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## Does labour regulation affect technical and allocative efficiency? Evidence from the banking industry

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### Abstract

In light of the ongoing restructuring of the European banking industry and the challenging macroeconomic environment, banks have increased their efforts to reduce operating costs. Yet, the institutional features that affect banks' ability to adjust costs and in particular personnel expenses, which comprise a significant part of banks' non-interest cost structure, have not been adequately studied. This paper investigates the effect of labour market institutions and regulations on bank performance in 15 European countries over the period 2005-2010, using the Fraser index for labour regulation and its disaggregated sub-components. We propose a novel methodology to measure performance, based on the seminal work of Kumbhakar and Tsionas (2005), which allows the estimation of technical and allocative efficiency and the examination of the effect of labour market regulations in a single stage. Results indicate the existence of a positive relationship between the liberalization of EU labour markets and allocative efficiency, while the effect on technical efficiency appears to be negative, although not statistically significant. When looking at the disaggregated components of the labour index, we further confirm that different forces are at play.

**Keywords:** *Labour regulation; banks; technical and allocative efficiency; Maximum Likelihood.*

## 1. Introduction

Over the past years, the European banking industry has undergone significant restructuring, which has been further triggered by the financial crisis. As part of this restructuring process, banks have tried to improve their performance through a reduction in operating costs and have implemented wide-ranging cost-cutting measures by implementing organizational changes and reducing both their branch networks and the number of their employees (ECB, 2003). Moreover, in the current challenging environment for banks' profitability, with low interest rates and slow credit growth, banks are forced to intensify their efforts to review their cost structures in order to reduce costs, including through personnel expenses (ECB, 2013).

Although personnel expenses comprise a relatively small fraction of banks' cost compared to other industries, they have been at the centre of bank managers' cost-cutting efforts during recent years. Data from the OECD Bank Profitability Report (2010)<sup>1</sup> suggest that the ratio of personnel expenses as a share of total cost in European banking systems exhibits a clear downward trend after 2005 in most countries. Moreover, OECD data show that there are significant differences across countries, as the percentage of staff expenses to total costs ranges from 5 per cent in Luxembourg to about 24 per cent in Greece. The observed cross-country differences may indicate that banks face different constraints across countries that affect their ability to adjust their labour costs. These constraints may be related, among other things, to the framework of labour institutions and regulations. According to Bertola (2009), labour regulations play a very important role in the allocation of a key production input, that is, labour. In particular, he finds that limited wage-setting flexibility, as well as of regulatory constraints on hiring and firing, and of employment protection legislation on labour mobility can have a significant effect on the allocation of labour. Boeri et al. (2008) also argue that labour market regulations can affect firms' choices over inputs, investments, technology and

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<sup>1</sup> See Figure C1 in the Appendix.

output. Consequently, banks' ability to adjust staff costs and their responsiveness to changing circumstances may be highly influenced, by labour institutions and regulations.

While a number of studies have examined the impact of labour regulations at a macro level (e.g., Botero et al., 2004; Lazear, 1990), very few microeconomic empirical studies analyse the impact of labour market rigidities on firm-level outcomes (Lafontaine and Sivadasan, 2007).<sup>2</sup> Moreover, to our knowledge no study has performed such an analysis for the banking system, with the exception of the study of Mamatzakis et al. (2013), which focuses on business regulation. The aim of this paper is to fill this gap in the literature and to investigate the effects of labour market regulation and labour institutions on bank efficiency in the European banking industry over the period 2005-2010. Moreover, our aim is to examine whether labour regulations affect banks' performance through the channel of technical efficiency or through allocative efficiency. To this end, we propose a new methodology, which builds on Kumbhakar and Tsionas (2005a) that allows us to estimate technical and allocative efficiency and examine the effect of labour regulations in a single stage.<sup>3</sup> In order to capture labour market regulations, we employ one of the five subcomponents of the Fraser Index of Economic Freedom, namely, labour market liberalization. This indicator quantifies the degree of stringency and distortions associated with existing labour regulations and institutions and provides a synthetic measure of the anti-competitive implications of existing regulations and institutions (European Commission, 2012).

Overall, our study aims to address a number of questions regarding the effect of labour regulation on bank performance and to discuss their policy implications: Do labour

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<sup>2</sup> At the aggregate level, the effect of labour market regulations on economic outcomes is the subject of an ongoing debate among economists and policymakers (Boeri et al., 2008). Some argue that regulations affect negatively economic efficiency and therefore are detrimental for growth, while others argue that they are essential tools to correct market imperfections and achieve goals of redistribution without hampering efficiency (see Boeri and van Ours, 2008 for a discussion).

<sup>3</sup> In particular, we opt for maximum likelihood estimation of technical and allocative efficiency, while allowing errors in the share equations also to be present in the cost function equation.

regulations and institutions affect banks' ability to adjust labour costs and do they have an impact on bank efficiency? Is this impact the same for technical and allocative efficiency or are there different forces at play? How do different aspects of labour market regulation, as captured by the sub-components of the labour liberalization index, affect banks' allocative and technical efficiency?

A first glimpse at the results shows a positive relationship between the liberalization of EU labour markets and allocative efficiency, while the relationship between technical efficiency and the labour market liberalization does not appear to be significant. When disaggregating the labour market regulation index into its components, we are able to capture the different forces at play. In particular, the analysis of the sub-components of the labour market regulation index provides evidence that price-related labour market regulations significantly affect bank performance through the channel of allocative efficiency. On the other hand, there appears to be no strong evidence of a significant relationship with technical efficiency.

The rest of the paper is structured as follows: Section 2 presents the theoretical framework and the hypotheses we examine in this study, while Section 3 presents the methodology. Section 4 describes the dataset, while empirical results are presented in Section 5. Finally, Section 6 offers some concluding remarks and possible policy implications.

## **2. Literature review and related hypotheses**

Labour market regulation is the subject of much theoretical work as well as extensive empirical research (Bertola, 2009). In particular, labour market regulations that constrain firms' ability to adjust employment levels are an important and controversial public policy issue in many countries around the world. The relevant literature has mainly focused on the macroeconomic effects of labour market regulation and its impact on output and

unemployment (Lazear, 1990; Blanchard and Wolfers, 2000; Botero et al., 2004; Nickell, 1997; Nickell and Layard, 1999; Heckman and Pages, 2003). More specifically, labour regulations are often cited as a determinant of economic performance in OECD countries predominantly suggests that a higher degree of labour market regulation leads to efficiency losses for firms (e.g. Freeman, 1988; Nickell and Layard, 1999). It appears that the literature predominantly suggests that a higher degree of labour market regulation leads to efficiency losses for firms (Freeman, 1988; Blanchard and Wolfers, 2000; Nickell, 1997; Nickell and Layard, 1999; Besley and Burgess, 2004). This is manifested in rising employment costs as a result of stricter employment protection legislation (Bassanini and Ernst 2002; Scarpetta and Tresselt 2004), which in turn, negatively affects firms' returns from innovation and technology, resulting in declining productivity growth (Malcomson 1997). On the other hand, other studies have shown that labour market regulations can cause increased wage pressures and could result in higher labour productivity due to capital deepening and investment in capital-intensive industries (Autor et al., 2007).

Overall, most labour market regulations were initially introduced with the aim of enhancing workers' welfare and improving employment conditions (OECD, 2004). However, the same provisions that protect employees translate into a cost for firms and thus could have a negative impact on firm performance through restrictions on the optimal amount of labour that firms employ or through affecting the price of the labour input. The literature on labour market regulation highlights both potential positive and negative effects for firm performance. For example, positive effects can result from the benefits of a high degree of employment security, which may create incentives for employees to invest in firm-specific human capital. Thus, employment security may enhance firm productivity by encouraging investment in human capital, since longer-lasting employment will increase the expected returns to training (Belot et al., 2002). In addition, Auer (2007) argues that strict employment

protection, and labour market regulation more generally, reduces excessive labour turnover, facilitates the reallocation of resources into activities having above-average productivity growth, and generates high-quality job matches. Furthermore, Autor et al., (2007) argue that labour market regulations that enhance wage pressures would induce higher labour productivity due to capital deepening and investment in capital-intensive technologies. This is also supported by Storm and Naastepad (2009), who showed that at the macro level a regulated and ‘rigid’ industrial relations system promotes labour productivity growth in twenty OECD countries. Moreover, Deakin and Sarkar (2008) also showed that labour regulation that strengthens dismissal laws has positive effects on productivity growth in France and Germany, and in the United States over the long term (from the 1970s to mid-2000s).

*Hypothesis 1: Under this approach, we would expect a negative relationship between labour market liberalization and bank performance.*

On the other hand, restrictive labour market regulations may diminish firms’ ability to cope with a rapidly changing environment driven by globalisation, technological change and the derived organisational innovation (OECD, 2004). Indeed, labour market regulations imposing for example high dismissal costs may affect firm’s decision on whether to hire new workers, as it has to take into account the likelihood that firing costs will be incurred in the future. Moreover, according to Scarpetta and Tressel (2004), strict labour market regulations that raise the cost of adjusting factor inputs, including labour, are likely to reduce incentives for innovation and adoption of new technologies, and lead to lower productivity performance.

*Hypothesis 2: Under this approach, we would expect a positive relationship between labour market liberalization and bank performance.*



Another interesting question that this study aims to address is whether the labour market regulation equally affects technical and allocative efficiency. As labour market regulations can directly affect both the price of the labour input and can also constrain the ability of firms to adjust the amount of labour they employ, they can thus have a potential impact on both technical and allocative efficiency. To this end, we test the following hypothesis:

*Hypothesis 3: Labour market regulations affect both technical and allocative efficiency in the same way.*

### 3. Decomposing efficiency into technical and allocative: a theoretical framework

In this section, we lay out the model proposed in Kumbhakar (1997) and Tsionas and Kumbhakar (2006). Let the production technology be specified as  $q_i = f(x_i e^{-u_i})$  where  $q_i$  is output and  $x_i$  is a vector of  $J$  inputs for firm  $i$  ( $i = 1, \dots, n$ ),  $f(\cdot)$  is the production function, and  $u_i \geq 0$  measures input-oriented (IO) technical inefficiency (Farrell, 1957). This specification implies that a technically inefficient bank over-uses all the inputs by  $u \cdot 100$  percent compared to an efficient bank producing the same output. Consequently, the IO measure of technical inefficiency is useful, when the objective of the banks is to allocate inputs in such a way that cost is minimized for an exogenously given level of outputs (which are services for banks). In allocating inputs banks may make mistakes. These mistakes are labelled as allocative inefficiency. Here we follow Schmidt and Lovell (1979) and Kumbhakar (1997) in modelling allocative inefficiency (non-fulfillment of the first-order conditions of cost minimisation), viz.,  $f_j(x_i e^{-u_i}) / f_1(x_i e^{-u_i}) = w_{j,i} e^{\xi_{j,i}} / w_{1,i}$ ,  $j = 2, \dots, J$ , where  $f_j(\cdot)$  is the marginal product of input  $j$  and  $w_j$  is the price of input  $j$ . Here a non-zero value of  $\xi_{j,i}$  indicates the presence of allocative inefficiency for the input pair  $(j, 1)$  for firm  $i$ .

