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Bank productivity growth and convergence in the European Union during the financial crisis

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ABSTRACT

This paper examines the bank productivity growth and integration process for the 28 EU countries during three main phases of the financial crisis: the U.S. subprime crisis (2007–2008), the global financial crisis (2009–2010) and the sovereign debt crisis (2010–2012). We extend the Malmquist Productivity Index by applying an additive two-stage DEA model. This allows us to explore the sources of growth in different stages of production. Furthermore, we assess the integration of European banks by analyzing the β-convergence and σ-convergence of the two-stage Productivity Index. Our results show a productivity growth during the U.S. subprime crisis, but a consistent decline during the global financial crisis. The loss of competitiveness of the European banking system is due to the drop in growth of the performance stage and technical change. Finally, we find a strong convergence pattern during the financial crisis, mainly driven by the catch up process of some Eastern countries and the drop in performance of Western countries.

1. Introduction

The recent Global Financial Crisis (GFC) and Eurozone sovereign debt crisis have severely undermined bank stability and destabilized the process of bank integration in Europe. From the onset of the financial crisis, national public authorities have adopted wide-ranging interventions, such as recapitalization, providing debt guarantees, and conducting asset purchases, to reduce the fragility of the banking system and restore confidence in the financial markets. Even though these interventions could have been beneficial for the stability of the banking system, they have also raised concerns as regards their impact on bank competition and consequently banking integration (e.g. Berger & Bouwman, 2013; Calderon & Schaeck, 2015). The global financial crisis (GFC) appears in fact to have contributed to a leveraging of the existing differences and fragmentation between countries in Europe, and slowed down the banking integration process (Matousek et al., 2015). More generally, the GFC has shown the fragility of the monetary union and the lack of a sufficient degree of financial and fiscal integration to react promptly to negative macroeconomic shocks (Lane, 2012). During the years 2007–2012, the European banking system went through three main financial crisis' phases that have exerted a heterogeneous and asymmetric impact across countries and especially the Euro area (Hristov et al., 2012). For example, countries with a great reliance on external funds, and especially on short-term debt markets, such as Ireland, were strongly affected by the global financial crisis (Milesi-Ferretti and Tille, 2011).

According to Aı¨t-Sahalia et al., (2012) and recently by Fiordelisi and Ricci (2015), the financial crisis period can be divided in the following three phases: the subprime financial crisis (2007–2008), the global financial crisis (2008–2010) and the sovereign debt crisis (2010–2012). At the beginning of the subprime financial crisis in 2007, the central banks' interventions seemed to work effectively (Fiordelisi and Ricci, 2015). Despite the large losses in the subprime mortgage market, the overall impression was that the worst was going to end soon (see Mishkin, 2011). However, in late 2008, as a consequence of the collapse of large US finan-

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cial institutions such as Lehman Brothers and AIG and the run on the Reserve Primary Fund, the financial crisis worsened (Mishkin, 2011). In this phase, the financial crisis started to affect Europe as much as the United States and it became "global". Through 2008 and 2009, the focus was on the interventions put forward by the European Central Bank in response to the global financial shock rather than on the country-specific financial risks (Lane, 2012). At that time there were no indications of a profound European sovereign debt crisis that since the second half of 2009 plunged economies in some EU countries into a deep recession, e.g. Greece, Ireland, Italy, Portugal, and Spain (GIIPS). These countries experienced a raise in deficit/GDP ratio and increasing estimates of prospective banking sector losses on bad loans (Mody and Sandri, 2012). The most shocking news was however originated in Greece with the revelation of the extreme violation of the euro's fiscal rules (Broner et al., 2014; Lane, 2012). All these events contribute to a sharp deterioration of the situation and a raising of the spreads on sovereign bonds between Germany and GIIPS countries. Nonetheless, not only the GIIPS countries suffered as a result of the sovereign debt crisis, but the entire Eurozone was affected by this phase of the crisis. The government bond markets in the Eurozone became more fragile and more susceptible to self-fulfilling liquidity crises, as they were associated with negative sentiments that were strong at the end of 2010 (De Grauwe and Ji, 2013). Even the European countries with the best competitive and growth prospects experienced an increase in spreads in a significant manner when their financial sectors were under stress (Mody and Sandri, 2012). However, such an effect was higher for countries facing a large debt burden.

All these adverse developments and events have impacted on the banks' productivity and harmed the process of integration as some countries were more vulnerable than others. The financial crisis exerted a pervasive pressure on banking system and undermined the banking activities from both the funding side and the lending side. From the funding side, banks were under pressure because of the freezing of the European Interbank market, and the threat of the drop of the deposit supply side because of "bank runs" (Iyer et al., 2014). From the lending supply, banks appear to have consistently reduced their lending activities and new loans (e.g. De Haas and Van Horen, 2013; Ivashina and Scharfstein, 2013). In addition, over the period 2008–2012, the EU-27 banking and financial received state aids in terms of total recapitalization and asset relief for EUR 1337.26 bn, and EUR 3931.71bn in terms of total guarantees and liquidity measures.[1]

In this context, some important empirical questions arise: How did the productivity of European banks change during the three phases of the crisis: The U.S. subprime crisis (2007–2008), the global financial crisis (2009–2010) and the sovereign debt crisis (2010–2012)? What were the sources of productivity change in Europe during the crisis? How and to what extent did the financial crisis affect the convergence process of the European banking system? How did the GIIPS countries and the countries in the Euro zone behave compared to the banks in other EU countries?

This paper address these issues and provides empirical evidence on these unexplored avenues of research. It specifically contributes to the existing literature on productivity and convergence in three ways. Firstly, we examine the patters of productivity growth. While previous papers mainly focus on the link between efficiency and integration (Weill, 2009; Casu and Girardone, 2010; Matousek et al., 2015), they divert their attention away from the sources of productivity growth. The productivity index encompasses different sources of growth that can play a pivotal role for the economic recovery of Europe after the financial crisis. Not only bank efficiency, but innovation is a relevant driver for economic growth as well (Aghion and Howitt, 1998; Grossman and Helpman, 1991). Therefore, our aim is to assess the sources of productivity growth and the underlying processes of European banking integration during the financial crisis.

Secondly, a further contribution of our study lies in providing new evidence on the drivers underlying the bank productivity and converge patterns between "Old Europe" and "New Europe" during the crisis period. The recent financial crisis could have slowed down the integration process of the "New Europe" with the "Old Europe" . Transaction economies have recently suffered from a sharp drop in the rate of investments. Moreover, there was a consistent deleveraging process in the banking system, which has contributed to a widening of the credit crunch of industrial firms (EBRD, 2015). In addition, the turmoil in the Euro zone exerted a negative effect on the growth of transition regions, especially for those countries whose banking sector is deeply integrated with Eurozone-based banks.[2]

Thirdly, this paper introduces an innovative methodological approach to examine the productivity and convergence of the EU banking system. To our best knowledge, this is the first paper that examines the productivity and convergence of the EU banking system by applying a two-stage data envelopment analysis (DEA) model. We apply a relational two-stage DEA model in order to assess the components of the productivity index. This model allows us to overcome the classical deposit dilemma that affects the identification strategy of empirical studies on bank efficiency. It in fact treats deposits as an intermediate variable (Fukuyama and Matousek, 2011; Fukuyama and Weber, 2010; Holod and Lewis, 2011). In other words, we use deposits as output in a first stage where employees and capital are inputs, and as input to produce financial assets (loans and other earning assets) in a second stage. In particular, we employ the Malmquist productivity index to evaluate the productivity of 539 commercial banks in the EU-28 countries during three periods of the financial crisis. We first disaggregate the productivity into efficiency change, technical change, and scale change using Ray and Desli's (1997) decomposition. Furthermore, drawing on Kumar and Russell (2002) we investigate the convergence of the overall bank productivity and the productivity of the above two stages. By disentangling the production process of a bank, we can better identify different sources of transmission of inefficiency or decline of innovation in the European banking system. This new approach enable us to examine both the sources of productivity for both banks' lending and funding activities. This is important to fully address our research questions.

The structure of the paper is as follows. Section 2 reviews the recent literature about productivity and convergence in the first part and two-stage DEA models and deposits dilemma in the second part. Section 3 describes the methodology; Section 4 presents and discusses the empirical results Last, Section 5 concludes.

2. Literature review

This section reviews the recent literature on the convergence of European banks and serves as a theoretical background for the examination of total factor productivity in banking industry and the two-stage DEA models and their application to banks.

2.1. Convergence in the European banking sector

Starting from the empirical work of Barro and Sala-i-Martin (1995) and Sala-i-Martin (1996), there has been an increasing

[1] Source: European Commission. Retrieved from http://ec.europa.eu/competition/state_aid/scoreboard/financial_economic_crisis_aid_en.html, May 2016.

[2] Retrieved from http://www.ebrd.com/downloads/research/REP/regional-economic-prospects1210.pdf, February 2016.

number of studies that have examined the link between cost efficiency and convergence in the European banking sector (Brissimis et al., 2010; Casu and Girardone, 2010; Goddard et al., 2010; Matousek et al., 2015; Weill, 2009). The process of financial integration across EU countries has attracted considerable attention from researchers and policy makers in the last two decades. Since the introduction of the First Banking Co-ordination Directive in 1977, and as a result of the deregulation process, the European Union has advanced several key policy initiatives in order to foster a Single European Market in banking and financial services. The scope of a well-integrated financial system was to increase the efficiency of European banks by improving the allocation of financial resources and promoting a more competitive and efficient financial system (Casu and Girardone, 2010). These regulatory changes have subsequently been the object of several studies to assess their effectiveness and impact on the banking system. The results of previous papers provide evidence of an increasing integration process, but also highlight discrepancies among countries mainly due to local customs, norms, and national characteristics (recently Casu and Girardone, 2010; Gropp and Kashyap, 2009; Rughoo and Sarantis, 2012). The general view is that more in-depth financial integration can improve the EU's financial system. However, it can also bring negative externalities with it. Casu and Girardone (2010) argue that the integration in a particular market segment can for example lead to a high degree of consolidation that can in turn harm the competition and catch-up process of some countries.

Even though the European Union has tried to stimulate the integration of financial systems to reduce regional dissimilarities by proposing several legislative and non-legislative measures (European Commission, 2014), formal and informal norms, and infrastructure still present considerable dissimilarities between European countries (Barros et al., 2007). In light of this, Goddard et al., (2010) maintain that barriers to the integration process consist of the consumers' preference towards local or national banks rather than to foreign banks, local banks' access to private information about borrowers' creditworthiness, and different prices charged by banks for each component of the bundle of financial services offered in different markets. The empirical results on European banking integration are rather inconclusive as they display mixed findings. Among them, a few papers make use of the β-convergence and the σ-convergence tests to examine the integration patterns of European banking system. For example, Weill (2009) investigates the banking efficiency convergence in Europe for the period 1994–2005. He finds evidence of convergence in cost efficiency for the European banking industry. In the same vein, Casu and Girardone (2010) find support for efficiency convergence and integration for European banks.

