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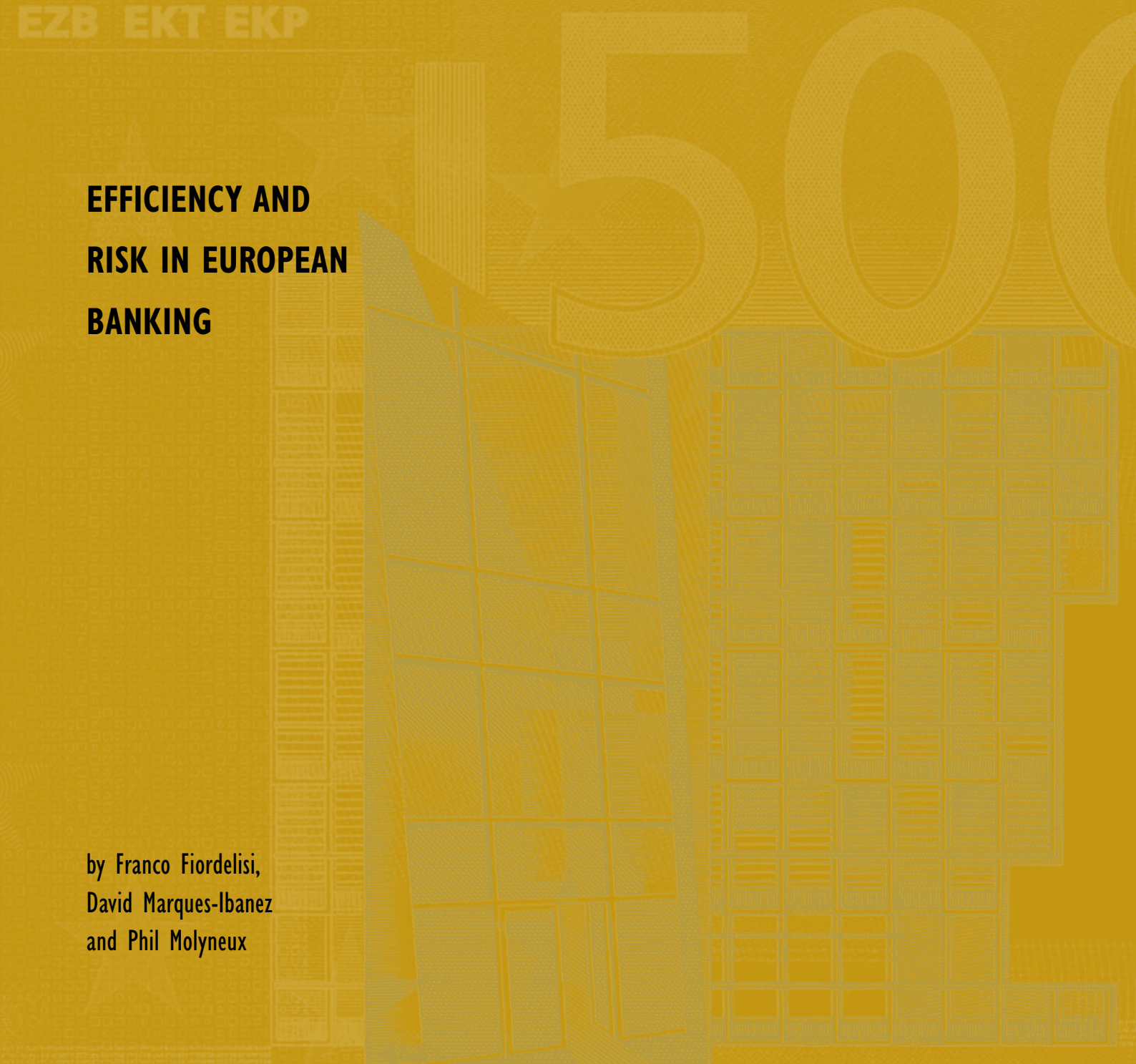

EFFICIENCY AND RISK IN EUROPEAN BANKING

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David Marques-Ibanez
and Phil Molyneux

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In 2010 all ECB publications feature a motif taken from the €500 banknote.

This paper can be downloaded without charge from http://www.ecb.europa.eu or from the Social Science Research Network electronic library at http://ssrn.com/abstract_id=1618296.

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Macroprudential Research Network

This paper presents research conducted within the Macroprudential Research Network (MaRs). The network is composed of economists from the European System of Central Banks (ESCB), i.e. the 27 national central banks of the European Union (EU) and the European Central Bank. The objective of MaRs is to develop core conceptual frameworks, models and/or tools supporting macro-prudential supervision in the EU.

The research is carried out in three work streams:
1. Macro-financial models linking financial stability and the performance of the economy;
2. Early warning systems and systemic risk indicators;
3. Assessing contagion risks.

MaRs is chaired by Philipp Hartmann (ECB). Paolo Angelini (Banca d'Italia), Laurent Clerc (Banque de France), Carsten Detken (ECB) and Katerina Šmídková (Czech National Bank) are workstream coordinators. Xavier Freixas (Universitat Pompeu Fabra) acts as external consultant and Angela Maddaloni (ECB) as Secretary.

The refereeing process of this paper has been coordinated by a team composed of Cornelia Holthausen, Kalin Nikolov and Bernd Schwaab (all ECB).

The paper is released in order to make the research of MaRs generally available, in preliminary form, to encourage comments and suggestions prior to final publication. The views expressed in the paper are the ones of the author(s) and do not necessarily reflect those of the ECB or of the ESCB.

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CONTENTS

Abstract

We analyze the impact of efficiency on bank risk. We also consider whether bank capital has an effect on this relationship. We model the inter-temporal relationships among efficiency, capital and risk for a large sample of commercial banks operating in the European Union. We find that reductions in cost and revenue efficiencies increase banks' future risks thus supporting the bad management and efficiency version of the moral hazard hypotheses. In contrast, bank efficiency improvements contribute to shore up bank capital levels. Our findings suggest that banks lagging behind in their efficiency levels might expect higher risk and subdued capital positions in the near future.

Keywords: banking risk; capital; efficiency

JEL classification: G21; D24; C23; E44

Non-technical summary

Following a process of de-regulation and innovation in credit markets over the two decades prior to the credit crisis that started in late 2007 European banking markets became increasingly integrated and more competitive. As a result of this process, there have been stronger pressures on banks' capital and a stronger emphasis on the importance of improved efficiency in the banking sector. That is, it forced banks to operate closer to the "best practice" or efficient production function.

Our aim is, first, to assess the impact of efficiency on bank risk. In this respect low levels of efficiency could lead banks to try to boost their performance via laxer credit standards and/or less intensive monitoring of credit. In turn, we will also have to consider if changes in bank risk have an influence on their efficiency levels. For instance, increases in bank risk may temporally precede a decline in cost efficiency related to lower credit screening.

Second, we aim to assess the impact of bank capital on the risk and efficiency trade-offs. Namely the relationship between efficiency and risk might be affected by the level of capital particularly in light of the decline of overall bank capital (as a proportion of total loans) at the macroeconomic level. For instance, moral hazard problems might increase incentives of thinly capitalized banks to augment their level of risk thereby incurring higher non-performing loans in the future.

To tackle these questions, we build on previous literature and asses the inter-temporal relationships between bank risk, efficiency and capital levels.[2] We use a large data set of European Union commercial banks from 26 European Union countries (EU-26) ranging from 1995 to 2007.

We use Granger-causality methods (Berger and De Young 1997, Williams 2004) in a panel data framework. Our model delves in the relationship between these factors by including several definitions of bank efficiency (i.e. cost, revenue and profit efficiency scores), risk (i.e. non-performing loans and probability of default) and capital (i.e. core equity and total capital).

In general, our results show that subdued bank efficiency (cost or revenue) Granger causes higher risk supporting the "bad management" hypothesis. We also show that increases in bank capital precede cost efficiency improvements suggesting that moral hazard incentives appear to fall as bank capital increases. Cost (and profit) efficiencies are also found to positively Granger-cause bank capital. In other words more efficient banks seem to eventually become more capitalized and higher capital also tend to have a positive effect on efficiency levels.

Overall we believe our results to be particularly interesting from a prudential supervisory perspective. The findings showing that low efficiency scores can harbinger future banking problems and that efficiency improvements tend to shore up banks' capital positions could be useful from a policy perspective. They emphasize the importance of attaining long-term efficiency gains also to support financial stability objectives.

[2] We focus on bank risk-taking, efficiency and capital level since these factors are free of measurement errors. Regarding the bank competition, there are various measures available (Goddard and Wilson, 2009), but it is still debated which one is the most accurate (Carbo et al., 2009).

1. Introduction

Over the last two decades prior to the credit crisis that started in late 2007, European banking markets became increasingly integrated. The twin forces of deregulation and technological change contributed to the progressive process of financial integration and increased competition in the financial services industry (ECB, 2010).[3] As a result of this process, there has been a tremendous emphasis on the importance of improved efficiency in the banking sector. That is, it has forced banks to operate closer to the "best practice" or efficient production function. At the same time, this increase in competition could – at least in the short term – lead to greater (and possibly excessive) risk-taking. This is because increased competition reduces the market power of banks thereby decreasing their charter value. The decline in banks´ charter values coupled with the banks' limited liability and the existence of 'quasi' flat rate deposit insurance could encourage banks to take on more risk (Matutes and Vives, 2000 and Salas and Saurina, 2003).[4] Regulators have tried to counterbalance these possible incentives by giving capital adequacy a more prominent role in the prudential regulatory process.[5]

In this environment a number of studies have focused on the impact of capital (Repullo, 2004; Allen et al., 2009; Gropp and Heider, 2010), operating efficiency (Casu and Girardone, 2009a) and business models (Demirgüc-Kunt and Huizinga, 2010) on bank risk.[6]

[3] See Goddard et al (2007).

[4] This issue is not undisputed; Boyd and Nicolo (2005) argue that the theoretical foundations linking more competition with increased incentives towards bank risk-taking are fragile. See Carletti and Hartmann (2002) for a useful survey of the literature linking competition and stability.

[5] For instance, in the aftermath of the introduction of the euro, Vives (2000, pg. 15) already argued that *'the general trend is to introduce competition in banking and to check risk- taking with capital requirements and appropriate supervision'*.

[6] A parallel literature has analysed the impact of bank competition on banks' risk and efficiency (e.g. Boyd and De Nicolo, 2003; De Nicolo et al., 2008, Cihak, Schaeck and Wolfe, 2009, Casu and Girardone, 2009).

Surprisingly, there are only a limited number of studies that assess inter-temporal relationships between bank risk, capital and efficiency. The recent credit crisis has highlighted the need for further understanding of the determinants of bank risk in an environment of enhanced bank efficiency and lower bank capital (Haldane and Alessandri, 2009).

Our aim is, first, to assess the impact of efficiency on bank risk. In this respect low levels of efficiency could lead banks to try to boost their performance via laxer standards and/or less intensive monitoring of credit.[7] In turn, we will also have to consider if changes in bank risk have an influence on efficiency levels. For instance, increases in bank risk may temporally precede a decline in cost efficiency related to lower credit screening.

