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ABSTRACT

How efficient are banks in Hungary?

Apparent characteristics of the Hungarian banking market such as large profits and high margins suggest weak competitive pressures. Weak competition in turn, may reduce efficiency in a lack of pressures to converge to marginal cost and to stimulate managerial efforts to reduce X-inefficiency. Such conditions call for a gauging of efficiency of banks to better assess what is needed for a competitive and well-functioning banking system. Although the level of efficiency is only an indirect measure of competitive pressures, it may be superior to other ones available for international comparison. Concentration ratios are only a very imperfect measure, moreover, the Hungarian banking market structure with one larger and several somewhat smaller banks of similar sizes would suggest an even playing field. In fact, different market segments show very different degrees of concentration and several conditions for a competitive market are missing. Moreover, interest margins, particularly on mortgage loans are high in international comparison and the downward stickiness and lagged reaction of retail lending rates to money market rates also suggests weak competitive pressures. In a lack of readily available data to obtain mark-ups, which would be a better measure of competition than concentration measures or interest margins, this paper estimates cost efficiency scores that allow for grasping the size of competitive pressures indirectly. Cost efficiency is estimated in the EU 25 context given that cross-border competition can be important in some market segments and that cross-border lending is significant in Hungary. The paper uses the stochastic frontier analysis with a Fourier-flexible specification of the cost function and a time-varying decay model. A specific feature of the methodology is that bank lending is corrected for non-performing loans. This way, the categorising of banks that boost their loan portfolio by excessive risk-taking - i.e. produce large amounts of bad loans - as efficient can be partly avoided. The results show that in Hungary, bank efficiency is not particularly high in either European or regional comparison. Competition could be the major push for efficiency gains and the paper lists a series of measures that could be adopted to boost competitive pressures.

This paper relates to the *2010 Economic Survey of Hungary*.

JEL: G21

Keywords: Hungary; banking efficiency; banking competition; stochastic frontier analysis; Fourier-flexible form;

RÉSUMÉ

Les banques hongroises sont-elles efficientes ?

Les caractéristiques apparentes du marché bancaire hongrois, comme l'importance des bénéfices et des marges financières, évoquent un manque de pressions concurrentielles. Cette faiblesse de la concurrence peut elle-même réduire l'efficience de ce marché, faute de pressions incitant à converger vers le coût marginal et à stimuler les efforts des dirigeants pour réduire l'inefficience-X. Cette situation invite à une évaluation de l'efficience des banques afin de mieux mesurer les conditions nécessaires à l'existence d'un système bancaire concurrentiel et fonctionnant bien. Bien que le niveau de l'efficience ne soit qu'un indicateur indirect des pressions concurrentielles, il présente peut-être plus d'intérêt que d'autres mesures disponibles pour effectuer des comparaisons internationales. Les ratios de concentration ne sont en effet qu'un instrument très imparfait ; de plus la structure du marché bancaire hongrois, marquée par la présence d'une plus grande banque et de plusieurs autres établissements plus petits de tailles similaires, semble témoigner de l'existence de conditions de concurrence équitables. En fait, les différents segments du marché présentent des concentrations très variées et il manque plusieurs conditions pour pouvoir parler d'un marché concurrentiel. De plus, les marges financières, notamment sur les prêts hypothécaires, sont élevées par rapport aux autres pays et la viscosité à la baisse et les réactions tardives des taux débiteurs des banques de réseau à l'évolution des taux du marché monétaire indiquent également un manque de pressions concurrentielles. En l'absence de données immédiatement disponibles permettant de calculer les marges bénéficiaires, qui constituerait un meilleur indicateur de la concurrence que les mesures de concentration ou les marges financières, cet article procède à une estimation des scores d'efficience coût qui permet de mieux saisir de façon indirecte l'importance des pressions concurrentielles. L'efficience coût est estimée dans le contexte de l'UE-25 car la concurrence transnationale peut être importante dans certains segments du marché et les opérations transnationales de crédit sont considérables en Hongrie. Cet article fait appel à l'analyse de frontière stochastique avec une forme flexible de Fourier de la fonction de coût et un modèle d'obsolescence variable en fonction du temps. Les caractéristiques spécifiques de la méthodologie utilisée tiennent au fait que le crédit bancaire est corrigé des prêts non productifs. De cette façon, on évitera en partie de considérer comme des établissements efficients les banques qui gonflent leur portefeuille de prêts en prenant des risques excessifs – et génèrent donc des volumes considérables de créances irrécouvrables. Les résultats montrent qu'en Hongrie, l'efficience des banques n'est pas particulièrement élevée au regard de la situation européenne ou régionale. La concurrence pourrait être un facteur majeur d'efficience et cet article énumère une série de mesures de nature à stimuler les pressions concurrentielles.

Ce document se rapporte à l'*Étude économique de l'OCDE de l'Hongrie*.

Classification JEL : G21
Mots clés : Hongrie ; efficience des banques ; concurrence des banques ; analyse de frontière stochastique ; forme flexible de Fourier ;

Table of contents

Boxes

Tables

HOW EFFICIENT ARE BANKS IN HUNGARY?

Margit Molnár[1] and Dániel Holló

A snapshot of competitive conditions in the Hungarian banking market

The Hungarian banking market is characterised by large profits and high margins in international comparison, which suggest weak competitive pressures. Theory suggests that perfect competition produces productive efficiency, *i.e.* when it is impossible to reallocate resources so as to produce more of some product without producing less of some other product (Pareto optimality). This is because (*i*) firms are motivated to produce at the lowest possible cost and (*ii*) all firms have the same marginal cost since firms in any one industry face the same price (*i.e.* firms in perfect competition are price-takers) to which they equate their marginal cost. Increased competition may improve allocative and X-efficiency resulting in a one-time increase in the level of output. Enhanced competition forces prices to converge to marginal cost, thereby boosts allocative efficiency. At the same time it may also stimulate managerial efforts as there are more firms to serve as reference for comparison and the threat of bankruptcy is more credible (Nickell, 1996), thereby reduce X-inefficiency (slack in the use of production inputs).

In the same vein, in a competitive banking market, banks are supposed to be price-takers: they take as given the price of funds or inputs and the price of outputs such as loans and other earning assets and products. The profit of the bank is the difference between the intermediation margin and management costs. Thus, in a competitive banking market, banks adjust their inputs and outputs in such a way that their intermediation margin equals their management costs. High cost efficiency in a competitive market would manifest in lower pricing of loans and higher output, this latter depending on the price elasticity of demand. This suggests that there is a clear, positive relationship between competition and efficiency, therefore the estimation of efficiency scores could allow for approximating competitive pressures, even though only indirectly.

To gauge competitive pressures, concentration ratios are often used, though they are only a very imperfect measure of competition. The Hungarian banking market does not appear to be concentrated at first sight and the market structure with over half a dozen similar-size players suggests competitive conditions. By asset size, the first five players command a share of nearly 60% with the largest player having a 20% share and the four others each with shares of close to 10%. The eight largest banks by asset size (the so-called large banks) own three-quarters of banking assets. Twenty other banks share the

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1 Molnár: Economics Department, OECD, Holló: European Central Bank and National Bank of Hungary. This Working Paper is based on empirical work to illustrate bank efficiency in Hungary for Chapter 3 of the OECD's 2010 Survey of Hungary which was prepared under the responsibility of the Economic and Development Review Committee. The authors are grateful for the valuable comments received on earlier drafts of this text from Andrew Dean, Bob Ford, Pierre Beynet and other colleagues in the Economics Department, as well as for discussions with participants of the CMTEA workshop in Luxembourg on September 23-24, 2010. Special thanks go to Gábor Fülöp, Consultant at the OECD Economics Department at the time of writing the paper, for statistical assistance and to Maartje Michelson for editorial assistance.

remaining 25% of the market. The value of the Hirschman-Herfindahl index calculated on total assets is 1149, far from the threshold of a highly concentrated market at 1800.

Concentration measures in terms of total assets, however, mask the differences in market segments. Differences are large in terms of concentration between loan and deposit as well as between retail and corporate markets and their sub-segments. In retail deposits, for instance, the largest player OTP (Országos Takarékpénztár) commands a market share of roughly 32%, largely owing to its country-wide branch network. Together with its mortgage bank, OTP Jelzálogbank, its share in the mortgage loan market is similar, at above 30%. OTP (combined with its mortgage bank) is also market leader in consumption loans (over 10% share) and the other loans category (over 20%) which comprises freely disposable retail loans. In contrast to the retail market, the corporate market appears to be less concentrated and OTP ranks much lower. In corporate deposits, CIB is the market leader with a share well over 10% followed by OTP, K&H (Kereskedelmi és Hitelbank), Raiffeisen, Unicredit and MKB (Magyar Külkereskedelmi Bank), each with a share of slightly over 10%. CIB is also leader in corporate lending with a market share of over 15% closely followed by MKB, then Raiffeisen and K&H with 10% each. As interest margins on retail lending tend to be well above those on commercial lending and the largest player is heavily specialised in this segment, not surprisingly, concentration in profits is also significant with OTP recording 50% of after tax profits of the entire banking sector in mid-2009.

