The Financial Crisis and Bank Convergence: Evidence from the European Union and Eurozone

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Abstract:

The objective of this study is three-fold. First we estimate and analyse bank efficiency and productivity changes in the EU27 countries with the application of a novel approach, a weighted Russell directional distance model. In so doing, we take into account non-performing loans, an undesirable output Second, we take a disaggregated approach and analyse the contribution of all the individual bank inputs and output on bank efficiency and productivity growth. Third, we test for convergence in EU27 bank productivity as well as in the inefficiency of individual bank inputs. We find that bank efficiency levels decreases during 2007-2008 as a reaction to the Global Financial Crisis. Additionally, labour savings and increased customer loans have boosted productivity consistently from 2005 onwards. There is evidence of convergence in bank productivity among the EU27 countries throughout the period 2005-2010. The driving force seems to be convergent technical change from the new EU Member States. We also find convergence in the total deposits of all EU27 banks. On the other hand, weak convergence is detected for the banks' individual inputs.

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1. Introduction

Numerous studies have recently been published on bank performance either on individual EU countries or the group of EU countries that include 'old' EU15 and/or new EU countries, see for example, Berger, (2003), Goddard et al. (2007), Barros et al. (2007), Fries and Taci (2005), Berger (2003, 2007), Casu and Girardone (2006), Matousek et al (2014), among others.

The focal point of these research studies has been to empirically find evidence of the degree of European banking markets integration. A large number of studies have particularly analysed differences at bank efficiency levels across the EU countries. Casu and Molyneux (2003) in their early study on bank integration conclude that there is evidence that EU banks have converged. Similar results are reported by Barros at al. (2007), who show the prevailing importance of country level characteristics in bank performance. Goddard et al. (2007) argue that the integration process has implications for systemic risk and is challenging for the supervisory and regulatory framework. The recent financial crisis documents that bank performance, particularly, in the 'old' EU countries have been affected by the adverse economic environment. Governments and Central Banks across EU countries have had to bail out a large number of commercial banks in order to avoid systemic crisis. European governments approved $5.3 trillion of aid, more than the annual gross domestic product of Germany, to support banks during the credit crunch (Bloomberg, 2009).

This unique and unprecedented event motivates our research on the analysis of bank performance before and during the crisis. We attempt to extend the current literature on the European banking markets by examining technical efficiency and productivity growth in the EU27 banking sector over the period 2005-2011. The study tries to shed light on bank performance during the financial crisis and its aftermath.

As discussed in Section 3, there is rather limited up to date research on bank efficiency in EU countries that takes into account the current disturbances in the banking markets. Most studies on bank efficiency provide results before the crisis (see Altunbas (2001), Casu and Molyneux (2003), Casu and Girardone (2006), Goddard et al (2007), Barros et al (2007), Brissimis et al. (2010) among others). Our study does not only fill the above mentioned gap but we also advance the methodological approach of how to estimate bank efficiency. We extend the current methodology introduced by Barros et al (2012) by introducing allocative efficiency with NPLs and cost efficiency. In addition, the European banking system faces the problem of deteriorating balance sheets because of the growing volume of non-performing loans (NPLs). We assume that NPLs undermine the performance and potential of the individual banks. We also open the black-box of how efficiency and productivity are measured. In so doing, we analyse in a unique way, the contribution of the individual inputs/outputs on the overall bank efficiency and Total Factor Productivity (TFP) change that account for NPLs directly in the model by considering NPLs as an undesirable output. Such an analysis is important for policy makers since it can disclose the main shortcomings within the individual banks and the system as a whole. This issue has been neglected in banking studies see, for example, Barros et.al. (2012) and Assaf et. al. (2013). The analysis of NPLs provides a means to reveal and recognise the problems within the system. Subsequently, this can lead to the implementation of an appropriate regulatory framework that would restore a sound and efficient functioning banking sector in EU countries.

We examine technical efficiency and productivity growth of the European banking over a seven year period, 2005-2011. In doing so, we apply an innovative methodological approach introduced by Chen et al. (2011) and Barros et al. (2012), who use weighted Russell directional distance model (WRDDM) to measure technical inefficiency of European banks. The uniqueness and contribution of our approach lies in resolving technical difficulties

involved in the empirical analysis of how to disaggregate and quantify the contribution of individual components (outputs/inputs) on bank efficiency. The model is based on a directional distance function, which we estimate in linear form. This process has the attractive advantage of easy computation and extension with the inclusion of undesirable outputs into the model.