Second, we aim to assess the impact of bank capital on risk and efficiency trade-offs. Namely, the relationship between efficiency and risk might be affected by the level of capital particularly in light of a decline in overall bank capital (as a proportion of total loans) at the macroeconomic level. For instance, moral hazard problems might increase incentives of thinly capitalized banks to augment their level of risk thereby incurring higher non-performing loans in the future. Similarly, highly capitalized banks may be subject to lower moral hazard problems and may be *both* more efficient and prudent than thinly capitalized institutions. Conversely, as capital is costly highly capitalized banks may, on average, increase their level of risk to maximize revenues.

To tackle these questions, we build on previous literature and assess the inter-temporal relationships between bank risk, efficiency and capital levels. We use a large data set of banks from 26 European Union countries (EU-26) ranging from 1995 to 2007. Our main variables of interest include both forward and backward-looking measures of bank risk, several measures of bank capital and three bank efficiency measures (revenue, cost and profit efficiencies).

[7] See section 3 for a detailed description of the main hypotheses.

The rest of this paper is organized as follows: section 2 includes a literature review while section 3 presents the main hypotheses of interest. The model specification, variables and data are explained in sections 4 and 5. Section 6 discusses the empirical results, section 7 presents the robustness checks and section 8 concludes.

2. Related literature

Bankruptcies in the financial sector are costly, not only for banks' equity and debt holders but often also for taxpayers. As a result the study of the determinants of banks' risk and, in particular, of the effectiveness of forcing banks to hold a certain amount of capital (to buttress bank stability) has a long history. An early line of US research on risk-taking incentives examined the effects of capital regulations (e.g. Peltzman, 1970 or Mayne, 1972).[8] The main concern of these early studies was to analyse the effectiveness of financial regulation and, especially, to consider whether the existence of a flat-rate deposit insurance scheme (i.e. not linked to banks' risk) created incentives for excessive risk. Overall, results from these earlier studies were sceptical about the effectiveness of banking capital regulation influencing banks' soundness (see Marcus, 1983).

The introduction of the 1988 Basel Accord on international bank capital standards (Basel I) reignited interest on the effectiveness of bank capital regulations. A new wave of studies (mostly for the US banking sector)[9] tended to find that regulatory capital constraints were buttressing banks' capital (e.g. Wall and Peterson, 1987 and Dahl and Shrieves, 1990). In the aftermath of the Basel I application and subsequent amendments, the interest on the effects of capital adequacy regulations on banks´ risk persisted. For instance, Ediz et al., (1997) found that bank capital regulation had been effective in increasing capital ratios

[8] Most of these earlier approaches build on Friedman's (1962) capital adjustment model.

[9] One exception is Barrios and Blanco (2003).

without substantially shifting bank portfolios and off-balance-sheet (OBS) exposures towards riskier assets in the US and UK. In this direction also, Demsetz et al., (1996) and Salas and Saurina (2003) found that banks with lower capital tended to operate with higher levels of credit risk in line with the moral hazard hypothesis.

In parallel, and depending on the focus and modelling strategy, the theoretical literature offers contradictory results as to the effects of capital requirements on bank risk-taking incentives (see Berger *et al*., 1995; Freixas and Rochet, 2008; Santos, 1999; Boot *et al*., 1998). Overall then, the issue of whether higher capital ratios reduce overall banking risk has remained largely unresolved.

A major contribution to the debate came from Hughes and Mester (1998, 2009) who argued for the need to consider *bank efficiency* when analysing the relationship between capital and risk. According to Hughes and Mester (1998, 2009) both capital and risk are likely to be determined by the level of bank efficiency. For instance, supervisory authorities may allow efficient banks (with high quality management) a greater flexibility in terms of their capital leverage or overall risk profile, *ceteris paribus*. On the other hand, a less efficient bank with low capital may be tempted to take on higher risk to compensate for lost returns due to moral hazard considerations.

In this line Berger and De Young (1997) and Kwan and Eisenbeis (1997) posit that it is crucial to recognise explicitly the concept of bank efficiency in empirical models analysing the determinants of banks´ risk.[10] Berger and De Young (1997) employ Granger-causality methods to assess the inter-temporal relationships among problem loans, cost efficiency, and capital for a sample of US banks from 1985 to 1994. Kwan and Eisenbeis (1997) use a simultaneous equation framework to test hypotheses about the interrelationships between

[10] Pastor and Serrano (2005) also examine the link between efficiency and risk-taking.

bank risk, capitalization, and operating efficiency. Both papers provide evidence that both efficiency and capital are relevant determinants of bank risk.

Berger and De Young (1997) show that declines in cost efficiency precede increases in problem loans (particularly at thinly capitalised banks). They also show that problem loans result in reductions in cost efficiency. Kwan and Eisenbeis (1997) also found that poorly performing banks are more vulnerable to risk-taking. They also find that that highly capitalised banks are more efficient than less capitalised institutions.

Williams (2004) and Altunbas et al., (2007) have replicated both papers in a European banking setting. Similar to Berger and De Young (1997), Williams (2004) uses Granger-causality techniques to assess the inter-temporal relationships among problem loans, cost efficiency, and financial capital. His sample includes European savings banks over the period 1990-1998 and finds that poorly managed banks tend to make more poor quality loans. Altunbas et al., (2007) follow an approach similar to Kwan and Eisenbeis (1997) and use a static simultaneous equation framework to investigate the relationship between capital, loan provisions and cost efficiency for a sample of European banks over the period 1992-2000. In stark contrast to Williams (2004), Altunbas et al., (2007) do not find a positive relationship between inefficiency and bank risk-taking. Inefficient European banks appear to hold more capital and take on less risk. Overall, the European studies yield contradictory findings as to the relationships between operating efficiency, capital and bank risk.

This paper sheds light on the relationship between bank efficiency, capital and risk in the European Union extending the established literature in three dimensions. First unlike previous studies our sample includes contemporaneous banking data from the 2000s. That is, for the first time the data also covers the period of monetary union that has led to radical changes in the European financial system increasing banks' pressures towards operate more efficiently (Goddard et al., 2007, Bos and Schmiedel, 2007). Second, compared with earlier

studies we investigate the risk-efficiency-capital relationships by constructing a broader set of variables accounting for each of these concepts. While previous studies mostly focus either on cost efficiency (e.g. Kwan and Eisenbeis 1997, Berger and DeYoung 1997, Williams 2004, Altunbas et al., 2007) or profit efficiency (Berger and Bonaccorsi 2006), we estimate both cost and revenue efficiency estimators (and do robustness checks with a profit efficiency measure). We focus on cost and revenue efficiencies as they reflect two different managerial abilities (i.e. the abilities to maximize revenues and minimize costs respectively). We posit that each of these measures can have a different link with bank risk and capital levels (see section 3). In line with previous studies we include a measure of bank risk derived from banks' financial statements (i.e. non-performing loans and total loans). We complement this measure with a forward-looking indicator of bank risk capturing the financial markets' view of banks' likelihood of default obtained from Moodys-KMV. Compared to previous studies we also resort to a wider measure of bank capital (i.e. total capital instead of equity capital). Finally, we also extend the earlier literature by using an econometric modelling framework that embeds Granger causality estimations in a GMM framework.[11] Previous studies mostly rely on OLS estimation but this may be problematic since the introduction of a lagged dependent variable among the predictors creates complications as the lagged dependent variable is often strongly correlated with the disturbance term.

3. Research hypotheses

Before introducing the empirical model and building on previous studies, we posit the major research hypotheses about the inter-temporal relationship between bank risk, capital and efficiency building on Berger and DeYoung (1997) and Kwan and Eisenbeis 1997.

[11] See Casu and Girardone (2009) for an application of this estimation procedure to banking.

Banks' efficiency levels may impact on future bank risk. In what Berger and DeYoung (1997), and Williams (2004) labeled as the "bad management" hypothesis, banks operating with low levels of efficiency have higher costs largely due to inadequate credit monitoring and inefficient control of operating expenses (which is reflected in lower cost efficiency almost immediately). Declines in cost (and revenue) efficiency will temporally precede increases in banks' risk due to credit, operational, market and reputational problems.

The "cost skimping" hypothesis assumes that there is a trade-off between short-term cost efficiency and future risk-taking due to moral hazard considerations. In such cases, banks appear to be more cost efficient as they devote fewer resources to credit screening and monitoring. As a result the stock of non-performing loans remains unaffected in the short run. In the medium term however, banks reach higher risk levels as they have to purchase the additional inputs necessary to administer future higher risks. In the case of revenue efficiency, higher levels of short-term profits are normally obtained at the cost of laxer credit screening. This will also normally result in higher future risks. In other words, a bank may be tempted to increase revenues simply by taking on higher risks to compensate for lost returns.

The "bad luck" hypothesis is related to the consequences of increases in bank risk on efficiency levels. It argues that external exogenous events (e.g., unexpected shocks) can precipitate increases in problem loans for the bank unrelated to managers' skills or their risk-taking appetite. These increases in risk result in additional costs and managerial effort. Thus, under this hypothesis, we expect increases in bank risk to precede falls in cost and revenue efficiency.

The 'moral hazard' hypothesis suggests a negative causal relationship between capital and risk pointing out that bank managers have incentives to take on more risk particularly when the level of bank capital is low (or banks are more inefficient). The moral hazard hypothesis could arise in the presence of informational frictions and the existence of relevant

'agency problems' between bank managers and owners (see Gorton and Rosen, 1995). A traditional moral hazard problem being when managers take-on risks that are borne entirely by the shareholders.[12] Better capitalised banks, in contrast, have less moral hazard incentives (Jeitschko and Jeung, 2005) and are more prone to adopt careful practices to reduce costs (e.g. shareholders may be more active in controlling bank costs or capital allocation). Regulators can also force banks to increase the amount of capital commensurably with the amount of risk taken (Gropp and Heider, 2010). Holding additional capital buffers above the regulatory minimum for banks with higher levels of risk aims to avoid the costs associated with having to issue fresh equity at short notice (Ayuso et al., 2004; Peura and Keppo, 2006). As indicated by Hellman, Murdock and Stiglitz (2000), banks could also respond to regulatory actions forcing them to hold more capital by increasing portfolio risk.

4. Methodology

We rely on Granger-Causality techniques to investigate the relationship between bank risk, capital and efficiency as this approach allows us to test unique time-ordered and signed relationships among pairs of variables.[13] While Granger-Causality tests have a number of limitations,[14] this approach has been widely used to analyze inter-temporal relationships in the economic literature (e.g. Jaeger and Paserman 2008, Assenmacher-Wesche and Gerlach 2008, Amato and Swanson 2001 and Bajo-Rubio et al., 2001) as well as in banking studies (e.g. Fiordelisi

[12] Bank managers may also have incentives to exploit flat rate deposit insurance schemes.