Due to different degrees of information asymmetries (Diamond, 1984; Rajan, 1998 and Bolton and Freixas, 2000) and other market-specific characteristics including mainly the sharp competition for the financing of large domestic companies between domestic and international credit markets, interest margins prevailing in wholesale and retail markets in Hungary are different. While interest margins on corporate loans are relatively low, the high margins on household lending in Hungary compared to other countries suggest little competitive pressure in this market. Weak price competition in retail markets is also manifest in the stickiness and lagged reaction of interest rates on consumption loans and short-term deposits to money market rates (Horváth *et al.*, 2004).

Price-cost margins are a superior measure of competition than concentration ratios as competition may stem from other sources than just the number of players, such as demanding customers. Competitive pressures originating from this source are rather limited in Hungary due to a lack of consumer awareness, a low level of financial literacy and weak consumer protection. Molnár *et al.* (2007) estimate price-cost margins for different retail market segments and find that competition is low in the overdraft, higher purchase loans, personal loan, demand deposit and short-term deposit markets, while the long-term deposit market is more competitive. Stiffer competition in the long-term deposit market is not surprising given the decreasing share of lending funded by deposits.

In a lack of readily available data that could allow for the estimation of mark-ups for the banking sector in an international comparison (ideally by market segment), competitive pressures can only be gauged indirectly and efficiency measures could well serve this purpose. A low level of efficiency in the banking sector would suggest a lack of competitive pressure and there could be several reasons for this.[2] Possible reasons could be competition-restraining behaviour between banks or high short-run costs (related to establishing new branches and hiring staff to handle the increased business volume) that an efficient bank would entail should it try to attract customers from competitors with its lower prices. Although there is no evidence of collusion among banks in Hungary to set interest rates and conditions for household loans, there are only limited signs of price competition which is manifest in a moderation of the effective net interest margin earned by banks from 4.2% in 2002 to 3.7% in 2006 and 2.6% in 2008. The virtual lack of price competition and the still substantially higher interest margins than in the EU prompted the Competition Authority to initiate an investigation in the mortgage lending market in 2005. While the

2 . Less risk adverse behaviour can also result in lower efficiency.

investigation did not find abusive behaviour or market power, it called for strengthening consumer protection, more transparency and information about products and a clearer definition of banking fees (GVH, 2005). The Hungarian banking market is still immature compared to those in countries with higher incomes and therefore offers high growth opportunities. Such opportunities can be exploited without venturing into throat-cut price competition (that made the customer king in highly developed banking markets) and risking reputation losses related to capacity constraints as the fast growing market would demand rapidly expanding infrastructure and personnel.

The lack of price competition has been particularly apparent in retail lending markets. In addition to a larger degree of information asymmetry in the retail lending market, the lack of price competition can, to a large extent, be attributed to switching costs, which comprise direct costs such as the fees related to early repayment of the loan or in an extreme case, a prohibition of "refinancing" the loan by another one extended by a different bank and to indirect costs such as the time costs of switching. Such switching costs are high in Hungary, where, in contrast to many other countries, early repayment of the loan is heavily penalised. Switching costs explain a low price elasticity of retail loans, limited price competition and the persistence of profits (Dermine, 2005; Degryse and Ongena, 2008). Entry barriers in the form of costs to establish branch networks necessary for retail lending also contribute to higher margins. Judging from the expansion of several large new entrants (most entered through acquisition, greenfield investments have been relatively rare) either through acquisition of smaller banks or through expansion of the branch network in the past decade, the lack of branch networks may be a significant barrier to competition in Hungary. Cross-border competition in the retail lending market may also be limited owing to prudential regulatory differences such as repayment regimes, ceilings on loan-to-value ratios and credit risk appraisal (Dermine, 2005).

There has been some competition at the margin: Austrian banks not present in Hungary extend cross-border loans to households in the west of the country at more favourable rates. Given the higher borrowing costs that banks in Hungary face due to higher country risk, cross-border lending could potentially provide effective competition in the domestic lending market. Cross-border lending is in particular competitive in the segment of long-term lending as higher fixed costs related to contract and translation fees may make short-term borrowing less attractive. Cross-border borrowers, however, also face some inconveniences such as the need to pay the monthly instalments either in Austria or by costly bank transfers and the payment obligation is in euros. Owing to such constraints, this scheme best fits people working in Austria or at least living in the proximity of the border and earning foreign currency. These contracts are typically signed at a Hungarian notary and the lenders have access to the same procedures for redress as banks with subsidiaries/branches in the country. Geographical proximity also helps reducing information asymmetry that can be important in retail lending. Local knowledge that can reduce information asymmetry between lenders and borrowers is more important in retail lending where products tend to be more customised. Notwithstanding the unexploited interest differential, the share of cross-border household lending remains low at below 1% of outstanding household loans.

Limited price competition, however, does not imply that there had not been competition for customers at all. Non-price competition had become apparent in the mid-2000s, in particular in the retail market, and was manifest in a relaxation of eligibility requirements for loans and the proliferation of agents. Without any ceiling on the portion of income that can be spent on servicing the loan, households were spending an increasing portion of their income on it with the average ratio reaching 13% in the first quarter of 2009. Some estimates put the recent figures at 20% as a result of the depreciation of the currency and deteriorating incomes. Such a creeping household indebtedness imposed an increasing systemic risk on the system as most loans were with flexible interest rates and in foreign currencies. Furthermore, the higher price elasticity of demand for domestic currency loans versus foreign currency loans and the asymmetric substitution effect towards foreign currency loans increase exchange rate risks and hence also credit risk (Holló, 2010). Also, in a lack of comprehensive credit registry, multiple loans became widespread. Agents (either independent or acting on behalf of banks) - attracted by a remuneration of 2.5% of the loan taken - started to intermediate an ever increasing amount of loans. Such loans, however, turn out to be of more inferior quality than the ones extended directly by bank branches, showing again, that the fierce non-price competition had adverse effects on the system. This is partly related to the non-transparent nature of such competition relative to price competition as products are more difficult to compare.

More intense competition, in particular in the retail lending market, would enhance market efficiency without necessarily endangering stability. Contrary to common perception, there is no empirical evidence on the trade-off between competition and stability in the banking sector. Empirical studies such as Beck *et al.* (2003) find that higher concentration is positively associated with banking crisis probability while entry restrictions have a negative association. This, however, may only show that concentration may not be the best measure of competition. Claessens (2009) confirms that market-structure-based measures of competition may not be the best, though they are used widely in the literature. A review of existing literature by Claessens (2009) concludes that competition has lowered the costs of financial intermediation, spurred product differentiation and enhanced stability. Competition has been driven by making markets more open and contestable and by internationalisation of financial services.

To empirically check the level of efficiency of banks in Hungary, efficiency scores were estimated for the EU 25 countries. As cross-border lending is significant (in particular in the corporate sector) in Hungary, bank efficiency is compared not to a domestic, but to a regional frontier. In the next section earlier results of efficiency estimates for Hungary are briefly described, followed by a discussion of different methodologies, data and the reasons for the choice of methodology for the present paper. Then the results obtained are discussed and the paper concludes with policy discussions and recommendations to increase competitive pressures and improve efficiency.

Earlier results of efficiency estimates

Efficiency analysis originating in the real economy has become widespread in the financial sector; nevertheless what constitutes banking efficiency is not straightforward. While most studies attempt to capture different levels of managerial efficiency[3] (X-efficiency) when they compare efficiency scores across banks and countries, there is little, if any comparability of such efficiency estimates across different studies. There are several reasons why comparability is hindered:

- First, the efficiency scores are often sensitive to the applied methodology, *i.e.* how to measure the efficiency frontier. Fethi *et al.* (2009) provided a thorough analysis using parametric, non-parametric and semiparametric methods to estimate bank efficiency in transition countries and showed that the estimated efficiency scores are sensitive to the choice of methodology. This may be related to what different methodologies are able to capture: non-parametric methods, for instance, do not only capture managerial ability differences in the inefficiency term, but also other, random factors which are unrelated to managerial ability. In this sense, parametric methods are more reliable as they are able to delineate the impact of managerial competencies from other random factors, nevertheless the strong assumption they require on the distribution of the inefficiency term and the necessity to define the functional form may introduce bias. The most common functional form is the translog form that long replaced the Cobb-Douglas and CES forms used earlier, though it underperforms the Fourier flexible form, which is a semi-nonparametric approach (discussed in the next section). Berger and Mester (1997) compared different assumptions regarding the inefficiency term and concluded that the efficiency scores were relatively robust to changes in these assumptions.

3. The dominance of X-efficiency in driving banks' profits over scale and scope efficiency has been recognised by Berger and Hannan (1998) and Vennet (2002).