As we have already indicated, we disaggregate and quantify the impact of not only of NPLs but also of all the individual inputs/outputs on bank efficiency. That is a new element in studies on bank efficiency and an important contribution to current research on bank efficiency in EU. The motivation to examine bank efficiency and productivity growth in this way is reinforced by the rapidly increasing volume of NPLs on the European Banks' balance sheets. Contemporary research on bank productivity has focused so far on the decomposition of TFP into Technical Change (TECHCH) and Efficiency Change (EFFCH).

Our contributions are summarised as follows: First, we examine the nexus between NPLs and bank efficiency. The innovative methodological approach makes it possible to quantify the impact of NPLs on bank efficiency. Secondly, we provide a comprehensive analysis of the effects of the individual bank inputs/outputs on overall banking efficiency and productivity. The decomposition of total technical efficiency into individual inputs and outputs is a key contribution to current research on bank efficiency. Third, we test for convergence in the efficiency and productivity as well as in the individual bank inputs of the EU27 banks to assess the integration process. We employ the dynamic Phillips and Sul (2007) panel convergence model which allows for individual heterogeneity and tests for a common growth component to do so. Fourth, the empirical analysis is the first of its type applied on the banking that examines bank efficiency and productivity changes and convergence after the extensive bank consolidation process in the 1990s and early 2000s in new EU countries. We examine the period 2005 to 2011. Furthermore, we introduce the

concept of firm 'innovator' (Fare et al. 1994) into our analysis. We quantitatively identify the best practice banks that shift upward the production frontier. The discussion on this concept is in Section 4. Finally, we outline the policy implication of our findings.

The paper is structured as follows: Section 2 provides an overview of European banking while Section 3 reviews the literature. Section 4 discusses the methodology and Section 5 presents the empirical results. Finally, Section 6 concludes.

2. An Overview: European Banking System and the Global Financial Crisis

In the last 20 years, the European banking market has undergone extensive regulatory changes, consolidation through mergers and acquisitions (M&As) and important technological changes that have considerably changed the banking industry. The implementation of the First Banking Coordination Directive in 1977 followed by the EU White Paper in 1985 and the Second Banking Coordination Directive of 1988 provided a cornerstone to the establishment of the Single Market for Financial Services in 1993. The Cecchini Report (1998) that analysed the cost-benefit analysis of a single financial market, argued that a single financial market reduces the costs of financial intermediation, enables more efficient allocation of capital, better access to markets, instrument and services and higher efficiency of the financial institutions and markets. The benefit of a single market was seen above all as an increase in competition that will lower the prices of financial services.

Undoubtedly, the European banking markets has been significantly reshaped and the degree of harmonisation has been improved compared to the pre-1993 level. Berger (2003) argues that the full efficiency effect of a single market for financial services in Europe requires an intensive wave of mergers and acquisitions of financial institution across the

countries. However, he shows that there have been rather a limited number of M&As among the EU financial institutions. Furthermore, Berger (2003) shows that universal banking particularly, can contribute to scope efficiency and cost improvements. Goddard et al (2007) argue that the integration of the banking sector has not been achieved yet. The main obstacles of the full integration are national economic conditions, differences in legal and fiscal system, cultural differences, among others. Barros et al (2007) support this view in their study by showing that country level characteristics (location and tradition), firm-level features (bank ownership, balance sheet structure and size) still matter. They also argue that smaller sized banks with higher loan intensity and foreign banks from countries with common low traditions have a higher chance of best performance. Other studies shows that the process of integration has advanced more in wholesale than in retail banking, see, for example, Cabral et al. (2002), Barros et al. (2005).

Financial integration requires that financial markets are underpinned by sound regulatory and supervisory practices. This has to be particularly enhanced in the case of the EU financial integration. The financial integration affects financial stability through variety of channels (ECB, 2012). The current global financial crisis has been to some extent a test of the degree of financial integration across the EU countries. With the benefit of hindsight, it is now evident that the financial crisis has thrown the financial integration into reverse. The crisis has caused the collapse or an almost collapse of a large number of well-established EU and US banks. The cost of the financial crisis in terms of provided aid by EU states to stabilise the EU banking during 2008 and 2012 amounted to EUR 1.5 trilion that is 12.3% of EU 2012 GDP (European Commission, 2014). The crisis disclosed the bottlenecks of the integration process. The main weakness of the integration process has been a weak and not fully implemented integrated framework for bank supervision and regulation. We have witnessed a typical systemic crisis across the individual EU countries. The extent of the crisis has been