[13] Granger's (1969, p. 428) notion of causality states that "… y_t is causing x_t if we are better able to predict x_t using all available information than if the information apart from y_t had been used". Granger's suggestion to regress x_t on its own lags and a set of lagged y_t has become a standard procedure. If lagged y_t provides a statistically significant explanation of x_t, y_t "Granger" causes x_t.

[14] Granger-testing does not prove economic causation between two variables but identifies gross statistical associations.

and Molyneux 2010, Casu and Girardone 2009, Beccalli 2007, Williams, 2004, Levine et al., 2000, Berger and DeYoung, 1997).

In order to disentangle the inter-temporal relationships between bank capital, efficiency and risk we estimate the following equations:

$$Risk_{i,t} = f_1(Risk_{i,lag}, x\text{-}eff_{i,lag}, \tau\text{-}eff_{i,lag}, E/TA_{i,lag}, Z_{i,t}) + \varepsilon_{i,t} \quad (1)$$

$$x\text{-}eff_{i,t} = f_1(Risk_{i,lag}, x\text{-}eff_{i,lag}, \tau\text{-}eff_{i,lag}, E/TA_{i,lag}, Z_{i,t}) + \varepsilon_{i,t} \quad (2)$$

$$\tau\text{-}eff_{i,t} = f_1(Risk_{i,lag}, x\text{-}eff_{i,lag}, \tau\text{-}eff_{i,lag}, E/TA_{i,lag}, Z_{i,t}) + \varepsilon_{i,t} \quad (3)$$

$$E/TAf_{i,t} = f_1(Risk_{i,lag}, x\text{-}eff_{i,lag}, \tau\text{-}eff_{i,lag}, E/TA_{i,lag}, Z_{i,t}) + \varepsilon_{i,t} \quad (4)$$

where the *i* subscript denotes the cross-sectional dimension across banks, *t* denotes the time dimension, *Risk* is the variable accounting for bank's risk, *X-EFF* and *τ-EFF* are the cost and revenue efficiency scores respectively. *E/TA* is the equity to total asset ratio while $Z_{(j=1,\ldots,4)}$ are control variables including factors influencing the efficiency-capital-risk relationship and $e_{i,t}$ is the random error term. The variable definitions are summarized in Table 1.

<< INSERT TABLE 1 HERE >>

Equation (1) tests if cost and revenue efficiency changes temporally precede variations in bank risk. Equations (2) and (3) assess if changes in bank risk temporally precede variations in cost and/or revenue efficiency and equation (4) considers whether bank capital levels temporally precede changes in risk.

We use two lags and estimate an *AR(2)* process for the risk, capital and efficiency variables.[15] Following Casu and Girardone (2009), Granger causality is assessed as the joint test of the null hypothesis that the two lags are equal to zero. With the *AR(2)* process, we analyze Granger causality as the joint test that the two lags of each of the determinants is distributed as a chi-square (χ^2) with two degrees of freedom. If the probability is less than 10%, then the null hypothesis that *x* does not Granger-cause *y* is rejected at the 10% significance level. We also assess the 'long-run effect' of *x* over the *y* by testing for the restriction that the sum of all lagged coefficients is zero: a rejection of the restriction implies that there is evidence of a long-run effect of *x* on *y*.

Various problems arise in the estimation of such a model.[16] The introduction of a lagged dependent variable among the predictors creates complications in the estimation as the lagged dependent variable is correlated with the disturbance (even under the assumption that $\varepsilon_{i,t}$ is not itself correlated). To tackle this problem, we use the system Generalized Method of Moments (GMM) estimators developed for dynamic panel models by Arellano and Bover (1995) and Blundell and Bond (1998). Hence we calculate the two-step system GMM estimator with Windmeijer (2005) corrected standard error to conduct our analysis.[17]

[15] We tested several specifications in terms of the number of lags (estimates available from the authors on request). Unlike Berger and DeYoung (1997) and Williams (2004) we resort to two lags which seem economically reasonable given the (annual) frequency of our data. We wish to thank the referee for this helpful comment.

[16] Various studies use the Granger causality test running OLS regressions (e.g. Berger and DeYoung, 1997; Williams, 2004), while more recently the approach has been applied using dynamic panel estimators (e.g. Casu and Girardone, 2009).

[17]The estimated asymptotic standard errors of the efficient two-step GMM estimator are severely downward biased in small samples and sos we correct for this bias using the method proposed by Windmeijer (2005).

5. Variables and data

Measurement error can be one of the main problems encountered when assessing bank risk and efficiency. As bank risk is a crucial measure in our analysis we try to capture its main dimensions by using two major measures: the 5-year ahead cumulative Expected Default Frequency (*EDF*) for each bank calculated by Moody's *KMV* and the traditional non-performing loans to total loans ratio *NPL\L*. The *EDF* is a forward-looking measure and refers to the expected probability of default within the short-term (1-year ahead) accounting for all banks' risks (i.e. not only credit risk). The *EDF* is a (well-known) indicator of credit risk, computed by Moody's KMV and builds on Merton's model to price corporate bond debt (Merton, 1974).[18] It uses data on stock market prices, banks' balance-sheet information and Moody's proprietary bankruptcy database. *EDF* figures are regularly used by financial institutions, investors, central banks and regulators to monitor the health of individual banks as well as the financial system overall. We also use the Creditedge database to obtain the 5 years ahead accumulated *EDF*.

Previous studies (e.g. Berger and De Young, 1997, Williams 2004) focus on the non-performing to total loans ratio (*NPL*) as a proxy for banks' credit risk. While the *NPL* is a widely used accounting indicator of banks' risk, this measure is subject to managerial discretion, focuses mostly on credit risk and is backward looking. Overall, both our measures of banks' risk are complementary. While *EDF* is forward-looking and a broader measure of banks' risks, *NPL* accounts for realized credit risk.

Regarding bank efficiency, we estimate both cost and revenue efficiency estimators using the stochastic frontier approach (details are outlined in the Appendix). While previous studies mostly focus either on cost efficiency (e.g. Kwan and Eisenbeis 1997, Berger and DeYoung

[18] Dwyer and Qu (2007) and Kealhofer (2003) provide further details on the construction of *EDFs*. For an empirical application of *EDFs* see, for instance, Garlappi et al. (2007).

1997, Williams 2004, Altunbas et al., 2007) or profit efficiency (Berger and Bonaccorsi 2006), we estimate both the cost and revenue efficiency estimators as: 1) prior literature would suggest that risk and capital may have different relationship with revenue or cost efficiency; 2) we prefer to disentangle the concept of bank efficiency into cost and revenue elements rather than estimating an all-encompassing single profit efficiency measure (capturing jointly cost and revenue effects) and then its relationship with bank capital and risk. We also estimate profit efficiency as a robustness check.

Bank capital adequacy is measured as the equity to assets ratio (*E/TA*), i.e. the value of total equity divided by the value of total assets. Equity capital is measured focusing on the Basel Committee definition of bank capital[19] by summing the *TIER I* (i.e. total equity, retained earnings and other disclosed equity reserves) and *TIER II* (i.e. undisclosed equity reserves, general provisions, hybrid capital instruments, and subordinated debts) components of bank capital. By focusing on a wider definition of banks' equity, we aim to consider supplementary items that are commonly used by banks to increase their capital on top of traditional equity. This measure is able to capture better the concept of bank capital adequacy (and management) than the book value of equity (Santos, 1999, Diamond and Rajan, 2000). As a robustness check, we also use a narrower definition of bank capital defined as the core value of equity to total assets (E_A/TA).

We build on the previous literature to control for other factors that may influence the relationship between capital, risk and efficiency. Namely, we include a set of controls accounting for: 1) banks' business model proxied using an income diversification variable (*ID*, i.e. the ratio between net non-interest income and net operating income);[20] 2) market structure

[19] We would like to thank an anonymous referee for this suggestion.

[20] Lepetit et al., (2008).

by controlling for domestic concentration (*CONC* using the Herfindahl–Hirschman Index) and number of credit institutions (*Ln(NCI)*;[21] 3) bank's size (*Ln(TA)*logarithm of total assets).

Turning to our sample, we focus on commercial banks from the European Union (EU-26)[22] between 1995 and 2007.[23] We focus on commercial banks[24] as their behavior, incentives and competitive environment differ from saving banks, investment banks and other special financial institutions. Information on banks' financial statements were obtained from Bankscope, a privately owned financial database maintained by Bureau Van Dijk. Macroeconomic information is taken from Datastream (managed by Thompson Financial Limited) while estimates for the 5-year ahead expected default frequencies are calculated by Moodys-KMV**.** Our final sample comprises 1,987 bank observations and mainly comprises French, UK, German, Italian and Spanish commercial banks (accounting for 14%, 10%, 9%, 8% and 8% of the observations, respectively).

<< INSERT TABLE 2 HERE >>

Mean cost- and revenue- efficiencies range between 37% and 59%, whereas the average *EDF* are slightly lower than 1% while non-performing loans are less than 3.5% of total bank loans. Non-interest income accounts, on average, for 20% of net operating income whereas total loans are, on average, around 78% of total bank assets. Correlation among the variables is usually negligible suggesting that our models are unlikely to suffer from major multicollinearity problems.[25]

[21] These two measures are found to be negatively correlated, but the magnitude of the Pearson correlation coefficient (i.e. -0.5027) suggest no serious multicollineary problems.

[22] Due to the specialist offshore business of Luxembourg banks these were excluded from the sample.

[23] We focus on this time period since data prior to 1995 (especially on the EDF) is often not available and after 2007 the implementation of the Basel II capital accord might have complicated the interpretation of the relationships. Overall, it has to be borne in mind that for most of this period credit risk has been at relatively benign levels.

[24] As defined by Bankscope.

[25] Estimated correlations coefficients are available upon request from the authors

6. Results

We report the results from models (1)-(4) using two lags on equity capital, cost efficiency, revenue efficiency and bank risk in table 3, where bank risk is measured using *EDF* (i.e. the 1-year ahead expected default frequency), the EDF_{5Y} (i.e. the 5-year ahead expected default frequency) and the *NPL/L* (i.e. the ratio of non-performing to total loans).

<<INSERT TABLE 3 >>

Cost (*x-eff*) and revenue (*τ-eff*) efficiencies are found to negatively Granger-cause bank's *EDF* (i.e. *y=EDF* in table 3). Our results show that a decline in the sum of the lagged efficiency coefficients, i.e. the 'long-run effect' (for both cost and revenue efficiency, respectively) temporally precede an increase in the *EDF.* This suggests that reductions in bank efficiency (either cost or revenue) Granger cause a higher probability of default – this confirms the "bad management" hypothesis and is in-line with the earlier findings of Berger and De Young (1997), Kwan and Eisenbeis (1997) and Williams (2004)

We also find a negative statistically significant (at the 1% level) link between *EDF* and the concentration index showing that bank risks are lower in more concentrated markets (i.e. less concentrated – possibly more competitive – banking systems might be less stable in the long-run in line with Boyd and Nicolo, 2003). These conclusions are also supported when an accounting measure is used to assess bank risk. In the *NPL/L* model (i.e. *y=NPL/L* in table 3): cost and revenue efficiency declines temporally precede *NPL* increases. There is also a negative link between the *NPL/L* ratio and the concentration index. When bank risk is measured using the EDF_{5Y} (so over a long-term horizon), we find no relationship between industry structure and risk suggesting that effects get blurred in terms of long-run risk expectations.