Since  $\xi_{j,i}$  represents allocative inefficiency for the input pair  $(j, 1)$  the relevant input prices to the firm  $i$  ( $i = 1, \dots, n$ ) are  $w_i^* \equiv (w_{1,i}, w_{2,i} \exp(\xi_{2,i}), \dots, w_{J,i} \exp(\xi_{J,i}))'$ , where  $\xi_{2,i}, \dots, \xi_{J,i}$  are random variables that capture allocative inefficiency. Kumbhakar (1997) showed that actual cost can be expressed as

$$\ln C_i^a = \ln C^*(w_i^*, q_i) + \ln G(w_i, q_i, \xi_i) + u_i \quad (1)$$

where  $C_i^a = \sum_j w_{j,i} x_{j,i}$  and  $C^*(w_i^*, q_i)$  is the minimum cost function obtained from solving the following problem:  $\min_{x_i e^{-u}} w_i^* x_i e^{-u}$  subject to  $q_i = f(x_i e^{-u})$ . The  $G(w_i, q_i, \xi_i)$  function in (1) is defined as  $G(.) = \sum_j S_{j,i}^* e^{-\xi_{j,i}}$ , where  $S_{j,i}^* = \partial \ln C^*(.) / \partial \ln w_{j,i}^*$ . Since (1) is strongly separable in  $u_i$ , cost of technical inefficiency (percentage increase in cost due to technical inefficiency) is represented by  $u_i \geq 0$ . The allocative inefficiency terms ( $\xi_j$ ) appear both in the  $C^*(.)$  and the  $G(.)$  functions. Thus, to separate the cost of allocative inefficiency, we need to define  $C^0(w_i, q_i)$ , the cost frontier (also labeled as the neoclassical cost function). For this, we rewrite the cost function in (1) as  $\ln C_i^a = \ln C^0(w_i, q_i) + \ln C^{AL}(w_i, q_i, \xi_i) + u_i$  where  $C^0(w_i, q_i)$  is the cost frontier (the neo-classical cost function), which can be obtained from the cost function in (1) by imposing restrictions that firms are efficient both technically and allocatively. That is,  $\ln C^0(.) = \ln C^*(.) | \xi_{j,i} = 0 \forall j, u_i = 0 = \ln C^*(.) | \xi_{j,i=0}$  (since  $\ln G(.) | \xi_{j,i=0} = 0$ ) and  $\ln C^{AL}(w_i, q_i, \xi_i) = \ln C^a |_{u_i=0} - \ln C^0(.) = \ln C^*(w_i^*, q_i) + \ln G(w_i, q_i, \xi_i) - \ln C^0(.)$ . The  $\ln C_i^{AL}$  term can be interpreted as the percentage increase in cost due to allocative inefficiency.

If we assume a parametric functional form (e.g., translog) for  $C^*(.)$ , i.e.,

$$\ln C^*(w_i^*, q_i) = \alpha_0 + \sum_j \alpha_j \ln w_{j,i}^* + \gamma_q \ln q_i + \frac{1}{2} \gamma_{qq} (\ln q_i)^2 + \frac{1}{2} \sum_j \sum_k \beta_{jk} \ln w_{j,i}^* \ln w_{k,i}^* + \sum_j \gamma_{jq} \ln w_{j,i}^* \ln q_i$$

the cost function and the associated cost share equations in terms of  $C^0(.)$  are (see Kumbhakar and Tsionas 2005), p. 738):

$$\ln(C_i^a / w_{1,i}) = \ln C_i^0(\tilde{w}_i, q_i) + \ln C_i^{AL}(\tilde{w}_i, q_i, \xi_i) + u_i, \quad (2)$$

$$S_{j,i}^a = S_{j,i}^0(\tilde{w}_i, q_i) + \eta_{j,i}(\tilde{w}_i, q_i, \xi_i), \quad i = 1, \dots, n; j = 2, \dots, J \quad (3)$$

where  $\tilde{w}_i = (w_{2,i} / w_{1,i}, \dots, w_{J,i} / w_{1,i})$ ,  $S_{j,i}^a = w_{j,i} x_{j,i} / C_i^a$  is the actual (observed) cost share of input  $j$  ( $j = 2, \dots, J$ ),  $C_i^0(\tilde{w}_i, q_i)$  is the normalized (by  $w_{1,i}$ ) cost frontier and  $S_{j,i}^0 = \partial \ln C_i^0(.) / \partial \ln w_{j,i}$  ( $j = 2, \dots, J$ ). For the above translog cost function  $\ln C_i^0(\tilde{w}_i, q_i)$  is

$$\ln C_i^0(.) = \alpha_0 + \sum_{j=2}^J \alpha_j \ln \tilde{w}_{j,i} + \gamma_q \ln q_i + \frac{1}{2} \gamma_{qq} (\ln q_i)^2 + \frac{1}{2} \sum_{j=2}^J \sum_{k=2}^J \beta_{jk} \ln \tilde{w}_{j,i} \ln \tilde{w}_{k,i} + \sum_{j=2}^J \gamma_{jq} \ln \tilde{w}_{j,i} \ln q_i, \quad (4)$$

$$S_{j,i}^0 = \alpha_j + \sum_{k=2}^J \beta_{jk} \ln \tilde{w}_{k,i} + \gamma_{jq} \ln q_i, \quad j = 2, \dots, J, \quad (5)$$

$$\ln C_i^{AL} = \ln G_i + \sum_{j=2}^J \alpha_j \xi_{j,i} + \sum_{j=2}^J \sum_{k=2}^J \beta_{jk} \xi_{j,i} \ln \tilde{w}_{k,i} + \frac{1}{2} \sum_{j=2}^J \sum_{k=2}^J \beta_{jk} \xi_{j,i} \xi_{k,i} + \sum_{j=2}^J \gamma_{jq} \xi_{j,i} \ln q_i, \quad (6)$$

$$\eta_{j,i} = \frac{S_{j,i}^0 \{1 - G_i \exp(\xi_{j,i})\} + a_{j,i}}{G_i \exp(\xi_{j,i})}, \quad j = 2, \dots, J \quad (7)$$

where

$$G_i = \sum_{j=2}^J (S_{j,i}^0 + a_{j,i}) \exp(-\xi_{j,i}), \quad (8)$$

and

$$a_{j,i} = \sum_{k=2}^J \beta_{jk} \xi_{k,i}. \quad (9)$$

The cost system defined in (2) and (3) serves two purposes.<sup>4</sup> First, technical and allocative inefficiencies are modeled in a coherent manner. Second, the exact link between allocative inefficiency ( $\xi_j$ ) and its cost is given in (6). The cost function decomposes the overall increase in cost due to inefficiency into two components, viz., the percentage increase in cost due to allocative inefficiency,  $\ln C_i^{AL}$ , and the percentage increase in cost due to technical inefficiency,  $u_i$ . The decomposition formula also establishes an exact link between the error terms in the cost share equations (which are functions of allocative inefficiency) and cost of allocative inefficiency, which is very important from estimation point of view.

In general, the link is provided by the relationship  $\ln C^{AL}(w_i, q_i, \xi_i) = \ln C^*(w_i^*, q_i) + \ln G(w_i, q_i, \xi_i) - \ln C^0(.)$ . For the Cobb-Douglas case, this link is established in Schmidt and Lovell (1979), viz.,  $\ln C^{AL} = \sum_{j=2}^J \alpha_j \xi_j + \ln \left[ \alpha_1 + \sum_{j=2}^J \alpha_j e^{-\xi_j} \right] - \ln \left[ \sum_{j=1}^J \alpha_j \right]$ . Since Schmidt and Lovell used the system consisting of the production function and the first-order conditions of cost minimization, it was not necessary to use the above link in estimation. It was, however, used to compute the cost of allocative inefficiency.

<sup>4</sup> The cost system of equations follows Kumbhakar and Tsionas (2005) and provides a way to estimate both technical and allocative efficiency when the underlying cost function is a flexible functional form such as a translog. This is not by any means an easy task as it entails the estimation, jointly, of the translog cost and the underlying cost increase due to each inefficiency component. This has been proposed in Kumbhakar (1997) for a cost function. Moreover, the proposed formulation opts for an input-oriented technical inefficiency, whilst allocative inefficiency is modeled as in Schmidt and Lovell (1979). By doing so, the specification problem is solved, yet it remains finding appropriate estimation techniques. The next section solves also this problem as it proposes a feasible estimation technique.

The crux of the problem is in estimating the cost system in (2) and (3) using the link between cost of allocative inefficiency and errors in the cost share equations (which are functions of allocative inefficiency), given in equations (6), (8) and (9). It can be seen that the error structure based on  $u$  and  $\xi_j$  in (2) and (3) is quite complicated. Because of this the model has not been estimated using cross-sectional data.<sup>5</sup> In the following section, we discuss an estimation method.

### 3.1 Maximum likelihood estimation

With both technical and allocative inefficiency the system is

$$y_i = X_i \beta + \begin{bmatrix} \ln C^{AL}(\xi_i, \beta) + v_i + u_i \\ \eta(\xi_i, \beta) \end{bmatrix} \equiv X_i \beta + \begin{bmatrix} \zeta_i \\ \eta_i \end{bmatrix} \quad (10)$$

where  $u_i \sim i.i.d.N(0, \sigma_u^2)$  ( $u_i \geq 0$ ) is distributed independently of  $v_i$  and  $\xi_i$ . The convolution  $\omega_i \equiv v_i + u_i$  has a familiar distribution, namely,  $f(\omega_i) = \frac{2}{\sigma} \phi\left(\frac{\omega_i}{\sigma}\right) \Phi\left(\frac{\lambda \omega_i}{\sigma}\right)$ , where  $\sigma^2 = \sigma_v^2 + \sigma_u^2$ ,  $\lambda = \sigma_u / \sigma_v$ , and  $\phi, \Phi$  denote, respectively the pdf and cdf of the standard normal variable (see Kumbhakar and Lovell (2000), p. 140). Consequently,  $p(\zeta_i | \xi_i) = p_\omega(\omega_i - \ln C^{AL}(\xi_i, \beta))$ .

Assuming  $\xi_i \sim i.i.d.N_{J-1}(0, \Omega)$  as before, we obtain the following joint probability density function

$$\begin{aligned} p(\zeta_i, \eta_i) &= p(\zeta_i | \eta_i) \cdot p_\eta(\eta_i) = p(\zeta_i | \xi_i(\eta_i, \beta)) \cdot p_\xi(\xi_i(\eta_i, \beta)) \cdot |\det D\xi_i(\eta_i, \beta)| \\ &= \frac{2}{\sigma} \Phi\left(\frac{\zeta_i}{\sigma} - \ln C^{AL}(\xi_i, \beta)\right) \cdot |\det D\xi_i(\eta_i, \beta)| \times \\ &\quad (2\pi)^{-J/2} \det(\Omega)^{-1/2} \exp\left\{-\frac{[\zeta_i - \ln C^{AL}(\xi_i, \beta)]^2}{2\sigma^2} - \frac{1}{2} e(\eta_i, \beta)' \Omega^{-1} e(\eta_i, \beta)\right\}. \end{aligned}$$

Using

$$\zeta_i = \ln C_i^a - \ln C_i^0(\beta) - \ln C_i^{AL}(\beta, \xi_i(\eta_i, \beta))$$

$$\eta_{j,i} = S_{j,i}^a - S_{j,i}^0(\beta), \quad j = 1, \dots, J-1,$$

<sup>5</sup> The system described in (2) and (3) is somewhat similar to the panel data model of Kumbhakar and Tsionas (2005) model which assumed the presence of additional error terms in the share equations. Integrability condition requires that if there are errors in the share equations, these errors should also appear in the cost function (McElroy (1987)). No such allowance was made in the Kumbhakar and Tsionas (2005a) model. Furthermore, they used a Bayesian approach to estimate the system. Here we propose a classical ML method without an extra error term in each cost share equation.