Following the financial crisis of 2007 and the subsequent Euro zone crisis of 2010, the theme of banking integration in Europe has been the object of renewed interest from policy makers and scholars. For example, Matousek et al., (2015) investigate the efficiency convergence during the financial crisis for EU-15 countries. While they show the presence of club formation with weak convergence, they however do not find any evidence of convergence following the financial crisis. Recently, Casu et al., (2016) examined the extent to which productivity converges within and across banking industries as a result of technological spillovers over the period 1992 to 2009 for EU-12 countries. They find evidence of technological spillovers that have led to progression toward the best technology, but also the existence of persistent differences in productivity.

Our study aims to provide additional evidence for the above literature by analyzing the link between productivity growth and convergence during different phases of the crisis (the U.S. subprime crisis (2007–2008), the global financial crisis (2009–2010) and the sovereign debt crisis (2010–2012)) for EU-28 countries. This will be of great interest to policy makers who need to assess the stability and competitiveness of the European banking system and identify prompt, corrective interventions. We elaborate on the methodological contribution in the next sections of this paper.

2.2. An overview of the studies on total factor productivity (TFP)

The concept of total factor productivity (TFP) refers to the ratio of all of outputs produced over all of the inputs employed to produce them. In the context of this paper, we employ the Malmquist index that has been proposed by Malmquist (1953) and further developed by Caves et al., (1982) and Färe et al., (1994a) drawing on the distance function approach. This index allows us to decompose and identify the productivity growth 's sources, efficiency change, and technical change. A best-practice bank is defined as the one with a score over 1 in Malmquist productivity index, efficiency change and technical change simultaneously (Barros et al., 2009). Despite the extensive empirical literature, it is still debated whether the primary source for productivity growth is either the efficiency change (Berg et al., 1992; Isik and Hassan, 2003), or the technical change (Alam, 2001; Assaf et al., 2011; Barros et al., 2010; Casu et al., 2004; Chang et al., 2012; Koutsomanoli et al., 2009; Mukherjee et al., 2001). Other methods also consider a factor for scale changes (Altunbas et al., 2001; Grifell-Tatje and Lovell, 1997; Ray and Desli, 1997; Sturm and Williams, 2004) as discussed in the methodological section.

A vast amount of literature has investigated bank productivity and its components. A number of these studies have also addressed this issue for the European banking system. One of the first studies to assess the productivity change in European banking industry was Berg et al., (1992) who focused on the impact of deregulation on Norwegian banks for the period 1980–1989. Similarly, other studies have examined the impact of financial deregulation and regulatory changes on productivity of banks in a single country context (e.g. Battese et al., 2000; Kumbhakar et al., 2001) or in an international institutional setting (e.g. Casu et al., 2004; Brissimis et al., 2010; Casu et al., 2016). Generally, these empirical findings advocate a declining technical efficiency but also suggest a technical progress and productivity growth for European Banks because of the liberalization process. Existing studies have used various econometric models and techniques (parametric and nonparametric) to assess banks efficiency and productivity growth (see among others, Casu et al., 2004; Goddard et al., 2007; Fethi and Pasiouras; 2010; Barros and Williams, 2013; Barros and Wanke, 2014; Wanke et al., 2015; Tzeremes, 2015; Wanke et al., 2016). With regard to the non-parametric approach, previous investigations have mainly made used of the traditional DEA model to examine the productivity of banks. As a novel contribution to this literature, this paper combines the TFP with the two-stage DEA model. The advantages of this latter method are explained in Section 2.3 and in the methodological part.

2.3. Two-stage data envelopment analysis and banking

Unlike the traditional DEA as formulated by Charnes et al., (1978), the two-stage DEA model separates the internal processes through which inputs are transformed in outputs. In particular, the two stage- DEA model requires the definition of intermediate variables to link different stages of production. These intermediates are treated as outputs in the first stage and inputs in the second stage. The general concept of two-stage DEA models is based on the pioneering work of Färe and Grosskopf (1996), who were the first to study the “black box” . Wang et al., (1997) and Seiford and Zhu (1999) were the first to construct a pure two-stage DEA model where all the outputs of the first stage are the only inputs of the second stage. Halkos et al., (2014) classified two-stage network DEA models into four categories relative to the relationship among the overall efficiency and the efficiency of each stage: independent (Wang et al., 1997; Seiford and Zhu, 1999), connected (Chen and Zhu, 2004), relational (Kao and Hwang, 2008; Chen et al., 2009) and game theoretic (Liang et al., 2006;2008). In this study, we use the additive relational model of Chen et al., (2009).

Over the last decade, this method has become very popular in the banking literature (e.g. Akther et al., 2013; Fukuyama and Weber, 2010; Fukuyama and Matousek, 2011; Holod and Lewis, 2011; Mukherjee et al., 2003; Wang et al., 2014; Wanke and Barros, 2014; Degl'Innocenti et al., 2016; Wu et al., 2016) because of the solution it offers to the so-called *deposits dilemma*. While the traditional approaches (namely the *asset* or *intermediation approach, value-added* or *production approach* and the *cost approach*) discussed by Berger and Humphrey (1992) treat deposits either as input or as an output, a two-stage DEA model handles deposits as an intermediate variable. In other words, at the first stage, deposits enter the production function as outputs, while in the second stage they are modelled as inputs to be invested in earning assets. Therefore, the dual role of deposits is kept intact.

Kao and Hwang (2014) extended the multiplicative two-stage DEA model to a multi-period Malmquist Productivity Index. In this study, we construct a Malmquist Productivity Index using the additive relational model of Chen et al., (2009). By combining the Malmquist Productivity Index with a two-stage DEA model, we are able to better explore the sources of growth in different stages of production. The two-stage DEA allows us to take into account the dual role of deposits and to identify where inefficiencies and impediments to innovation are located in the first and/or in the second stage of the production process. This also enables us to examine how and to what extent the financial crisis exerted pressure on the banking system and undermined the banking activities from both the funding side and the lending side.

3. Methodology

3.1. The additive two-stage DEA model

In this section, we outline our methodological approach. The proposed model is based on the additive efficiency decomposition approach proposed by Chen et al., (2009).[3] Given n DMUs, x_{ij} $(i = 1, \dots, m)$, z_{dj} $(d = 1, \dots, D)$ and y_{rj} $(r = 1, \dots, s)$ are respectively the ith input, the dth intermediate variable, and the rth output respectively of the jth DMU $(j = 1, \dots, n)$. Moreover, v_i, w_d and y_r are the multipliers of the model. The overall efficiency E_0 is in the following form:

$$E_0 = \xi_1 \frac{\sum_{d=1}^{D} w_d z_{d_0}}{\sum_{i=1}^{m} v_i x_{i_0}} + \xi_2 \frac{\sum_{r=1}^{s} u_r y_{r_0}}{\sum_{d=1}^{D} w_d z_{d_0}} \tag{1}$$

The relative contribution of each stage to the whole process is represented by ξ_1 and ξ_2 where $0 \le \xi_1, \xi_2 \le 1$ and $\xi_1 + \xi_2 = 1$. These are not chosen in an arbitrary way; instead they are proxied by the size of each stage. Chen et al., (2009) define the overall size of the DMU as the sum of the first stage and the second stage inputs.

The VRS version of the additive two-stage DEA model of Chen et al., (2009) is as follows[4]:

$$\begin{aligned}
E_0 &= max \sum_{d=1}^{D} \mu_d z_{d_0} + \sum_{r=1}^{s} \gamma_r y_{r_0} + u^1 + u^2 \\
&\text{s.t. } \sum_{i=1}^{m} \omega_i x_{i_0} + \sum_{d=1}^{D} \mu_d z_{d_0} = 1 \\
&\sum_{d=1}^{D} \mu_d z_{d_j} - \sum_{i=1}^{m} \omega_i x_{i_j} + u^1 \le 0, \\
&\sum_{r=1}^{s} \gamma_r y_{r_j} - \sum_{d=1}^{D} \mu_d z_{d_j} + u^2 \le 0, \\
&\gamma_r, \mu_d, \omega_i \ge 0 \\
&j = 1, \dots, n;\ i = 1, \dots, m;\ d = 1, \dots, D;\ r = 1, \dots, s \\
&u^1 \text{ and } u^2 \text{ are free in sign}
\end{aligned} \tag{2}$$

There may be more than one optimal solution in (2) because the optimal multipliers γ_r^*, ω_i^* and μ_d^* may not be unique either. Chen et al., (2009) give pre-emptive priority to one of the stages while maintaining the overall efficiency as calculated before. Here, we choose to give priority to the second stage as depicted in the next section.

$$\begin{aligned}
E_0^2 &= max \sum_{r=1}^{s} \gamma_r y_{r_0} + u^2 \\
&\text{s.t. } \sum_{d=1}^{D} \mu_d z_{d_0} = 1 \\
&\sum_{d=1}^{D} \mu_d z_{d_0} + \sum_{r=1}^{s} \gamma_r y_{r_0} - E_0 \sum_{i=1}^{m} \omega_i x_{i_0} + u^1 + u^2 = E_0, \\
&\sum_{d=1}^{D} \mu_d z_{d_j} - \sum_{i=1}^{m} \omega_i x_{i_j} + u^1 \le 0, \\
&\sum_{r=1}^{s} \gamma_r y_{r_j} - \sum_{d=1}^{D} \mu_d z_{d_j} + u^2 \le 0 \\
&\gamma_r, \mu_d, \omega_i \ge 0 \\
&j = 1, \dots, n;\ i = 1, \dots, m;\ d = 1, \dots, D;\ r = 1, \dots, s \\
&u^1 \text{ and } u^2 \text{ are free in sign}
\end{aligned} \tag{3}$$

Finally, the first stage efficiency based on (2) and (3) is calculated as[5]:

$$E_0^1 = \frac{E_0 - \xi_2^* E_0^2}{\xi_1^*} \tag{4}$$

3.2. Malmquist productivity index

Benchmark technology is to be distinguished from a best practice technology in terms of returns to scale (Lovell, 2003). While the former satisfies constant returns to scale, the later satisfies variable returns to scale. The departure of the best practice technology from benchmark technology can be accounted as scale effects. According to Färe et al., (1994a), the Malmquist Productivity Index (MPI) is defined on a benchmark technology. Suppose that we want to find the change in productivity between two periods, t and t + 1. Using a specific period as benchmark technology, MPI is calculated as the ratio of the distance functions of period t + 1 to period t. Since it is arbitrary to address either of these periods as the benchmark technology, it is a common practice to define MPI

[3] See Halkos et al. (2014) for a literature review.

[4] The constant returns to scale version of the model is obtained by omitting u^1 and u^2.