- Second, it is also crucial what type of efficiency the study is looking at. Although most studies estimate cost efficiency, *i.e.* how efficient managers are in reducing costs to produce a given output, but some (also) estimate alternative profit efficiency, looking at how much profits managers can produce with given output levels.

- Third, the definition of inputs and outputs in the banks' production function also play a role in shaping the efficiency scores. The most common approach is the intermediation approach where deposits enter as inputs to the banks' production function, thus they look at how efficiently bank managers can intermediate available funds into loans and other earning assets and other types of income. In contrast, the production approach defines deposits as outputs of the banks' production process. This approach is more distant from theory.

- Fourth, different studies control for different conditions prevailing in banking markets which are unrelated to managerial ability. This can also result in difficulties with comparing and interpreting efficiency scores (Berger and Humphrey, 1997).

- Fifth, the quality of banking services differs largely across countries and to some extent across banks, for which conventional efficiency estimations cannot account for. Therefore comparison should be done with caution not only across studies but even across countries.

- Sixth, efficiency scores for different samples, even if the same methodology is applied, are not comparable as the estimated efficiency frontiers differ by sample.

With these caveats in mind, the following paragraphs provide a brief review of studies estimating bank efficiency scores for Hungary focusing on cost efficiency estimates.

The literature on bank efficiency estimates offers a myriad of studies over the past few decades, but most are limited to one country, mainly the United States and very few estimate efficiency for Hungary, in particular in international comparison. One of the few such studies is Holló and Nagy (2006), which used the SFA (stochastic frontier approach) and the DFA (distribution-free approach) to estimate cost efficiency for 2459 banks in 25 EU countries (all except Bulgaria and Romania) over 1998-2003 and found that by both methods Hungary is in the lowest quartile of the efficiency distribution. They also observed an efficiency gap between old and new member states of the European Union. Bems and Sorsa (2008) also applied the stochastic frontier approach to estimate cost efficiency for 594 banks in 16 countries over 1995-2007 but defined inputs and outputs slightly differently and observed that Hungary was performing somewhat better than its regional peers, but it was far behind most old EU members. Košak *et al.* (2009) examined banking efficiency in 8 European transition countries over 1996-2003 and showed that Hungary ranks fourth in the eight-country sample, just after Slovakia, Poland and Slovenia. Their setting, however, is very different as they designated deposits as outputs for banks, *i.e.* used the production approach (in contrast to the intermediation approach applied in Holló and Nagy, 2006 and in this paper) and their sample is relatively small (100 banks altogether in the eight countries).

Grigorian and Manole (2002) used the DEA to obtain bank efficiency scores for commercial banks in a large number of transition economies and found that Central European economies (which include Hungary) are better performing in terms of banking efficiency than Southern European ones or the Commonwealth of Independent States (CIS). Within Central Europe, however, Hungarian banks do not appear among the best performers over 1993-1998.

A strand of the literature investigates the impact of ownership on efficiency and shows that foreign majority banks tend to be more efficient than domestically owned ones, but there does not seem to be a sizeable efficiency gap between private and state-owned banks. Bonin *et al.* (2005) used data of 225 banks in eleven transition economies over 1996-2000 to show that privatisation did not increase bank efficiency while foreign-owned banks were more efficient than domestically owned ones. Hasan and Marton (2000) also confirmed that banks with higher foreign ownership share were more efficient. Košak *et al.* (2009) showed that foreign-owned banks were less efficient than banks with different ownership structures and explained their different finding from most of the literature by a better capturing of foreign ownership in their study. In contrast to Bonin *et al.* (2005) and most other studies that did not account for the time variability of bank ownership in their estimation, Košak *et al.* (2009) constructed a unique data series for each bank in the sample incorporating ownership changes. This is no doubt a great improvement in the quality of the variable capturing ownership changes; nevertheless, the method used in their paper is subject to endogeneity bias. This is related to the fact that ownership itself influences the level of efficiency, but they first estimated the efficiency scores without allowing for an impact by ownership on efficiency (in fact none of the external variables were controlled for when estimating the efficiency scores) then in the second stages explained efficiency scores by different variables related to the macroeconomic, regulatory and institutional environments.

Methodology

At present, the most commonly applied method of efficiency analysis is the estimation of the so-called efficiency frontier and the distance from such frontier indicates the extent of X-inefficiency. Such efficiency frontier can be generated by parametric or non-parametric methods. The major advantage of parametric methods is that they have a solid theoretical ground, *i.e.* the estimation of efficiency is based on economic optimisation given the underlying assumption of a stochastic optimal frontier.[4] They require, however, prior distributional assumptions regarding the inefficiency component, which is delineated from the noise component of the distance from the frontier. A commonly used parametric method is the Stochastic Frontier Approach (SFA) developed independently by Aigner *et al.* (1977) and Meeusen and van den Broeck (1977). Another parametric method, the Distribution Free Approach (DFA), pioneered by Sickles (1984) and Berger (1993), does not require the (somewhat restrictive) assumptions about the distribution of the inefficiency components, but has the caveat of assuming invariant efficiency level over time. Thus, the DFA works well for cross-section data, but may result in flawed efficiency estimates, if the decay parameter varies over time.

Non-parametric methods are free of the restrictive assumptions to which the SFA is subject to and there is not even a need to specify the functional form of the bank's production function. For these reasons, however, such approaches are often labelled atheoretical. Their major disadvantage, however, is that they are unable to decompose the deviation from the efficiency frontier into inefficiency and noise components, thus assume that the entire deviation is due to inefficiency. An additional shortcoming of non-parametric methods is that they do not take into account prices when estimating either how efficiently banks produce given output levels (*i.e.* with the lowest level of inputs) or how high output they can achieve with the given level of inputs. The non-parametric method was first proposed by Farrell (1957), then first applied by Charnes *et al.* (1978) and got known as Data Envelopment Analysis (DEA).

This paper applies the SFA approach to estimate the efficiency frontier where the results are obtained from the banks' optimisation and this approach is also capable of treating time-variant efficiency in panel data. In this process, not only the size of inputs and outputs is entered, but also the prices of inputs. In general, a firm is technically efficient if it uses the minimal level of inputs given output and the input mix or produces the maximal level of output given inputs. For measuring bank efficiency, in this paper the intermediation approach is applied, *i.e.* the obtained efficiency scores indicate how efficiently banks transform collected funds into loans, other earning assets and other type of income. As in Hungary most

4 . In contrast to the deterministic frontier, the stochastic frontier allows for measurement errors, thus does not assume that all deviations from the frontier are due to inefficiency.

bank activities belong to traditional banking, *i.e.* intermediating of collected funds into earning assets and fees, the intermediation approach appears most appropriate for characterising bank behaviour. Following Sealey and Lindley (1977), it is assumed that banks are minimising their costs given the optimal amount of earning assets and non-interest income to be generated, prices for inputs and technological constraints.

To measure banks' efficiency, first of all a certain relationship between operational costs, input prices and output quantities needs to be assumed. The form of the cost function is:

$$\ln TC_{it} = C(y_{it}, w_{it}; \beta) + \varepsilon_{it} \quad (1)$$

where TC_{it} is total cost of bank *i*, at time *t*, y_{it} is the output in logarithmic form, w_{it} is input prices in logarithmic form and β is the unknown parameter vector to be estimated. The efficiency scores are derived from the error term of equation (1) using the stochastic frontier approach. The error term is thus composed of an idiosyncratic and stochastic error term v_{it} with a symmetric, normal distribution and an inefficiency component u_{it} with a one-sided distribution:

$$\ln TC_{it} = C(y_{it}, w_{it}; \beta) + u_{it} + v_{it} \quad (2)$$

The inefficiency component u_{it} captures deviations from the frontier that are due to factors under control of management, while v_{it} captures those not under management control. Here the inefficiency component is added to the equation as the most cost efficient bank has the lowest cost and any inefficiency relative to this most cost efficient bank is manifest in higher costs. The SFA requires prior distributional assumptions regarding the inefficiency component u_{it} to solve for the parameters using maximum likelihood estimation.

In contrast to many other studies estimating efficiency, here the Fourier-flexible functional form is used, not the translog functional form. The main disadvantage of the translog functional form,[5] as McAllister and McManus (1993) pointed out, is that the high level of sample heterogeneity may cause White-type bias (White, 1980). Furthermore, multi-collinearity between independent variables limits the accuracy of parameter estimates. Berger *et al.* (1997) and Mitchell and Onvural (1996) stated that the Fourier flexible form is the global approximation of the underlying true cost function and that it dominates the conventional translog form, a local approximation.[6] They also tested the significance of the trigonometric parameters and confirmed that they differed significantly from zero. This implies that the estimates obtained by the Fourier-flexible form are more efficient than those obtained by the translog

5 . From the mid-1980s, the translog functional form became widespread in the literature estimating cost efficiency of banks, replacing the Cobb-Douglas and CES cost functions. This was a significant development as the shortcomings of the Cobb-Douglas and CES forms are well known: the former assumes constant returns to scale and the elasticity of substitution between inputs is one, while the CES, although does not restrict the elasticity of substitution between inputs to one, still requires it to be constant. Moreover, if there are more than two inputs, the CES's restriction of the elasticity of substitution between any input pair to be the same is unrealistic. In contrast, the translog form does not require any restriction with regards to input elasticities.