We show that the capital ratio (*E/TA*) is found to positively Granger-cause cost efficiencies (*x-eff*) (statistically significant at 5% or less) in all the model (2) estimations (i.e. *y=x-eff* in table 3). Namely, an increase in the sum of the lagged capital ratio coefficients temporally precede cost efficiency increases although there is no impact on risk. This suggests that moral hazard incentives appear to fall as bank capital increases and these banks are more likely to reduce costs (e.g. shareholder may be more active in controlling bank costs or capital allocation) than thinly capitalised banks. These conclusions are independent from the bank risk measure adopted in estimating model (2): namely, the long-run positive causation effect between capital and cost efficiency is found in all models using different definitions of bank risk (i.e. *EDF, EDF_{5Y}, NPL/L*). We also find a positive statistically significant (at the 1% level) link between cost efficiency and the number of credit institutions (*NCI*) suggesting that cost efficiency levels are positively linked to the number of competitors in the market (supporting the view that competition makes banks more cost effective). We also find a negative statistically significant (at the 5% level or less) link between cost efficiency and income diversification (*ID*) suggesting that more specialised banks benefit from scale and learning economies that enable them to reduce costs more than their diversified counterparts. These conclusions are also independent from the bank risk measure adopted.

We also show that the cost efficiency indicator (*x-eff*) is found to positively Granger-cause bank's capital (*E/TA*) (statistically significant at 10% or less) in all the models (4) estimations (i.e. *y=E/TA* in table 3). Increases in the sum of the lagged cost efficiency coefficients temporally precede equity ratio increases and the result holds for all bank risk measures (i.e. *EDF, EDF_{5Y}, NPL/L*) used in estimating model (4). This finding is consistent with Berger and DeYoung (1997) and Williams (2004) where short-term cost efficiency gains (driven by reducing loan underwriting, monitoring and control costs) would feed

through into higher capital. This is probably because more efficient banks have higher earnings which Granger-cause increases in capital.

We also find a positive statistically significant (at the 1% level) link between the capital ratio and the number of credit institutions (*NCI*) tentatively suggesting that high capital levels are positively linked to the number of competitors in the market (so supporting the view that bank competition might encourage higher equity capital levels).

Surprisingly and unlike most of the previous literature we find no strong causal relationship between capital and risk (when measured using *EDF* or EDF_{5Y}) for our period of study. There is however evidence of positive bi-directional Granger causality when *NPL/L* is our risk measure. This suggests that capital is more likely to be related to past credit risks than broader-based (future) banking risks.

7. Robustness tests

In order to confirm the validity of the aforementioned findings, we conducted a number of robustness checks. Firstly, we calculate the equity ratio in a standard accounting way (E_A/TA) by focussing on the book value of total equity (rather than the Basel Committee capital definition) and we re-estimate models (1) to (4). As in table 3, table 4 reports all the results obtained from estimating models (1)-(4) using the three different measures of bank risk (i.e. the *EDF*, the EDF_{5Y} and the *NPL/L*). While we are able to confirm that cost efficiency (*x-eff*) and revenue efficiency (τ-*eff*) negatively Granger-cause bank's *EDF* and *NPL/L* (statistically significant at 10% or less), in the estimation of model (1) we cannot confirm our previous results concerning capital ratios. We find no evidence of Granger-causation between our narrow measure of capital (E_A/TA) and bank cost efficiencies. This suggests that the use of supplementary capital items such as subordinated debt and hybrid capital instruments (commonly used by European banks) may influence capital cost efficiency relationships. As

in our previous results we find little relationship between equity capital and risk apart from evidence that *EDF* negatively causes equity capital – higher long-run risk seems to Granger cause reductions in equity capital over time although we find no such relationship for our other risk measures.

<<INSERT TABLE 4 >>

Secondly, we also estimate profit efficiency (rather than cost and revenue efficiency as noted above) and re-estimate models (1) to (4). Our results (table 5) show that profit efficiency (π-*eff*) is found to positively Granger-cause bank's capital (*E/TA*) (statistically significant at 10% or less) in all the model (4) estimations (i.e. *y=E/TA* in table 5). This result is consistent with the positive causation between cost efficiency and the capital-asset ratio. We also find evidence that profit efficiency negatively Granger-causes (at the 10% confidence level) bank's *EDF* or *NPL/L* in the model (1) estimations. As in Table 3 we also find a bi-directional causal relationship between capital and *NPL/L*.

<<INSERT TABLE 5 >>

Thirdly, we re-estimate equations (1)-(4) positing a *AR(4)* lag structure for bank risk, capital and efficiency. This change has substantial effects on our sample composition by reducing the number of bank observations from 1,987 to 667. As shown in table 6, the *AR(4)* specification cannot be safely assumed since longer lags may be weak instruments. As expected, test statistics are found to be insignificant at three and four lags and, overall, we find little evidence to support the claim that causal relationships exist (in the long run) beyond a single or two-lag (i.e. two years) period.

<<INSERT TABLE 6 >>

8. Conclusions

We assess the inter-temporal relationships among bank efficiency, capital and risk for the European commercial banking industry. We build on previous work using Granger-causality methods (Berger and De Young 1997, Williams 2004) in a panel data framework. Our model delves into the relationships by including several definitions of bank efficiency (i.e. cost, revenue and profit efficiency scores), risk (i.e. non-performing loans and probability of default) and capital (i.e. core equity and total capital).

In general, our results show that subdued bank efficiency (cost or revenue) Granger causes risk supporting the "bad management" and the "efficiency version of the moral hazard" hypotheses. We also show that increases in bank capital precede cost efficiency improvements suggesting that moral hazard incentives appear to fall as bank capital increases. Better capitalized banks are more likely to reduce their costs compared to their thinly capitalized counterparts. Cost (and profit) efficiencies are also found to positively Granger-cause bank capital. In other words more efficient banks seem to eventually become better capitalized and higher capital levels also tend to have a positive effect on efficiency levels.

We find only limited evidence of relationships between capital and risk in line with the moral hazard hypothesis. The main finding seems to be a bi-directional causal link between capital and our accounting measure of risk (*NPL/L*). There is little evidence of any strong causal link between capital (total capital or equity capital) and our market-based bank risk indicators.

Overall we believe our results to be particularly interesting from a prudential

supervisory perspective. The findings showing that lower efficiency scores (either cost or revenue) suggest greater future risks and efficiency improvements tend to shore up banks' capital positions. Our findings also emphasize the importance of attaining long-term efficiency gains to support financial stability objectives.

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Table 1
Variables description

Variables	Symbol	Description
Cost Efficiency	*x-eff*	Estimated using Stochastic Frontier analysis.(*)
Revenue Efficiency	*τ-eff*	Estimated using Stochastic Frontier analysis.(*)
Profit Efficiency	*π-eff*	Estimated using Stochastic Frontier analysis.(*)
Non Performing Loans	*NPL/L*	Non-performing loans over the total gross value of total bank loans.(1)
1-Year Ahead Expected Default Frequency™	*EDF*	Probability that a company (bank) will default within a year. (2)
5-Years Ahead Expected Default Frequency™	EDF_{5Y}	Cumulative probability that a company (bank) will default within 5 years.(3)
Capital to Asset Ratio	*E/TA*	Value of total equity divided by total assets. Equity capital is measured focusing on the Basel Committee definition of capital by summing total equity, retained earnings, general banking risk reserves, other equity reserves, hybrid capital instruments and subordinated debts.(1)
Book value of Capital to Asset Ratio	E_A/TA	Total equity divided by total assets. Equity capital is measured by the book value of total equity.(1)
Income Diversification	*ID*	Net non-interest income to net operating income.(1)
Bank Asset Size	*BAS*	BAS is the Euro value of its total assets.(1)
Domestic Banking Industry Concentration	*CONC*	Herfindahl-Hirschman Index.(4)
Number of Credit Institutions	*NCI*	NCI is the number of credit institutions.(5)
Interest Rate	*IR*	3-month money market interest rate.(6)
GDP Per-capita	*Ln(GDPP)*	Natural logarithm of the domestic *GDP* (in Euro) divided by the number of inhabitants.(6)
GDP Annual Growth Rate	*GDPG*	Domestic *GDP* growth rate between two consecutive years.(6)
Population Density	*Ln(POPD)*	Natural logarithm of the number of inhabitants per $Km.^2$ (6)

[k] More detail for the estimation procedures are provided in the Annex.
1) Source of data: Bankscope.
2) Source of data: KMV-Moody's.
3) Source of data: KMV-Moody's.
4) Source of data: ECB, EU Banking Structures, reports.
5) Source of data: ECB, MFI statistical reports.
6) Source of data: The United Nations.

Table 2
The evolution of the main variables (Mean values) used to analyse the sample of EU-26 area banks over the period 1995-2007 (1,987 year-observations)

	x-EFF	*τ-EFF*	*π-EFF*	*EDF*	EDF_{5Y}	*NPL/L*	*E/TA*	*ID*	*BAS*(*)
1995	0.5148	0.6095	0.5200	0.0031	0.0049	0.0334	0.0865	0.1285	327.990
1996	0.4801	0.5967	0.4954	0.0042	0.0043	0.0366	0.0769	0.1433	307.286
1997	0.4899	0.6218	0.5247	0.0038	0.0049	0.0354	0.0697	0.1656	403.618
1998	0.4785	0.6267	0.5211	0.0042	0.0043	0.0356	0.0668	0.1686	377.709
1999	0.4726	0.6336	0.5339	0.0047	0.0043	0.0343	0.0685	0.1800	336.366
2000	0.4771	0.6309	0.5320	0.0042	0.0052	0.0343	0.0687	0.1916	428.367
2001	0.4591	0.6304	0.5336	0.0073	0.0060	0.0354	0.0699	0.2002	343.293
2002	0.4520	0.6355	0.5500	0.0084	0.0068	0.0364	0.0689	0.2068	345.334
2003	0.4458	0.6341	0.5436	0.0101	0.0090	0.0355	0.0702	0.2047	377.329
2004	0.4215	0.6254	0.5333	0.0070	0.0061	0.0341	0.0706	0.2248	552.397
2005	0.4238	0.6285	0.5343	0.0058	0.0077	0.0333	0.0748	0.2228	708.129
2006	0.4188	0.6204	0.5284	0.0087	0.0083	0.0328	0.0747	0.2107	792.808
2007	0.4170	0.6529	0.5333	0.0042	0.0074	0.0301	0.0763	0.1860	902.372
Total	0.4446	0.6311	0.5342	0.0067	0.0067	0.0342	0.0715	0.2014	579.947

(*) Values are in Euro millions

Table 3
Granger causality for the relationship among banking capital, efficiency and risk-taking in the EU-26 commercial banking