spread across the EU countries through the balance sheets of financial institutions. A number of banks have been forced to sell external assets or been required to close their exposure with domestic and/or overseas institutions. Such activities then spread from one bank to other regardless the geographical frontier. During the crises the effect of bank balance-sheet contagion was naturally even stronger in those markets where the qualitative and quantitative aspects of supervisory and regulatory principles are rather poorly performed. For example, the UK's estimated package should reach US $1.1 trillion in order to restore confidence in the banking system. In Denmark, 13 of the country's 140 banks were bailed out by the central bank or acquired by their competitors. The expected volume of the rescue package is estimated to be EUR 593.9 billion. EU governments approved about 311.4 billion euros for capital injections, 2.92 trillion euros for bank liability guarantees, 33 billion euros for relief of impaired assets and 505.6 billion euros for liquidity and bank funding support, a total of 3.77 trillion euros.

It is evident that the international financial integration increases economic efficiency and growth. However, it may also increase the probability of a systemic banking crisis by transmitting international shocks via bank balance sheets. Empirical analysis, not surprisingly, finds strong evidence that bank balance-sheet contagion has indeed been amplified by exposure to borrowing from cross-border banks (ECB, 2012). There are no empirical studies that investigate the impact of the current global financial crisis on bank efficiency across EU27 banks[1]. As we have already mentioned above, such an analysis has important policy making implications. In particular, it should disclose the weakest links in the banking integration in EU27countries as well as the contagion channels that undermine bank performance.

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[1] Matousek et al (2014) analyse the impact of the global financial crisis on EU15 bank efficiency.

3. Literature Review

In the following Section, we briefly overview the empirical studies on the integration process of the European banking system. The second part of the review summarises and outlines the current development of methodological research in estimating efficiency and productivity in general. As we show the applied methodology contribute to the overall literature on bank efficiency and productivity measurements.

3.1. Empirical Research on the European integration Process

The enlargement of the European Union to 27 member countries has been a significant step in the history of the European Union and the ramifications in terms of the integration process are profound. In theory, a single market in banking across the 27 member states should enable greater consumer choice and boost competition and banking efficiency. Indeed, if a homogenous banking market and competition do lead to further integration, then the impact would be felt on the cost structures and performance of banks (i.e banking efficiency). As noted by Kasman et al (2010), the new EU member countries embarked on large-scale privatisation programmes in the mid-1990s in order to boost banking competition and efficiency. As a result, bank consolidation among the Central and Eastern European (CEE) countries peaked in the 2000s and the countries' banking systems are now more viable and efficient (Kasman et al, 2010). Hence a higher level of competition and the presence of an integrated market should translate into convergence in banking efficiency.

There are several studies that investigate the process of European banking integration by using banking efficiency as an indicator for integration (Molyneux et al. 1997; Goddard et al. 2007; Brissimis et al. 2010, Fiordelisi et al. 2011; Weill 2009., Casu and Molyneux 2003.; Casu and Girardone 2010.). All these studies, however, focus on the performance of EU15

banks prior to the financial crisis. For instance, Casu and Molyneux (2003) investigate whether productive efficiency in European banking for the period 1993 and 1997 has converged to a common European frontier. Their results point to an improvement in the average efficiency scores, but the efficiency gap between the countries has widened over this period and thus conclude that there is little evidence of convergence. Weill (2009) applies the beta and sigma convergence test[2] to estimated cost efficiency scores[3] for banks from ten[4] European countries for the period 1994 to 2005. Weill (2009) finds evidence in support of convergence in cost efficiency in the EU banking. Casu and Girardone (2010), also apply the β-and σ-convergence tests to mean efficiency scores to test for the convergence in the EU15 countries during the period 1997 to 2003. The authors find evidence of convergence in bank efficiency and further argue that the introduction of the single currency has had no effect on the convergence and improvement in efficiency levels in the EU15 countries. A recent study by Matousek et al (2014) investigates the process of convergence in EU15 bank efficiency over the period 2005 to 2012 using a new approach that factors in non performing loans. The authors find no evidence of group convergence following the onslaught of the global financial crisis. Kasman et al (2013), on their part, analyse the convergence of total factor productivity within EU22 countries using the concepts of β-convergence and σ-convergence over the period 1995 to 2006 and find evidence of convergence. An overview of the studies on bank efficiency and convergence reveals a significant gap in the literature. There is a clear lack of studies that encompass banks from all the EU27 countries over a recent period of time that includes the financial crisis. We aim to address both lacunas in our paper with an