the likelihood function becomes:

$$L(\beta, \sigma_v, \sigma_u, \Omega; y, X) \propto \sigma^{-n} \prod_{i=1}^n \Phi\left(-\frac{\lambda}{\sigma} [\zeta_i - \ln C^{AL}(\xi_i, \beta)]\right) \cdot \prod_{i=1}^n |\det D\xi_i(\eta_i, \beta)| \times \det(\Omega)^{-n/2} \exp\left\{-\frac{1}{2\sigma^2} \sum_{i=1}^n [\zeta_i - \ln C^{AL}(\xi_i, \beta)]^2 - \frac{1}{2} \sum_{i=1}^n e_i(\eta_i, \beta)' \Omega^{-1} e_i(\eta_i, \beta)\right\}, \quad (11)$$

where  $e_i(\eta_i, \beta) = \xi_i(\eta_i, \beta) - \bar{\xi}(\eta_i, \beta)$ , and  $\bar{\xi}(\eta_i, \beta) = n^{-1} \sum_{i=1}^n \xi_i(\eta_i, \beta)$ . The above likelihood function can be concentrated with respect to  $\Omega$ , the ML estimator of which is:

$$\hat{\Omega}(\beta) = n^{-1} \sum_{i=1}^n e_i(\eta_i, \beta) e_i(\eta_i, \beta)'.$$

Thus, the concentrated log-likelihood function is proportional to:

$$\ln L^C(\beta, \sigma_v, \sigma_u; y, X) = -\frac{n}{2} \ln(\sigma^2) + \sum_{i=1}^n \ln \Phi\left(-\frac{\lambda}{\sigma} [\zeta_i - \ln C^{AL}(\xi_i, \beta)]\right) + \sum_{i=1}^n \ln |\det D\xi_i(\eta_i, \beta)| - \frac{n}{2} \det(\hat{\Omega}(\beta)) - \frac{1}{2\sigma^2} \sum_{i=1}^n [\zeta_i - \ln C^{AL}(\xi_i, \beta)]^2. \quad (12)$$

Here,  $\sigma$  and  $\lambda$  are functions of the original parameters  $\sigma_v$  and  $\sigma_u$ . The model can be generalized so that  $\mu$  is the mean vector of allocative distortion parameters. This means vector can be made function of a vector of exogenous variables, say  $z_i$ , so we have:

$$\mu_i = \Gamma z_i.$$

In this way the exogenous variables have an impact on allocative efficiency, which can be measured easily (e.g., using elasticities) after the parameters have been estimated by the method of ML.

To allow for determinants of inefficiency we assume  $\log \sigma_{ui}^2 = \delta' z_i$ . This model was favored over the standard Battese-Coelli / Kumbhakar-Ghosh-McGuckin specification in terms of the BIC criterion and it is known to have a number of desirable features (see Kumbhakar and Parmeter, 2014).

To maximize the log-likelihood functions shown in (12) we use the Nelder-Mead simplex maximization technique that does not require numerical derivatives. To compute standard errors for the parameters we have used the BHHH formula, which is based on first-order derivatives of the log-density with respect to the parameters.

#### 4. Dataset

Unconsolidated bank-level data for the estimation of efficiency are obtained from the Fitch IBCA-Bankscope database. Our sample cover the period 2005-2010 and includes commercial, savings and cooperative banks in EU-15 countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the UK). After removing errors and related inconsistencies, as well as banks for which we don't have data for the entire period under examination, we end up with a sample of 2,410 banks.<sup>6</sup>

We define inputs and outputs in line with the intermediation approach of Sealey and Lindley (1977). Outputs include loans and other earning assets (government securities, bonds, equity investments, CDs, T-bills, equity investment etc.), while total cost is defined as the sum of overheads (personnel and administrative expenses), interest, fees, and commission expenses. With regards to input prices, we proxy the price of labour by the ratio of personnel expenses to total assets, while we measure the price of deposits as the ratio of total interest expenses to total borrowed funds and the price of physical capital as the ratio of other operating expenses to fixed assets. Equity is specified as a fixed netput and is included to account for both the risk-based capital requirements and the risk-return trade-off that banks face (Färe et al., 2004).

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<sup>6</sup> We opt for a balanced sample because our aim is to examine the effect of labour regulation on bank performance and we want to keep the number of banks in our sample stable over time so as to avoid our results being driven by the entry and exit of banks from our sample (due to data availability, mergers and acquisitions, failures etc.). We acknowledge that our sample suffers from "survival bias", as it includes only the banks that have survived over the sample period, which are usually the most efficient ones, and also that this affects the average efficiency scores we report, but we consider that this does not affect the main aim of this study, which is to examine the effect of institutional framework of labour market regulations on a sample of European banks.

#### 4.1 Measuring labour market regulation

We capture labour market regulations by the Fraser Index of Economic Freedom (Gwartney et. al, 2011) and in particular we employ one of the five components of the index, namely, labour market liberalization.<sup>7</sup> This indicator measures the degree of stringency and the distortions associated with labour regulations and institutions, and provides a synthetic measure of their anti-competitive implications (European Commission, 2012). The index ranges from 0 to 10, with 0 indicating the lowest and 10 the highest degree of liberalization in the labour market, respectively.<sup>8</sup>

Figure 1 presents the evolution of the Fraser Index on labour regulation (*LR*) over the period 2000-2010 for all EU-15 countries. Overall, we observe significant liberalization in European labour markets in all EU countries except Luxembourg. In particular, UK and Ireland appear to have the most liberalized labour markets, while Ireland is also among the countries that exhibit the highest improvement over time. The significant progress observed across EU countries in the liberalization of their labour markets is not surprising, as the need to improve the functioning of EU labour markets has featured prominently in the priorities of the EU strategy.<sup>9</sup> For example, the objectives of the Lisbon strategy included policies to promote flexibility in the labour market combined with employment security and to reduce labour market segmentation, while at the same time ensure employment-friendly labour cost

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<sup>7</sup> The Fraser Index of Economic Freedom consists of five factors: size of government; legal structure and security of property rights; access to sound money; freedom to exchange with foreigners; and regulation of credit, labour, and business. These are weighted components that form a composite index ranging from 0 to 10, with 0 indicating the lowest and 10 the highest level of economic freedom. The use of this index is common in the economic literature (see for example Carlsson and Lundstrom, 2002).

<sup>8</sup> The data used to construct the Fraser Index and its sub-components are from external sources such as the IMF, World Bank, and World Economic Forum that provide data for a large number of countries. These raw data are transformed into component ratings, which are then used to construct the scores. Complete methodological details can be found in the “Economic Freedom of the World: Annual Report 2012” (Appendix: Explanatory Notes and Data Sources (page 271)).

<sup>9</sup> For a comprehensive review of labour market reforms implemented in EU countries over the last decade, see European Commission (2012) and Turrini et al. (2014).

developments and wage-setting mechanisms (see Council Decision 2005/600/EC on Guidelines for the employment policies of the Member States).

According to the European Commission (2012): *'Since the onset of EMU, there was clear awareness that a successful monetary union would have required reforming labour markets where needed in such a way to ease adjustment in the face of asymmetric shocks and to permit a prompt reaction of price competitiveness as a tool to absorb idiosyncratic shocks and favour the correction of macroeconomic imbalances.'* The need for timely and comprehensive labour market reforms has been further highlighted in the priorities identified in EU surveillance, including in the context of the EU Semester, the Macroeconomic Imbalance Procedure, and financial assistance programme conditionality for countries under IMF/EC/ECB programs. Against the background of an increased urgency to reform labour markets, and broadly in line with the recommendations by European institutions, most EU countries have stepped up their labour market reform agenda, focusing on reforms of labour market institutions and regulation that are key to ensure effective adjustment (Turrini et al., 2014). According to data from the European Commission (DG ECFIN LABREF database), most reforms were undertaken in the areas of active labour market policy and labour taxation, while the 2008 crisis has triggered increased policy action in reform areas with macro-structural relevance, such as employment protection legislation and wage-setting frameworks (Turrini et al., 2014).

Figure 1 also reveals that there appears to be no clear relationship between the initial conditions of labour market performance and subsequent reform efforts, which is also consistent with the findings of the OECD (Brandt et al., 2005). In addition, according to the European Commission (2012) the distribution of reforms across countries reveals that there is a relatively low degree of cross-country synchronization of reforms over the examined period.



*(Insert Figures 1 and 2 about here)*

In our analysis, we also employ the sub-components of the Fraser Index on labour regulation. In particular, the index is decomposed into the following factors: i) hiring regulations and minimum wage (*MW*), ii) hiring and firing regulations (*HF*), iii) centralized collective bargaining (*CCB*), iv) regulation of hours of work (*HR*), v) mandated cost of worker dismissal (*DISS*) and vi) conscription.<sup>10</sup> Note that the sub-components of the labour regulation index also take values from 0 to 10, with higher values suggesting greater economic freedom and low values indicating the existence of market rigidities.

In more detail, the first subcomponent of Fraser labour market regulation index, “*hiring regulations and minimum wage*”, focuses on the difficulty of hiring and captures some fundamental labour market issues, such as: whether fixed-term contracts allow for permanent tasks, the maximum cumulative duration of fixed-term contracts; and the ratio of the minimum wage for a trainee or first-time employee to the average value added per worker. Looking at Figure 2 (*upper left panel*) we observe significant differences across countries, both with regards to the trend of reforms, as well as their direction and intensity. Most countries exhibit a trend towards liberalization of hiring regulations and minimum wage, with Austria, Denmark, Ireland and the UK presenting the highest progress over time. On the other hand, the opposite trend is observed in France and Portugal.

The second subcomponent of the Fraser Labour Index is “*hiring and firing regulations*” and captures whether labour market regulations hinder the hiring and firing of workers. Figure 2 (*upper right panel*), shows a somewhat slow trend towards greater liberalization in hiring and firing regulations in most countries, suggesting that there may be room for additional

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<sup>10</sup> We exclude the 6<sup>th</sup> sub-component of the Fraser Index on labour regulation from our analysis, as we consider it less relevant for the banking system.

liberalization in this area. Denmark and Finland are the countries exhibiting the highest improvement in reforms in this area.

The third subcomponent of the Fraser Labour Index is “*centralized collective bargaining*”, which refers to country-level industrial relations, and captures whether wages are set by a centralized bargaining process or are left up to each individual company. As we can observe from Figure 2 (*middle left panel*), there are diverging trends across countries, with about half of EU Member States exhibiting a trend towards higher centralization over time and the other half moving towards decentralization. France and Ireland exhibit the highest improvement of this sub-component over time, while the UK, although presents a trend towards higher centralization, it still remains the country with most liberalized system of collective bargaining.

The fourth subcomponent of the Fraser labour Index, “*hours regulations*” captures various elements including: restrictions on night work; restrictions on weekly holiday work and weekly hours, including overtime, and paid annual vacation. Figure 2 (*middle right panel*), shows a trend towards more liberalization over the period 2000-2010 across all countries except Greece and Spain, while Ireland presents the highest score in this area (a fully liberalized system).

The “*mandated cost of worker dismissal*” comprises the fifth subcomponent of the Fraser Labour Index and captures the cost of the advance notice requirements, severance payments, and penalties due when dismissing a redundant worker. In Figure 2 (*down left panel*), we observe that the vast majority of countries (except from Greece) exhibits significant progress in liberalizing mandated dismissal costs over the examined period. Moreover, several countries, such as Austria, Belgium, Denmark, Finland, Italy, Netherlands and Sweden, have a fully liberalized system in this area.

#### 4.2 Control Variables

A number of control variables are also included in our analysis in order to account for heterogeneity both across banks and across countries. In particular, the inclusion of variables capturing individual bank characteristics that could affect cost efficiency and variables accounting for cross-country heterogeneity is common in the efficiency literature (see for example, Dietsch and Lozano-Vivas, 2000). To this end, the following bank-specific variables are included, capturing differences across banks in terms of size, credit risk and profitability:

*Bank Size (TA)*: Although banks in the EU-15 banking systems have similar organizational structures and objectives, they vary significantly in size. Therefore, we include the logarithm of total assets to account for differences in the size of each bank. Bank size is also a proxy for economies or diseconomies of scale and can lead to either higher or lower costs for banks. If large banks exercise market power, they may increase the costs for the sector through slack and inefficiency. In a similar vein, small banks operating mostly in local markets may have access to “soft” information about local conditions, engage in “relationship lending” and become more efficient than large banks (Berger, 2007). By contrast, if the size of a bank reflects economies of scale and consolidation through the survival of more efficient banks, larger banks may be more cost efficient. Empirical evidence on the relationship between bank size and efficiency is inconclusive (see Altunbas et al., 2001; Carbo et al., 2002; Maudos and De Guevara, 2007).