	Models where Risk = *EDF*				Models where Risk = EDF_{5Y}				Models where Risk = *NPL/L*			
	Model (1) y=EDF	Model (2) y=x-EFF$_t$	Model (3) y= τ-EFF$_t$	Model (4) y=E/TA$_t$	Model (1) Y= EDF$_{5Y}$	Model (2) y=x-EFF$_t$	Model (3) y= τ-EFF$_t$	Model (4) y=E/TA$_t$	Model (1) Y=NPL/L	Model (2) y=x-EFF$_t$	Model (3) y= τ-EFF$_t$	Model (4) y=E/TA$_t$
Intercept	0.0354 (0.0274)	0.2005 (0.2773)	0.2155 (0.4279)	1.7344*** (0.4407)	0.0046 (0.0132)	0.1499 (0.2704)	0.2242 (0.4553)	1.5940*** (0.4499)	0.3352 (0.3156)	0.0636 (0.2790)	0.1060 (0.4625)	1.5918*** (0.4578)
$Risk_{t-1}$	1.0713*** (0.0644)	0.3480 (0.5627)	-0.3860 (0.6997)	0.4324 (0.7852)	1.4145*** (0.0633)	2.9658** (1.2116)	-1.1697 (1.5821)	8.0712*** (1.5029)	0.4035*** (0.1126)	0.1285** (0.0646)	-0.0229 (0.1075)	0.1534* (0.0875)
$Risk_{t-2}$	-0.0437 (0.0676)	-0.3686 (0.5838)	0.2680 (0.7354)	-0.5049 (0.7876)	-0.4059*** (0.0648)	-2.9730** (1.2391)	1.2344 (1.6143)	-8.2233*** (1.5686)	0.2329** (0.1063)	-0.1270* (0.0682)	-0.1154 (0.0942)	0.1752* (0.0902)
$Risk_{total}$	1.0277*** (0.0100)	-0.0205 (0.0777)	0.1179 (0.0978)	-0.0725 (0.1002)	1.0086*** (0.0052)	-0.0072 (0.0842)	0.0647 (0.1157)	-0.1521 (0.1469)	0.6364*** (0.0919)	0.0015 (0.0885)	-0.1383 (0.1218)	0.3286*** (0.1094)
$x\text{-}eff_{t-1}$	-0.0116* (0.0063)	0.4762*** (0.0639)	0.0398 (0.0736)	0.0010 (0.0836)	-0.0040 (0.0029)	0.4627*** (0.0723)	0.0187 (0.0540)	-0.0411 (0.0894)	-0.1289** (0.0597)	0.4552*** (0.0665)	0.0569 (0.0782)	-0.0274 (0.0826)
$x\text{-}eff_{t-2}$	-0.0114* (0.0060)	-0.0129 (0.0684)	-0.1031 (0.0739)	0.1546*** (0.0718)	0.0006 (0.0028)	-0.0222 (0.0628)	0.0151 (0.0851)	0.2235*** (0.0791)	0.0249 (0.0570)	0.0090 (0.0614)	-0.0989 (0.0774)	0.1988*** (0.0750)
$x\text{-}eff_{total}$	-0.0231*** (0.0067)	0.4633*** (0.0761)	-0.0633 (0.0710)	0.1556* (0.0887)	-0.033 (0.0028)	0.4405*** (0.0734)	-0.0267 (0.0723)	0.1824* (0.1078)	-0.1040* (0.0604)	0.4642*** (0.07355)	-0.0421 (0.0711)	0.1714* (0.0957)
$\tau\text{-}eff_{t-1}$	-0.0114** (0.0046)	0.0122 (0.0530)	0.0050 (0.0555)	0.0515 (0.0599)	-0.0042* (0.0023)	0.0428 (0.0547)	0.0319 (0.0730)	0.0751 (0.0565)	-0.1948*** (0.0748)	0.0828 (0.0627)	-0.0005 (0.0804)	0.1369* (0.0773)
$\tau\text{-}eff_{t-2}$	-0.0068 (0.0059)	-0.0350 (0.0427)	0.0244 (0.0756)	-0.0168 (0.0489)	0.0013 (0.0031)	0.0010 (0.0423)	-0.0587 (0.0785)	0.0553 (0.0560)	-0.1103 (0.0821)	0.0410 (0.0608)	-0.0242 (0.1012)	0.0861 (0.0683)
$\tau\text{-}eff_{total}$	-0.0182** (0.0072)	-0.0227 (0.0698)	0.0294 (0.0927)	0.0347 (0.0851)	-0.0029 (0.0036)	0.0439 (0.0745)	0.0338 (0.0958)	0.1304 (0.0876)	-0.3050*** (0.0756)	0.1238 (0.0960)	-0.0247 (0.1148)	0.2229** (0.0987)
E/TA_{t-1}	0.0046* (0.0026)	0.0230 (0.0219)	-0.0357 (0.0295)	0.2347*** (0.0262)	-0.0040*** (0.0012)	0.0191 (0.0207)	-0.0317 (0.0325)	0.2156*** (0.0239)	0.0695*** (0.0271)	0.0128 (0.0219)	-0.0295 (0.0293)	0.2176*** (0.0267)
E/TA_{t-2}	-0.0015 (0.0022)	0.0507*** (0.0190)	0.0271 (0.0347)	0.1911*** (0.0168)	0.0034*** (0.0011)	0.0646*** (0.0207)	0.0077 (0.0392)	0.2200*** (0.0195)	0.0045 (0.0277)	0.0452** (0.0196)	0.0247 (0.0346)	0.1835*** (0.0174)
E/TA_{total}	0.0031 (0.0031)	0.0737*** (0.0277)	-0.0086 (0.0442)	0.4259*** (0.0316)	-0.0006 (0.0012)	0.0837*** (0.0265)	-0.0241 (0.0495)	0.4356*** (0.0320)	0.0740** (0.0367)	0.0580** (0.2815)	-0.0047 (0.0458)	0.4011*** (0.0342)
Ln (TA)	-0.0031* (0.0017)	-0.0113 (0.0172)	-0.0119 (0.0273)	-0.1227*** (0.0280)	-0.0007 (0.0008)	-0.0071 (0.0169)	-0.0136 (0.0291)	-0.1095*** (0.0282)	-0.0257 (0.0201)	-0.0033 (0.0174)	-0.0049 (0.0286)	-0.1147*** (0.0290)
CONC	-0.0200*** (0.0064)	-0.0951 (0.0679)	0.0198 (0.0721)	0.1316** (0.0576v	0.0022 (0.0024)	-0.1350* (0.0741)	0.0055 (0.0752)	0.0786 (0.0699)	-0.1473*** (0.0534)	-0.1108 (0.0718)	0.0305 (0.0741)	0.1045* (0.0614)
Ln(NCI)	-0.0016 (0.0058)	0.2455*** (0.0442)	-0.0200 (0.0610)	0.3076*** (0.0565)	0.0009 (0.0023)	0.2149*** (0.0483)	-0.0568 (0.0642)	0.2577*** (0.0674)	0.0454 (0.0545)	0.2328*** (0.0449)	-0.0268 (0.0603)	0.2810*** (0.0602)
ID	-0.0197*** (0.0076)	-0.1923*** (0.0711)	-0.2111*** (0.0797)	-0.3801*** (0.1060)	0.0024 (0.0031)	-0.1467** (0.0700)	-0.1635** (0.0810)	-0.3498*** (0.1092)	0.0637 (0.0687)	-0.2234*** (0.0587)	-0.1639** (0.0769)	-0.4362*** (0.1032)
Sample period:	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007
Observations:	1271	1271	1271	1271	1271	1271	1271	1271	1271	1271	1271	1271
Hansen test, 2nd step, $\chi^2(246)$	169.92	196.61	173.82	212.72	187.94	187.66	153.39	258.27	179.88	192.63	182.97	200.97
AB test AR(1)	-3.73***	-3.21***	-5.06***	-8.71***	-5.86***	-3.15***	-4.98***	-8.04***	-4.21***	-3.16***	-4.77***	-8.71***
AB test AR(2)	0.98	-0.09	-0.21	1.43	2.77***	-0.07	-0.01	1.98**	-0.68	-0.43	-0.41	1.09

Note: We use the two-step system GMM estimator with Windmeijer (20005) corrected standard error (reported in brackets).
The symbols *, **, and *** represent significance levels of 10%, 5% and 1% respectively.
The variables $Risk_{total}$, $x\text{-}eff_{total}$, $\tau\text{-}eff_{total}$ and E/A_{total} are the estimated coefficients for the test that the sum of lagged terms (for the bank risk-taking, the cost efficiency, the revenue efficiency and the equity-asset ratio variables, respectively) is equal to zero. A significance level lower than 10% enables to reject the null hypothesis of no causality from the *x* to the *y*. A coefficient greater than zero show a positive causation from the *x* to the *y*; a coefficient smaller than zero show a negative causation from the *x* to the *y*.
The Sargan/Hensen test of over-identifying restrictions for the GMM estimators: the null hypothesis is that instruments used are not correlated with residuals and so the over-identifying restrictions are valid.
Arellano-Bond (AB) test for serial correlation in the first-differenced residuals. The null hypothesis is that errors in the first difference regression do not exhibit second order serial correlation.

Table 4
Robustness check: Granger causality for the relationship among capital (using the Equity to Total Assets ratio), efficiency and credit risk in the EU-26 commercial banking