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[2] The β-convergence is drawn from the growth literature and models the "catch-up effects" by regressing the growth rate of a variable on the initial level while σ-convergence looks at the dispersion of the cross-section. Convergence is evident is the dispersion decreases over time. See Rughoo and Sarantis (2012) for a comparison of this methodology with the Phillips and Sul method.
[3] Estimated through the stochastic frontier approach
[4] Austria, Belgium, Denmark, France, Germany, Italy, Luxembourg, Portugal, Spain, UK

extensive analysis of bank productivity across EU27 banks and the application of robust methodologies.

3.2 Bank Performance with Undesirable Outputs: Methodological concepts

Despite the fact that NPLs are important determinants affecting bank performance, except for the study by Matousek et al (2014), there is a lack of studies that integrate and examine the role of NPLs on the overall bank efficiency and performance.

Assaf et al. (2013) show that NPLs have to be incorporated in the production process otherwise the results are biased. For example, when a standard estimation of bank performance is considered, i.e. without including NPLs directly in the model, then a high performance bank is not necessarily better than other banks, as it might be doing that at the expense of producing a high percentage of undesirable outputs. Thus, a production process must be clearly defined based on both desirable and undesirable outputs; using only desirable outputs will fail to credit a bank for its effort to reduce undesirable outputs (Fernandez et al. 2002).

There has been an expansion of methodological approaches to empirical research on performance measurement models with undesirable outputs. Most of these studies have been published in the field of environmental and energy research Färe and Grosskopf (2010), Färe et al.(2005), Zhou et al. (2006) among others. Färe and Lovell (1978) argue that to measure technical efficiency relative to an isoquant rather than to an efficient subset can lead to the identification of a unit as being technically efficient when it is not. Even recent studies show that non-radial efficiency measures have a higher discriminating power in evaluating the efficiencies of DMUs, for example, Fukuyama and Weber (2009), Chen at al. (2011) and Barros et al. (2012) among others.

However, research studies that estimate bank performance do not include in their models undesirable output (NPLs) as a part of the production process. NPLs are considered as a control variable in the specified efficiency function see, for example, Mester (1996), Berger and Mester (1997) among others. Alternatively NPLs measure management behaviour through bad luck or bad management hypotheses introduced by Berger and De Young (1997), Williams (2004).

In the seminal paper, Berg et al. (1992) propose to incorporate the quality of bank assets directly into the model. They measure bank productivity of the Norwegian banking sector by applying Malmquist index. The quality of loan evaluations is measured through loan losses that are used as an additional output in the model. This type of research has only recently been extended by Park and Weber (2006), who reopened the debate on NPLs and their inclusion in the production process. Park and Weber (2006) treats NPLs as an undesirable output for measuring bank efficiency and productivity of the Korean banks for the period 1992–2002. NPLs are an undesirable by-product output arising from the production of loans. The methodological approach is based on the directional technology distance function and allows to controls for loan losses that are an undesirable by-product arising from the production of loans. Fukuyama and Weber (2008) then investigate efficiency and shadow prices for NPLs within the Japanese commercial banks during the period 2002-2004. They concluded that NPLs should not be ignored in the efficiency analysis of Japanese banks. Barros et al. (2012) show that the implementation of NPLs into the efficiency model provides bank managers and regulators an additional dimension in their decision process since they affect bank efficiency. The most recent study by Assaf et al (2013) confirms this point.

It is evident that the performance of European banks has been extensively analysed from different perspectives. However, none of these studies, except for one, account directly in

their model for an undesirable output, i.e., NPLs. In addition, our study provides a unique analysis of the individual factors of the production process and the final outputs. Thus, we attempt to open the black-box of bank performance by singling out the contribution of the individual production factors and final outputs. Last but not least, we use a dataset that enables us to examine the recent trend in the European banking system.

4. Methodology

This study measures allocative efficiency of input resources and productivity change in the European banking sector. In productivity change estimation, we decompose TFP by contribution ratios of each input/output. Additionally, we apply the convergence test to clarify the time trend.