6 . The translog function approximates the true cost function only locally, i.e. in the proximity of a given point in the cost function. This is due to the second-order Taylor series approximation, which, if using least squares estimation, may lead to a distortion when extending the series (i.e. least squares estimates of a second-order polynomial such as the translog do not generally correspond to the Taylor series expansion of the underlying function at an expansion point and, hence, are biased estimates of the series expansion). Such an extrapolation may be misleading and may not properly describe the true cost function because the cost structure of banks may differ largely by scale of production (McAllister and McManus, 1993).

functional form. Moreover, Altunbaş *et al.* (2001) pointed out that the global property is important in banking where scale, product mix and other inefficiencies are heterogenous. The Fourier-flexible form allows for adjustment for distortions arising from heterogeneity and it is used to tackle the problem arising when the true functional form of the relationship is unknown. A major shortcoming of the Fourier-flexible approach is its weak ability to capture economies of scale at the top end of the sample (Altunbaş and Chakravarty, 2001). The equation estimated to obtain efficiency scores is as follows:

$$\ln TC = \beta_o + \sum_m \alpha_m y_m + \sum_n \beta_n w_n + \frac{1}{2}\sum_m \sum_p \alpha_{mp} y_m y_p + \frac{1}{2}\sum_n \sum_r \beta_{nr} w_n w_r + \sum_n \sum_m \gamma_{nm} w_n y_m + \\ + \sum_m [\delta_m \cos z_m + \theta_m \sin z_m] + \sum_m \sum_p [\delta_{mp} \cos(z_m + z_p) + \theta_{mp} \sin(z_m + z_p)] + u + v \qquad (3)$$

where TC is total cost, y_m is the mth output (m = 1,2,3), w_n is the nth input price (n = 1,2,3), p and r are equal to 1,2,3 according to the number of outputs and inputs, u is the non-negative inefficiency term and v is the two-sided error term. The inefficiency term is added to the random noise as the estimated frontier represents the minimum costs, hence any inefficiency appears as additional cost. Bank and year subscripts are subsumed for the sake of simplicity. Here three outputs (loans, other earning assets and non-interest income) and three inputs (labour, capital and borrowed funds) are assumed.

The duality theorem implies symmetry of the second-order parameters and linear homogeneity in input prices for the cost function which require the following parameter restrictions:

$$\alpha_{mp} = \alpha_{pm}, \beta_{nr} = \beta_{rn}, \sum_{n=1}^{3} \beta_n = 1, \sum_{r=1}^{3} \beta_{nr} = 0, \sum_{n=1}^{3} \gamma_{nm} = 0 \qquad (4)$$

The imposition of homogeneity in prices is ensured by normalising input prices in equation 3 with the price of borrowed funds.

The use of Fourier-flexible form implies the necessity of scaling the variables as in Holló and Nagy (2006):

$$z_m = 0.2\pi + (1.6\pi)\frac{y_m - y_{m,\min}}{y_{m,\max} - y_{m,\min}} \qquad (5)$$

where y_m is the mth output (m = 1,2,3). The scaling ensures that the scaled variables satisfy $0 < \min z_m < \max z_m < 2\pi$. It should be noted that as in Berger *et al.* (1997), Altunbaş *et al.* (2001) and Holló and Nagy (2006), the Fourier terms are applied only for the output variables, while the input price effects are determined by the translog terms. As Altunbaş *et al.* (2001) state, the major reason is to use a limited number of Fourier terms for describing the scale and inefficiency measures associated with differences in bank size. In addition, the input price homogeneity restrictions can be easily imposed on logarithmic prices terms, whereas they cannot be easily imposed on the trigonometric terms. Gallant (1982) showed that this does not prevent the estimated Fourier flexible cost equation from closely approximating the true cost function.

Further, the Battese-Coelli (Battese and Coelli, 1992) parameterisation of the inefficiency term is used to allow for time-varying inefficiency where the inefficiency term is modelled as a truncated-normal random variable multiplied by a specific function of time:

$$u_{it} = \exp\{-\eta(t - T_i)\}u_i \qquad i=1,2,\ldots N; \qquad t=1,2,\ldots T \qquad (6)$$

where T_i is the last period in the *i*th panel, η is the decay parameter and u_i has a mean μ and variance δ_u^2. Cost efficiency is obtained as:

$$CE_{it} = E(TC_{it} \mid u_{it} = 0, \quad x_{it}) / E(TC_{it} \mid u_{it}, \quad x_{it}) \tag{7}$$

Cost efficiency is the ratio of minimum incurred cost to observed expenditure for bank *i*.

Data

Bank-level data are obtained from the Bankscope database[7] for over 1600 banks and for the five years of 2004-2008. All commercial, cooperative and savings banks available in the Bankscope database for 25 EU members (EU-27 excluding Bulgaria and Romania) are included as these banks are assumed to have similar cost functions. Finance companies and other non-deposit taking institutions were excluded as they have different sources of funds and hence cost structure. So were investment banks as they neither collect deposits nor extend lending. It should be noted that while in general, the Bankscope has 70%-90% coverage in terms of assets, for some countries such as Sweden and the United Kingdom, the coverage appears to be only half of that. Where available, the unconsolidated financial statements were used as the main interest of the paper is related to bank activities in a given country.

For estimating equation 3, the following variables are used from the Bankscope database: for total costs, the sum of interest paid and non-interest expense; for other earning assets the difference between total earning assets and total loans and for non-interest income, total non-interest operating income. For loans, net loans (loans net of non-performing loans) are used following the rational that high efficiency could possibly mask bad loan production and therefore could be misleading unless subtracting the effect of non-performing loans (Mester, 1996). The three inputs are labour, capital and borrowed funds, and their prices are personnel expenses, the difference of non-interest expense and personnel expenses and interest expense, respectively. Total cost and inputs are scaled by the standard deviation of the respective variable in a given year, personnel expenses by the number of employees, the price of capital by fixed assets and the price of borrowed funds by the sum of interest bearing liabilities, including customer deposits, other deposits, short-term borrowing, long-term borrowing and subordinated debt. To better account for heterogeneity related to bank size, as mentioned above, the Fourier-flexible form is applied. Also, input prices were normalised by the price of borrowed funds to meet the homogeneity constraint as discussed under the section on methodology.

In a separate specification, to account for different operational environments, the rate of inflation, the depth of financial intermediation and an indicator of banking reforms are used as control variables. For the rate of inflation, the GDP deflator is obtained for OECD countries from the OECD ADB database and for Cyprus, Latvia, Lithuania and Malta from the Eurostat database. For the depth of financial intermediation, the ratio of total loans outstanding to GDP is calculated using total loans data from the Eurostat database and GDP data from the OECD ADB database for OECD members and the Eurostat database for Cyprus, Latvia, Lithuania and Malta. The indicator of banking reforms is obtained from the European Bank for Reconstruction and Development (EBRD). The EBRD indicators range from 0 to 4, with 4 indicating a fully liberalised market.

Estimation results

First the total cost function in equation 3 was estimated using the maximum likelihood method for 25 countries over 2004-2008 without variables controlling for the economic environment. In the next step, the technical efficiency scores were computed assuming exponential distribution of the X-inefficiency

7. Published by Bureau van Dijk (2009).

components as in equations 6 and 7. The efficiency scores computed for each bank were weighted by total assets of each bank to get the weighted averages in Table 1. Unweighted scores, especially in countries with a small number of banks in the sample, could provide a distorted picture as small banks with excessively high or low efficiency would be overrepresented in the (unweighted) average. The absolute level of the scores seems to be rather low in comparison with other studies. This is due to the inclusion of outliers in the estimation as their exclusion would have reduced the sample size substantially. The weighting of efficiency scores by total assets partly corrects for this. Another reason for the lower absolute efficiency scores compared to other studies, in particular with Holló and Nagy (2006) which uses a basically identical methodology may be the shifting of the efficiency frontier due to the pre-crisis lending spree. A couple of dozens of banks, which do not appear to be outliers *a priori* judging from their balance sheet and income statement data, exhibit extremely high efficiency scores, thereby "squeezing" the relative efficiency scores of other banks in the sample. It should be noted in general, that given the (sometimes substantial) differences in estimation methods or definition of variables, the estimated technical efficiency scores should not be directly compared across studies.