*Credit risk (LLP/L)*: Managing credit risk is an important part of bank operations. Changes in credit risk may reflect changes in the quality of a bank’s loan portfolio and may affect bank performance. As a proxy for credit risk we use the ratio of loan loss provisions to gross loans.

The relationship between inefficiency and credit risk could be positive according to the ‘*bad management*’ or the ‘*bad luck*’ hypotheses developed by Berger and DeYoung (1997), or negative under the ‘*skimping*’ hypothesis.<sup>11</sup>

*Capitalization (EQ/A)*: The ratio of equity to assets is a proxy for bank capitalization and also accounts for different risk preferences. If financial capital is ignored, the efficiency of banks that may be more risk averse than others and may hold a higher level of financial capital would be mis-measured, even though they are behaving optimally given their risk preferences. The capitalization ratio is thus included in order to account for both the risk-based capital requirements and the risk-return trade-off that bank owners face.

*Net interest margin (NIM)*: Despite the rising importance of fee-based income as a proportion of total income, net interest margins remain one of the principal elements of bank net cash flows and profits. We employ the net interest margin as a traditional measure of bank performance, which captures banks’ primary intermediation function, while it also serves as a proxy for bank competition.

(Insert table 1 about here)

Moreover, we also include two macroeconomic variables, namely GDP growth (*GDPgr*) and the inflation rate (*INFL*) as proxies for fluctuations in economic activity across countries and over time. This is consistent with the vast majority of the literature (see for example, Dietsch and Lozano-Vivas, 2000). Descriptive statistics for the bank-specific and country-specific control variables are presented in Table 1, which also includes the average value for the labour market indicator and its decomposition for each country over the period 2005-2010.

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<sup>11</sup> Under the ‘*bad luck*’ hypothesis of Berger and DeYoung (1997), exogenous events may cause an increase in a bank’s problem loans and the additional managerial effort required to deal with these non-performing loans, will increase bank costs. The ‘*bad management*’ hypothesis assumes that an inefficient bank manager will apply poor senior management practices to both day-to-day operations (increased cost inefficiency) and to managing the loan portfolio (lower credit quality). Under the ‘*skimping*’ hypothesis, a bank may appear more cost efficient in the short run, if it allocates fewer resources to monitoring loans, as less operating expenses can support the same quantity of loans and other outputs.

## 5. Results and discussion

### 5.1 Technical and allocative efficiency scores

Table 2 presents the average technical and allocative efficiency scores by country over the period 2005-2010.<sup>12</sup> Looking at the cross-country results, average technical efficiency stands at 0.84, ranging from 0.77 in Belgium to 0.92 in Finland, while average allocative efficiency is estimated at 0.89, ranging from 0.86 in Ireland to 0.91 in Finland.

Over time (see Figure 3), average technical efficiency remains broadly stable up to 2007 and decreases significantly thereafter, following the advent of the global financial crisis. Technical efficiency starts improving slightly in 2009 and continues its upward trend also in 2010. Allocative efficiency exhibits a similar trend, showing a clear downward trend after 2007, and starts improving in 2010. Cross-country analysis reveals similar patterns in the evolution of efficiency scores over time across countries. Looking at the distribution of technical and allocative efficiency over time, we observe (Figure 4) that during the financial crisis (for the years 2008 and 2009) the distribution of both technical and allocative efficiency flattens and moves to the left (to lower efficiency scores). Overall, our efficiency analysis shows that the financial crisis has significantly affected banks' allocative and technical efficiency and that some improvement is observed in 2010, which could reflect banks' increasing efforts to cut down their costs.<sup>13</sup>

*(Insert Table 2 and Figures 3 and 4 about here)*

<sup>12</sup> The average efficiency scores presented in Table 2 are derived from equation (12) using the aggregate labour index to capture labour market regulations and institutions (Table 3 results). Efficiency results derived from the rest of the models presented in this paper (using the sub-components of the aggregate labour index-see tables 4 and 5) are broadly similar and we do not observe any marked sensitivity of the distributions of technical and allocative efficiency. Results are available from the authors upon request.

<sup>13</sup> The methodology of this paper allows us to derive estimates of both allocative and technical efficiency distributions for each individual period in the sample. Thus, the advantage is that any structural change in the underlying performance measures due to the credit crunch is dealt adequately from a complete set of information such as the distributions of allocative and technical efficiency per year.

Figure 5 presents the distribution of price distortions, across the entire sample, for the prices of borrowed funds (straight line) and labour (dotted line). These parameters are the  $\xi$ 's in system (2)-(3). The labour price distortion averages approximately 10% and can be as large as about 30-40%. The price distortion of borrowed funds ranges between -20% and 10%, its average is close to -5% and there is clearly some heterogeneity of its distribution across banks –evidenced by the distinct bimodality of the sample distribution. These results indicate that banks effectively face much higher labour costs compared to the nominal prices, while most of them buy their borrowed funds cheap. However, there is considerable heterogeneity among banks regarding their funding cost, as evidenced by the sizable probability to the right of zero in the distribution of borrowed fund distortions. The increased variability in the price of borrowed funds across banks could be explained by differences in banks' business models and funding structures across countries and across banks of different size and with different institutional characteristics (ECB, 2009).

*(Insert Figures 5 and 6 about here)*

In Figure 6, we present the sample distributions of price distortions for borrowed funds (upper panel) and labour (bottom panel). We observe that the distributions clearly change over time. For example, after the sub-prime crisis borrowed funds become more expensive, while wage costs decrease from about 10% or 15% in previous periods to about 5% on the average in 2010. This is consistent with the effect of the global financial crisis on banks' funding cost, which has increased significantly, putting an end to a period of ample liquidity observed prior to the crisis (ECB, 2009). Similarly, the ramifications of the financial crisis for executives' compensations and for the financial sector's employees' salaries are possibly evident in the fall in labour costs.

In addition, it is, perhaps, of interest to disentangle the effects of various inputs on allocative inefficiency as the focus of this study is on labour regulation. To perform this decomposition, apparently, we cannot regress allocative inefficiency scores on different input distortions as according to (4)-(8) our model relies on consistent measurement of technical and allocative inefficiency.

One may think that we can re-estimate the model assuming certain distortions are zero. New allocative efficiency scores can be computed. These new scores can then be compared to allocative efficiency scores from the general model. The problem, however, is that if the general model is correct (which is obvious as it nests all the alternatives where certain distortions are zero) estimates of distortions and scores will be biased.

The proper way to proceed is as follows. Given the distortions arising from borrowed funds, labor and capital (denoted by  $\xi_B, \xi_L, \xi_K$ ) and the estimated model, denote allocative efficiency by  $AE$ . We can set  $\xi_L = 0$ , say. Next, we compute allocative efficiency scores denoted by  $AE_0$  using (6). The ratio:

$$\Delta = \frac{AE_0 - AE}{AE},$$

is a measure of the contribution of labor to allocative efficiency. In other words,  $\Delta$  measures by how much allocative efficiency can be improved if labor input was used efficiently. We present estimates for labour and borrowed funds in the following table.

*(Insert Table 3 about here)*

## 5.2 The impact of aggregate labour regulation index

Table 4 presents the output from estimating Eq. (12) on the relationship between bank efficiency (both technical and allocative) and labour market regulation using the aggregate labour market regulation index.

*(Insert Table 4 about here)*

Our results indicate that the relationship between labour market liberalization and bank efficiency is a complex one. On the one hand, we observe a negative relationship between labour market liberalization and technical efficiency, which is marginally statistically significant at the 10% level in line with Hypothesis 1, while the effect of labour market liberalization on allocative efficiency appears to be positive and statistically significant at the 1% level, which is consistent with Hypothesis 2. Our findings are in line with the mixed evidence that the labour economics literature provides with regard to the impact of labour regulation on economic performance (Bassanini et al., 2009). The negative relationship between technical efficiency and labour liberalization seems to be consistent with the positive effects of employment protection on employees' incentives to invest in firm-specific knowledge, improving their productivity (Black and Lynch, 1996; Bassanini et al., 2009). Moreover, specific to the banking sector, a higher degree of labour market liberalization that increases turnover and labour mobility, may negatively impact on '*relationship lending*' in banking, which is based on the personal interaction and relationship between customers and bank employees, thus negatively affecting technical efficiency.

On the other hand, the positive effect of labour liberalization on allocative efficiency indicates that less restrictive labour market regulations reduce the cost of labour for banks and the cost of adjusting the labour input, leading to higher efficiency. This is consistent with Lafontaine and Sivadasan (2007), who find a significant impact of labour laws on labour



adjustment and related decisions at the micro level. In particular, our finding indicates that in a more liberalized labour market, banks are able to respond more efficiently to changes in the price of labour and to adjust their labour input accordingly. This positive relationship between allocative efficiency and labour market liberalization is also consistent with the findings of Scarpetta and Tressel (2004), who found evidence that high labour adjustment costs (proxied by the strictness of employment protection legislation) can have a strong negative impact on productivity, as they reduce incentives for innovation and adoption of new technologies.

Looking at the effect of bank-specific variables on technical and allocative efficiency, our results are consistent with the literature. More specifically, we observe that bank size has a positive effect on both technical and allocative efficiency, while banks with a higher capital ratio exhibit higher technical efficiency, but lower allocative efficiency. The ratio of loan loss provisions to loans, which captures credit risk and the quality of banks' loan portfolio, exhibits a negative relationship with bank technical efficiency, which is consistent with the '*bad management hypothesis*' of Berger and DeYoung (1997), while it has a positive coefficient in the case of allocative efficiency, consistent with the '*skimping hypothesis*' (see Berger and DeYoung, 1997). The net interest margin appears to assert a negative effect on technical efficiency, while it affects positively allocative efficiency. Finally, regarding the macroeconomic variables, we find that the coefficient of GDP growth is only statistically significant in the case of allocative efficiency and takes a positive sign, while inflation appears to have a negative and statistically significant effect in both specifications.

### 5.3 *The impact of sub-components of labour regulation*

As a next step and in order to get a more accurate assessment of the effect of labour market regulation on bank performance, we decompose the aggregate labour regulation index into its different components, which are, in turn, grouped into two categories. The first category incorporates the indicators with a direct effect on the price of labour (i.e. the minimum wage, the cost of dismissals) that are expected to have an impact on banks' allocative efficiency through their ability to respond to changes in input prices. The second category of indicators includes variables that affect the general institutional setting in the labour market and banks' ability to adjust the input of labour (i.e. hiring and firing regulations, centralized collective bargaining and mandated hours worked) and are expected to have an impact on banks' technical efficiency. Tables 5 and 6 present the estimated results for allocative and technical efficiency, respectively.

*(Insert Tables 5 and 6 about here)*

Table 5 shows that there is a negative and statistically significant relationship between allocative efficiency and the sub-components of the labour regulation index that affect the price of labour, in line with Hypothesis 1. This relationship is confirmed in all specifications (models 1-3 in Table 5). In particular, we find that the dismissal cost sub-index has a negative and statistically significant effect on allocative efficiency. According to Cappelli (2000) increased dismissal costs that raise the costs of workforce adjustment, may reduce incentives for firms to expand and innovate, thus affecting their cost performance. In particular, hiring and firing costs increase labour adjustment costs and create disincentives for firms to foster internal efficiency through the adoption of leading technologies and innovation (see e.g., Audretsch and Thurik, 2001).