   We apply two non-parametric productive efficiency estimation methods, the data envelopment analysis (DEA) and weighted Russell directional distance model (WRDDM). We apply DEA to evaluate input resource allocative efficiency, and WRDDM to measure TFP and contribution ratios of each input/output factors. Both nonparametric approaches propose a measure based on linear programing form, and hence possess the attractive advantages of easy computation and easy extension with the inclusion of additional undesirable outputs into the programming problems. Our main objective is to understand the differences in input resource allocation efficiency and TFP between old and new countries. We also focus on the impact of the changes of individual input/output on bank productivity by considering contribution ratio. This is a novel approach, which has not been hitherto applied, in contemporary research on bank efficiency and productivity.

4.1 Data envelopment analysis (DEA)

4.1.1. Technical efficiency of input resource use

Many productivity evaluation techniques are based on the frontier efficiency concept originally proposed by Farrell (1957): to evaluate inefficiency by specifying the production frontier with the best performing observations, and measuring the distance of inefficient samples from the frontier. DEA approach was developed by Charnes et al. (1978), where nonparametric linear programming techniques are applied.

Let $x \in \Re_+^L, b \in \Re_+^R, y \in \Re_+^M$ be vectors of inputs, undesirable output, and desirable output, respectively, and then define the production technology as:

$$P(x) = \{(x, y, b): x \ can \ produce \ (y, b)\}. \tag{1}$$

We assume that the good and bad outputs are null joint; a production unit cannot produce desirable output without producing undesirable outputs (Shephard *et al.*, 1974):

$$(y, b) \in P(x); \ b = 0 \Rightarrow y = 0. \tag{2}$$

Weak disposability can be mathematically expressed as below (Färe *et al.*, 1989):

$$(y, b) \in P(x) \text{ and } 0 \leq \beta \leq 1 \Rightarrow (\beta y, \beta b) \in P(x). \tag{3}$$

Under the null-joint hypothesis and weak disposability, this DEA can be computed technical efficiency (TE) of input resource use for country *k* by solving the following optimization problem:

$$TE_k = Minimize \ \beta_k, \tag{4}$$

$$\text{s.t.} \quad \sum_{i=1}^{N} \lambda_i x_i^l \leq \beta_k x_k^l \qquad l = 1, \cdots, L, \tag{5}$$

$$\sum_{i=1}^{N} \lambda_i y_i^m \geq y_k^m \qquad m = 1, \cdots, M, \tag{6}$$

$$\sum_{i=1}^{N} \lambda_i b_i^r = b_k^r \qquad r = 1, \cdots, R, \tag{7}$$

$$\lambda_i \geq 0 \qquad\qquad (i = 1, \cdots, N), \tag{8}$$

where *l*, *m*, *r* represent types of input, desirable output, and undesirable output, respectively. *x* is an input matrix with dimensions $L \times N$, *y* is a desirable-output matrix with dimensions $M \times N$, and *b* is an undesirable-output matrix with dimensions $R \times N$. β_k is the technical efficiency score of the firm *k* which is defined from zero to one, and λ_i is the weight variable. To estimate the technical efficiency score of all firms, the model needs to be applied independently to each of the *N* firms.

4.1.2. Cost and allocative efficiency of input resource use

In previous section, technical efficiency is defined by each input and each output ratio. However, decision maker of bank focus on total input cost efficiency to evaluate their financial performance, especially balance of the input resource. In this case, an objective efficiency score is needed to consider the balance of multiple input resources.

According to Coelli et.al. (2002), cost efficiency and allocative efficiency can be estimated by DEA. The cost efficiency evaluates how much total input cost can be decreased without decreasing desirable output. To estimate cost efficiency, following cost minimization program is needed to calculate. Cost minimization program of country *k* can be described as follows.

$$Minimize \ \sum_{l=1}^{L} \left\{ p_k^l x_k^{*l} \right\} \tag{9}$$

$$\text{s.t.} \quad \sum_{i=1}^{N} \lambda_i x_i^l \leq x_k^{*l} \qquad l = 1, \cdots, L, \tag{10}$$

$$\sum_{i=1}^{N} \lambda_i y_i^m \geq y_k^m \qquad m = 1, \cdots, M, \tag{11}$$

$$\sum_{i=1}^{N} \lambda_i b_i^r = b_k^r \qquad r = 1, \cdots, R, \tag{12}$$

$$\lambda_i \geq 0 \qquad (i = 1, \cdots, N), \tag{13}$$

where p is an input price matrix with dimensions $L \times N$, x^* is optimal input amount to minimize total input cost. *Cost efficiency* (CE) *can be defined as equation (14) by using result of cost minimization program. CE is calculated by minimized total input cost divided by actual total input cost.*

$$CE = \sum_{l=1}^{L} p_k^l x_k^{*l} \bigg/ \sum_{l=1}^{L} p_k^l x_k^l \tag{14}$$