Table 1. Weighted average technical efficiency scores for the uncontrolled model

	2004	2005	2006	2007	2008	Average of 2003-2008	Ranking
AT	0.42	0.42	0.42	0.44	0.48	0.44	10
BE	0.43	0.46	0.48	0.49	0.43	0.46	6
CY	0.33	0.29	0.32	0.32	n.a.	0.31	23
CZ	0.35	0.36	0.37	0.35	0.42	0.37	16
DE	0.33	0.33	0.34	0.35	0.32	0.33	22
DK	0.41	0.44	0.46	0.47	0.48	0.45	8
EE	0.35	0.36	0.38	0.47	0.38	0.39	14
ES	0.74	0.62	0.52	0.44	0.47	0.56	1
FI	0.43	0.44	0.45	0.47	0.49	0.45	7
FR	0.44	0.45	0.47	0.32	0.37	0.41	12
GB	0.50	0.44	0.45	0.46	0.46	0.46	5
GR	0.31	0.35	0.36	0.36	0.38	0.35	19
HU	0.31	0.31	0.34	0.35	0.38	0.34	21
IE	0.49	0.64	0.52	0.69	0.31	0.53	3
IT	0.32	0.34	0.37	0.43	0.30	0.35	18
LT	0.43	0.44	0.46	0.47	0.39	0.44	9
LU	0.53	0.54	0.56	0.57	n.a.	0.55	2
LV	0.39	0.40	0.41	0.43	0.46	0.42	11
MT	0.32	0.33	0.34	0.36	0.36	0.34	20
NL	0.31	0.32	0.32	0.33	0.51	0.36	17
PL	0.28	0.29	0.30	0.32	0.35	0.31	24
PT	0.32	0.41	0.42	0.43	n.a.	0.39	13
SE	0.49	0.47	0.48	0.49	0.51	0.49	4
SI	0.34	0.36	0.39	0.41	0.43	0.38	15
SK	0.26	0.28	0.30	0.32	0.33	0.30	25

Note: Efficiency scores are averages weighted by total assets of each bank.

Source: Authors' estimation.

The estimated efficiency scores in Table 1 indicate that Spain leads the efficiency ranking, followed by Luxembourg, Ireland, the United Kingdom and the Scandinavian EU members. The high efficiency scores for Scandinavian countries match the results of Holló and Nagy (2006); Luxembourg, being a financial centre, not surprisingly has also one of the most efficient banking sectors in the EU. The same may also explain high efficiency of British banks. The high efficiency scores for Ireland and Spain, which were not observed in earlier studies, may partly reflect the lending booms in these countries prior to the global recession. The bad loans that such lending sprees may result in were not yet reflected in the data during the estimation period of 2004-2008.

Most new EU member states are at the bottom of the ranking, with the Slovak Republic, Poland and Cyprus occupying the three lowest places. Surprisingly, Germany ranks in the lower quartile of the distribution and is the only old member state with such a low ranking. Among banks in the new EU states, Lithuanian banks appear to be the most efficient, followed by Latvian ones. Hungary ranks 21st out of the 25 EU members, exactly the same as in the uncontrolled model of Holló and Nagy (2006). An increasing tendency in efficiency can be observed over 2005-2008, which may be explained by increasing access to wholesale funding and the pickup of bank lending growth. As for the level of relative efficiency, according to these estimates, there is room for Hungarian banks to increase efficiency by 60-70 percentage points to reach the level of the most efficient banks in the EU 25. As noted earlier, however, this frontier may well reflect the surge in lending prior to the global recession and even though gross loans are corrected for NPLs, future potential NPLs may still be included. That is, it is quite possible that many of these banks at the frontier will be saddled with NPLs that may only show up with a couple of years' lag.

Given that the macroeconomic environment in which banks operate may have a bearing on the efficiency with which they intermediate funds, the cost function was re-estimated by including variables controlling for different macroeconomic environments and stages of financial development and liberalisation. The set of control variables comprise the loan-to-GDP ratio to capture financial deepening, the GDP deflator to account for inflationary environments and the EBRD financial regulation indicator to capture the degree of financial liberalisation.

Table 2. Weighted average technical efficiency scores for the controlled model

	2004	2005	2006	2007	2008	Average of 2004-2008	Ranking
AT	0.42	0.42	0.42	0.44	0.48	0.44	10
BE	0.44	0.47	0.48	0.49	0.43	0.46	6
CY	0.32	0.29	0.31	0.31	n.a.	0.31	24
CZ	0.35	0.36	0.37	0.35	0.42	0.37	16
DE	0.33	0.33	0.34	0.35	0.32	0.34	21
DK	0.41	0.44	0.45	0.46	0.47	0.45	9
EE	0.34	0.34	0.36	0.46	0.36	0.37	15
ES	0.73	0.61	0.51	0.43	0.46	0.55	1
FI	0.43	0.45	0.46	0.47	0.49	0.46	7
FR	0.44	0.45	0.46	0.32	0.37	0.41	13
GB	0.51	0.44	0.45	0.46	0.46	0.46	5
GR	0.31	0.34	0.35	0.36	0.37	0.35	19
HU	0.31	0.30	0.33	0.34	0.37	0.33	22
IE	0.50	0.64	0.53	0.69	0.31	0.53	3
IT	0.32	0.34	0.36	0.42	0.30	0.35	18
LT	0.46	0.47	0.48	0.49	0.40	0.46	8
LU	0.52	0.53	0.54	0.56	n.a.	0.54	2
LV	0.38	0.40	0.41	0.42	0.44	0.41	11
MT	0.31	0.32	0.34	0.35	0.36	0.34	20
NL	0.31	0.32	0.32	0.33	0.50	0.35	17
PL	0.30	0.31	0.31	0.33	0.37	0.32	23
PT	0.32	0.40	0.41	0.42	n.a.	0.39	14
SE	0.49	0.47	0.48	0.49	0.51	0.49	4
SI	0.38	0.39	0.42	0.44	n.a.	0.41	12
SK	0.26	0.29	0.31	0.32	0.33	0.30	25

Note: Efficiency scores are averages weighted by total assets of each bank.

Source: Authors' estimation.

The estimated technical efficiency scores (Table 2) indicate that the ranking of countries does not change significantly if accounting for different macroeconomic and regulatory environments in which banks operate. There is only one country which moves more than one rank in the controlled model: Slovenia improves its position by three ranks when controlling for the macroeconomic and institutional environment. Germany and Poland's position improves one rank, and Cyprus', Denmark's, Estonia's, France's, Hungary's and Portugal's deteriorates by one rank.

The efficiency gap between old and new EU member states observed in Holló and Nagy (2006) thus still exists. The persistence of the efficiency gap even after controlling for the macroeconomic and regulatory environments suggests that there may be a skill gap leading to different manifestations of managerial abilities in old and new EU countries.

How do the estimated efficiency scores compare with accounting ratios?

Accounting data derived from financial statements may not be appropriate measures of efficiency in banking. A reduction of costs *per se*, for example, does not necessarily imply an increase in efficiency. In contrast, a reduction in the number of branches, for instance, may lead to losing customers, and hence, lowering profitability in some cases. Similarly, lay-offs may lead to capacity constraints that may result in losing market share. Therefore, it is impossible to draw far-reaching conclusions with regards to cost efficiency simply by following trends in costs.

More sophisticated accounting ratios such as costs over total assets may reveal somewhat more about bank costs, nevertheless are still far away from accurately reflecting cost efficiency. This is because the denominator effect may result in swings in this ratio: the value of the ratio may increase/decrease just because of a decrease/increase in total assets. The cost/net income ratio is similarly an imperfect measure of efficiency (rather used as a proxy for profit efficiency than cost efficiency) as it is very much dependent on corporate taxation rules, for instance, which may largely differ across countries. In addition, net income is also influenced by the ability of banks to exercise market power in pricing products and earn higher profits. Thus a higher value of the cost/net income ratio does not necessarily mean lower efficiency *per se*, it can alternatively mean lower pricing power of the bank or a combination of these factors, thus is not very useful to assess a bank's efficiency. There may be a case for looking at efficiency ratios defined as non-interest expense to net income or total assets as this is the part of costs that bank managers have more influence on, given that interest expense may be rather exogenous to their decision. Nevertheless, this ratio still has the drawbacks related to the denominators used as those above. The net interest margin is mostly used to measure bank profitability rather than cost efficiency and high margins may reflect a lack of competitive pressure in the market.

Bank analysts often use peer group analyses of banks with similar activities to compare their performance. Such analyses, however, in addition to the flaws related to the indicators and their components discussed above may also be unreliable, in particular if the banks are located in different countries as the different performances may stem from different macroeconomic, or regulatory environments and different levels of financial development. Estimated efficiency scores are immune to the above flaws: they are not sensitive to any denominator effect, are flexible to take into account a large number of factors that may influence X-efficiency. Such factors include those related to the external environment in which banks operate such as macroeconomic conditions, regulatory settings and the level of financial development.