Moreover, the coefficient for the minimum wage sub-component also asserts a negative and statistically significant effect on allocative efficiency. Our results are consistent with Agell (1999), who argues that significant employment security together with a compressed wage structure stimulates investment in education by workers, with positive effects on their productivity by providing workers with insurance against wage risk. Lower wage risk could also have a positive effect on '*relationship lending*' in banking, thus positively affecting bank efficiency through improved personal relationships between customers and bank employees. Our results are further confirmed when looking at models 2 and 3, where we examine the separate effect of each subcomponent of the labour regulation index. Both the coefficients of the minimum wage sub-component and the dismissal cost sub-index retain their sign and significance. Regarding the remaining bank-specific and macro variables, they all take the expected signs and confirm our previous findings. On the other hand, when looking at the results for technical efficiency (Table 6), we find that the relationship between technical efficiency and the sub-components of the labour regulation index that affect banks' ability to adjust their labour input is not statistically significant in any of the specifications (models 1-4 in table 6).

These results are of interest as they provide for the first time insights into the relationship between specific aspects of labour regulation and bank performance. In particular, the analysis of the sub-components of the labour market regulation index provides evidence that labour market regulations that affect the price of labour significantly affect bank performance through the channel of allocative efficiency. On the other hand, there appears to be no strong evidence of a significant relationship with technical efficiency.

## 6. Conclusion

The labour economics literature provides mixed evidence regarding the impact of labour regulation on economic performance of firms, whilst the bank performance literature has so far neglected to examine the importance of labour regulation. This paper fills this gap in the literature and examines the impact of labour regulation on technical and allocative efficiency of the EU-15 banking system over the period 2005-2010. In particular, we employ the Fraser index for labour regulation and its sub-components and propose a novel methodology based on Kumbhakar and Tsionas (2005) to investigate the relationship between labour market liberalization and technical and allocative efficiency in European banking.

Overall, our evidence shows that the relationship between bank efficiency and labour market regulation is complex. We find that labour market regulation affects bank efficiency mainly through the allocative efficiency channel, while its effect on technical efficiency is not significant. More specifically, we find a positive effect of labour market liberalization on allocative efficiency, which is consistent with the findings of Autor et al., (2007) and Lafontaine and Sivadasan (2007). However, when looking at the various sub-components of the labour market regulation index, we find that diverging forces are at play. In particular, we observe that the liberalization of the minimum wage regulations and of the cost of dismissals has a negative effect on allocative efficiency. Moreover, our results indicate that insurance against wage risk and job security in general, as reflected by a lower level of labour market liberalization, can have a positive effect on '*relationship lending*' in banking, with positive effects on bank efficiency through improved personal relationships between customers and bank employees. Regarding policy implications, our findings clearly demonstrate the complex relationship between efficiency and labour market regulations and the need for policy makers to take these complex interactions into consideration when designing labour market reforms.

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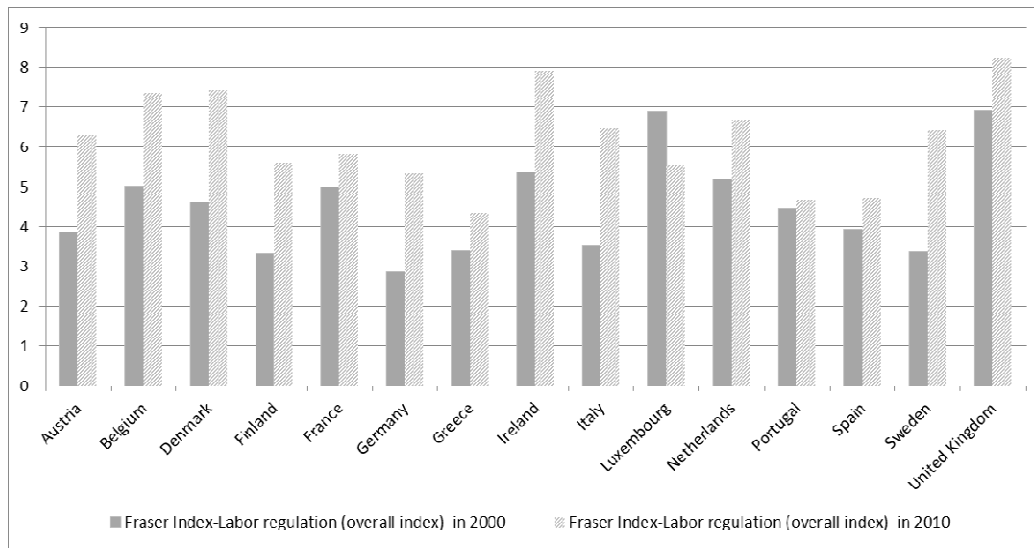
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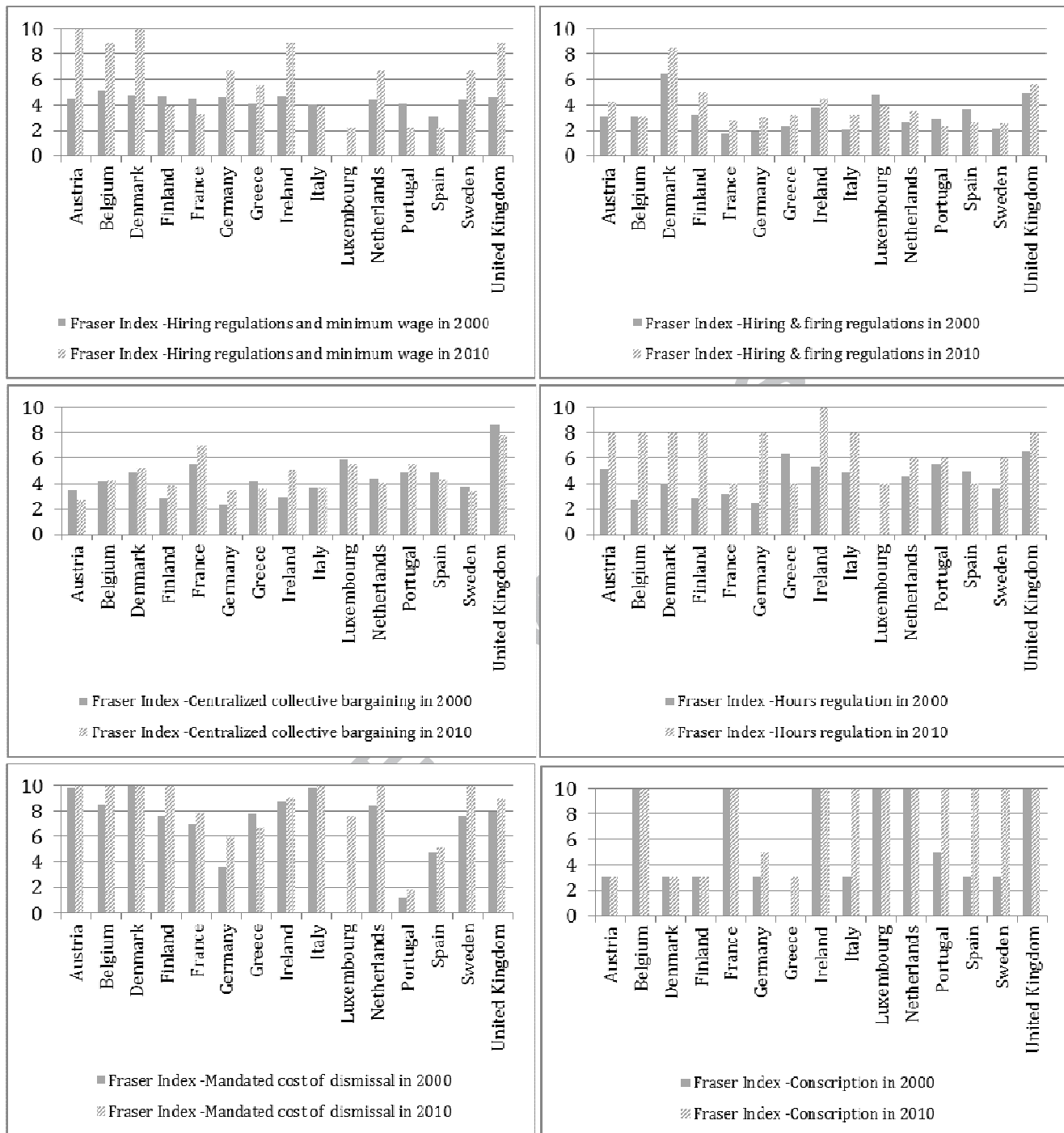
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**Figure 1: Fraser Index – Labour regulation in the EU (2000-2010)**

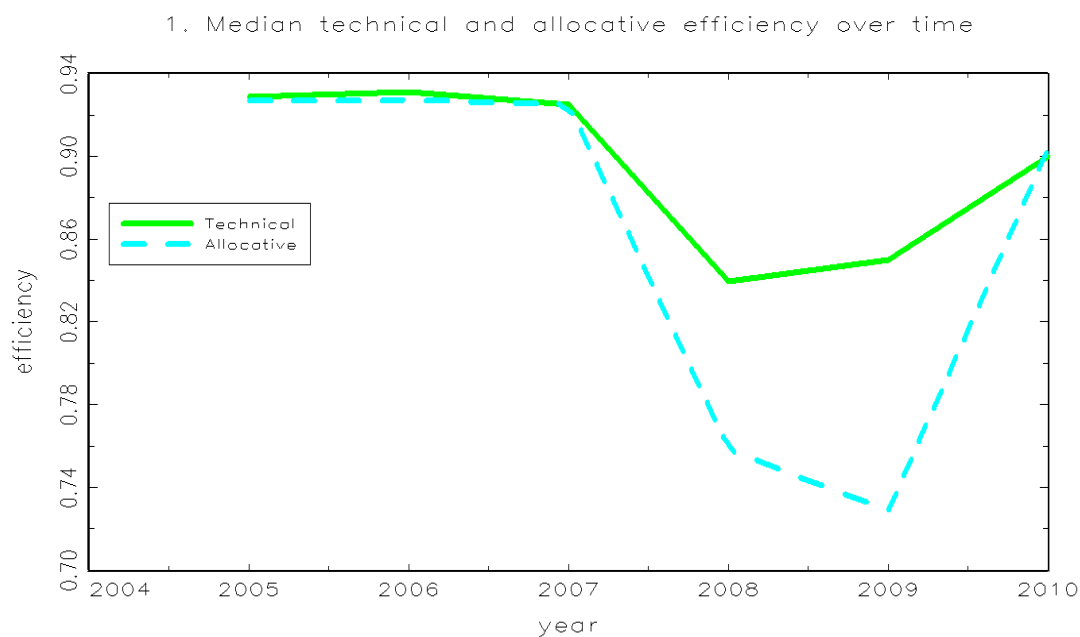
**Source:** Fraser Institute, Economic Freedom Network.