By using technical efficiency (TE) and cost efficiency (CE), we can estimate allocative efficiency(AE). Allocative efficiency evaluates the allocation of input resources and described by equation (15). The score of AE is defined from zero to one, and AE equal one represent input resource allocation is efficient. AE<1 represents that input resource allocation is inefficient.

$$AE = CE / TE \tag{15}$$

4.2 Weighted Russell Directional Distance Model (WRDDM)

The WRDDM seeking to increase the desirable outputs and decrease the undesirable outputs and inputs directionally can be defined by the following:

$$\vec{D}(x, y, b|g) = \sup\{\beta : (x + \beta g, y + \beta g, b + \beta g) \in P(x)\} \tag{16}$$

Where the vector $g = (-g_x, g_y, -g_b)$ determines the directions in which inputs, desirable outputs, and undesirable outputs are scaled. The WRDDM for inefficiency calculation of firm$k$ can be described as follows:

$$\vec{D}(x, y, b|g) = maximize \left(\frac{1}{N} \sum_{n=1}^{N} \beta_n^k + \frac{1}{M} \sum_{m=1}^{M} \beta_m^k + \frac{1}{L} \sum_{l=1}^{L} \beta_l^k \right) \tag{17}$$

subject to

$$\sum_{j=1}^{J} z_k y_{mj} \geq y_{mk} + \beta_m^k g_{ymk} \tag{18}$$

$$\sum_{j=1}^{J} z_k b_{lj} = b_{lk} + \beta_l^k g_{blk} \tag{19}$$

$$\sum_{j=1}^{J} z_k x_{nj} \leq x_{nk} + \beta_n^k g_{xnk} \tag{20}$$

$$Z_j \geq 0, \ \ j = 1, 2, \cdots, k, \cdots, J \tag{21}$$

where β_m^k, β_l^k, and β_n^k are the individual inefficiency measures for desirable outputs, undesirable outputs, and inputs, respectively. Z_k is the intensity variable to shrink or expand the individual observed activities of firm k for the purpose of constructing convex combinations of the observed inputs and outputs. To estimate productivity change indicators, we set directional vector$g = \left(-g_{xnk}, g_{ymk}, -g_{blk} \right) = (-x_{nk}, y_{mk}, -b_{lk})$;, the WRDDM is shown as follows:

$$\vec{D}(x_k, y_k, b_k|g) = maximize \left(\frac{1}{N} \sum_{n=1}^{N} \beta_n^k + \frac{1}{M} \sum_{m=1}^{M} \beta_m^k + \frac{1}{L} \sum_{l=1}^{L} \beta_l^k \right) \tag{22}$$

subject to

$$\sum_{j=1}^{J} z_k y_{mj} \geq y_{mk}(1 + \beta_m^k) \tag{23}$$

$$\sum_{j=1}^{J} z_k b_{lj} = b_{lk}(1 - \beta_l^k) \tag{24}$$

$$\sum_{j=1}^{J} z_k x_{nj} \leq x_{nk}(1 - \beta_n^k) \tag{25}$$

$$Z_j \geq 0, \quad j = 1,2,\cdots,k,\cdots,J \tag{26}$$

This type of directional vector assumes that an inefficient firm can decrease productive inefficiency while increasing desirable outputs and decreasing undesirable outputs and/or inputs in proportion to the initial combination of actual inputs and outputs.

One of the strong points of the WRDDM is that it is able to determine each variable's contribution effect for inefficiency. This contribution effect cannot be determined in conventional productive inefficiency analysis. The contribution effects enable us to discuss how and why each firms successfully decreased its productive inefficiency.