[5] There exists an extreme case for the additive two-stage DEA model where either ξ_1^* or ξ_2^* is zero, and therefore the individual stages' efficiencies are undefined. Chen et al. (2009) address this problem by restricting ξ_1^* and ξ_2^* in order to be positive. Halkos et al. (2015) proposed an alternative weight assurance region model to deal with the problem of the additive two-stage DEA model. This model is able to solve the aforementioned problem of ξ_1^* or ξ_2^* and incorporates any available prior information regarding the contribution of each stage to the whole process.

as the geometric mean of these two ratios. Subscript "c" stands for constant returns to scale and "D" for distance function. For example, $D_c^t(x^{t+1}, y^{t+1})$ is the distance function of inputs-outputs (x,y) in period t + 1 using period t as a benchmark technology.

$$MPI_c\left(x^t, y^t, x^{t+1}, y^{t+1}\right) = \left[\frac{D_c^t\left(x^{t+1}, y^{t+1}\right)}{D_c^t(x^t, y^t)} \cdot \frac{D_c^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_c^{t+1}(x^t, y^t)}\right]^{1/2} \tag{5}$$

Färe et al., (1994a) decomposed the MPI index into an efficiency change and a productivity change in terms of benchmark technology. Färe et al., (1994b) redefined the efficiency change term into efficiency change relative to best practice technology and scale change. There is a wide debate across the literature regarding this decomposition. The major objection is that the technical change term continues to be estimated relative to benchmark technology, therefore it captures the change in the maximum average product. Ray and Desli (1997) questioned the internal consistency of this decomposition, and Lovell (2003) criticized it for inadequacy and vague economic interpretation. Ray and Desli (1997) proposed an alternative decomposition that estimates the technical change term relative to a best practice technology and measures the sources of productivity in economically meaningful way. However, the disadvantage of this approach is that it yields a number of infeasible scores due to variable returns to scale in mixed periods (Grosskopf, 2003). The subscript *"v"* stands for variable returns to scale.

$$\begin{aligned} &MPI_c\left(x^t, y^t, x^{t+1}, y^{t+1}\right) \\ &= \frac{D_v^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_v^t(x^t, y^t)} \cdot \left[\frac{D_v^t\left(x^{t+1}, y^{t+1}\right)}{D_v^{t+1}\left(x^{t+1}, y^{t+1}\right)} \cdot \frac{D_v^t\left(x^t, y^t\right)}{D_v^{t+1}(x^t, y^t)}\right]^{1/2} \cdot \\ &\cdot \left\{\left[\frac{D_c^t\left(x^{t+1}, y^{t+1}\right)/D_v^t\left(x^{t+1}, y^{t+1}\right)}{D_c^t(x^t, y^t)/D_v^t(x^t, y^t)}\right.\right. \\ &\left.\left.\cdot \frac{D_c^{t+1}\left(x^{t+1}, y^{t+1}\right)/D_v^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_c^{t+1}(x^t, y^t)/D_v^{t+1}(x^t, y^t)}\right]\right\}^{1/2} \end{aligned} \tag{6}$$

The first term outside the brackets is the efficiency change, the second term outside the brackets is the technical change and the term inside the brackets is the scale change. Apart from the consistency and meaningful economic interpretation, Ray and Desli's (1997) decomposition is better suited for the additive two-stage model of Chen et al., (2009). Ang and Chen (2016) found that the weights of Chen et al., (2009) are non-increasing which means that the weights of the first stage are larger than the weights of the second stage. However, this is only true for the CRS version of the model. The VRS version of the model allows the weights of the second stage to be larger. Evidently, the present paper contains such cases. Therefore, Ray and Desli's (1997) decomposition which is based on variable returns to scale is better suited for our model.

Appendix A modifies the additive model (2-4) in order to calculate all the components for the MPI index (6) for the overall model, the first stage and the second stage.

3.3. Tests of convergence

This section presents the tests that we use to investigate the convergence of productivity. Barro and Sala-i-Martin (1995) constructed two tests for convergence, β-convergence and σ-convergence. The β-convergence regresses[6] the growth rate on the initial level of any variable, for example productivity. If the coefficient is statistically significant and reveals a negative relationship among growth rate and initial level, then there is a convergence while if the relationship is positive there is a divergence. The interpretation of this type of convergence is that countries with lower levels of productivity experience faster growth than countries with higher initial levels of productivity. Eq. (7) shows the regression for β-convergence of the MPI index.

$$\ln MPI_{j,t} - \ln MPI_{j,t-1} = \alpha + \beta \ln MPI_{j,t-1} + \varepsilon_{j,t} \tag{7}$$

where $MPI_{j,\,t}$ is the Malmquist Productivity Index for DMU j in time t, $MPI_{j,t-1}$ is the Malmquist Productivity Index for DMU j in time t-1, α and β are the parameters which will be estimated and $\varepsilon_{j,\,t}$ is the error term.

The σ-convergence for the estimation of cross-sectional dispersion indicates how quickly the productivity change of each DMU is converging to the average productivity change.

$$\Delta\left(\ln MPI_{j,t} - \ln \overline{MPI_t}\right) = \alpha + \beta\left(\ln MPI_{j,t-1} - \ln \overline{MPI_{t-1}}\right) + \varepsilon_{j,t} \tag{8}$$

where the left term is the first difference of $\ln MPI_j$ from its mean. Again, there is convergence if the coefficient is statistically significant and reveals a negative relationship between the dependent and independent variables.

4. Empirical application

4.1. Data and model description

We collected unconsolidated annual income statements and balance sheet data from the Fitch-IBCA BankScope (BSC) database. For our analysis, we only include commercial banks from 28 EU countries. We dropped banks with negative equity values and missing values for total assets. Hence, our sample consists of 539 commercial banks for 28 EU countries. All data is deflated to 2010 prices. Following Fukuyama and Weber (2010), we construct a two-stage banking efficiency model in order to keep the dual role of deposits. The overall index includes a value added activity index in the first stage and a profitability index in the second stage. We follow a similar input-output framework with Fukuyama and Matousek (2011) and Holod and Lewis (2011) (Figure 1). In the first stage we use total assets and the number of employees as inputs, while deposits function as the output. Deposits then enter the second stage as inputs, whereas loans and securities are the final outputs. Bank assets are traditionally composed of loans and securities. All data comes from the Bankscope database. Table 1 presents the descriptive statistics of the inputs and outputs. All the variables are in values of thousand. The high standard deviation for all the variables suggests the presence of big differences across banks and countries. In countries such as Italy, France, Spain and Portugal, banks are more specialized in lending activities and tend to have more loans compared to banks of similar size in other countries (Casu et al., 2016). Therefore, it is more plausible to find a higher standard deviation for output variables such as loans and securities.

We use the additive two-stage DEA model of Chen et al., (2009) for the evaluation of the efficiency scores. We choose to give pre-emptive priority to stage two because the focus during the crisis is on deposits and loans.

Next, we employ the DEA-based Malmquist Productivity Index measures for the calculation of the productivity change over time, as presented in Appendix A. Banks with productivity change over 1 experience productivity growth, while banks with productivity change under 1 experience a decline in productivity. Ray and Desli (1997) decomposition is applied as presented in (7). As depicted earlier, following Fiordelisi et al. (2014) and Fiordelisi and Ricci

[6] A GLS regression (Kumar and Russell, 2002).

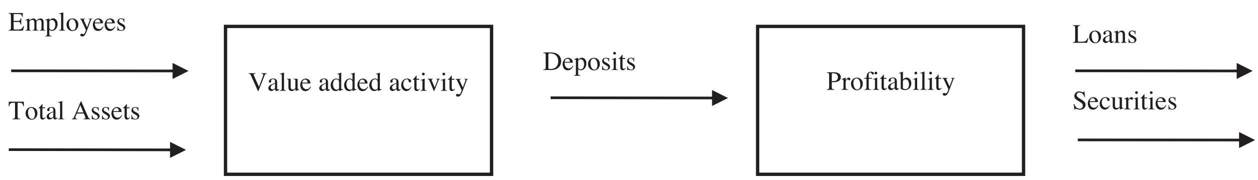

Fig. 1. Two-stage bank process.

Table 1
Descriptive statistics.

		2007	2008	2010	2012
Number of employees	Mean	4996	5307	5335	5258
	Std. dev	17,398	19,140	19,406	19,197
Fixed assets (*)	Mean	72,388,032	76,162,809	71,621,239	71,775,550
	Std. dev	282,385,300	310,595,325	277,369,541	277,379,219
Deposits (*)	Mean	39,665,765	38,185,549	40,753,124	40,949,427
	Std. dev	139,955,377	127,491,258	145,799,024	141,945,967
Loans (*)	Mean	32,116,759	32,479,529	33,474,178	31,769,372
	Std. dev	113,954,364	110,648,904	117,079,977	109,018,777
Securities (*)	Mean	27,839,922	31,505,927	23,941,448	24,237,030
	Std. dev	150,406,207	184,886,958	118,506,217	122,390,558

Note: The Table presents descriptive statistics (mean values and standard deviation) for all banks in our sample.
* Values are in thousands of Euros.

Table 2
Overall Malmquist productivity index.

	2007–2008				2008–2010				2010–2012			
	MPI	eff	tech	scale	MPI	eff	tech	scale	MPI	eff	tech	scale
Overall Process	1.072	1.197	0.923	0.981	0.804	2.231	0.453	0.970	0.986	1.016	0.974	1.001
Value Added	1.105	1.275	0.937	0.955	0.740	3.643	0.289	0.981	1.022	1.030	1.007	0.997
Profitability	0.936	1.080	0.851	1.030	1.795	0.678	3.963	0.963	0.825	1.177	0.738	1.021

Note: The Table reports the main summary results from all the countries in the sample during the U.S. subprime crisis (2007–2008), the global financial crisis (2009–2010) and the sovereign debt crisis (2010–2012). *MPI* is the Malmquist productivity index; *eff* is technical efficiency; *tech* is technical change; *scale* is scale efficiency.

(2015) we consider three periods of the financial crisis to examine the productivity change: the U.S. subprime crisis (2007–2008), the global financial crisis (2008–2010) and the sovereign debt crisis (2010–2012). Finally, we split our sample for GIIPS countries and Euro countries as a robustness test.

4.2. Results

In this section, we first discuss the productivity change scores and their decomposition. Then we examine the convergence trend among European countries. In Table 2, we describe the overall trend of productivity growth for the entire sample. We specifically report the results for the overall process, the value-added stage and the performance stage. In general, we notice that during the first period of the US subprime crisis (2007–2008), the overall two-stage system of European banks experience productivity growth (1.07 on average), which can be mainly attributed to the efficiency growth (1.19) rather than to technical change (0.92) and scale change (0.98). This result can be explained by the fact that the crisis started to exert an impact on Europe in 2009. This could shed light on why we still observe an overall improvement of productivity during the 2007–2008 period until the onset of the global financial crisis.

The second period of the global financial crisis (2008–2010) appears to have been harsher for the European banks in terms of productivity with respect to the previous one. The overall productivity growth is (0.81), which is mainly driven by a major decline in technical change (0.45). European banks also appear to have experienced a decline in the productivity growth. This drop especially refers to the banks' performance in the first stage (0.74) and is mainly due to the decrease of technical change (0.29). In contrast, we find evidence of a productivity growth in the second stage (1.80). Finally, the third period during the sovereign debt crisis (2010–2012) is characterized by a relative stability for the overall model (0.99) and the first stage (1.02) in terms of both productivity and its subcomponents. At the same time, there is a significant decline in the productivity of the second stage (0.83) mainly driven by a drop of technical change (0.73).

Table 3 shows the components of the productivity growth for each country.