	Models where Risk = *EDF*				Models where Risk = EDF_{5Y}				Models where Risk = *NPL/L*			
	Model (1) y=EDF	Model (2) y=x-EFF	Model (3) y= τ-EFF$_t$	Model (4) y=E_A/TA_t	Model (1) Y= EDF_{5Y}	Model (2) y=x-EFF$_t$	Model (3) y= τ-EFF$_t$	Model (4) y=E_A/TA_t	Model (1) Y=NPL/L	Model (2) y=x-EFF$_t$	Model (3) y= τ-EFF$_t$	Model (4) y=E_A/TA_t
Intercept	0.0463	0.4336*	0.1691	0.0843	0.0050	0.3784	0.1673	-0.0022	0.5220*	0.2036	0.1357	0.0156
	(0.0287)	(0.2565)	(0.4138)	(0.2953)	(0.0150)	(0.2348)	(0.3711)	(0.3129)	(0.3041)	(0.2726)	(0.4331)	(0.2779)
$Risk_{t-1}$	1.0773***	0.4899	-0.2834	-1.6387**	1.3467***	3.1079**	-1.5279	-1.6200	0.4202***	0.1338	-0.0258	-0.1512*
	(0.0645)	(0.5630)	(0.7428)	(0.6921)	(0.0642)	(1.2734)	(1.4612)	(1.3142)	(0.1036)	(0.0671)	(0.1444)	(0.0871)
$Risk_{t-2}$	-0.0491	-0.5137	0.2112	1.4433**	-0.3345***	-3.1189**	1.5936	1.7757	0.2747***	0.1601**	-0.1076	-0.0105
	(0.0689)	(0.5856)	(0.7871)	(0.7116)	(0.0662)	(1.2940)	(1.4911)	(1.3470)	(0.1019)	(0.0688)	(0.1300)	(0.0885)
$Risk_{total}$	1.0282***	-0.0237	-0.0722	-0.1954**	1.0122***	-0.0109	0.0656	0.1557	0.6948***	0.2939***	-0.1334	-0.1617
	(0.0111)	(0.0816)	(0.1021)	(0.0926)	(0.0067)	(0.0894)	(0.1150)	(0.1113)	(0.0915)	(0.0973)	(0.1175)	(0.1016)
$x\text{-}eff_{t-1}$	-0.0097	0.5017***	0.0360	-0.1624**	-0.0051*	0.4896***	0.0202	-0.1726**	-0.0933***	0.4755***	0.0550	-0.1570**
	(0.0066)	(0.0589)	(0.0764)	(0.0677)	(0.0030)	(0.0696)	(0.0751)	(0.0736)	(0.0248)	(0.0658)	(0.0788)	(0.0680)
$x\text{-}eff_{t-2}$	-0.0112*	0.0047	-0.0956	0.0718	0.0007	-0.0023	-0.0572	0.0588	0.0258	0.0196	-0.0938	0.0936
	(0.0059)	(0.0689)	(0.0760)	(0.0651)	(0.0029)	(0.0625)	(0.0755)	(0.0709)	(0.0294)	(0.0649)	(0.0732)	(0.0638)
$x\text{-}eff_{total}$	-0.0209***	0.5064***	-0.0595	-0.0906	-0.0044	0.4873***	-0.0369	-0.1138*	-0.0674*	0.4951***	-0.0388	-0.0634
	(0.0066)	(0.0654)	(0.0729)	(0.0643)	(0.0031)	(0.0739)	(0.0713)	(0.0692)	(0.0394)	(0.0705)	(0.0697)	(0.0591)
$\tau\text{-}eff_{t-1}$	-0.0110***	0.0182	0.0316	-0.0217	-0.0056**	0.0562	0.0334	-0.0311	-0.2160***	0.0928	0.0163	-0.1101*
	(0.0041)	(0.0563)	(0.0604)	(0.0495)	(0.0024)	(0.0525)	(0.0574)	(0.0482)	(0.0750)	(0.0732)	(0.0832)	(0.0607)
$\tau\text{-}eff_{t-2}$	-0.0063	-0.0336	0.0329	0.0508	0.0012	0.0129	0.0172	0.0272	-0.1340*	0.0653	-0.0135	0.0649
	(0.0061)	(0.0407)	(0.0729)	(0.0536)	(0.0029)	(0.0408)	(0.0768)	(0.0499)	(0.0807)	(0.0617)	(0.1271)	(0.0711)
$\tau\text{-}eff_{total}$	-0.0173***	-0.0154	0.0645	0.0292	-0.0043	0.0692	0.0505	-0.0039	-0.3500***	0.1580	0.0028	-0.0452
	(0.0067)	(0.0693)	(0.0900)	(0.0676)	(0.0032)	(0.0682)	(0.0884)	(0.0638)	(0.0842)	(0.1077)	(0.1196)	(0.0833)
E_A/TA_{t-1}	0.0063	0.0284	0.0598	0.1669**	-0.0056	0.0293	0.0201	0.2111**	0.0099	0.0271	0.0802	0.1977**
	(0.0059)	(0.0600)	(0.0788)	(0.0812)	(0.0035)	(0.0626)	(0.0810)	(0.0903)	(0.0612)	(0.0638)	(0.0744)	(0.0895)
E_A/TA_{t-2}	-0.0029	0.0291	0.0185	0.1796**	0.0000	0.0405	-0.0083	0.1696**	-0.0270	0.0461	-0.0030	0.2042***
	(0.0068)	(0.0563)	(0.0768)	(0.0808)	(0.0032)	(0.0524)	(0.0758)	(0.0844)	(0.0661)	(0.0541)	(0.0789)	(0.0760)
E_A/TA_{total}	0.0034	0.0575	0.0783	0.3465***	-0.0055	0.0698	0.0118	0.3807***	-0.0171	0.0732	0.0772	0.4019
	(0.0086)	(0.0582)	(0.1039)	(0.0995)	(0.0039)	(0.0712)	(0.1048)	(0.1090)	(0.786)	(0.0659)	(0.1057)	(0.1036)
Ln (TA)	-0.0038**	-0.0251	-0.0081	-0.0029	-0.0007	-0.0208	-0.0095	0.0019	-0.0373*	-0.0117	-0.0066	0.0021
	(0.0018)	(0.0159)	(0.0264)	(0.0191)	(0.0009)	(0.0152)	(0.0239)	(0.0199)	(0.0192)	(0.0173)	(0.0273)	(0.0178)
CONC	-0.0201***	-0.0905	0.0302	0.0189	0.0003	-0.1258	0.0140	-0.0328	-0.1517***	-0.0848	0.0411*	0.0237
	(0.0062)	(0.0757)	(0.0732)	(0.0592)	(0.0028)	(0.0791)	(0.0746)	(0.0630)	(0.0537)	(0.0690)	(0.0834)	(0.0536)
Ln(NCI)	-0.0011	0.2467***	0.0025	-0.0591	-0.0017	0.2315***	-0.0549	-0.0686	0.0432	0.2669***	-0.0020	-0.0493
	(0.0054)	(0.0473)	(0.0644)	(0.0602)	(0.0027)	(0.0493)	(0.0668)	(0.0575)	(0.0594)	(0.0511)	(0.0698)	(0.0507)
ID	-0.0204**	-0.1593**	-0.2094**	0.0304	0.0029	-0.1154*	-0.1716**	0.0415	0.0965	-0.2134***	-0.1667**	0.0866
	(0.0085)	(0.0629)	(0.0858)	(0.0829)	(0.0030)	(0.0700)	(0.0819)	(0.0785)	(0.0786)	(0.0598)	(0.0809)	(0.0778)
Sample period:	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007
Observations:	1271	1271	1271	1271	1271	1271	1271	1271	1271	1271	1271	1271
Hansen test, 2nd step, $\chi^2(246)$	174.23	213.16	180.06	172.17	177.85	195.09	176.20	173.75	183.73	195.04	185.62	170.90
AB test AR(1)	-3.77***	-3.16***	-4.99***	-3.19***	-5.64***	-3.15***	-5.00***	-2.99***	-4.04***	3.11***	-4.95***	-3.11***
AB test AR(2)	1.01	0.07	-0.09	-0.78	2.55**	-0.02	0.10	-0.68	-0.96	-0.33	0.33	-0.90

Note: We use the two-step system GMM estimator with Windmeijer (20005) corrected standard error (reported in brackets).
The symbols *, **, and *** represent significance levels of 10%, 5% and 1% respectively.
The variables $Risk_{total}$, $x\text{-}eff_{total}$, $\tau\text{-}eff_{total}$ and E/A_{total} are the estimated coefficients for the test that the sum of lagged terms (for the bank risk-taking, the cost efficiency, the revenue efficiency and the equity-asset ratio variables, respectively) is equal to zero. A significance level lower than 10% enables to reject the null hypothesis of no causality from the *x* to the *y*.
A coefficient greater than zero shows a positive causation from the *x* to the *y*; a coefficient smaller than zero shows a negative causation from the *x* to the *y*.
The Hensen test of over-identifying restrictions for the GMM estimators: the null hypothesis is that instruments used are not correlated with residuals and so the over-identifying restrictions are valid.
Arellano-Bond (AB) test for serial correlation in the first-differenced residuals. The null hypothesis is that errors in the first difference regression do not exhibit second order serial correlation.

Table 5
Robustness check: Granger causality for the relationship among capital, efficiency (measured using profit efficiency) and credit risk in the EU-26 commercial banking

	Models where Risk = *EDF*			**Models where Risk = EDF_{5Y}**			**Models where Risk = *NPL/L***		
	Model (1) y=EDF	Model (5) y= π-EFF_t	Model (4) y=E/TA_t	Model (1) Y= EDF_{5Y}	Model (5) y= π-EFF_t	Model (4) y=E/TA_t	Model (1) Y=NPL/L	Model (5) y= π-EFF_t	Model (4) y=E/TA_t
Intercept	0.0277	0.3496	1.9096***	0.0044	0.1332	1.7495***	0.4153	0.4396	1.7975***
	(0.0303)	(0.3298)	(0.4106)	(0.0133)	(0.3336)	(0.3806)	(0.3093)	(0.3370)	(0.4003)
$Risk_{t-1}$	1.1257***	0.4410	-0.2236	1.4040***	-1.3386	7.2335***	0.2656***	-0.1026	0.0483
	(0.0645)	(0.8324)	(0.7518)	(0.0620)	(1.1907)	(1.4169)	(0.0735)	(0.0671)	(0.0603)
$Risk_{t-2}$	-0.0969	-0.5435	0.1493	-0.3963***	1.1822	-7.3504***	0.1955***	-0.1624**	0.0610
	(0.0677)	(0.8491)	(0.7482)	(0.0634)	(1.2046)	(1.4837)	(0.0723)	(0.0696)	(0.0755)
$Risk_{total}$	1.0287***	-0.1025	-0.0743	1.0007***	-0.1564*	-0.1169	0.4611***	-0.2650***	0.1093*
	(0.0103)	(0.0675)	(0.1030)	(0.0052)	(0.848)	(0.1389)	(0.0853)	(0.0915)	(0.0958)
π-eff_{t-1}	-0.0065	0.1919***	-0.0684	-0.0050*	0.1773***	-0.0687	-0.0803	0.1388**	-0.0764
	(0.0079)	(0.0590)	(0.0738)	(0.0028)	(0.0659)	(0.0756)	(0.0722)	(0.0676)	(0.0744)
π-eff_{t-2}	-0.0073	0.1613***	0.2773***	0.0000	0.1587***	0.2404***	-0.0530	0.0893	0.2478***
	(0.0049)	(0.0509)	(0.0660)	(0.0027)	(0.0492)	(0.0668)	(0.0481)	(0.0648)	(0.0740)
π-eff_{total}	-0.0138*	0.3532***	0.2089**	-0.0051	0.3360***	0.1717*	-0.1333*	0.2280**	0.1714*
	(0.0080)	(0.0807)	(0.0946)	(0.0031)	(0.0863)	(0.0988)	(0.0803)	(0.1014)	(0.0984)
E/TA_{t-1}	0.0020	0.0047	0.2309***	-0.0049***	0.0275	0.2188***	0.0728***	0.0117	0.2318***
	(0.0029)	(0.0284)	(0.0246)	(0.0012)	(0.0269)	(0.0218)	(0.0269)	(0.0294)	(0.0229)
E/TA_{t-2}	-0.0044*	-0.0069	0.2118***	0.0032***	0.0031	0.2368***	0.0085	-0.0027	0.2104***
	(0.0023)	(0.0254)	(0.0161)	(0.0011)	(0.0268)	(0.0190)	(0.0261)	(0.0248)	(0.0159)
E/TA_{total}	-0.0024	-0.0022	0.4426***	-0.0017	0.0306	0.4555***	0.0813**	0.0090	0.04421***
	(0.0032)	(0.0385)	(0.0275)	(0.0013)	(0.0371)	(0.0275)	(0.0334)	(0.0395)	(0.0256)
Ln (TA)	-0.0026	-0.0214	-0.1340***	-0.0007	-0.0095	-0.1196***	-0.0310*	-0.0277	-0.1271***
	(0.0019)	(0.0212)	(0.0261)	(0.0008)	(0.0213)	(0.0239)	(0.0181)	(0.0219)	(0.0252)
CONC	-0.0163***	-0.0894*	0.0895	0.0026	-0.0356	0.0326	-0.1240**	-0.0984**	0.0870
	(0.0064)	(0.0536)	(0.0567)	(0.0024)	(0.0506)	(0.0629)	(0.0560)	(0.0474)	(0.0545)
Ln(NCI)	-0.0058	-0.0727*	0.3329***	0.0002	-0.0455	0.2698***	0.0004	-0.0681*	0.3193***
	(0.0052)	(0.0418)	(0.0592)	(0.0022)	(0.0390)	(0.0573)	(0.0487)	(0.0407)	(0.0523)
ID	-0.0168**	0.0469	-0.4113***	0.0034	0.0740	-0.3598***	0.1380*	0.0959	-0.4165***
	(0.0085)	(0.0748)	(0.1105)	(0.0029)	(0.0734)	(0.1080)	(0.0753)	(0.0761)	(0.0998)
Sample period:	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007
Observations:	1271	1271	1271	1271	1271	1271	1271	1271	1271
Hansen test, 2^{nd} step, $\chi^2(246)$	179.06	191.66	286.49	192.52	196.69	256.10	187.93	198.58	289.15
AB test AR(1)	-3.76***	-3.47***	-8.50***	-6.02***	-3.43***	-8.10***	-4.40***	-3.43***	-8.59***
AB test AR(2)	1.14	-1.78	0.54	2.72***	-1.47	1.47	-0.87	-1.83*	0.49