According to Fujii et.al. (2014), total factor productivity (TFP) change and contribution ratio of each input/output factor can be estimated by using inefficiency score of WRDDM. We employ the *Luenberger Productivity Indicator* as a TFP measure because the *Luenberger Productivity Indicator* is believed to be more robust than the widely used *Malmquist Index* (Chambers *et al.*, 1998). Change in the *Luenberger Productivity Indicator* (TFP) is further decomposed into technical change and efficiency change. TFP is computed with the results of the WRDDM and derived as follows:

$$\text{TFP}_t^{t+1} = \frac{1}{2}\{\vec{D}^{t+1}(x_k^t, y_k^t, b_k^t) - \vec{D}^{t+1}(x_k^{t+1}, y_k^{t+1}, b_k^{t+1}) + \vec{D}^t(x_k^t, y_k^t, b_k^t) - \vec{D}^t(x_k^{t+1}, y_k^{t+1}, b_k^{t+1})\} \tag{27}$$

$$\text{TECHCH}_t^{t+1} = \frac{1}{2}\{\vec{D}^{t+1}(x_k^t, y_k^t, b_k^t) + \vec{D}^{t+1}(x_k^{t+1}, y_k^{t+1}, b_k^{t+1}) - \vec{D}^t(x_k^t, y_k^t, b_k^t) - \vec{D}^t(x_k^{t+1}, y_k^{t+1}, b_k^{t+1})\} \tag{28}$$

$$\text{EFFCH}_t^{t+1} = \vec{D}^t(x_k^t, y_k^t, b_k^t) - \vec{D}^{t+1}(x_k^{t+1}, y_k^{t+1}, b_k^{t+1}) \tag{29}$$

$$\text{TFP}_t^{t+1} = \text{TECHCH}_t^{t+1} + \text{EFFCH}_t^{t+1} \tag{30}$$

where x_t represents the input for year t, x_{t+1} is the input for year t+1, y_t is the desirable output for year t, and y_{t+1} is the desirable output for year t+1. b_t is the undesirable output for year t, and b_{t+1} is the undesirable output for year t+1. $\vec{D}^t(x_k^t, y_k^t, b_k^t)$ is the inefficiency score of year t based on the frontier curve in year t. Similarly, $\vec{D}^{t+1}(x_k^t, y_k^t, b_k^t)$ is the inefficiency of year t based on the frontier curve in year t+1. The TFP score indicates the productivity change as compared to the benchmark year. The TFP includes all categories of productivity change, which can be broken down into Technical Change (TECHCH) and Efficiency Change (EFFCH) as equation (30).

Here, we decompose TFP using the inefficiency score of input, desirable output, and undesirable output variables' contribution effect for inefficiency. The detailed decomposition of TFP is discussed in Appendix 1.

$$TFP_t^{t+1} = TFP_{t,x}^{t+1} + TFP_{t,y}^{t+1} + TFP_{t,b}^{t+1}$$

$$TECHCH_t^{t+1} = TECHCH_{t,x}^{t+1} + TECHCH_{t,y}^{t+1} + TECHCH_{t,b}^{t+1}$$

$$EFFCH_t^{t+1} = EFFCH_{t,x}^{t+1} + EFFCH_{t,y}^{t+1} + EFFCH_{t,b}^{t+1}$$

$TFP_{t,x}^{t+1}$ represents a contribution effect of input variables for TFP change. $TFP_{t,y}^{t+1}$ represents a contribution effect of desirable output variables for TFP change. $TFP_{t,b}^{t+1}$ represents a contribution effect of undesirable output variables for TFP change.

4.3   Convergence in productivity change

We employ the dynamic panel method Phillips and Sul (2007) convergence methodology to test for convergence in the estimated total factor productivity, efficiency change and in the inefficiency of 3 individual inputs, namely personal expenses, total fixed assets and total deposits. We consider all the banks in our sample of EU27 banks as well as, separately, banks from the EU15 countries and from the new EU countries respectively. This approach has the

benefit of testing for convergence within a heterogeneous setup that allows for a wide range of possible time paths. As such, the model incorporates both a common and individual specific components and is formulated as a nonlinear time varying factor model as follows:

$X_{it} = \delta_{it}\mu_t$ for all i and t,

$$(31)$$

Where μ_t is a single common component and δ_{it} is a time varying idiosyncratic element. δ_{it} measures the idiosyncratic distance between the common trend component μ_t and the systematic part of X_{it}.

The time varying behaviour of δ_{it} is modelled in semiparametric form as

$\delta_{it} = \delta_i + \sigma_i\xi_{it}L(t)^{-1}t^{-\alpha}$ 　　　　　　　　　(32)

Where δ_i is fixed, ξ_{it} is iid (0,1) across i but weakly dependent over t, and L(t) is a slowly varying function for which L(t) $\rightarrow \infty\ as\ t \rightarrow \infty$. This model ensures that δ_{it} converges to δ_i for all $\alpha \geq 0$.