We report the results for the overall process, the value-added stage and the performance stage. At first glance, we can tell that each country responds to the crisis in a different way. In the first period during the US subprime crisis, banks in small peripheral economies such as Greece and new EU countries such as Lithuania and Romania experienced a productivity growth while banks in more advanced economies such as the UK and France experienced either a slow or null productivity growth. A potential explanation is that global European banks were involved more in securities backed by subprime mortgage loans and other US "toxic" assets that were conduits for international shock transmission (Cetorelli and Goldberg, 2011). Global European banks are highly leveraged financial institutions in larger economies such as the UK, France, and Germany (Noeth and Sengupta, 2012). Therefore, banks in these countries were the first to be affected by the economic crisis.

The second period during the global economic crisis yields quite different results. The whole European Union is unproductive, however banks in larger economies such as France and Germany experienced moderate effects relative to banks in peripheral countries (Greece, Spain and Portugal) and new EU countries

Table 3
Malmquist Productivity Index per Country.

Bank	Country	2007–2008				2008–2010				2010–2012			
		MPI	eff	tech	scale	MPI	eff	tech	scale	MPI	eff	tech	scale
Overall bank process													
Austria	34	1.041	1.119	0.942	1.003	0.785	1.680	0.527	0.958	0.954	1.009	0.975	0.976
Belgium	16	1.040	1.079	0.960	1.005	0.894	1.542	0.663	0.966	0.979	1.033	0.957	0.991
Bulgaria	3	1.137	1.273	0.882	1.012	0.653	3.322	0.214	0.981	1.033	1.033	0.991	1.008
Croatia	18	1.018	1.180	0.886	0.990	0.701	3.253	0.220	1.004	1.022	1.026	0.996	1.001
Cyprus	3	1.106	1.214	0.912	0.999	0.877	2.098	0.428	0.925	0.941	0.935	0.981	1.026
Czech Rep.	11	1.030	1.127	0.932	0.984	0.783	1.679	0.497	0.964	0.972	1.019	0.965	0.990
Denmark	27	1.011	1.098	0.925	0.998	0.815	1.802	0.505	0.975	1.038	1.074	0.965	1.000
Estonia	3	1.040	1.146	0.909	1.000	0.648	2.441	0.313	0.943	0.958	0.966	0.995	0.998
Finland	5	1.126	1.226	0.930	0.990	0.813	1.739	0.539	0.954	0.952	1.018	0.938	0.998
France	75	1.024	1.113	0.933	0.991	0.861	1.962	0.499	0.981	1.010	1.115	0.981	0.991
Germany	75	1.061	1.122	0.950	1.002	0.856	1.673	0.599	0.968	0.953	0.995	0.959	0.997
Greece	7	1.237	1.335	0.905	1.025	0.607	1.730	0.377	0.949	1.019	1.016	0.991	1.013
Hungary	9	1.105	1.539	0.906	0.826	0.738	2.493	0.330	0.922	0.976	0.987	0.971	1.021
Ireland	7	1.096	1.143	0.951	1.009	0.909	1.248	0.743	0.957	1.020	0.985	0.990	1.049
Italy	47	1.063	1.174	0.919	0.990	0.846	2.003	0.451	0.971	1.011	1.046	0.975	0.993
Latvia	11	1.159	1.294	0.894	1.001	0.918	3.344	0.267	1.026	0.929	0.950	0.981	0.995
Lithuania	6	1.165	1.298	0.892	1.006	0.874	3.691	0.296	0.997	0.996	1.003	0.993	0.999
Luxembourg	35	1.058	1.060	0.987	1.008	0.843	1.267	0.710	0.984	1.043	1.066	0.978	1.001
Malta	4	1.006	1.083	0.935	0.999	0.944	2.237	0.524	0.980	0.917	1.003	0.908	1.011
Netherlands	14	1.022	1.165	0.960	0.957	0.872	1.626	0.658	0.977	1.025	1.045	0.977	1.006
Poland	13	1.134	1.403	0.894	0.903	0.706	3.340	0.290	0.923	0.953	0.977	0.974	1.002
Portugal	11	1.064	1.141	0.930	1.002	0.721	1.502	0.509	0.960	1.005	1.046	0.954	1.007
Romania	6	1.164	1.404	0.894	0.916	0.701	4.183	0.221	0.951	0.988	1.005	0.990	0.994
Slovakia	6	1.054	1.348	0.892	0.889	0.826	3.171	0.265	0.985	0.984	1.006	0.971	1.008
Slovenia	12	1.075	1.178	0.900	1.014	0.896	2.639	0.360	0.976	0.998	1.015	0.982	1.002
Spain	16	1.033	1.120	0.945	0.974	0.786	1.583	0.566	0.988	0.977	1.040	0.975	0.979
Sweden	10	0.970	1.072	0.924	0.979	0.843	1.708	0.513	1.001	0.985	1.011	0.982	0.993
UK	55	0.984	1.057	0.951	0.996	0.799	1.517	0.587	0.982	0.956	1.020	0.966	0.976
Value added activity													
Austria	34	1.092	1.184	0.953	0.994	0.719	2.391	0.348	0.968	0.969	0.997	1.005	0.973
Belgium	16	1.117	1.151	0.981	0.989	0.783	2.110	0.474	0.981	1.027	1.012	1.013	1.001
Bulgaria	3	1.147	1.281	0.899	0.997	0.609	5.849	0.116	1.003	1.065	1.067	1.005	0.995
Croatia	18	1.037	1.188	0.899	0.997	0.647	5.598	0.119	0.988	1.059	1.057	1.005	0.997
Cyprus	3	1.116	1.252	0.919	0.973	0.838	3.172	0.250	0.961	1.000	1.002	1.005	0.994
Czech Rep.	11	1.078	1.201	0.940	0.959	0.708	2.428	0.313	0.976	0.997	0.995	1.005	0.997
Denmark	27	1.040	1.123	0.943	0.987	0.697	2.648	0.314	0.999	1.102	1.098	1.005	0.999
Estonia	3	1.024	1.130	0.915	0.992	0.578	4.138	0.170	0.938	0.928	0.924	1.005	1.000
Finland	5	1.203	1.444	0.950	0.918	0.686	2.269	0.369	0.979	1.063	1.062	1.005	0.996
France	75	1.051	1.166	0.947	0.973	0.799	3.173	0.322	0.990	1.069	1.278	1.025	1.024
Germany	75	1.133	1.194	0.961	0.993	0.753	2.378	0.396	0.981	0.984	0.984	1.005	0.998
Greece	7	1.269	1.426	0.916	0.978	0.494	2.554	0.213	0.952	1.053	1.057	1.005	0.991
Hungary	9	1.042	1.746	0.916	0.713	0.737	4.603	0.182	0.922	1.027	1.027	1.005	0.996
Ireland	7	1.184	1.380	0.974	0.903	0.816	1.484	0.536	0.962	1.134	1.112	1.027	0.998
Italy	47	1.071	1.188	0.934	0.973	0.801	3.186	0.278	0.969	1.064	1.064	1.005	0.996
Latvia	11	1.180	1.293	0.906	1.004	0.991	6.444	0.145	1.028	0.906	0.900	1.005	0.999
Lithuania	6	1.211	1.327	0.905	1.007	0.835	6.744	0.156	1.006	1.002	0.997	1.004	1.001
Luxembourg	35	1.127	1.121	1.006	0.993	0.764	1.587	0.534	0.999	1.123	1.114	1.008	1.000
Malta	4	1.041	1.117	0.958	0.983	0.899	3.665	0.362	0.987	0.996	0.993	1.008	0.995
Netherlands	14	1.049	1.230	0.984	0.924	0.809	2.658	0.449	0.992	1.094	1.092	1.005	0.998
Poland	13	1.165	1.414	0.908	0.965	0.653	6.190	0.163	0.911	0.958	0.957	1.005	0.997
Portugal	11	1.120	1.195	0.947	0.984	0.622	1.970	0.337	0.981	1.031	1.026	1.005	1.001
Romania	6	1.178	1.546	0.898	0.872	0.634	7.525	0.116	0.942	0.984	0.981	1.005	0.998
Slovakia	6	1.109	1.834	0.903	0.796	0.843	5.556	0.142	1.078	1.015	1.011	1.005	0.999
Slovenia	12	1.113	1.232	0.915	0.990	0.873	4.703	0.203	0.971	1.042	1.038	1.005	1.000
Spain	16	1.053	1.169	0.965	0.933	0.686	2.197	0.380	1.011	0.986	1.016	1.012	0.992
Sweden	10	0.986	1.092	0.939	0.963	0.742	2.613	0.311	1.007	0.971	0.968	1.005	0.999
UK	55	1.007	1.085	0.966	0.982	0.716	2.161	0.407	0.979	0.980	1.004	1.009	0.973
Profitability													
Austria	34	0.831	0.941	0.851	1.041	2.549	0.923	3.590	0.967	0.738	1.322	0.684	0.975
Belgium	16	0.828	0.934	0.845	1.055	1.928	0.742	3.112	0.967	0.638	1.096	0.608	0.990
Bulgaria	3	1.031	1.133	0.858	1.054	1.137	0.270	5.146	0.921	0.895	1.163	0.829	0.989
Croatia	18	0.978	1.156	0.844	1.005	1.332	0.303	4.485	1.004	0.985	1.122	0.891	1.011
Cyprus	3	0.996	1.120	0.842	1.061	1.733	0.768	3.587	0.770	0.378	0.391	0.772	1.287
Czech Rep.	11	0.810	0.935	0.850	1.024	1.720	0.595	3.396	0.946	0.740	1.287	0.612	0.953
Denmark	27	0.895	1.039	0.838	1.032	1.969	0.628	3.755	0.902	0.800	1.232	0.675	0.966
Estonia	3	1.015	1.177	0.864	0.994	1.265	0.264	4.874	1.008	0.953	1.287	0.860	0.987
Finland	5	0.828	0.993	0.851	1.004	2.090	0.892	3.230	0.921	0.558	0.850	0.661	1.015
France	75	0.987	1.122	0.867	1.015	1.677	0.484	4.647	0.989	0.802	1.012	0.795	0.996
Germany	75	0.864	1.010	0.854	1.020	2.259	3.991	3.561	1.030	0.794	1.269	0.679	0.995
Greece	7	0.982	1.141	0.848	1.016	2.279	0.580	4.326	0.989	0.773	0.882	0.840	1.093
Hungary	9	1.076	1.279	0.844	0.998	1.470	0.453	3.908	0.925	0.856	1.211	0.728	0.987

(continued on next page)

Table 3 (*continued*)