Figure 2: Fraser Index – sub-components of the labour regulation index in the EU (2000-2010)



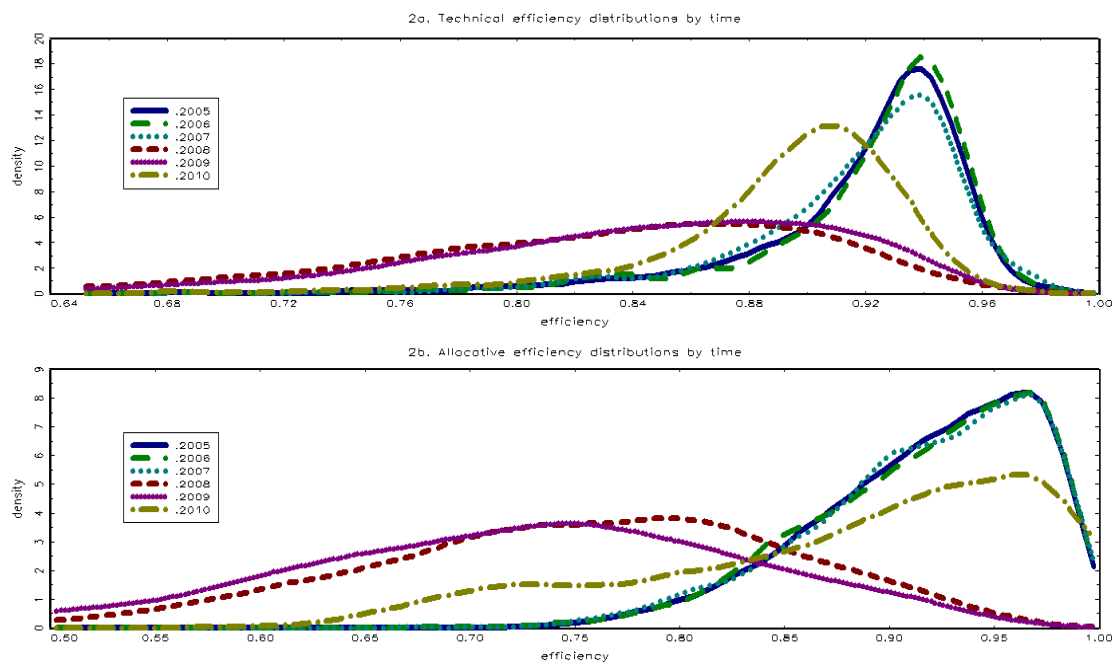
Source: Fraser Institute, Economic Freedom Network. Note: Data for Fraser Index – Mandated cost of dismissal are for 2002 for all countries. Data for Luxembourg are for 2003 (due to data availability issues).

**Figure 3: Technical and allocative efficiency in the EU (2005-2010)**



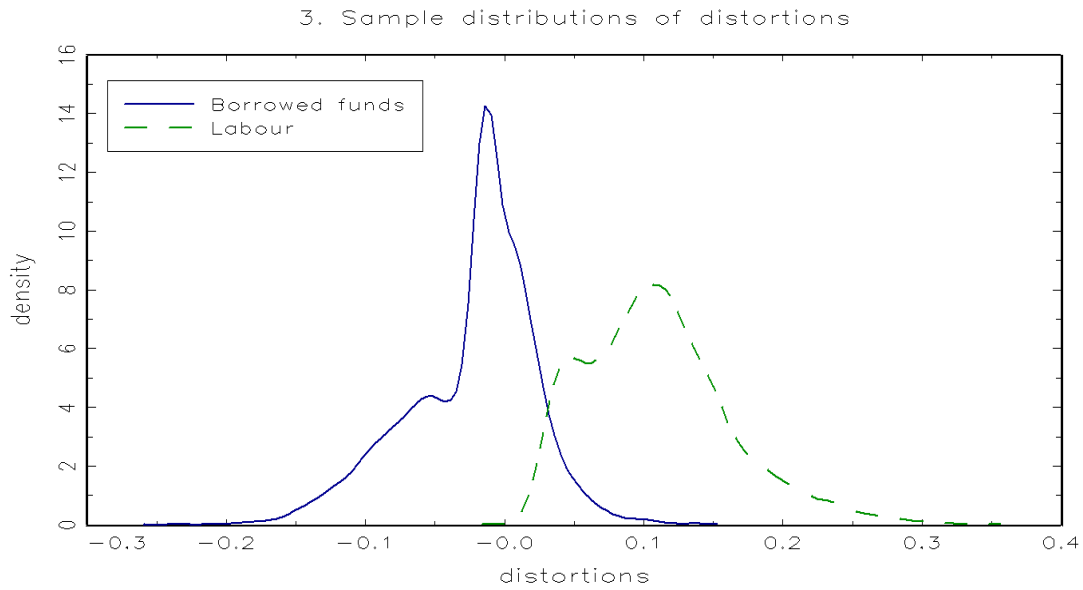
Note: Authors' estimations, median efficiency scores are reported.

**Figure 4: Technical and allocative efficiency in the EU by time.**



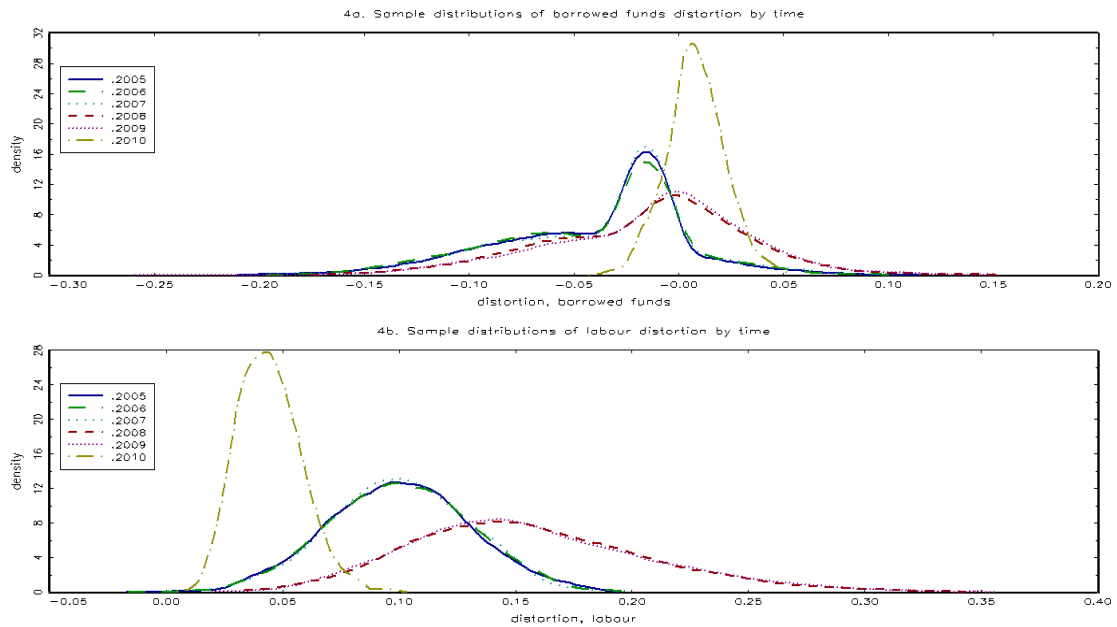
Note: Authors' estimations.

**Figure 5: Sample distributions of distortions of inputs**



**Note:** Authors' estimations.

**Figure 6: Sample distributions of input price distortions over time**



**Note:** Authors' estimations.

**Table 1: Descriptive statistics for the period 2005-2010**

	Labour regulation						Bank-specific Control Variables				Macro		
	LR-FR	MW-FR	HF-FR	CCB-FR	HR-FR	DISS-FR	LLP/L	EQ/A	NIM	TA	GDPgr	INFL	Obs
Austria	6.08	9.82	4.17	2.57	7.13	9.87	0.83	7.87	2.29	3.85	1.58	1.90	846
Belgium	6.97	8.90	2.97	4.22	6.67	9.00	0.40	7.45	2.06	24.61	1.33	2.17	96
Denmark	7.47	10.00	8.00	5.73	8.00	10.00	1.18	12.92	3.60	11.32	0.42	2.07	312
Finland	5.18	5.03	4.35	3.70	6.67	8.40	0.17	7.71	1.17	71.24	1.28	1.72	24
France	5.62	3.30	2.70	6.48	4.00	7.30	0.43	9.10	2.21	57.94	0.85	1.55	666
Germany	4.38	6.70	2.53	3.23	5.80	4.40	0.88	6.50	2.59	2.28	1.32	1.58	8124
Greece	4.40	5.78	3.17	3.60	3.53	7.63	1.03	7.98	2.92	26.16	0.52	3.28	78
Ireland	7.63	8.90	4.30	4.12	10.00	8.48	3.46	5.01	1.67	94.03	0.90	1.65	30
Italy	6.45	6.05	2.63	3.67	6.67	9.60	0.57	11.53	3.01	5.63	-0.02	1.93	2880
Lux.	5.55	2.93	3.80	5.95	4.00	6.60	0.69	6.72	1.11	10.62	2.48	2.27	144
Netherlands	6.68	7.77	3.27	4.17	6.00	8.93	0.44	7.72	1.78	161.21	1.50	1.58	60
Portugal	5.17	5.77	2.50	5.62	5.53	1.43	0.52	6.18	1.70	28.97	0.52	1.83	66
Spain	5.13	2.20	2.82	5.27	5.67	4.93	0.55	9.06	2.35	30.46	1.35	2.55	486
Sweden	5.38	7.23	2.95	3.48	6.00	8.40	0.32	14.04	2.84	10.29	1.97	1.37	360
UK	8.20	8.90	5.38	7.92	8.67	8.33	1.26	9.60	2.07	122.81	0.97	2.62	288
<b>EU-15</b>	<b>5.19</b>	<b>6.55</b>	<b>2.88</b>	<b>3.71</b>	<b>6.06</b>	<b>6.30</b>	<b>0.78</b>	<b>8.20</b>	<b>2.62</b>	<b>10.79</b>	<b>1.04</b>	<b>1.75</b>	<b>14460</b>

**Note:** Figures are in means over the period 2005-2010. LR = aggregate labour market regulations index; MW: hiring and minimum wage regulation, HF: hiring and firing regulation, CCB: centralized collective bargaining, DISS: dismissal cost, HR: hours regulations. Higher values for labour regulation imply a more liberal regulatory environment. LLP/L=loan loss provisions to loans ratio (in %). EQ/A= equity to total assets (in %); NIM= net interest margin (in %); TA= total assets in billion euros. GDPgr=GDP growth; INFL= inflation rate. Obs= number of observations. **Sources:** Fitch-IBCA database for all bank-specific variables and own estimations and the 2011 version of the Fraser Index of Economic Freedom for labour regulation variables, World Development Indicators Database by the World Bank for all macroeconomic variables.

**Table 2: Technical and allocative efficiency scores**

	TEFF	AEFF
Austria	0.8817	0.8933
Belgium	0.7662	0.8971
Denmark	0.8710	0.8927
Finland	0.9192	0.9140
France	0.8629	0.8900
Germany	0.8843	0.8926
Greece	0.8041	0.8775
Ireland	0.8020	0.8626
Italy	0.8888	0.8763
Lux.	0.8006	0.8928
Netherlands	0.8335	0.8978
Portugal	0.8460	0.8810
Spain	0.8374	0.8725
Sweden	0.8155	0.8978
UK	0.8204	0.8869
<b>EU-15</b>	<b>0.8422</b>	<b>0.8883</b>

Note: Authors' estimations. Figures are in means over the period 2005-2010. TEFF: Technical Efficiency; AEFF: Allocative Efficiency.

**Table 3: Disentangling allocative inefficiency due to inefficient use of labour and borrowed funds by country,  $\Delta$  (%)**

	Labour	Borrowed funds
Austria	19.25	14.50
Belgium	27.22	15.35
Denmark	12.45	16.16
Finland	15.35	18.16
France	25.67	17.89
Germany	11.81	15.16
Greece	57.12	42.16
Ireland	45.45	23.18
Italy	30.12	21.12
Lux.	17.15	15.45
Netherlands	16.22	18.12
Portugal	38.35	22.34
Spain	39.22	25.31
Sweden	19.12	12.12
UK	16.56	11.17
<b>EU-15</b>	<b>38.12</b>	<b>17.25</b>

Note: Authors' estimations. For EU-15 the  $\Delta$  measure was calculated assuming a simultaneous reduction in the distortion factors for all countries. Therefore, this is not an average.