Note: We use the two-step system GMM estimator with Windmeijer (20005) corrected standard error (reported in brackets).
The symbols *, **, and *** represent significance levels of 10%, 5% and 1% respectively.
The variables $Risk_{total}$, π-eff_{total} and E/A_{total} are the estimated coefficients for the test that the sum of lagged terms (for the bank risk-taking, the profit efficiency and the equity-asset ratio variables, respectively) is equal to zero. A significance level lower than 10% enables to reject the null hypothesis of no causality from the *x* to the *y*.
A coefficient greater than zero shows a positive causation from the *x* to the *y*; a coefficient smaller than zero shows a negative causation from the *x* to the *y*.
The Hensen test of over-identifying restrictions for the GMM estimators: the null hypothesis is that instruments used are not correlated with residuals and so the over-identifying restrictions are valid.
Arellano-Bond (AB) test for serial correlation in the first-differenced residuals. The null hypothesis is that errors in the first difference regression do not exhibit second order serial correlation.

Table 6
Robustness check: Granger causality for the relationship among capital, efficiency and credit risk in the EU-26 commercial banking assuming a AR(4) structure

	Models where Risk = *EDF*				Models where Risk = EDF_{5Y}				Models where Risk = *NPL/L*			
	Model (1)	Model (2)	Model (3)	Model (4)	Model (1)	Model (2)	Model (3)	Model (4)	Model (1)	Model (2)	Model (3)	Model (4)
	y=EDF	y=x-EFF_t	y=τ-EFF_t	y=E_A/TA_t	Y=EDF_{5Y}	y=x-EFF_t	y=τ-EFF_t	y=E_A/TA_t	Y=NPL/L	y=x-EFF_t	y=τ-EFF_t	y=E_A/TA_t
Intercept	0.0365	0.3610	0.5549	1.3582***	0.0101	0.4447	0.4614	1.5611***	0.2611	0.4588*	0.4468	1.4890***
	(0.0370)	(0.2847)	(0.4851)	(0.3804)	(0.0195)	(0.2863)	(0.5223)	(0.3957)	(0.3854)	(0.2778)	(0.5207)	(0.4090)
$Risk_{t-1}$	0.9382***	0.4864	-0.6669	-1.1339	1.1658***	0.7864	-0.1230	1.6846	0.3581***	0.5180***	-0.0544	0.1715***
	(0.0775)	(0.5530)	(0.8149)	(0.7107)	(0.0774)	(1.2566)	(1.9136)	(1.5700)	(0.1371)	(0.0500)	(0.0709)	(0.0370)
$Risk_{t-2}$	0.1780	-1.0952	0.0562	0.2769	0.0334	-1.4939	2.7887	-1.5734	0.3281***	-0.0065	-0.0998	0.2163***
	(0.1341)	(1.0147)	(1.1905)	(0.9273)	(0.1035)	(2.2472)	(2.5967)	(1.7204)	(0.1123)	(0.0865)	(0.0779)	(0.0226)
$Risk_{t-3}$	0.0245	2.1252**	1.4208	1.9949**	-0.1291	1.7657	-2.8548	2.5799	-0.0167	-0.0718	-0.0716	0.0702**
	(0.1091)	(0.9989)	(1.1532)	(0.8474)	(0.1228)	(2.5904)	(3.2180)	(2.0850)	(0.1045)	(0.0872)	(0.0902)	(0.0279)
$Risk_{t-4}$	-0.1133	-1.5025**	-1.1639	-1.0960	-0.0622	-1.0461	0.0886	-2.5692*	0.0550	0.0730	-0.0529	0.3010***
	(0.0754)	(0.6083)	(0.8644)	(0.8467)	(0.0844)	(1.3077)	(2.5761)	(1.5637)	(0.1345)	(0.0583)	(0.0988)	(0.0408)
$Risk_{total}$	1.0274***	0.0139	-0.3539**	0.0420	1.0079***	0.0121	-0.1004	0.1220	0.7245***	0.1281	-0.1802	-0.2794***
	(0.0145)	(0.0840)	0.1719	(0.1504)	(0.0078)	(0.0823)	(0.2073)	(0.1336)	(0.1722)	(0.1099)	(0.1596)	(0.1464)
$x\text{-}eff_{t-1}$	-0.0107	0.5405***	-0.0406	0.0569	0.0022	0.5206***	-0.0838	0.0233	-0.0506	0.0304	-0.0358	-0.0751
	(0.0077)	(0.0538)	(0.0909)	(0.0802)	(0.0033)	(0.0547)	(0.0900)	(0.0858)	(0.0709)	(0.0743)	(0.0925)	(0.0768)
$x\text{-}eff_{t-2}$	-0.0154*	0.0004	-0.0317	0.1134	-0.0020	-0.0002	-0.0173	0.1368*	-0.0696	-0.0152	0.0026	-0.0345
	(0.0080)	(0.0908)	(0.0923)	(0.0725)	(0.0038)	(0.0808)	(0.0951)	(0.0768)	(0.0748)	(0.0779)	(0.0905)	(0.0740)
$x\text{-}eff_{t-3}$	-0.0048	-0.0621	-0.0370	-0.1736**	-0.0014	-0.0631	0.0397	-0.1671**	0.1065	0.0810	-0.0175	-0.1775**
	(0.0068)	(0.0894)	(0.0932)	(0.0711)	(0.0035)	(0.0952)	(0.1053)	(0.0698)	(0.0739)	(0.0872)	(0.1051)	(0.0702)
$x\text{-}eff_{t-4}$	0.0161**	0.0702	-0.1825*	0.1326*	-0.0022	0.0400	-0.2155*	0.1090	-0.0348	0.0318	-0.1912*	-0.0315
	(0.0069)	(0.0596)	(0.1066)	(0.0695)	(0.0041)	(0.0617)	(0.1164)	(0.0698)	(0.0868)	(0.0907)	(0.1147)	(0.0740)
$x\text{-}eff_{total}$	-0.0147	0.5490***	-0.2918**	0.1292	-0.0035	0.4973***	-0.2769*	0.1020	-0.0484	0.5127***	-0.2420**	0.1280
	(0.0103)	(0.0685)	(0.1376)	(0.1134)	(0.0051)	(0.0660)	(0.1549)	(0.1251)	(0.1147)	(0.0661)	(0.1234)	(0.1109)
$\tau\text{-}eff_{t-1}$	-0.0043	-0.0908	-0.0613	0.0581	-0.0008	-0.0591	-0.0072	0.0526	0.2387***	-0.0723	0.0081	0.0984
	(0.0056)	(0.0564)	(0.0749)	(0.0645)	(0.0024)	(0.0553)	(0.0845)	(0.0626)	(0.0846)	(0.0635)	(0.0904)	(0.0915)
$\tau\text{-}eff_{t-2}$	-0.0070	-0.0251	0.0061	0.0269	-0.0017	-0.0259	0.0125	0.0110	0.0963	-0.0500	-0.1800	0.1183*
	(0.0061)	(0.0410)	(0.0635)	(0.0581)	(0.0028)	(0.0407)	(0.0862v	0.0591)	(0.0793)	(0.0556)	(0.0991)	(0.0716)
$\tau\text{-}eff_{t-3}$	-0.0005	-0.0111	-0.0886	-0.0910*	0.0005	-0.0253	-0.1085	-0.0723	0.0854	0.0190	0.0130	-0.1736**
	(0.0058)	(0.0439)	(0.0718)	(0.0469)	(0.0029)	(0.0492)	(0.1111)	(0.0518)	(0.0905)	(0.0725)	(0.1225)	(0.0767)
$\tau\text{-}eff_{t-4}$	-0.0024	-0.0922**	-0.0186	-0.0972*	-0.0024	-0.0840**	-0.0705	-0.0879*	-0.0371	-0.0748	-0.0213	0.0849
	(0.0053)	(0.0393)	(0.0740)	(0.0549)	(0.0021)	(0.0357)	(0.0796)	(0.0524)	(0.1016)	(0.0672)	(0.1035)	(0.0727)
$\tau\text{-}eff_{total}$	-0.0142	-0.2192**	-0.1625	-0.1033	-0.0043	-0.1942*	-0.1737	-0.0965	0.3832***	-0.1781	-0.2786	-0.3186*
	(0.0127)	(0.1018)	(0.1531)	(0.1523)	(0.0049)	(0.1013)	(0.1681)	(0.1447)	(0.1710)	(0.1170)	(0.1829)	(0.1936))
E/TA_{t-1}	0.0072*	-0.0812**	0.0686	0.1887***	-0.0093***	-0.0762**	0.0686	0.1804***	0.0066	-0.0732**	0.0496	-0.2165***
	(0.0038)	(0.0338)	(0.0426)	(0.0377)	(0.0020)	(0.0337)	(0.0452)	(0.0376)	(0.0387)	(0.0325)	(0.0453)	(0.0792)
E/TA_{t-2}	-0.0056	0.0195	-0.0039	0.2091***	0.0025*	0.0262	-0.0182	0.2108***	0.0245	0.0198	-0.0017	-0.0922
	(0.0034)	(0.0342)	(0.0452)	(0.0232)	(0.0013)	(0.0357)	(0.0576)	(0.0274)	(0.0379)	(0.0355)	(0.0443)	(0.0933)
E/TA_{t-3}	-0.0023	0.0188	-0.1313***	0.0694***	-0.0015	0.0064	-0.0923	0.0671**	0.0453	0.0175	-0.1177***	-0.1208
	(0.0036)	(0.0264)	(0.0489)	(0.0267)	(0.0024)	(0.0287)	(0.0567)	(0.0278)	(0.0379)	(0.0247)	(0.0449)	(0.0920)
E/TA_{t-4}	0.0050	0.0316	-0.0134	0.3180***	-0.0034*	0.0242	-0.0052	0.3008***	-0.0451	0.0347	-0.0087	0.1500
	(0.0046)	(0.0354)	(0.0666)	(0.0350)	(0.0020)	(0.0343)	(0.0709)	(0.0359)	(0.0529)	(0.0378)	(0.0698)	(0.0948)
E/TA_{total}	0.0043	-0.0113	-0.0799	0.7852***	-0.0117***	-0.0194	-0.0471	0.7591***	0.03122	-0.0011	-0.0785	0.7590***
	(0.0085)	(0.0665)	(0.0982)	(0.0725)	(0.0045)	(0.0636)	(0.1016)	(0.0699)	(0.0839)	(0.0707)	(0.0981)	(0.0766)
Ln (TA)	-0.0034	-0.0228	-0.0308	-0.1247***	-0.0008	-0.0281	-0.0234	-0.1315***	-0.0176	-0.0305*	-0.0257	-0.1308***
	(0.0023)	(0.0170)	(0.0315)	(0.0234)	(0.0012)	(0.0178v	(0.0377)	(0.0250)	(0.0238)	(0.0171)	(0.0343)	(0.0251)
CONC	-0.0053	0.0117	0.0896	0.0220	-0.0012	-0.0022	-0.0053	-0.0940	-0.1084	0.0221	-0.0066	0.0311
	(0.0101)	(0.0816)	(0.1383)	(0.0721)	(0.0053)	(0.0698)	(0.1811)	(0.0919)	(0.0876)	(0.0673)	(0.1084)	(0.0689)
Ln(NCI)	-0.0046	0.3345***	0.0520	0.1297	-0.0007	0.3261***	-0.0934	0.0406	0.0750	0.3442***	-0.0386	0.1761**
	(0.0128)	(0.0761)	(0.1173)	(0.0803)	(0.0055)	(0.0673)	(0.1562)	(0.1013)	(0.0930)	(0.0646)	(0.1013)	(0.0779)
ID	-0.0151	-0.2449***	0.0543	-0.4926***	-0.0025	-0.2319**	0.1080	-0.4376***	-0.0562	-0.2791***	0.0563	-0.4619***
	(0.0092)	(0.0891)	(0.0988)	(0.1579)	(0.0036)	(0.0959)	(0.1653)	(0.1578)	(0.1132)	(0.0804)	(0.1221)	(0.1619)
Sample period:	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007	1995-2007
Observations:	667	667	667	667	667	667	667	667	667	667	667	667
Hansen test, 2nd step, $\chi^2(208)$	130.72	130.74	109.40	157.20	132.10	124.18	107.49	144.10	127.53	128.15	112.51	155.42
AB test AR(1)	-2.83***	-2.24**	-3.49**	-5.35***	-3.79***	-2.26***	-3.26***	-5.46***	-3.24***	-2.31***	-3.40***	-5.15***
AB test AR(2)	-1.09	-0.68	-0.08	-2.21**	-0.13	-0.62	0.04	-1.06	-0.72	-0.76	-0.18	-2.43**