Bank	Country	2007–2008				2008–2010				2010–2012			
		MPI	eff	tech	scale	MPI	eff	tech	scale	MPI	eff	tech	scale
Ireland	7	0.909	1.002	0.854	1.087	2.567	0.713	4.290	0.989	0.770	1.170	0.770	1.157
Italy	47	0.966	1.105	0.857	1.046	1.961	0.633	4.381	0.975	0.734	1.023	0.791	0.974
Latvia	11	1.156	1.458	0.854	0.968	0.962	0.280	4.423	1.027	1.247	1.766	0.753	0.984
Lithuania	6	0.931	1.105	0.837	1.009	1.253	0.326	4.437	0.955	0.884	1.077	0.889	0.986
Luxembourg	35	0.887	0.992	0.859	1.046	2.041	0.609	3.875	1.071	1.047	1.792	0.727	1.065
Malta	4	0.835	0.936	0.843	1.057	1.466	0.593	2.785	0.940	0.644	1.186	0.543	1.013
Netherlands	14	0.857	0.994	0.849	1.020	1.817	0.550	3.826	0.989	0.651	0.834	0.757	1.036
Poland	13	0.928	1.124	0.849	0.995	1.602	0.511	3.641	0.951	0.744	1.012	0.725	1.038
Portugal	11	0.891	1.041	0.844	1.034	2.315	0.668	3.677	0.962	0.934	1.493	0.674	1.023
Romania	6	1.074	1.220	0.886	0.990	1.667	0.344	4.825	1.052	0.952	1.286	0.791	0.948
Slovakia	6	0.924	1.031	0.838	1.086	1.694	0.551	3.634	0.909	0.744	1.080	0.672	1.056
Slovenia	12	0.920	1.031	0.843	1.063	1.332	0.364	4.000	0.937	0.728	0.937	0.771	1.022
Spain	16	0.953	1.116	0.846	1.011	2.371	0.739	3.770	0.924	1.068	1.483	0.708	0.983
Sweden	10	0.918	1.037	0.849	1.046	1.960	0.520	4.405	0.969	1.069	1.325	0.799	1.009
UK	55	0.934	1.065	0.850	1.057	1.834	0.689	3.382	0.979	0.973	1.363	0.666	1.054

Note: The Table reports the main results for each country in the sample during the U.S. subprime crisis (2007–2008), the global financial crisis (2009–2010) and the sovereign debt crisis (2010–2012). *MPI* is the Malmquist productivity index; *eff* is technical efficiency; *tech* is technical change; *scale* is scale efficiency.

(Estonia, Bulgaria, Romania, Croatia, Poland). Since October 2008, large banks recur to huge recapitalization efforts and also benefit from the injections of further public funds. Despite massive state aid, the overall productivity of the European banks was very low during this phase of the crisis. Furthermore, starting from May 2010 Europe's Finance ministers established the European Financial Stability Facility to ensure financial stability across the Euro zone (Molyneux, 2013). This especially aided European banks holding a large share of sovereign debt, which is typical in Germany and France. This could provide an explanation for our results. On the contrary, our finding shows that Greece fell from the first place during the first period to the last place during the second period. As shown in Table 3, the problem of Greece lies at the first stage, which is the value added activity where banks utilize their inputs to produce deposits. During the first period, Greece experienced a productivity change of 1.269 at the value added activity stage, while during the second period this was a highly unproductive stage (0.494). By January 2009, ten Central and Eastern European countries had already asked for a bailout. At the end of 2009, Greece's credit rating received a downgrade from Fitch (initially from A- to BBB+) followed by downgrades from S&P and Moody's. In addition, banking crises in Ireland in 2008 and in Spain in 2012, exacerbated the liquidity and solvency troubles of the banking sector, which caused a large fiscal burden (Correa and Sapriza, 2014). This then pushed the financial crisis into a sovereign debt crisis for these countries. As argued by Reinhart and Rogoff (2010), banking crises typically precede or coincide with sovereign debt crises. The results in the sovereign debt crisis period reveal a stability in productivity change across the majority of the countries. This may be due financial support mechanisms such as the European Financial Stability Facility (EFSF) and the European Stability Mechanism (ESM), along with supportive policies from European Central Bank, which also contributed to enhance the banking stability.

Interestingly, Portugal, Ireland, Italy and Greece show an overall improvement of productivity in this phase of the crisis, mainly driven by their value added activities. At the same time, they exhibit a strong drop in the performance stage during the sovereign debt crisis as one should expect since the strong economic recession they went through.[7] These countries received large amount state aids in different form: recapitalization (Ireland: 51.8 mln Euros; Greece: 33.5 mln Euros), guarantees (Ireland: 393 mln Euros, Greece: 145 mln Euros; Portugal: 30.1 mln Euros; Italy 97 mln Euros), and other liquidity measures (Greece: 16.3 mln Euros; Portugal: 6.5 mln Euros).[8] In the case of Greece, the financial crisis led to strict fiscal consolidation (Arghyrou, 2015). As a part of the fiscal consolidation, staff reductions and wage cuts took place. Evidently, in our dataset, six out of seven Greek banks reduced both their inputs, with employee reductions up to 23% from 2010 to 2012. The drop of inputs explains why the productivity of the value added stage is constant during this period of the crisis despite the decrease of deposits in Greece.

However, we find a strong drop in the profitability stage for several countries. This is plausible since banks tend to change the composition of their securities portfolio during sovereign stress (Acharya and Steffen, 2015; Correa and Sapriza, 2014). Some European banks have for example purchased sovereign debt from distressed countries because of high returns. Banks in some countries (especially the UK) also reported a huge amount of credit losses and write downs (Molyneux, 2013). This has also affected their productivity in the second stage (for UK is 0.973). In addition, we find that some Eastern countries such as Bulgaria, Romania, Latvia, and Croatia display a positive or constant (as in the case of Hungary) productivity growth during the sovereign debt crisis (2010–2012). Many transaction economies went through some enforcement actions to decrease abuse of market power and to promote a competitive environment (such as Romania).[9] The Eurozone sovereign debt crisis slowed down the growth of transaction countries, which were particularly exposed to Eurozone stress, but only starting from the first half of 2012. At that time, there was a strong cross-border bank deleveraging going on, related to the deepening Eurozone crisis, especially in Central Europe and the Baltics (CEB) and South-Eastern Europe (SEE).[10]

Table 4 presents the results of the productivity convergence among European banks. The first line shows the convergence results for the first (2007–2008) and the second (2008–2010) period and the second line shows the convergence for the second and the third (2010–2012) period. The second and the third col-

[7] International Monetary Fund, World Economic Outlook Database, April 2016.

[8] Data retrieved from European Commission http://ec.europa.eu/competition/state_aid/scoreboard/financial_economic_crisis_aid_en.html, February 2016.

[9] Data retrieved from Transition indicators by country provided by EBRD, http://www.ebrd.com/what-we-do/economic-research-and-data/data/forecasts-macro-data-transition-indicators.html, January 2016.

[10] Data retrieved from http://www.ebrd.com/downloads/research/REP/regional-economic-prospects1210.pdf, December 2015.

Table 4
Overall: EU-28. β-convergence and σ-convergence coefficients.

PERIOD	Overall model		1st stage		2nd stage	
	β-convergence	σ-convergence	β-convergence	σ-convergence	β-convergence	σ-convergence
1st-2nd period	−1.154***	−1.149***	−1.098***	−1.098***	−1.506***	−1.506***
2nd-3rd period	−0.969***	−0.969***	−0.994***	−0.994***	−1.204***	−1.204***

Note: The Table reports the main results for all the countries in the sample. The U.S. subprime crisis (2007–2008) and the global financial crisis (2009–2010) are the 1st-2nd period of the crisis; the global financial crisis (2009–2010) and the sovereign debt crisis (2010–2012) are the 2nd-3rd period. *MPI* is the Malmquist productivity index; *eff* is technical efficiency; *tech* is technical change; *scale* is scale efficiency.

*** The coefficient is statistically significant at 0.001.

umn present the β-convergence and σ-convergence scores for the overall model. Finally, the fourth and fifth columns report the corresponding results for the first stage, while the last two columns do so for the second stage.

Both β-convergence and σ-convergence coefficients for the overall model, the first stage and the second stage are negative and statistically significant for 0.001. We recall here that a negative coefficient indicates a convergence trend among the banks in our sample. Therefore, our results provide strong support for the convergence hypothesis among European banks during the financial crisis. Our findings are in line with a few recent studies that examine the integration patterns among European banks (Weill, 2009; Casu and Girardone, 2010). Instead, it does not coincide with Matousek et al., (2015)'s paper, which explores the convergence trend during the recent financial crisis as we do as well. Differently from the above mentioned papers, we examine the convergence of productivity growth rather than solely focusing on efficiency scores. We recall here that productivity growth encompasses three different components, namely efficiency change, technical change and scale change. This makes our results unique.

Fig. 2a and c present scatterplots of productivity growth on the initial level of productivity change with a fitted GLS regression line. Fig. 2b and d show the densities of productivity change. In addition, Fig. 2a and b examine the convergence of the first and the second period, whereas Fig. 2c and d show the convergence of the second and the third period. For all these Figures, there is evidence

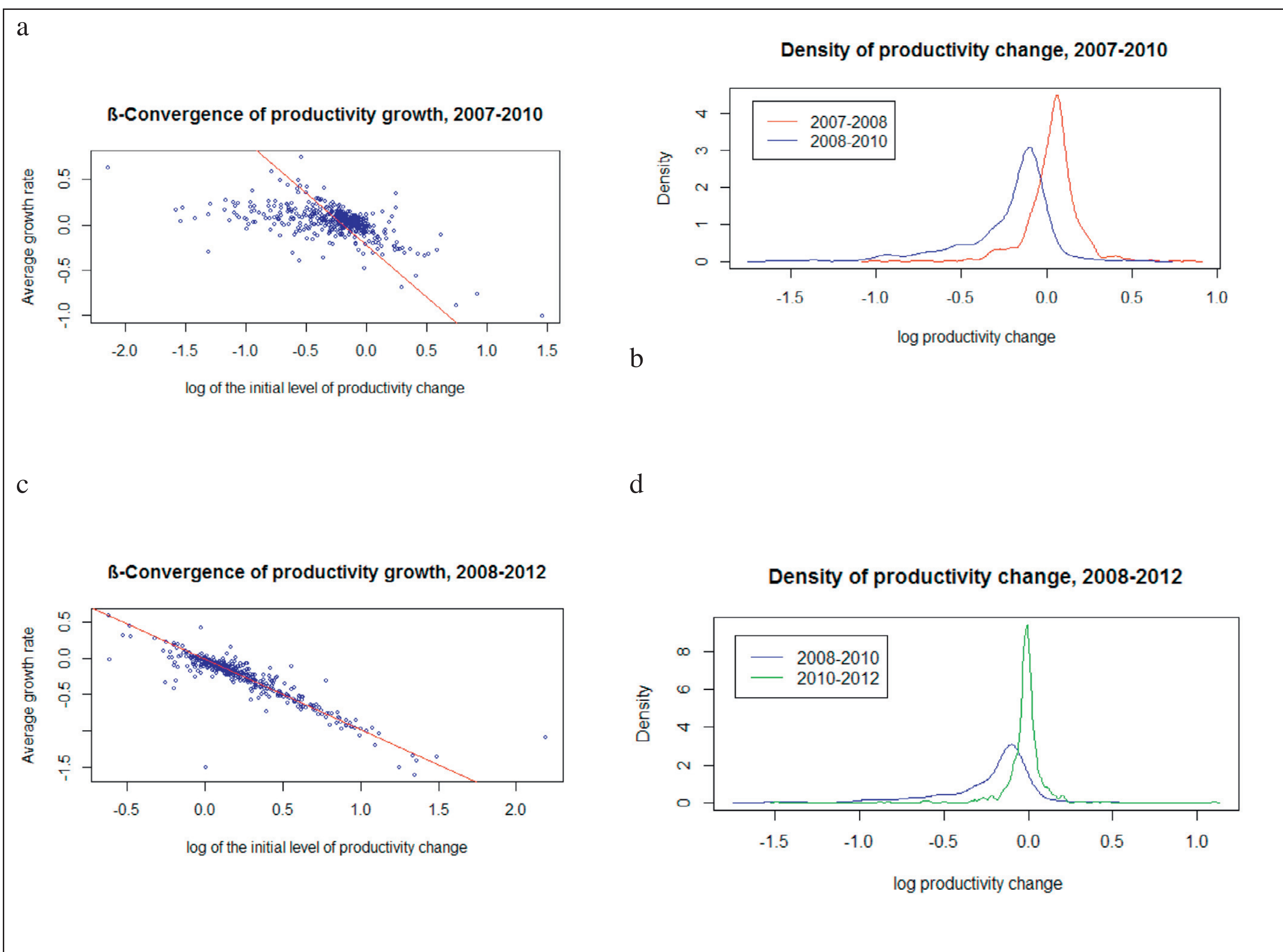

Fig. 2. (a-d): β-convergence and density functions for the overall model.

of a strong pattern of convergence. There is in fact a strong negative correlation between the productivity growth and the log of the initial level of productivity change.