**Table 4: Technical and allocative efficiency and aggregate labour market regulation**

	TECHNICAL EFF	ALLOCATIVE EFF
<i>constant</i>	0.517*** (0.0156)	0.617*** (0.0441)
<i>LR</i>	-0.073* (0.04)	0.256*** (0.0217)
<i>GDPgr</i>	0.00416 (0.0177)	0.0202*** (0.000151)
<i>INFL</i>	-0.0036 (0.0021)	-0.03313*** (0.00187)
<i>lnTA</i>	0.0044* (0.0023)	0.0003*** (0.00011)
<i>NIM</i>	-0.0015*** (0.00018)	0.0033*** (0.0012)
<i>EQ/A</i>	0.0017*** (0.00022)	-0.00015*** (0.00001)
<i>LLP/L</i>	0.0015*** (0.00022)	-0.0026*** (0.00019)

**Note:** \*\*\*, \*\* and \* indicate 1%, 5% and 10% significance levels respectively. S.E. are in parentheses. Standard errors are derived from the sandwich estimator of the covariance matrix of the ML estimator.

**Table 5: Allocative efficiency and labour market regulation (disaggregated)**

	Model (1)	Model (2)	Model (3)
<i>constant</i>	0.874*** (0.00415)	0.877*** (0.0315)	0.881*** (0.0182)
<i>MW-FR</i>	-0.0554*** (0.00718)	-0.0447*** (0.0042)	
<i>DISS-FR</i>	-0.0570*** (0.00414)		-0.0628*** (0.0025)
<i>GDPgr</i>	0.0116*** (0.0005)	0.0116*** (0.00011)	0.0255*** (0.00035)
<i>INFL</i>	-0.032*** (0.0033)	-0.0295*** (0.0023)	-0.0305*** (0.0044)
<i>lnTA</i>	0.000337 (0.0002)	0.000393*** (0.000102)	0.00142*** (0.00036)
<i>NIM</i>	0.00281 (0.0027)	0.00285*** (0.000262)	0.00151*** (0.00042)
<i>EQ/A</i>	-0.0004*** (0.0001)	-0.00025*** (0.00001)	-0.00044*** (0.00003)
<i>LLP/L</i>	-0.0025*** (0.00022)	-0.00261*** (0.00022)	-0.00355*** (0.00027)

**Note:** \*\*\*, \*\* and \* indicate 1%, 5% and 10% significance levels respectively. S.E. are in parentheses. Standard errors are derived from the sandwich estimator of the covariance matrix of the ML estimator.

**Table 6: Technical efficiency and labour market regulation (disaggregated)**

	Model (1)	Model (2)	Model (3)	Model (4)
<i>constant</i>	0.661*** (0.0241)	0.681*** (0.0177)	0.681*** (0.0177)	0.6723*** (0.0163)
<i>HF-FR</i>	0.0215 (0.218)	0.0088 (0.117)		
<i>CCB-FR</i>	0.0145 (0.118)		0.061 (0.125)	
<i>HR-FR</i>	0.0230 (0.0491)			0.0214 (0.337)
<i>GDPgr</i>	0.00335 (0.0227)	0.0032 (0.0454)	0.0029 (0.0388)	0.0032 (0.0215)
<i>INFL</i>	-0.0035 (0.0454)	-0.0041 (0.171)	-0.0038 (0.161)	-0.0035 (0.177)
<i>lnTA</i>	0.00361 (0.0447)	0.00291 (0.220)	0.00117 (0.181)	0.00128 (0.100)
<i>NIM</i>	-0.00143 (0.0187)	-0.0016 (0.0841)	-0.0019 (0.0723)	-0.0021 (0.0815)
<i>EQ/A</i>	0.002157*** (0.00011)	0.00313 (0.0185)	0.0022 (0.0140)	0.0025 (0.0217)
<i>LLP/L</i>	0.00154*** (0.0008891)	0.00150 (0.116)	0.00162 (0.202)	0.00155 (0.335)

**Note:** \*\*\*, \*\* and \* indicate 1%, 5% and 10% significance levels respectively. S.E. are in parentheses. Standard errors are derived from the sandwich estimator of the covariance matrix of the ML estimator.



## Appendix A: Derivation of the likelihood function in the presence of only allocative inefficiency

Since the error vector is  $(\varepsilon_i, \eta_i)'$ , for the ML method one has to derive the joint pdf of  $(\varepsilon_i, \eta_i)'$  starting from the distributions on  $v_i$  and  $\xi_i$ . For ML, we need to derive the joint pdf of  $(\varepsilon_i, \eta_i)'$ , that is  $p(\varepsilon_i, \eta_i) = p_{\varepsilon|\eta}(\varepsilon_i | \eta_i) p_{\eta}(\eta_i)$  where  $\varepsilon_i | \eta_i \sim N(\ln C^{AL}(\xi_i(\eta_i), \beta), \sigma_v^2)$  and  $\xi_i(\eta_i)$  is the solution of  $\xi_i$  in terms of  $\eta_i$  from  $\eta_i = \eta_i(\xi_i, \beta)$ . Furthermore, the pdf of  $p_{\eta}(\eta_i)$  can be expressed as

$$p_{\eta}(\eta_i) = p_{\xi}(\xi_i(\eta_i)) | \det D\xi_i(\eta_i) |, \quad (\text{A.1})$$

where  $D\xi_i(\eta_i)$  is the Jacobian matrix (derivatives of  $\xi_i$  with respect to  $\eta_i$ ). Therefore, the joint pdf of the error vector in (11) is

$$p(\varepsilon_i, \eta_i) = p_{\varepsilon|\eta}(\varepsilon_i | \eta_i) p_{\eta}(\eta_i) = (2\pi)^{-J/2} (\sigma_v^2)^{-1/2} \det(\Omega)^{-1/2} \times \\ \exp \left\{ -\frac{[\xi_i - (\ln C^{AL}(\xi_i(\eta_i), \beta))]^2}{2\sigma_v^2} - \frac{1}{2} e_i(\eta_i, \beta)' \Omega^{-1} e_i(\eta_i, \beta) \right\} | \det D\xi_i(\eta_i) | \quad (\text{A.2})$$

where  $e_i(\eta_i, \beta) = \xi_i(\eta_i, \beta) - \mu$ , and  $\mu$  is the mean vector of allocative distortion parameters.

In practice, to implement the likelihood function based on (A.2) we have to show that (i)  $\xi$  can be solved in terms of  $\eta$ , and (ii) the Jacobian matrix can be derived analytically. We show these next.

For notational simplicity now we drop the observation index  $i$ . The first task is to solve for  $\xi$  in terms of  $\eta$ . Note that:

$$\eta_j = S_j^a - S_j^0 = \frac{S_j^0[1 - G \exp(\xi_j)] + \sum_{k=1}^J \beta_{jk} \xi_k}{G \exp(\xi_j)}$$

$$\Rightarrow (\eta_j + S_j^0) G \exp(\xi_j) = S_j^0 + \sum_{k=1}^J \beta_{jk} \xi_k$$

$$\Rightarrow S_j^a G \exp(\xi_j) = S_j^0 + \sum_{k=1}^J \beta_{jk} \xi_k = S_j^0 + \sum_{k=2}^J \beta_{jk} \xi_k, \quad j=1, \dots, J. \quad (\text{A.3})$$

For the last equality we used the normalization  $\xi_1 = 0$ . The equations in (A.3) can be expressed in ratio form to generate the following system of nonlinear equations,

$$\lambda_j \exp(\xi_j) = \frac{S_j^0 + \sum_{k=2}^J \beta_{jk} \xi_k}{S_j^0 + \sum_{k=2}^J \beta_{jk} \xi_k}, \quad j=2, \dots, J, \quad (\text{A.4})$$

where  $\lambda_j = S_j^a / S_1^a$ . In Appendix B we use fixed point arguments to show that a solution of  $\xi_j$  exists and is unique. Once the  $\xi_j$ s are obtained, the value of  $G$  can be obtained as

$$G = \frac{S_1^0 + \sum_{k=2}^J \beta_{1k} \xi_k}{S_1^a} = \frac{S_1^*}{S_1^a}. \text{ Note that we need } G \text{ to compute } \ln C^{AL}(\xi, \beta).$$

The second task is to derive the Jacobian of the transformation from  $\xi$  to  $\eta$ . To compute it we start again from the definition of  $\eta_j$ , i.e.,

$$\eta_j = \frac{S_j^0(1 - h_j) + \sum_{k=2}^J \beta_{jk} \xi_k}{h_j}, \quad j=2, \dots, J, \text{ where } h_j = G \exp(\xi_j). \text{ Differentiating it with respect}$$

to  $\eta_l$  gives:

$$h_j \delta_{jl} + S_j^a \sum_k \frac{\partial h_j}{\partial \xi_k} \frac{\partial \xi_k}{\partial \eta_l} = \sum_k \beta_{jk} \frac{\partial \xi_k}{\partial \eta_l}, \quad (\text{A.5})$$

where  $\delta_{jl}$  is the Kronecker delta. The system in (A.5) can be written as:

$$\Theta D = M, \quad (A.6)$$

where  $\Theta_{jk} = S_j^a \frac{\partial h_j}{\partial \xi_k} - \beta_{jk}$ ,  $D_{kj} = \frac{\partial \xi_k}{\partial \eta_j}$ ,  $M = -diag(h_2, \dots, h_J)$ . Here,  $D$  (the short form of  $D\xi_j(\eta_j)$ ) is

the Jacobian of the transformation. The solution of  $D$  from (A.6) is  $D = \Theta^{-1}M$ , and

$\det(D) = \det(\Theta)^{-1} \prod_{j=2}^J h_j$ . To evaluate the components of  $\Theta$  we obtain

$$\frac{\partial h_j}{\partial \xi_k} = \left( \frac{\partial G}{\partial \xi_k} + G \delta_{jk} \right) \exp(\xi_j), \quad j, k = 2, \dots, J,$$

$$\frac{\partial G}{\partial \xi_k} = \sum_m \beta_{km} \exp(-\xi_m) - \exp(-\xi_k) S_k^*, \quad k = 2, \dots, J,$$

with the understanding that all the previous expressions are evaluated at the solution of the system which is  $\xi = \xi(\eta)$ . Thus, the solution for the  $i$ th observation can be written as

$\xi_i = \xi_i(\eta_i, \beta)$ , and the likelihood function is

$$L(\beta, \sigma_v, \Omega; y, X) = (2\pi)^{-Jn/2} (\sigma_v^2)^{-n/2} \det(\Omega)^{-n/2} \times \exp \left\{ -\frac{1}{2\sigma_v^2} \sum_{i=1}^n [\varepsilon_i - \ln C^{AL}(\beta, \xi_i(\eta_i, \beta))]^2 - \frac{1}{2} \sum_{i=1}^n e_i(\eta_i, \beta)' \Omega^{-1} e_i(\eta_i, \beta) \right\} \prod_{i=1}^n |\det D\xi_i(\eta_i, \beta)| \quad (A.7)$$

where  $e_i(\eta_i, \beta) = \xi_i(\eta_i, \beta) - \mu$ .

The ML estimators of  $\sigma_v^2$ ,  $\mu$  and  $\Omega$  are:

$$\hat{\sigma}_v^2(\beta) = n^{-1} \sum_{i=1}^n [\varepsilon_i - (\ln C^{AL}(\xi_i(\eta_i, \beta)))]^2, \quad \hat{\mu}(\beta) = n^{-1} \sum_{i=1}^n \tilde{\xi}_i(\beta) \equiv \bar{\xi}(\beta),$$

$$\hat{\Omega}(\beta) = n^{-1} \sum_{i=1}^n [\tilde{\xi}_i(\beta) - \bar{\xi}(\beta)][\tilde{\xi}_i(\beta) - \bar{\xi}(\beta)]',$$

where  $\tilde{\xi}_i(\beta) \equiv \xi_i(\tilde{\eta}_i, \beta)$ , and  $\tilde{\eta}_i$  is the cost share residual vector. In fact, in this study we want to make allocative inefficiency function of a vector of exogenous variables, say  $z_i$ , so we have:

$$\mu_i = \Gamma z_i,$$

and we do not use the estimator  $\tilde{\mu}(\beta)$ ; therefore, we have  $\bar{\xi}(\beta) \equiv \bar{\xi}_i(\beta) = \mu_i$ .