To illustrate the large gap between accounting ratios and the efficiency ratios obtained by statistical methods, simple correlation ratios between selected accounting ratios attempting to capture cost efficiency and the estimated efficiency scores were calculated (Table 3). Cost measures, either defined as total cost or non-interest costs and either related to total assets or net income, have only a weak (negative) correlation with the estimated efficiency scores. Only the net interest margin has a relatively strong correlation with the efficiency scores, and the coefficient is negative, indicating that banks with low interest margins (and high competitive pressure) may be more efficient.

Table 3. Simple correlation coefficients of accounting ratios and estimated efficiency scores

	Non-interest expense/net income	Non-interest expense/total assets	Total costs/net income	Total costs/total assets	Net interest margin
Non-interest expense/net income	1				
Non-interest expense/total assets	0.224	1			
Total costs/net income	0.895	0.135	1		
Total costs/total assets	0.156	0.733	0.128	1	
Net interest margin	0.267	0.658	0.178	0.448	1
Efficency scores	-0.267	-0.403	-0.211	-0.315	-0.634

Source: Authors' calculation.

Policy discussion and recommendations

The low ranking of Hungarian banks in the EU 25 efficiency ladder may be explained by the lack of incentives to boost efficiency given the lucrative opportunities prevailing in some market segments, in particular retail lending where interest margins are substantially higher than in other neighbouring and EU countries. Notwithstanding the extremely high share of banks with majority foreign ownership, and their continuous entry during the past couple of decades to the banking market, competitive pressures did not seem to boost efficiency. This may be explained by the adaption of new comers to the local environment with weak competitive pressures and to the low level of consumer awareness and protection - in particular prior to the global financial crisis - which could have potentially constituted a source of competitive pressure.

A major lesson learnt from the crisis is that the approach towards lending, in particular household lending needs to change: stronger protection for borrowers needs to be combined with tighter regulation of lenders. In both directions the right balance needs to be struck, as neither the overprotection of households nor the overregulation of banks is a desirable outcome. The former can lead to moral hazard and boost the pool of "subprime" borrowers, while the latter can hurt the efficient functioning of the financial system and hence of the whole economy. Furthermore, to minimise the use of taxpayers' money, agents should be held accountable for their risk taking. In particular, households' borrowing should be determined by their repayment ability and banks should share the risks related to foreign exchange lending which is perceived as riskier and which can pose a threat to financial stability if its share is large. Furthermore, it is also essential to curb business practices that boost uncertainty and unnecessarily raise borrowing costs such as the unilateral change of lending contracts by banks.

Competition could be the major push for efficiency gains, but (i) in lack of mechanisms to impose discipline on applied fees, (ii) with high switching costs between institutions, (iii) non-portable housing loan subsidies, (iv) limited external competition in some market segments and (v) the lack of incentives to compete in prices, such gains are still to be realised. The global recession that also hit Hungary hard, has brought about some changes in regulations that can potentially boost competition and hence efficiency in the banking market. The possibility for banks to change the contract unilaterally has been curbed, therefore it has become more difficult to transfer increased costs to borrowers. The unilateral change of contracts, however, is in not in line with international lending practices and increases uncertainty on the borrowers' side, which, in times of crisis may pose a threat to financial stability if it is large scale. Moreover, it weakens competitive pressures as banks can resort to transferring the increased cost burden to borrowers instead of finding ways to reduce costs. Therefore, the possibility to change contracts unilaterally should be phased out.

Banking agents (both independent and belonging to a bank) played an important role in expanding the number of borrowers, in particular households. Loans intermediated by agents, however, *ex post* turned out to be worse performing than those extended directly by banks to customers. The temporary suspension of agents intermediating loans between banks and customers has temporarily halted the non-transparent and often abusive lending process where the agents' income depended on the size of the loan (including interest and other payments). To avoid such adverse incentives, agents' remuneration should be disclosed to the borrower and should not depend on the size of the gross loan. Moreover, as in other countries, agents could be a potential source of competitive pressure: by being obliged to present several alternatives to the customer, they could incite competition among banks.

Switching costs between banks had been temporarily reduced (in particular if the lender decided to change the loan servicing terms unilaterally, the borrower could switch to another bank offering lower costs) and the transparency of lending contracts has increased. After the expiry of this possibility, however, there remains ample room to reduce switching costs. In particular subsidised housing loans are not portable at all, either across banks or properties. This hinders bank competition and labour market mobility, in particular in a country where over 80% of households are home-owners.

The OECD Economic Survey of Hungary suggests several ways to boost competitive pressure in the banking market, which could then lead to increasing efficiency (OECD, 2010 and Molnár, 2010). In addition to the measures adopted or announced by the government, the OECD recommends the following reforms (Box 1):

Box 1. Foster competition to enhance efficiency in the banking market

- A comprehensive credit registry should be established to enhance efficiency in the household lending market.
- Financial products should be made more transparent and comparable. Contract conditions should be made available to the borrower before signing the contract.
- Independent agents should receive fees only from the customer and a fixed amount per type of transaction. They should be required to present several options to the customer. Those agents who work for or on behalf of banks should disclose the nature and the amount of their remuneration to the customer.
- Portability for housing loan subsidies across properties (as long as the new property is eligible) and across banks should be introduced.
- Unilateral change of contracts should not only be limited, but phased out altogether.

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ANNEX 1. DESCRIPTION OF THE DATASET USED

The Bankscope is the most comprehensive dataset available for bank-level microdata. Nevertheless, it has several shortcomings. First, the coverage of banks varies largely across countries: in the EU 25, for instance, Germany and Italy are relatively well covered, but Sweden and the United Kingdom are less so. Also, the coverage of variables and the available years vary by country. Moreover, different vintages include different variables, some may disappear and new ones are created, which makes it difficult to keep a consistent database. The same applies for observations, therefore it is crucial to keep data from older vintages when updating a database instead of overwriting it with new editions. Owing to such limitations, only unbalanced panel estimation was possible. The dataset remaining after dropping banks with missing observations contains 1674 banks in the 25 EU countries. This dataset was constructed continuously over mid- to end-2009 updating it with newly published data while keeping the old ones. The following variables were directly taken or constructed from the Bankscope:

- Total cost is the sum of interest paid and non-interest expense
- Loans are total loans (gross loans) net of impaired loans
- Other earning assets are the difference between total earning assets and total loans
- Non-interest income is total non-interest operating income
- Number of employees
- Fixed assets
- Borrowed funds are the sum of customer deposits, other deposits, short-term borrowing, long-term borrowing and subordinated debt.
- Price of labour is personnel expenses divided by the number of employees
- Price of capital is the difference between non-interest expenses and personnel expenses divided by fixed assets
- Price of borrowed funds is total interest expense divided by total borrowed funds (defined above)
- Total assets

As mentioned above, some variables appear in different ways, for instance at different levels of aggregation in different vintages. An example is total earning assets, which is not always available; in this case the non-earning asset types such as goodwill, foreclosed properties etc. were deducted from total assets along with fixed assets. Consistency checks were conducted to ensure that the corresponding variable is calculated.