Next, we verify whether the inclusion of specific countries in our sample has affected our results as concerns the convergence of productivity among European Banks (Appendix B, Tables B1–B4, Figs. B1–B4). The Euro countries have increased the fiscal risk during the peak of the crisis and made the duration of recovery process longer than for other countries (Lane, 2012). This could have had an impact on the convergence process of Euro countries. In addition, in the Euro area, the GIIPS countries experienced a harsh sovereign debt crisis in late 2009. Therefore, we re-run the analysis by splitting the Euro countries from the countries that have their own currency, and the GIIPS countries from the other ones. Our results and conclusions are robust to all specified sub-samples.

4.3. Discussion and policy implications

There are two possible explanations for our findings regarding the strong convergence pattern among the banks in the EU28. First, an important warning comes from the decomposition of the productivity growth in the two stages. As is evident from Table 2, the decline of performance in the second stage is the main driver for the drop of the overall productivity. This is due to the decline of technical change for the period 2010–2012. As discussed by recent papers, banks reduced their lending activities. New loans fell dramatically during the financial crisis (De Haas and Van Horen, 2013). This could explain why we find a very low performance in the second stage of the production function, where loans are the outputs. However, we find that countries that exhibit higher productivity in the first stage tend to perform worse in the second stage.

In addition, the threat of the drop of deposit supply because of the “bank run” could have harmed the lending activities of banks. Moreover, the freeze of the European interbank market has contributed to a credit supply reduction especially for Small and Medium Enterprises (Iyer et al., 2014). Furthermore, several banks in Europe have become extremely conservative as they have raised capital and their liquidity position but at the same time reduced their lending activities (Molyneux, 2013). This is also because they suffer from huge credit losses. These phenomena could have led to the drop of banks’ productivity, especially in the performance stage as indicated by our results. In particular, in 2012 the European area went through a recession period with countries experience a low or even a negative GDP growth (such as Finland, Italy, Portugal, Ireland, Netherlands, Cyprus).[11]

Second, our findings suggest that convergence among European banks is mainly driven by the loss of competitiveness of the Western banking system and catch-up process of some Eastern banks especially during the sovereign debt crisis period. However, as depicted earlier, this could be explained by the fact that transaction countries started to be expose to the Euro zone sovereign debt crisis only starting from the first half of 2012.

The recent financial crisis has highlighted the limits of the Euro area to put forward cohesive and effective adjustment mechanisms in response to the financial crisis. What emerges from this analysis is that, even though the response to the crisis was heterogeneous among countries, the European banking system overall has shown itself to be vulnerable in a period of macroeconomic and financial shocks. Part of the fragility of Europe can be attributed to the fragmentation of the regulatory system and weakness of the supervision system. In the case of the Euro area, the retaining of national responsibility for financial regulation and fiscal policy and the lack of a unified framework has also played an important role in the weak response to financial and macroeconomic shocks (Lane, 2012). Moreover, national approaches to the crisis management resulted to not be effective in restoring banking stability and investor confidence, and they had adverse spillover effects over the European countries. In addition, despite the European government launching several loan and fiscal schemes, and bank rescue plans to preserve the banking system, there was however little agreement and cooperation as regards the sharing the fiscal costs generated by the crisis (Molyneux, 2013). This could explain why the European banks experience a sharper drop of their productivity especially in the second period of the global financial crisis (2008–2010) and consequently a low productivity growth in the following period.

These findings suggest the need for new policy initiatives by the EU, which aim to provide a more unified regulatory system that nowadays is still rather fragmented and nationally oriented. EU countries should move towards joint decision-making regarding their national budgets and economic policies. In other words, steps should be made towards the Financial Union and a unified banking supervision system to promptly react to crisis periods and limit the consequences of negative spillover effects across the European countries. The European Commission is moving towards this direction. According to the so-called Five Presidents’ Report (European Commission, 2015), there is a need to put forward economic policies to ensure the smooth and correct functioning of the “Economic and Monetary Union” . This process requires together with an Economic, Fiscal and Political Union, also a Financial Union which also encompasses the promotion of a Banking Union. In particular, for the Banking Union three pillars have been established: the Single Supervisory Mechanism (SSM) to harmonize supervisory actions and corrective measures and ensure the consistent application of regulations and supervisory policies; the Single Resolution Mechanism (SRM) for prompt effective and unified actions to restore confidence in the marks and prevent banking runs and contagions; the European Deposits Insurance Scheme (EDIS). The latter pillar has yet to be implemented. This is of crucial importance since most of the money in the EU (and worldwide) is in deposit form. Restoring confidence in the safety of bank deposits irrespective of the place/country the bank operates would be a major step for the resilience against future crisis and can further boost banking productivity. However, such initiatives should improve the ability of banks to absorb shocks caused by financial and economic stress and to promote resilience in banking systems without burdening their productivity or lending activities.

Lastly, our findings show that European banks experienced a very low scale efficiency especially during the global financial crisis (2008–2010). This would suggest that the size of operations was not optimal during the peak of the financial crisis. An important question for policy makers arising from this finding is whether there is the need to impose limits on the size of banks. This would eventually also minimize potential moral hazard problems and the risk-taking attitude associated with the size of banks because of the high probability of being bailed out, which could also potentially harm the medium-long term productivity.

5. Conclusion

In this paper, we investigate the sources of bank productivity growth and the underlying patters of the integration process for the 28 EU countries during the financial crisis. By combining the Malmquist Productivity Index and an additive two-stage DEA model we explore the sources of growth in different stages of production and we quantify the contribution of individual components (inputs and outputs) to productivity change. We then investigate

[11] Source: International Monetary Fund, World Economic Outlook Database, April 2015.

the convergence of the overall bank productivity and the productivity of the above two stages by applying the regression framework proposed by Kumar and Russell (2002).

This paper provides important new findings and policy implications. Our results show a productivity growth (+ 7%), mainly driven by efficiency changes (+ 19%), especially for peripheral countries and new EU countries during the U.S. subprime crisis (2007–2008). However, we find evidence of an overall consistent drop of the productivity growth during the global financial crisis (2008–2010). In particular, during this phase the productivity growth displays a decreasing trend (- 19%). The low level of productivity was also persistent during the sovereign debt crisis (2010–2012). This latter phenomenon was a generic trend especially for the performance stage (−17%). The drop of technical change and of the productivity in the second stage are the main factors responsible for the performance' decrease of European banks during the financial crisis. The deterioration of lending activities and new loans could have strongly contributed to the loss of competitiveness of the European system. The tests for β-convergence and σ-convergence show evidence for productivity growth convergence for every period and every model (overall, first and second stage). Our results are robust to different sub-samples.

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Appendix A

Formula (1a) shows the VRS model in period t for the DMU under evaluation where the benchmark technology and the observed values are both in period t. Furthermore, the same model is also used for period t+ 1, $D_v^{t+1}(x^{t+1}, y^{t+1})$. The CRS version can be calculated by omitting u^1 and u^2 terms.

$$
\begin{aligned}
D_v^t\left(x_0^t, y_0^t\right) = max \sum_{d=1}^{D} \mu_d z_{d_0}^t + \sum_{r=1}^{s} \gamma_r y_{r_0}^t + u^1 + u^2 \\
\text{s.t.} \sum_{i=1}^{m} \omega_i x_{i_0}^t + \sum_{d=1}^{D} \mu_d z_{d_0}^t = 1 \\
\sum_{d=1}^{D} \mu_d z_{d_j}^t - \sum_{i=1}^{m} \omega_i x_{i_j}^t + u^1 \le 0, \\
\sum_{r=1}^{s} \gamma_r y_{r_j}^t - \sum_{d=1}^{D} \mu_d z_{d_j}^t + u^2 \le 0, \\
\gamma_r, \mu_d, \omega_i \ge 0 \\
j = 1, \dots, n;\ \ i = 1, \dots, m; d = 1, \dots, D; r = 1, \dots, s \\
u^1 \text{ and } u^2 \text{ are free in sign}
\end{aligned}
\tag{1a}
$$

Similarly, the VRS model for the second stage in period t takes the following form:

$$
\begin{aligned}
D_v^{t,2}\left(x_0^t, y_0^t\right) = max \sum_{r=1}^{s} \gamma_r y_{r_0}^t + u^2 \\
\text{s.t.} \sum_{d=1}^{D} \mu_d z_{d_0}^t = 1 \\
\sum_{d=1}^{D} \mu_d z_{d_0}^t + \sum_{r=1}^{s} \gamma_r y_{r_0}^t \\
-E_0 \sum_{i=1}^{m} \omega_i x_{i_0}^t + u^1 + u^2 = D_v^t\left(x_0^t, y_0^t\right), \\
\sum_{d=1}^{D} \mu_d z_{d_j}^t - \sum_{i=1}^{m} \omega_i x_{i_j}^t + u^1 \le 0, \\
\sum_{r=1}^{s} \gamma_r y_{r_j}^t - \sum_{d=1}^{D} \mu_d z_{d_j}^t + u^2 \le 0 \\
\gamma_r, \mu_d, \omega_i \ge 0 \\
j = 1, \dots, n;\ \ i = 1, \dots, m; d = 1, \dots, D; r = 1, \dots, s \\
u^1 \text{ and } u^2 \text{ are free in sign}
\end{aligned}
\tag{2a}
$$

Likewise for the first stage:

$$
D_v^{t,1}\left(x_0^t, y_0^t\right) = \frac{D_v^t\left(x_0^t, y_0^t\right) - \xi_2^* \cdot D_v^{t,2}\left(x_0^t, y_0^t\right)}{\xi_1^*} \tag{3a}
$$

The mixed period problem where the benchmark technology and the observed values are in different time periods represents the most challenging aspect in calculating Malmquist Productivity indices. Here we present the VRS model for the DMU under evaluation. The benchmark technology is in period t and the observed values in period t + 1. The opposite can be easily yielded by setting benchmark in period t + 1 and observed values in period t. Again, the CRS version can be calculated by omitting u^1 and u^2 terms.

