.6883	0.6323	0.6993	0.6929	0.7000	0.7117	0.7078	0.7504	0.7631
Germany	0.8744	0.8709	0.8727	0.8714	0.8679	0.8745	0.8757	0.8634	0.8664	0.8659	0.8568	0.8557	0.8529	0.8455	0.8382
Italy	0.9115	0.8709	0.8414	0.8365	0.8452	0.8616	0.8396	0.8224	0.7807	0.8665	0.7540	0.8801	0.8946	0.8785	0.8739
Luxembourg	0.5144	0.5412	0.5527	0.5683	0.5630	0.5337	0.5011	0.5440	0.5848	0.5939	0.5680	0.5978	0.6041	0.5886	0.5961
UK	0.8081	0.7323	0.6439	0.7020	0.6727	0.5920	0.5343	0.6620	0.6320	0.6423	0.6233	0.5513	0.5518	0.6000	0.6224

Notes: Loan, total securities and ton non-interest operating incomes are the outputs of the banking system and inputs refer to total deposits, fixed assets and employees. Production function estimates with risk and size variable.

Source: Authors' calculations.

Table 10 Efficiency Estimates

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Austria	0.9353	0.5405	0.5303	0.6305	0.9418	0.7436	0.8401	0.8130	0.9456	0.7643	0.9270	0.7068	0.9348	0.9427	0.6456
Belgium	0.7599	0.9996	0.8147	0.9183	0.9995	0.9199	0.7644	0.9281	0.7326	0.9180	0.7680	0.8147	0.8982	0.7410	0.6972
Denmark	0.4910	0.5313	0.5341	0.4669	0.5265	0.5614	0.5909	0.5856	0.5636	0.5726	0.6225	0.6501	0.6758	0.6302	0.6052
France	0.9194	0.9258	0.7922	0.7647	0.7024	0.7376	0.7687	0.7385	0.7074	0.7364	0.7207	0.7118	0.7176	0.7128	0.6994
Germany	0.9419	0.9265	0.9200	0.9128	0.9126	0.8403	0.9235	0.5968	0.5922	0.4276	0.7828	0.9040	0.7050	0.6669	0.6593
Italy	0.5617	0.5124	0.4841	0.3682	0.3377	0.2719	0.3256	0.3800	0.4995	0.5181	0.5944	0.5879	0.4816	0.9968	0.4266
Luxembourg	0.9200	0.6272	0.5443	0.6710	0.6016	0.9988	0.9011	0.6680	0.4811	0.8747	0.5695	0.4000	0.4164	0.8846	0.5346
UK	0.9353	0.5405	0.5303	0.6305	0.9418	0.7436	0.8401	0.8130	0.9456	0.7643	0.9270	0.7068	0.9348	0.9427	0.6456

Notes: Total loans are the outputs of the banking system and inputs refer to total deposits, fixed assets and employees. Standard production function estimates for subsample.

Source: Authors' calculations.

Table 11 Efficiency Estimates (Including Quality)

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Austria	0.8580	0.6425	0.9338	0.9438	0.9547	0.7405	0.8073	0.9985	0.9474	0.9385	0.9406	0.9980	0.9460	0.9438	0.6409
Belgium	0.8319	0.9198	0.9308	0.8371	0.9989	0.9983	0.7998	0.6810	0.8199	0.8053	0.9628	0.8191	0.9180	0.9705	0.7388
Denmark	0.9907	0.6891	0.5879	0.5013	0.6035	0.6136	0.6206	0.6072	0.5910	0.6482	0.6328	0.6688	0.6544	0.6500	0.6588
France	0.9312	0.9992	0.9352	0.9376	0.8341	0.8237	0.8490	0.7921	0.7602	0.9991	0.8304	0.8373	0.7742	0.7813	0.7603
Germany	0.9497	0.9320	0.9237	0.9240	0.9194	0.7729	0.9255	0.6354	0.6780	0.6357	0.9090	0.9744	0.7183	0.6704	0.6618
Italy	0.6195	0.9578	0.5060	0.4670	0.9878	0.8690	0.4758	0.4957	0.9153	1.0000	0.9614	0.9321	0.5473	0.9992	0.8948
Luxembourg	0.8722	0.6481	0.7671	0.7453	0.6996	0.9793	0.8488	0.7418	0.9074	0.8241	0.7771	0.5450	0.9469	0.9243	0.6371
UK	0.8580	0.6425	0.9338	0.9438	0.9547	0.7405	0.8073	0.9985	0.9474	0.9385	0.9406	0.9980	0.9460	0.9438	0.6409

Notes: Total loans are the outputs of the banking system and inputs refer to total deposits, fixed assets and employees. Production function estimates with quality variable for subsample.

Source: Authors' calculations.

5. Conclusions

Bank efficiency seems to be one of the most important "assets" for banks and is given priority in recent decades, because banks operate in an extremely competitive environment where survival has become uncertain. In this paper, bank efficiency across eight European countries has been estimated over the period 1994-2008 using the translog production function and by differentiating the initial model by adding risk and size variables.

Banking efficiency is estimated for two different dimensions of output: in the first case total loans is the only output of banks; in the second case output consists of total loans, total securities and total non-interest operating income. The latter is to include in the analysis the "broader" operation of the banks which has altered from the traditional production of loans only. The estimates of efficiency are closer to reality and differ in the second case, but do not change the ranking dramatically. Furthermore, the analysis also includes quality of loans in the estimation, showing that inefficiency tends to be overstated when this factor is not taken into account.

Overall the results indicate that Germany, Denmark and Austria seem to have the most efficient banking systems, whereas Luxembourg and France are last in the ranking among the specific group of countries. One possible explanation for these differences in estimates is bank and market-specific characteristics. In particular, the level of risk each bank faces expressed by financial capital or the composition of assets may influence the efficiency of each country (Maudos et al. 2002). Differences may also arise from certain market-specific characteristics such as environmental or regulatory conditions as well as banking technology. As Michel Dietsch and Ana Lozano-Vivas (2000) point out, differences in the demand for banking products and services may be produced by population density or per capita income.

Further research in this field could be made examining potential correlations of efficiency with specific characteristics, as well as using different types of efficiency, such as cost or profit efficiency.

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