Table A1.1 Descriptive statistics of the variables used for estimation

		Loans EUR '000	Other earning essets EUR '000	Non-interest income EUR '000	Number of employees	Fixed assets EUR '000	Borrowed funds EUR '000	Price of labour EUR '000	Price of capital EUR '000	Price of borrowed funds EUR '000	Total assets EUR '000	Total costs EUR '000	Number of banks
AT	Average	7578491	6637562	145893.4	3419.36	147534.4	8334206	92.80	1.42	0.08	1.53E+07	722063.6	46
	Standard Deviation	2.06E+07	1.52E+07	433365.4	11496.38	387751.8	2.09E+07	219.76	3.67	0.25	3.86E+07	1883541	
BE	Average	1.32E+07	1.40E+07	249594.3	3310.96	147015.1	1.58E+07	82.46	3.92	0.07	2.91E+07	1090655	15
	Standard Deviation	3.34E+07	3.68E+07	777044.1	9052.51	388113.9	4.10E+07	56.75	4.97	0.13	7.37E+07	2922211	
CY	Average	3237590	2382870	61099.89	1491.33	69193.33	5332926	45.89	1.11	0.05	6239707	271998	8
	Standard Deviation	5237154	3025381	103161	2581.76	112055.7	7593753	9.04	1.13	0.06	8761104	403172.4	
CZ	Average	1883962	1977011	65881.48	1350.38	43405.64	3353327	28.08	2.84	0.02	4089782	160677.8	11
	Standard Deviation	2124613	2741278	99764.62	2097.45	89692.4	4121323	7.90	3.25	0.01	4951151	205622.3	
DE	Average	1958277	1912614	33854.46	442.1	22304.54	2202527	53.04	1.18	0.06	4821884	168253.6	839
	Standard Deviation	1.90E+07	2.31E+07	442489.3	1565.46	68796.07	2.14E+07	22.66	3.94	0.52	6.44E+07	1727204	
DK	Average	4773705	4455608	64066.78	799.89	41505.39	5006100	68.94	2.91	0.04	1.08E+07	384216.5	41
	Standard Deviation	1.98E+07	1.89E+07	217660.1	2556.35	177968.4	2.15E+07	13.78	8.78	0.05	4.63E+07	1658955	
EE	Average	251875	101218.3	5263	172.7	2304.1	224720.4	19.20	1.23	0.03	379918.9	15714.9	3
	Standard Deviation	573586.8	86644.92	9995.19	174.67	1908.55	341485.7	4.72	0.88	0.01	702499.4	28185.75	
ES	Average	6011383	1308870	56039.13	897.22	47326.09	4836504	65.58	0.83	0.04	7562265	255687	68
	Standard Deviation	5634017	1569647	66256.19	924.69	47291.97	4871028	35.72	0.46	0.03	7182401	283105.6	
FI	Average	1.06E+07	3141422	194377.8	2085.56	41822.22	1.17E+07	52.34	4.43	0.03	1.50E+07	571022.2	4
	Standard Deviation	7651561	2105700	237873.8	1233.05	17718.62	8468613	7.78	4.22	0.01	1.03E+07	468082.2	
FR	Average	1.75E+07	2.87E+07	419500.1	3588.28	150092.8	2.13E+07	78.01	6.71	0.26	5.66E+07	1819506	86
	Standard Deviation	5.64E+07	1.09E+08	1312602	10042.41	487640.1	7.14E+07	51.09	14.53	1.23	2.09E+08	6209523	
GB	Average	4.80E+07	8.29E+07	1556150	11914.27	615250.9	6.15E+07	72.34	4.70	0.08	1.36E+08	3609433	29
	Standard Deviation	1.18E+08	2.69E+08	4031540	32421.23	1521988	1.59E+08	37.89	7.78	0.09	3.90E+08	9038809	
GR	Average	1.45E+07	6396370	134665	3620	211675	1.59E+07	47.81	1.04	0.04	2.23E+07	1069405	12
	Standard Deviation	1.37E+07	6999851	132563.7	2896.21	219271.4	1.53E+07	10.11	0.60	0.01	2.16E+07	1098550	
HU	Average	1984237	1204743	213042.7	2084.85	56173.72	2744443	37.47	15.89	0.06	3511397	294039	16
	Standard Deviation	2618795	2123443	374402	4610.27	81106.44	3771950	13.25	54.75	0.03	5012756	440796.1	
IE	Average	3824418	4770313	23126.33	182.44	6327.94	3652232	96.60	6.37	0.32	8830774	318624.7	15
	Standard Deviation	8333009	4854760	39915.87	472.77	17208.49	5189461	33.81	4.37	0.53	1.10E+07	415231.8	
IT	Average	1679369	1450756	33613.14	448.78	26336.34	2005985	70.26	1.93	0.03	3314513	146661.9	359
	Standard Deviation	5283542	1.26E+07	117609.8	1340.99	97532.3	7615595	130.76	10.05	0.03	1.68E+07	857829	
LT	Average	504028.1	210688.2	12347.23	459	7014.31	408582.1	14.62	1.96	0.05	780275.5	35643.31	4
	Standard Deviation	361837.3	200119	14610.82	129.70	3932.15	225615.4	3.48	1.44	0.02	424456.8	22883.38	
LU	Average	98675	159900	325436	185	825	253950	70.28	0.97	0.02	264775	6775	36
	Standard Deviation	10250	3508.09	95.74	211.95	150	11827.23	2.63	0.20	0.01	12291.02	1894.51	
LV	Average	676508.6	442710.3	21168.11	591.24	10442.45	739747.3	20.12	1.61	0.03	1162396	50029.55	9
	Standard Deviation	976147.1	419344.3	23073.07	695.43	11771.57	738564.6	7.93	0.88	0.02	1322486	66515.29	
MT	Average	1360868	1089106	23259.47	840.82	41598.06	2092244	31.59	1.10	0.03	2633727	101648.2	4
	Standard Deviation	1177197	1011830	19404.74	699.06	35800.94	1771053	10.92	1.81	0.02	2221744	84248.37	
NL	Average	4.75E+07	4.84E+07	928795.3	10342.23	614730.2	5.71E+07	85.13	4.70	0.07	1.02E+08	4011263	17
	Standard Deviation	1.14E+08	1.38E+08	2655477	29044.26	1878422	1.43E+08	26.39	7.51	0.07	2.65E+08	1.03E+07	
PL	Average	4399858	3236627	213231.7	11050.74	128970.1	5874285	30.14	3.27	0.05	8389419	417551.7	19
	Standard Deviation	4420611	2973818	221625.6	19032.4	145989.8	6032156	23.52	3.43	0.04	7938308	380759.5	
PT	Average	1.57E+07	1.10E+07	273350	3284.67	176716.7	1.59E+07	70.71	2.48	0.06	2.85E+07	1260750	8
	Standard Deviation	1.43E+07	9669429	201648.7	3014.83	168550.5	1.37E+07	34.64	2.12	0.01	2.51E+07	1111787	
SE	Average	2.02E+07	3.12E+07	412000.9	3290.93	23987.13	2.64E+07	79.21	30.93	0.03	5.41E+07	1821173	7
	Standard Deviation	2.55E+07	3.99E+07	506576	3871.45	46748.5	3.24E+07	17.34	42.48	0.02	6.71E+07	2391324	
SI	Average	1000488	520929	23624.23	565.5	24552.23	1060550	32.54	0.87	0.04	1606302	74332.88	8
	Standard Deviation	684756.4	321099.9	16312.22	393.86	19174.09	688724.8	3.65	0.60	0.03	991987.1	46762.31	
SK	Average	1118323	1125308	36185.39	1188.65	47124.57	1916401	27.35	1.80	0.04	2438747	116117.7	10
	Standard Deviation	1398790	1495559	47435.82	1582.55	67088.71	2532157	11.31	1.49	0.02	3052254	139845	
Total		9.18E+06	1.03E+07	2.21E+05	2.70E+03	1.08E+05	1.10E+07	54.90	4.25	0.06	2.10E+07	7.52E+05	1674

Source: Authors' calculations.

ANNEX 2. ESTIMATION RESULTS OF THE COST FRONTIER

First the total cost function in equation 3 was estimated using the maximum likelihood method for 25 countries over 2004-2008 without variables controlling for the economic environment (Table A2.1). Coefficients for all the output variables (loans, other earning assets and non-interest income) and all the input prices (the prices of labour, capital and borrowed funds) appear with the expected positive sign and all, except for loans are highly statistically significant. The non-significant coefficient on the loan variable may be explained by the use of net loans (total outstanding loans net of bad loans) in this estimation in contrast to other studies which use gross loans (including bad loans). Considering the fixed costs of screening and evaluation that a loan officer has to assume, it is the gross amount of loans that matters for costs not the net, at least until the loan is written off. Therefore, the coefficient on net loans is not significant. For the purpose of estimating efficiency scores, however, it is net loans that matter as the use of gross loans may classify banks that produce large amount of bad loans as highly efficient.

The sign of the decay parameter indicates that inefficiency has declined (efficiency increased) over 2004-2008 in the sample of 1674 banks in the EU-25 countries. In addition, separate Wald-type tests indicate that the hypothesis of time-invariant inefficiency is rejected at a statistically significant level, implying that inefficiency varies over time. This result justifies the use of the time varying decay model and the stochastic frontier instead of, for instance, the distribution free analysis. The non-stochastic part of the error-term (sigma_u) is much larger than the stochastic component indicating that estimation using non-parametric techniques such as the data envelopment analysis method, where all error is assumed to be owing to inefficiency, would not have been a big mistake.