$$
\begin{aligned}
& D_v^t\left(x_0^{t+1}, y_0^{t+1}\right) \\
& = max \sum_{d=1}^{D} \mu_d z_{d_0}^{t+1} + \sum_{r=1}^{s} \gamma_r y_{r_0}^{t+1} + u^1 + u^2 \\
& \text{s.t.} \sum_{i=1}^{m} \omega_i x_{i_0}^{t+1} + \sum_{d=1}^{D} \mu_d z_{d_0}^{t+1} = 1 \\
& \sum_{d=1}^{D} \mu_d z_{d_j}^t - \sum_{i=1}^{m} \omega_i x_{i_j}^t + u^1 \le 0, \\
& \sum_{r=1}^{s} \gamma_r y_{r_j}^t - \sum_{d=1}^{D} \mu_d z_{d_j}^t + u^2 \le 0, \\
& \gamma_r, \mu_d, \omega_i \ge 0 \\
& j = 1, \dots, n;\ \ i = 1, \dots, m; d = 1, \dots, D; r = 1, \dots, s \\
& u^1 \text{ and } u^2 \text{ are free in sign}
\end{aligned}
\tag{4a}
$$

Similarly, the VRS model for the second stage takes the following form:

$$
\begin{aligned}
& D_v^{t,2}\left(x_0^{t+1}, y_0^{t+1}\right) \\
& = \max \sum_{r=1}^{s} \gamma_r y_{r_0}^{t+1} + u^2 \\
& \text{s.t.} \sum_{d=1}^{D} \mu_d z_{d_0}^{t+1} = 1 \\
& \sum_{d=1}^{D} \mu_d z_{d_0}^{t+1} + \sum_{r=1}^{s} \gamma_r y_{r_0}^{t+1} - D_v^t\left(x_0^{t+1}, y_0^{t+1}\right) \\
& \sum_{i=1}^{m} \omega_i x_{i_0}^{t+1} + u^1 + u^2 = D_v^t\left(x_0^{t+1}, y_0^{t+1}\right)
\end{aligned}
$$

$$\sum_{d=1}^{D}\mu_d z_{d_j}^t - \sum_{i=1}^{m}\omega_i x_{i_j}^t + u^1 \le 0,$$
$$\sum_{r=1}^{s}\gamma_r y_{r_j}^t - \sum_{d=1}^{D}\mu_d z_{d_j}^t + u^2 \le 0$$
$$\gamma_r, \mu_d, \omega_i \ge 0$$
$$j = 1, \ldots, n;\; i = 1, \ldots, m; d = 1, \ldots, D; r = 1, \ldots, s$$
$$u^1 \text{ and } u^2 \text{ are free in sign} \tag{5a}$$

Likewise for the first stage:

$$D_v^{t,1}\left(x_0^{t+1}, y_0^{t+1}\right) = \frac{D_v^t\left(x_0^{t+1}, y_0^{t+1}\right) - \xi_2^* \cdot D_v^{t,2}\left(x_0^{t+1}, y_0^{t+1}\right)}{\xi_1^*} \tag{6a}$$

Appendix B

Tables B1–B4, Figs. B1–B4

Table B.1
Eurozone: 19. β-convergence and σ-convergence coefficients.

PERIOD	Overall model		1st stage		2nd stage	
	β-convergence	σ-convergence	β-convergence	σ-convergence	β-convergence	σ-convergence
1st-2nd period	−1.188***	−1.183***	−1.101***	−1.101***	−1.500***	−1.500***
2nd-3rd period	−0.978***	−0.978***	−0.985***	−0.985***	−1.700***	−1.700***

Note: The Table reports the main results for the countries in the Eurozone. The U.S. subprime crisis (2007–2008) and the global financial crisis (2009–2010) are the 1st-2nd period of the crisis; the global financial crisis (2009–2010) and the sovereign debt crisis (2010–2012) are the 2nd-3rd period. *MPI* is the Malmquist productivity index; *eff* is technical efficiency; *tech* is technical change; *scale* is scale efficiency.
*** The coefficient is statistically significant at 0.001.

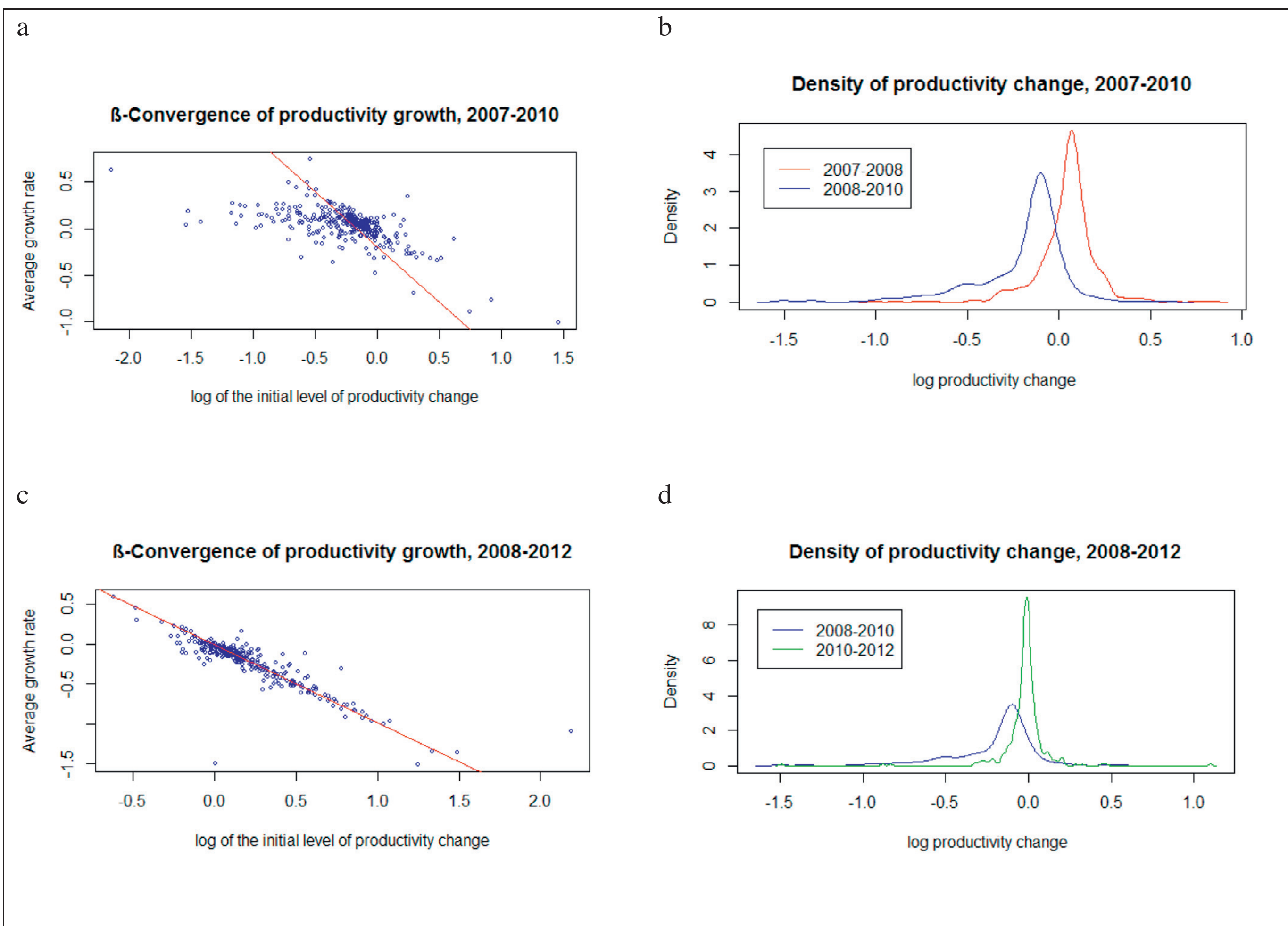

Fig. B.1. β-convergence and density functions for Eurozone.

Table B.2
Non-euro. β-convergence and σ-convergence coefficients.

PERIOD	Overall model		1st stage		2nd stage	
	β-convergence	σ-convergence	β-convergence	σ-convergence	β-convergence	σ-convergence
1st-2nd period	−1.094***	−1.098***	−1.193***	−1.193***	−1.522***	−1.522***
2nd-3rd period	−0.959***	−0.959***	−1.023***	−1.023***	−1.397***	−1.397***

Note: The Table reports the main results for the countries outside the Eurozone. The U.S. subprime crisis (2007–2008) and the global financial crisis (2009–2010) are the 1st-2nd period of the crisis; the global financial crisis (2009–2010) and the sovereign debt crisis (2010–2012) are the 2nd-3rd period. *MPI* is the Malmquist productivity index; *eff* is technical efficiency; *tech* is technical change; *scale* is scale efficiency.
*** The coefficient is statistically significant at 0.001.

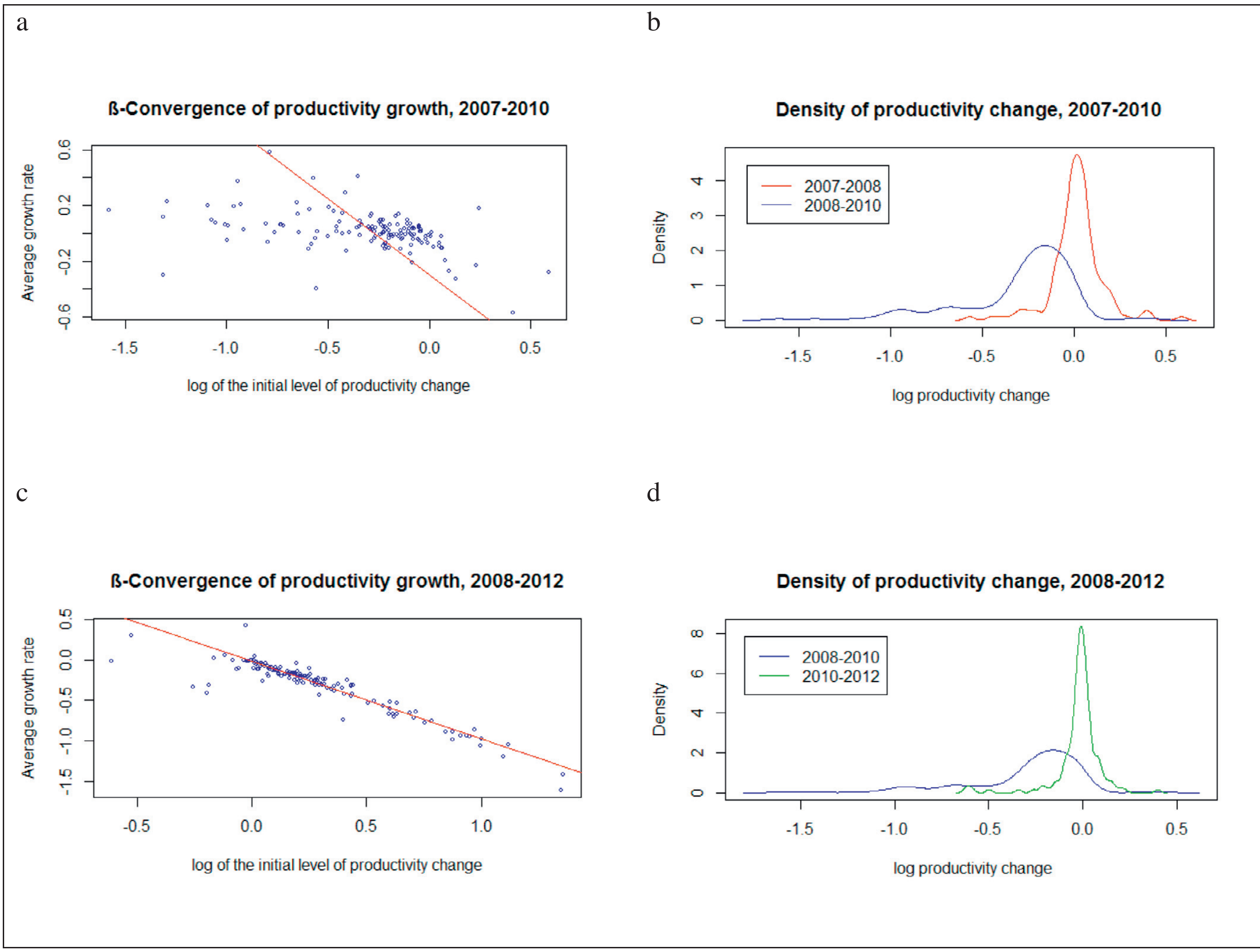

Fig. B.2. β-convergence and density functions for the countries outside the Eurozone.