Note: We use the two-step system GMM estimator with Windmeijer (20005) corrected standard error (reported in brackets).
The symbols *, **, and *** represent significance levels of 10%, 5% and 1% respectively.
The variables $Risk_{total}$, , $x\text{-}eff_{total}$, | $\text{-}eff_{total}$ and E/A_{total} are the estimated coefficients for the test that the sum of the four lagged terms (for the bank risk-taking, the profit efficiency and the equity-asset ratio variables, respectively) is equal to zero. A significance level lower than 10% enables to reject the null hypothesis of no causality from the *x* to the *y*.
A coefficient greater than zero shows a positive causation from the *x* to the *y*; a coefficient smaller than zero shows a negative causation from the *x* to the *y*.
The Hensen test of over-identifying restrictions for the GMM estimators: the null hypothesis is that instruments used are not correlated with residuals and so the over-identifying restrictions are valid.
Arellano-Bond (AB) test for serial correlation in the first-differenced residuals. The null hypothesis is that errors in the first difference regression do not exhibit second order serial correlation.

Appendix

Efficiency estimation

Cost efficiency is measured using the Stochastic Frontier (*SF*) analysis. Namely, the Battese and Coelli's (1995) stochastic frontier model is estimated:

$$Ln\ TC_{i,t} = x_{i,t}\,® + (V_{i,t} + U_{i,t}) \qquad (2)$$

where *t* denotes the time dimension, *ln* TC_i is the logarithm of the cost of production of the *i-th* bank, x_i is a *kx1* vector of standardised input prices and output of the *i-th* bank, ® is a vector of unknown parameters, V_i is a random variable, which is assumed to be *i.i.d.* distributed as a $N(0, \lceil^2_v)$ and independent of U_i. U_i is a non-negative random variable, which is assumed to account for the cost inefficiency in production and is assumed to be *i.i.d.* as truncations at zero of the $N(\lceil, \lceil_U^2)$ distribution, $\lceil$ is a parameter to be estimated. We use the following translog functional form[26] to estimate a common benchmark frontier in the EU26[27]:

[26] The choice of the use of translog is motivated by two reasons. First, Altunbas and Chakravraty (2001) identified some problems associated with using the Fourier functional form, especially when dealing with heterogeneous data sets. Secondly, Berger and Mester (1997) observe that the translog functional form and Fourier-flexible form are substantially equivalent from an economic viewpoint and both rank individual bank efficiency in almost the same order.

[27] We would like to thank the referee for suggesting this approach. Following the work of Bos (2009), we estimate a common benchmark frontier in the EU-26. We include three environmental variables *(z)* and use them for modelling the inefficiency distribution without directly including these in the production frontier in order to reduce the heterogeneity in our data set. The inefficiency components u_i are assumed to be distributed independently, but not identically. For each *i-th* firm the technical inefficiency effect is obtained as truncation at zero of a normal distribution $N(\mu_i, \sigma^2)$ where the mean μ_i is a function of M factors representing the firm specific environment: $\mu_i = \delta_0 + \sum_{j=1}^{3} \delta_j Z_{j,i}$,

$$
\begin{aligned}
ln\,TC = {} & \alpha_0 + \sum_{i=1}^{3} \alpha_i \ln y_i + \sum_{i=1}^{3} \beta_i \ln w_i + \tau_1 \ln E + t_1 T + \\
& + \frac{1}{2}\left[\sum_{i=1}^{3}\sum_{j=1}^{3} \delta_{ij} \ln y_i \ln y_j + \sum_{i=1}^{3}\sum_{j=1}^{3} \gamma_{ij} \ln w_i \ln w_j + \phi_1 \ln E \ \ln E + t_{11} T^2 \right] + \\
& + \sum_{i=1}^{3}\sum_{j=1}^{3} \rho_{ij} \ln y_i \ln w_j + \sum_{j=1}^{3} \psi_i \ln y_i \ln E + \sum_{j=1}^{3} \varphi_i \ T \ln y_i + \\
& + \sum_{j=1}^{3} \theta_i \ln w_i \ln E + \sum_{j=1}^{3} \vartheta_i \ T \ln w_i + \ln u_c + \ln \varepsilon_c
\end{aligned}
\tag{3}
$$

where *TC* is the logarithm of the cost of production, y_i *(i=1, 2, 3)* are output quantities, w_j *(j=1, 2, 3)* are input prices, *ln E* is the natural logarithm of total equity capital, *T* is the time trend, u_c are the cost inefficiency components. In order guarantee the linear homogeneity in factor prices. That is:

$$\sum_{j=1}^{3} \beta_j = 1 \quad \sum_{i=1}^{3} \gamma_{ij} = 0 \quad \sum_{j=1}^{3} \rho_{ij} = 0$$

it is necessary (and sufficient) to apply the following restrictions: 1) the standard symmetry: according with this restriction, it is assumed that:

$$\delta_{ij} = \delta_{ji}$$

and

$$\gamma_{ij} = \gamma_{ji}$$

2) linear restriction of the cost function.

In particular, we take into account economic growth (*LnGDPP*) and prosperity (GDP per-capita). We also include a demographic variable that may impact on the bank delivery channels (i.e. population density - *POPD*) and money market interest rates *IR* (a proxy for the stance of monetary policy). These macro factors include *GDP* pro-capita (Z_1), Population density *(Z_2)* and Short term Interest rates *(Z_3)*. In this way, we assume that all banks in our sample share the same technology and environmental factors influence only the distance between each firm and the best practice.

Bank inputs and outputs are defined according to the value-added approach, originally proposed by Berger and Humphrey (1992). We posit that labour, physical capital and financial capital are inputs[28], whereas demand deposits (y_1), total loans (y_2) and other earning assets (y_3) are outputs[29]. We also estimate the alternative revenue efficiency measures: in this "alternative" approach, banks take input and output quantities as given and we selected these measures since prices are often inaccurately measured in banking.[30] The revenue efficiency is estimated using the same translog functional model adopted for the cost efficiency, by using as dependent variable the total bank's revenue in the revenue function. The bank input and output definition adopted is the same adopted to estimate the cost efficiency.

[28] Input prices are obtained as total personnel expenses over total assets (w_1) , total depreciation and other capital expenses over total fixed assets (w_2) and total interest rate expenses over total funds (w_3).

[29] This selection of inputs and outputs follows the studies by Sathye (2001) and Dietsch and Lozano (2000), Aly et al. (1990) and Hancock (1986), wherein the author develops a methodology based on user costs to determine the outputs and inputs of a banking firm. Although off-balance sheet (OBS) items may play a role in generating bank value-added, we omit to consider OBS items since our sample also includes small banks that do not have OBS items or data are not available in the Bankscope database. By including the OBS in the output selection, the sample size would have been substantially reduced, especially because we use a AR(3) process in model (1).

[30] Berger and Mester (1997, p. 904) notes that "if prices are inaccurately measured –as is likely, given the available banking data – the predicted part of the standard profit function would explain less of the variance of profits and yield more error in the estimation of the efficiency terms $ln\ u_{\square}$. In this event, it may be appropriate to try specifying other variables in the profit function that might yield a better fit, such as the output quantity vector, y, as in the alternative profit function".