Table A2.1 Maximum likelihood parameter estimates of the cost frontier

Dependent variable: total cost

	Coefficient	Standard Error	z-value	p-value
y1	0.01	0.04	0.25	0.80
y2	0.38	0.03	11.41	0.00
y3	0.19	0.06	3.28	0.00
w1	0.14	0.03	4.92	0.00
w2	0.41	0.02	16.89	0.00
w3	0.44	0.04	11.38	0.00
y1_sq	0.06	0.00	14.88	0.00
y2_sq	0.05	0.00	16.47	0.00
y3_sq	0.03	0.01	4.01	0.00
y1y2	-0.09	0.00	-20.28	0.00
y1y3	-0.06	0.01	-9.50	0.00
y2y3	-0.01	0.00	-2.60	0.01
w1w2	-0.09	0.00	-21.57	0.00
w1w3	-0.06	0.01	-8.50	0.00
w2w3	-0.01	0.00	-4.16	0.00
w1_sq	-0.03	0.00	-14.47	0.00
w2_sq	-0.01	0.00	-2.87	0.00
w3_sq	-0.01	0.00	-4.57	0.00
w1y1	0.03	0.00	7.51	0.00
w1y2	-0.02	0.00	-4.80	0.00
w1y3	-0.01	0.00	-2.19	0.03
w2y1	0.00	0.00	-1.18	0.24
w2y2	-0.01	0.00	-2.10	0.04
w2y3	0.01	0.00	3.56	0.00
w3y1	-0.03	0.00	-7.49	0.00
w3y2	0.02	0.00	7.17	0.00
w3y3	0.00	0.00	-0.59	0.56
cos_z1	-0.07	0.15	-0.47	0.64
cos_z2	-0.12	0.10	-1.22	0.22
cos_z3	0.40	0.12	3.19	0.00
sin_z1	-0.72	0.10	-7.38	0.00
sin_z2	-0.48	0.05	-10.17	0.00
sin_z3	0.12	0.14	0.85	0.40
cos_z1_z1	-0.30	0.05	-5.39	0.00
cos_z1_z2	0.20	0.09	2.22	0.03
cos_z1_z3	-0.01	0.09	-0.07	0.94
cos_z2_z3	0.16	0.07	2.34	0.02
cos_z2_z2	-0.30	0.05	-5.97	0.00
cos_z3_z3	-0.03	0.04	-0.74	0.46
sin_z1_z1	-0.46	0.07	-6.91	0.00
sin_z1_z2	0.28	0.09	3.25	0.00
sin_z1_z3	-0.02	0.08	-0.28	0.78
sin_z2_z3	0.07	0.06	1.20	0.23
sin_z2_z2	-0.20	0.04	-4.65	0.00
sin_z3_z3	-0.11	0.05	-2.14	0.03
cos_z1_z1_z1	-0.16	0.02	-7.00	0.00
cos_z1_z2_z1	0.21	0.05	4.45	0.00
cos_z1_z2_z2	-0.03	0.05	-0.64	0.53
cos_z1_z2_z3	-0.12	0.06	-1.91	0.06
cos_z2_z2_z2	-0.18	0.02	-7.83	0.00
cos_z2_z3_z2	0.21	0.04	5.21	0.00
cos_z2_z3_z3	-0.02	0.03	-0.71	0.48
cos_z3_z3_z3	0.05	0.02	2.29	0.02
cos_z3_z3_z1	-0.07	0.04	-1.73	0.08
cos_z3_z3_z2	-0.02	.	.	.
sin_z1_z1_z1	-0.25	0.03	-9.15	0.00
sin_z1_z2_z1	0.20	0.04	4.42	0.00
sin_z1_z2_z2	-0.01	0.05	-0.22	0.83
sin_z1_z2_z3	0.01	0.07	0.17	0.87
sin_z2_z2_z2	0.07	0.02	2.94	0.00
sin_z2_z3_z2	-0.12	0.04	-3.47	0.00
sin_z2_z3_z3	0.44	0.03	13.14	0.00
sin_z3_z3_z3	-0.04	0.02	-1.65	0.10
sin_z3_z3_z1	-0.11	0.04	-2.79	0.01
sin_z3_z3_z2	-0.38	.	.	.
constant	-1.01	0.19	-5.27	0.00
Decay parameter	0.04	0.00	13.32	0.00
sigma_u2	0.03	0.00		
sigma_v2	0.01	0.00		
Log likelihood	3680.58			
No. of observations	5334			

Source: Authors' estimation.

The estimation results of the cost function with control variables are in Table A2.2. Coefficients of the major variables of interest (outputs and input prices) appear with the expected positive signs and similarly to the estimation without controlling variables, only the coefficient on net loans is not statistically significant.

Among the control variables, the impact of financial deepening on total costs is negative, but not significant. Intuitively, deeper financial markets should help economising on costs owing to scale and scope economies, thus a negative sign is expected. The coefficient on the inflation variable is also negative and statistically significant, implying that higher inflation reduces costs for banks. This is plausible if considering that most cost components in general are not indexed for inflation. The impact of financial liberalisation on banks' total costs is also negative and statistically significant. This result is not surprising as higher degrees of liberalisation of the banking markets are supposed to reduce costs.

As in the model without variables controlling for the macroeconomic and regulatory environments, the sign of the decay parameter indicates that inefficiency has declined (efficiency increased) over 2004-2008 in the sample of 1674 banks in the EU-25 countries. In addition, separate Wald-type tests indicate that the hypothesis of time-invariant inefficiency is rejected at a statistically significant level, implying that inefficiency varies over time. Again, the choice of the time-varying decay model was the right one. The non-stochastic part of the error-term (sigma_u) is again much larger than the stochastic component.

Table A2.2 Maximum likelihood parameter estimates of the cost frontier with macroeconomic and institutional environment variables

Dependent variable: total cost

	Coefficient	Standard Error	z-value	p-value
y1	0.01	0.04	0.34	0.74
y2	0.38	0.03	11.26	0.00
y3	0.20	0.06	3.31	0.00
w1	0.13	0.03	4.35	0.00
w2	0.40	0.02	16.38	0.00
w3	0.47	0.04	11.98	0.00
y1_sq	0.06	0.00	15.12	0.00
y2_sq	0.05	0.00	16.30	0.00
y3_sq	0.03	0.01	4.01	0.00
y1y2	-0.08	0.00	-20.14	0.00
y1y3	-0.06	0.01	-9.67	0.00
y2y3	-0.01	0.00	-2.61	0.01
w1w2	-0.09	0.00	-20.87	0.00
w1w3	-0.07	0.01	-9.20	0.00
w2w3	-0.01	0.00	-4.21	0.00
w1_sq	-0.03	0.00	-14.66	0.00
w2_sq	0.00	0.00	-2.72	0.01
w3_sq	-0.01	0.00	-4.65	0.00
w1y1	0.03	0.00	7.58	0.00
w1y2	-0.02	0.00	-4.78	0.00
w1y3	-0.01	0.00	-2.39	0.02
w2y1	0.00	0.00	-1.04	0.30
w2y2	-0.01	0.00	-2.30	0.02
w2y3	0.01	0.00	3.62	0.00
w3y1	-0.03	0.00	-7.67	0.00
w3y2	0.02	0.00	7.28	0.00
w3y3	0.00	0.00	-0.41	0.68
cos_z1	-0.04	0.15	-0.30	0.76
cos_z2	-0.10	0.10	-1.08	0.28
cos_z3	0.41	0.12	3.34	0.00
sin_z1	-0.72	0.10	-7.35	0.00
sin_z2	-0.49	0.05	-10.23	0.00
sin_z3	0.12	0.14	0.88	0.38
cos_z1_z1	-0.27	0.06	-4.93	0.00
cos_z1_z2	0.20	0.09	2.30	0.02
cos_z1_z3	0.00	0.09	-0.06	0.96
cos_z2_z3	0.17	0.07	2.43	0.02
cos_z2_z2	-0.31	0.05	-6.02	0.00
cos_z3_z3	-0.04	0.04	-0.88	0.38
sin_z1_z1	-0.46	0.07	-6.98	0.00
sin_z1_z2	0.30	0.09	3.50	0.00
sin_z1_z3	-0.01	0.08	-0.07	0.94
sin_z2_z3	0.07	0.06	1.16	0.25
sin_z2_z2	-0.21	0.04	-4.84	0.00
sin_z3_z3	-0.11	0.05	-2.12	0.03
cos_z1_z1_z1	-0.15	0.02	-6.51	0.00
cos_z1_z2_z1	0.21	0.05	4.48	0.00
cos_z1_z2_z2	-0.04	0.05	-0.79	0.43
cos_z1_z2_z3	-0.11	0.06	-1.70	0.09
cos_z2_z2_z2	-0.18	0.02	-7.82	0.00
cos_z2_z3_z2	0.22	0.04	5.35	0.00
cos_z2_z3_z3	0.41	0.03	12.12	0.00
cos_z3_z3_z3	0.05	0.02	2.32	0.02
cos_z3_z3_z1	-0.07	0.04	-1.83	0.07
cos_z3_z3_z2	-0.46	.	.	.
sin_z1_z1_z1	-0.25	0.03	-9.29	0.00
sin_z1_z2_z1	0.21	0.04	4.69	0.00
sin_z1_z2_z2	-0.02	0.05	-0.36	0.72
sin_z1_z2_z3	0.02	0.07	0.30	0.77
sin_z2_z2_z2	0.07	0.02	2.86	0.00
sin_z2_z3_z2	-0.12	0.04	-3.53	0.00
sin_z2_z3_z3	-0.83	0.03	-24.62	0.00
sin_z3_z3_z3	-0.04	0.02	-1.92	0.06
sin_z3_z3_z1	-0.11	0.04	-2.61	0.01
sin_z3_z3_z2	0.90	.	.	.
lloangdp	-0.01	0.02	-0.35	0.73
lpgdp	-0.15	0.05	-2.80	0.01
lebrd	-0.60	0.18	-3.37	0.00
constant	-0.06	0.32	-0.19	0.85
Decay parameter	0.03	0.00	11.69	0.00
sigma_u2	0.03	0.00		
sigma_v2	0.01	0.00		
Log likelihood	3691.20			
No. of observations	5331			

Source: Authors' estimation.

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