Table B.3
GIIPS: Greece, Ireland, Italy, Portugal, Spain. β-convergence and σ-convergence coefficients.

PERIOD	Overall model		1st stage		2nd stage	
	β-convergence	σ-convergence	β-convergence	σ-convergence	β-convergence	σ-convergence
1st-2nd period	−1.062***	−1.062***	−0.985***	−0.985***	−1.080***	−1.080***
2nd-3rd period	−1.045***	−1.045***	−1.009***	−1.009***	−1.042***	−1.042***

Note: The Table reports the main results for GIIPS countries. The U.S. subprime crisis (2007–2008) and the global financial crisis (2009–2010) are the 1st-2nd period of the crisis; the global financial crisis (2009–2010) and the sovereign debt crisis (2010–2012) are the 2nd-3rd period. *MPI* is the Malmquist productivity index; *eff* is technical efficiency; *tech* is technical change; *scale* is scale efficiency.
*** The coefficient is statistically significant at 0.001.

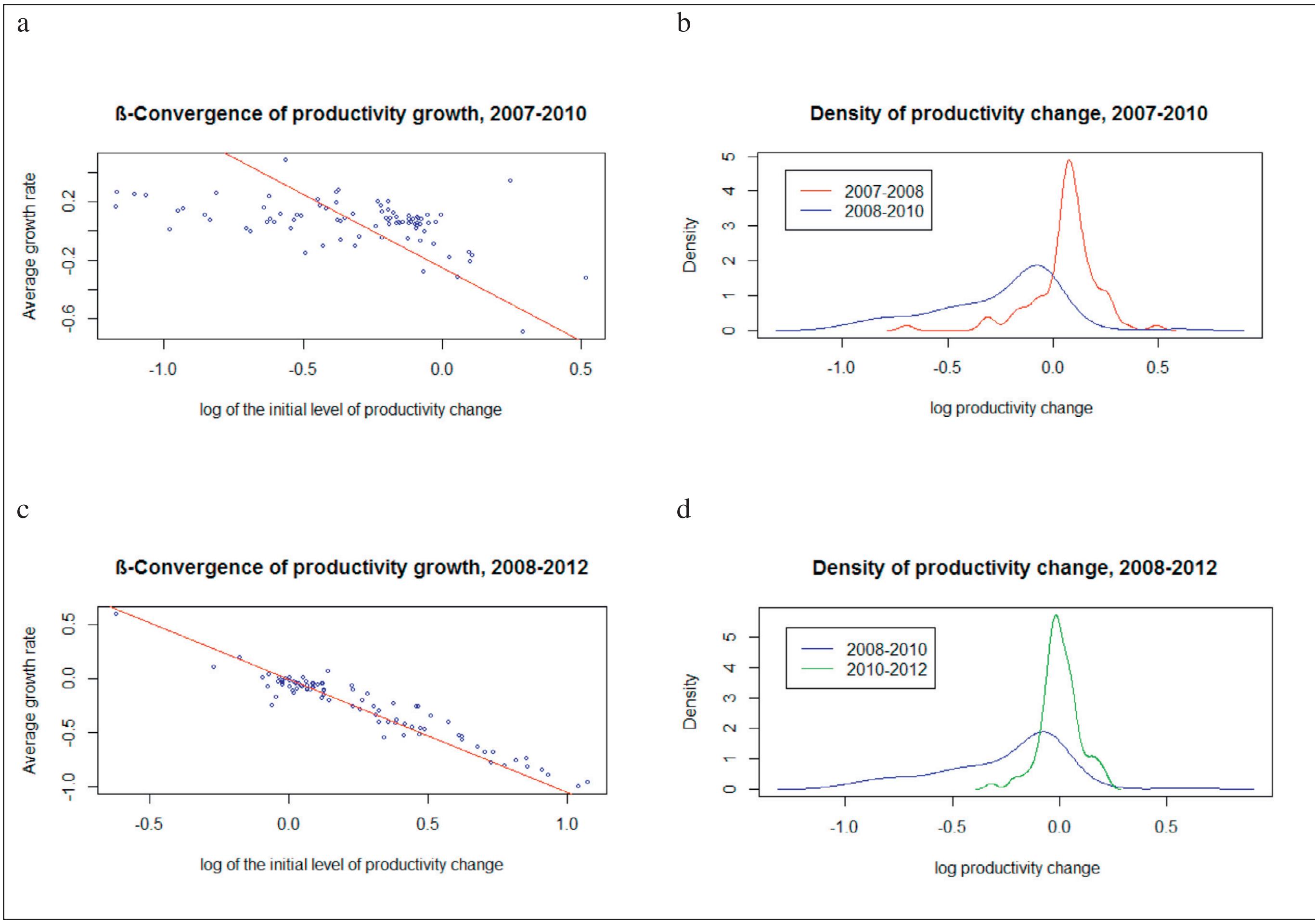

Fig. B.3. β-convergence and density functions for GIIPS countries.

Table B.4
Euro non-GIIPS. β-convergence and σ-convergence coefficients.

PERIOD	Overall model		1st stage		2nd stage	
	β-convergence	σ-convergence	β-convergence	σ-convergence	β-convergence	σ-convergence
1st-2nd period	−1.215***	−1.211***	−1.135***	−1.135***	−1.615***	−1.615***
2nd-3rd period	−0.945***	−0.945***	−0.967***	−0.967***	−1.198***	−1.198***

Note: The Table reports the main results for Euro non-GIIPS countries. The U.S. subprime crisis (2007–2008) and the global financial crisis (2009–2010) are the 1st-2nd period of the crisis; the global financial crisis (2009–2010) and the sovereign debt crisis (2010–2012) are the 2nd-3rd period. *MPI* is the Malmquist productivity index; *eff* is technical efficiency; *tech* is technical change; *scale* is scale efficiency.

*** The coefficient is statistically significant at 0.001.

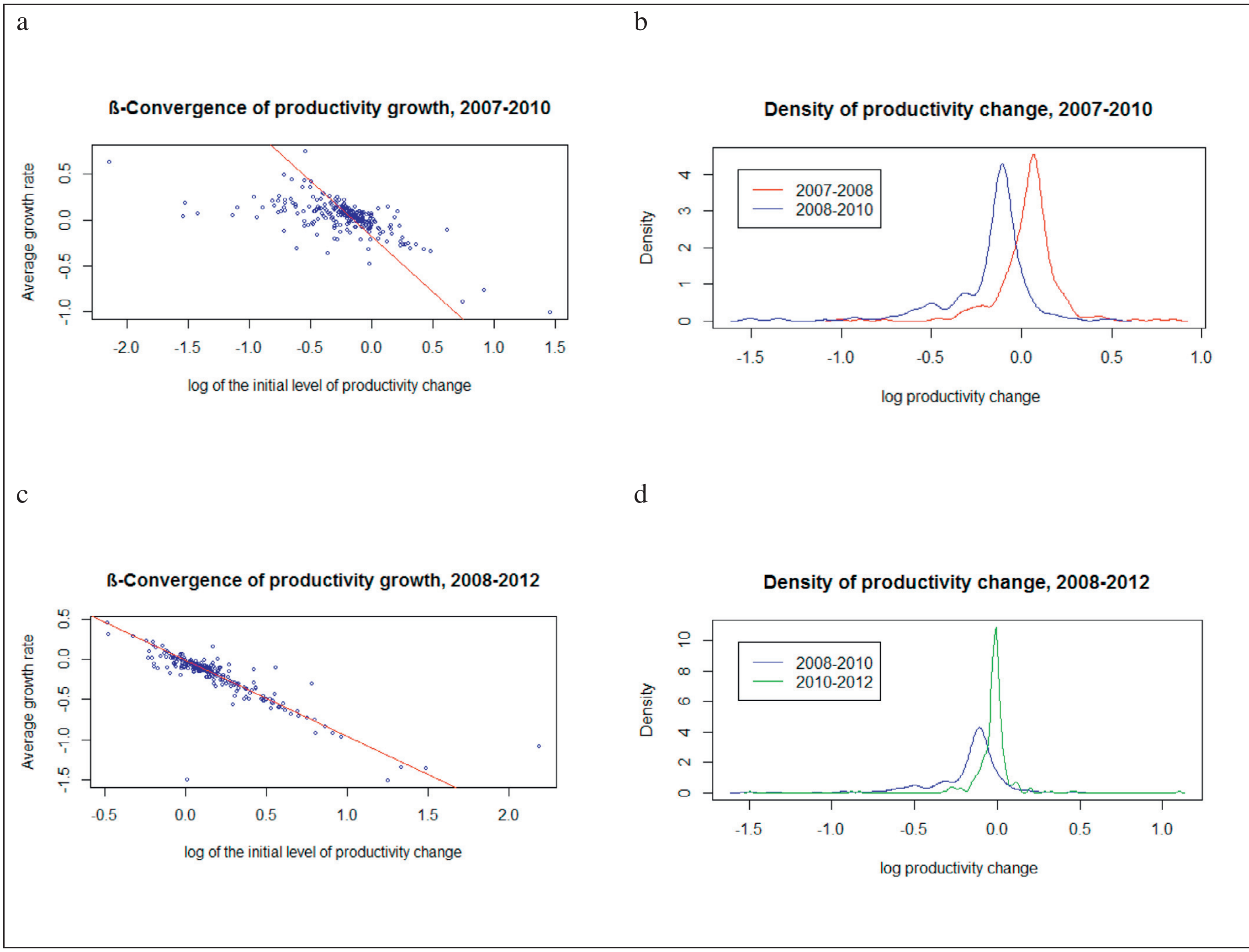

Fig. B.4. β-convergence and density functions for Euro non-GIIPS countries.

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