The concentrated log-likelihood function is:

$$\ln L^C(\beta; y, X) = \text{const.} - (n/2) \ln \tilde{\sigma}_v^2(\beta) - (n/2) \ln(\det(\tilde{\Omega}(\beta))) + \sum_{i=1}^n \ln |\det D\xi_i(\tilde{\eta}_i, \beta)|. \quad (\text{A.8})$$

## Appendix B: Existence and uniqueness of solution to the system of equations

**Theorem:** If (B1) the actual share  $S_i^a > 0$  for all  $i \in \mathbb{Z} = \{1, \dots, J\}$ , (B2) for every  $i \in \mathbb{Z}$ , we have ( $\beta_{ij} \neq 0$  for some  $j \in \mathbb{Z}$ ), where  $\beta_{ij}$  represents the second-order translog coefficients with respect to prices, (B3)  $\sum_{j \in \mathbb{Z}} \beta_{jk} = 0$ , and (B4)  $\sum_{j \in \mathbb{Z}} S_j^0 = 1$ , then (i) there exists a solution of  $\xi$  in the system of equations in (14), and (ii) the solution is unique.

**Proof:** Before proving the existence and uniqueness, we note that the condition in (B1) follows from the definition of cost shares, while that in (B2) is necessary for flexibility of the translog cost function. Finally, the conditions (B3) and (B4) follow from homogeneity (of degree one in input prices) of the cost function.

(i) *Existence.*

The system in (14) is of the form  $S_j^a \exp(\xi_j) G = S_j^0 + \sum_{k \in \mathbb{Z}} \beta_{jk} \xi_k$ ,  $j \in \mathbb{Z}$ . Note that here we are considering the system in which the homogeneity restrictions are not directly imposed by expressing all prices and cost relative to one input price. Let  $\kappa_j = S_j^a \exp(\xi_j) G$ ,  $j \in \mathbb{Z}$ , so that  $\ln \kappa_j = \ln S_j^a + \xi_j + \ln G$ ,  $j \in \mathbb{Z}$ . Then the system in (14) can be written in the form

$$\kappa_j = S_j^0 - \sum_{k \in \mathbb{Z}} \beta_{jk} \ln S_k^a + \sum_{k \in \mathbb{Z}} \beta_{jk} \ln \kappa_k - \ln G \sum_{k \in \mathbb{Z}} \beta_{jk} = S_j^0 - \sum_{k \in \mathbb{Z}} \beta_{jk} \ln S_k^a + \sum_{k \in \mathbb{Z}} \beta_{jk} \ln \kappa_k, \quad j \in \mathbb{Z}. \quad (\text{B.1})$$

such that  $\sum_{j \in \mathbb{Z}} \kappa_j = 1$ . Then  $\kappa \in \mathbb{S} \equiv \{\kappa \in \square_+^n \mid \sum_{j \in \mathbb{Z}} \kappa_j = 1\}$ , the unit simplex in  $\square^n$ . Write the residual from the cost share system (3) as:

$$f_j(\kappa) = \kappa_j - S_j^0 + \sum_{k \in \mathbb{Z}} \beta_{jk} \ln S_k^a - \sum_{k \in \mathbb{Z}} \beta_{jk} \ln \kappa_k, \quad j \in \mathbb{Z}. \quad (\text{B.2})$$

Define the mapping:

$$g_j(\kappa) = \frac{\kappa_j + f_j(\kappa)^2}{1 + \sum_{k \in \mathbb{Z}} f_k(\kappa)^2}, \quad j \in \mathbb{Z}.$$

Clearly,  $g: \mathbb{S} \rightarrow \mathbb{S}$ , i.e., it maps  $\mathbb{S}$  into itself and is continuous. By Brouwer's fixed point theorem, there exists a  $\kappa^* \in \mathbb{S}$  such that  $g(\kappa^*) = \kappa^*$ , which implies that:

$$f_j(\kappa^*)^2 = \kappa_j^* \sum_{k \in \mathbb{Z}} f_k(\kappa^*)^2, \quad j \in \mathbb{Z}.$$

Multiplying both sides by  $f_j(\kappa^*)$  and summing over  $j$  we obtain:

$$\sum_{j \in \mathbb{Z}} f_j(\kappa^*)^3 = \sum_{j \in \mathbb{Z}} \kappa_j^* f_j(\kappa^*) \sum_{k \in \mathbb{Z}} f_k(\kappa^*)^2.$$

Suppose  $f_j(\kappa^*) = 0$  for all  $j \neq l$  but  $f_l(\kappa^*) \neq 0$ . Then the above equation implies  $f_l(\kappa^*)^3 = \kappa_l^* f_l(\kappa^*)^3$ , which gives  $\kappa_l^* = 0$ . Write  $\kappa_l^* = S_l^a \exp(\xi_l^*)$ . By assumption (B1) since  $\kappa_l^* = 0$  we have  $\xi_l^* = -\infty$ . For  $\kappa_l^* = 0$  by (B.2) we obtain  $f_j(\kappa^*) = \pm\infty$  for some  $j \in \mathbb{Z}$  provided assumption (B2) holds. Now,  $g_l(\kappa^*) = \kappa_l^* = \frac{\kappa_l^* + f_l(\kappa^*)^2}{1 + f_l(\kappa^*)^2}$ . Although  $\kappa_l^* = 0$ , the limit of the right hand side expression as  $\kappa_l^* \rightarrow 0$  (and therefore as  $f_l(\kappa^*)^2 \rightarrow +\infty$ ) is equal to one, a contradiction since  $g_l(\kappa)$  is continuous. Therefore, we conclude that at the fixed point  $\kappa^*$  we must have  $f_j(\kappa^*) = 0$  for all  $j \in \mathbb{Z}$  which means that  $\kappa^*$  represents a solution.

(ii) *Uniqueness.*

Suppose  $\{\xi_j\}$  and  $\{\varphi_j\}$  are distinct solutions. Therefore they must satisfy:

$$\begin{aligned} S_j^a \exp(\xi_j) G &= S_j^0 + \sum_{k \in \mathbb{Z}} \beta_{jk} \xi_k \\ S_j^a \exp(\varphi_j) G &= S_j^0 + \sum_{k \in \mathbb{Z}} \beta_{jk} \varphi_k, \end{aligned} \tag{B.3}$$

for all  $j \in \mathbb{Z}$ , and they also satisfy the following equality:

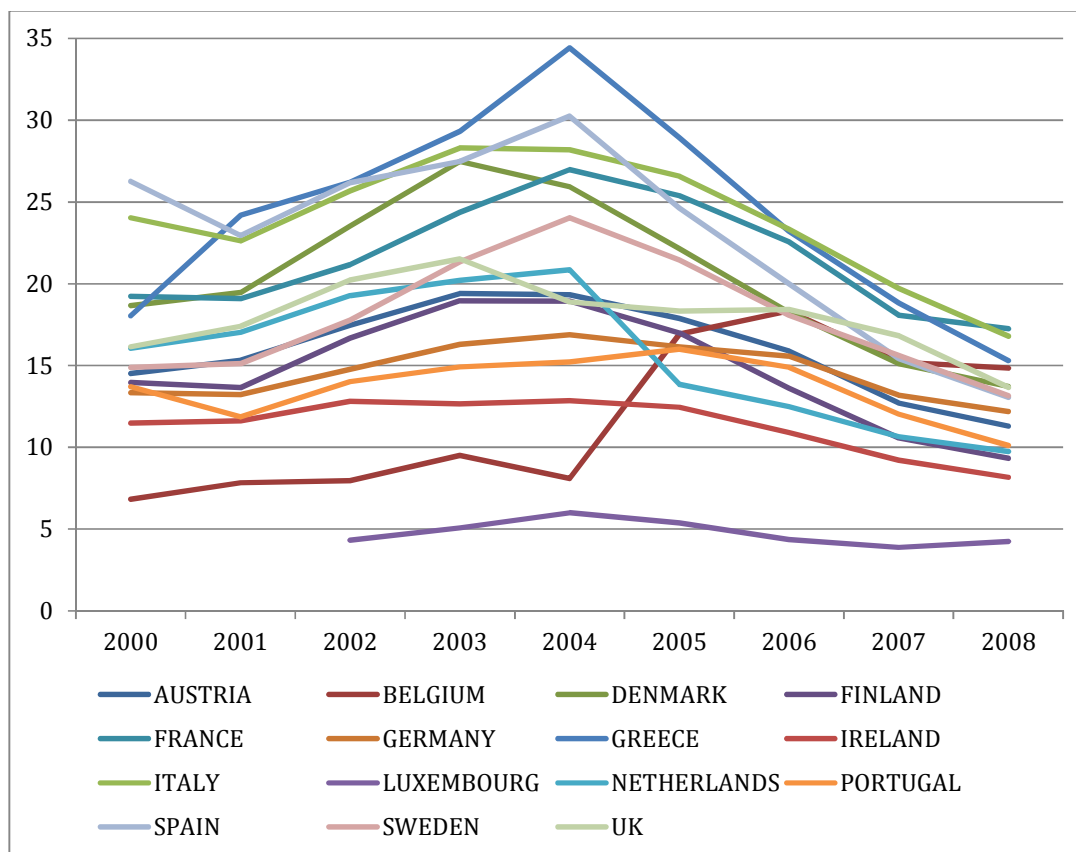
$$\sum_{j \in \mathbb{Z}} S_j^a \exp(\xi_j) = \sum_{j \in \mathbb{Z}} S_j^a \exp(\varphi_j) = 1. \quad (\text{B.4})$$

Define  $\varepsilon_k = \xi_k - \varphi_k$  so that we have  $S_j^a \exp(\varphi_j) [\exp(\varepsilon_j - 1)] = \sum_{k \in \mathbb{Z}} \beta_{jk} \varepsilon_k$ . Let  $\Lambda_j = S_j^a \exp(\varphi_j)$  and notice that  $\exp(\varepsilon_j - 1) \geq \varepsilon_j$  to obtain  $\sum_{k \in \mathbb{Z}} \beta_{jk} \varepsilon_k \geq \Lambda_j \varepsilon_j$ . This system can be written in the form  $[B - \text{diag}(\Lambda)]\varepsilon \geq 0$ . Now choose a vector  $c$  such that  $c' \varepsilon < 0$ , which is always possible provided not all the  $\varepsilon_j$ s are zero (a fact that we have to accept since we have assumed the existence of two different solutions). By applying the Farkas' lemma we obtain that since the above system has a solution, the system  $[B - \text{diag}(\Lambda)]\varepsilon = c$ ,  $\varepsilon \geq 0$  must have no solution. Therefore, there exists no nonnegative vector  $\varepsilon$  to satisfy  $\sum_{k \in \mathbb{Z}} \beta_{jk} \varepsilon_k = \Lambda_j \varepsilon_j + c_j$ . We set  $\varepsilon_j = w$  for all  $j$  so we know that there exists no nonnegative  $w$  to satisfy  $c_j = -w \Lambda_j$ . We will obtain an obvious contradiction provided we can show that the inequality  $c' \varepsilon < 0$  is satisfied. But  $c' \varepsilon = \sum_{j \in \mathbb{Z}} c_j \varepsilon_j = - \sum_{j \in \mathbb{Z}} w^2 \Lambda_j < 0$  since the  $\Lambda_j$ s are positive. The contradiction shows that the solution must be unique.

**Farkas' lemma:** The system  $Ax = c$ ,  $x \geq 0$  has no solution if and only if the system  $A'y \geq 0$ ,  $c'y < 0$  has a solution.

Appendix C: Data from OECD Bank Profitability Report

Figure C1: Staff costs (in % of total cost) by country over time



Source: OECD Bank Profitability Report (2010).