 To test whether the components of δ_{it} are converging, Phillips and Sul (2007) define the transition coefficient as h_{it} and information about δ_{it} can be extracted as follows:

$$h_{it} = \frac{X_{it}}{\frac{1}{N}\sum_{i=1}^{N} X_{it}} = \frac{\delta_{it}\mu_{it}}{\frac{1}{N}\sum_{i=1}^{N} \delta_{it}\mu_{it}} = \frac{\delta_{it}}{\frac{1}{N}\sum_{i=1}^{N} \delta_{it}} \qquad (33)$$

The *relative transition parameter h_{it}* measures δ_{it} in relation to the panel average at time *t* and describes the transition path for variable *i* relative to the panel average. Moreover, the convergence process can be graphically illustrated by plotting the transition parameter for each variable over time.

Phillips and Sul (2007) propose a regression based 'logt' test[5] of the null hypothesis of convergence:

$H_0 : \delta_i = \delta$ and $\alpha \geq 0$

Against the alternative $H_1 : \delta_i \neq \delta$ for all i or $\alpha < 0$

Phillips and Sul's (2007) procedure involves construction the cross sectional variance $\dfrac{H_1}{H_t}$

where

$$H_t = \frac{1}{N} \sum_{i=1}^{N} (\hat{h}_{it} - 1)^2 \tag{34}$$

Then, the following OLS regression is performed:

$$\text{Log} \frac{H_1}{H_t} - 2\log(logt) = a + \gamma \log t + u_t, \text{ for t} = T_0, \ldots\ldots, T$$

Where L(t) = log(t+1) and the fitted coefficient of log t is $\gamma = 2\hat{\alpha}$, where $\hat{\alpha}$ is the estimate of α in H_0. The test statistic t_λ is normally distributed and hence at the 5% level, the null hypothesis of convergence is rejected if $t_\lambda < $-1.65. γ measures the speed and magnitude of convergence.

5. Data and Empirical results

The dataset used in this study was obtained from BankScope. The data comprises the inputs and outputs variables for the period 2005 to 2011. All data were deflated to 2010 prices. We construct aggregate efficiency and bank productivity measures. Banks are assumed to produce three outputs: other earning assets, customer loans and bad loans by using three inputs: labour, deposits and premises.

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[55] See Phillips and Sul (2007, 2009) for a detailed explanation and Rughoo and Sarantis (2014) and Matousek et al. (2014), for an application.

There are several approaches to modelling the bank production process. The standard methods are the intermediation and production approaches. Under the intermediation approach, banks use purchased funds together with physical inputs to produce various assets (measured by their value). According to the production approach, banks use only physical inputs such as labour and capital to produce deposits and various assets (measured by the number of deposit and loan accounts at a bank, or the by the number of transactions for each product). We adopt the intermediation approach to model bank production and consider banks to be intermediaries of financial services that purchase input in order to generate earning assets (Sealey and Lindley, 1977). Berger and Humphrey (1997) suggest the intermediation approach is best suited for evaluating bank efficiency, whereas the production approach is appropriate for evaluating the efficiency of bank branches.

We present our results in two parts. First, we report results for bank inefficiency and its components. The second part then focuses on the detailed analysis of productivity growth and its drivers.

5.1. Bank Efficiency

We report AE and TE under the assumption of VRS and CRS. Next we try to discern between the efficiency levels of new and old EU countries. From Figure 1, it is evident that bank efficiency scores in new EU countries are still bellow bank efficiency scores in old EU countries.

In Table 1, we report results for technical efficiency, allocative efficiency and cost efficiency under the assumption of constant return to scale (CRS) and variable return to scale ((VRS). We list the average efficiency levels for the individual countries. The highest efficiency scores are achieved on the average in Germany and Netherlands. The lowest then

in Estonia although the results can be biased by having only two banks in the sample. Bank efficiency in France is also surprisingly low. On the other hand the score for technical efficiency are more homogenous across the individual countries. We report also cost efficiency in the last two columns in Table 1.

<Insert Table 1>

The efficiency scores are very volatile across the countries and the banks from new EU countries show the lowest efficiency levels. In Table 2, we provide a comparison bank efficiency levels in old and new EU countries. It is evident that new EU banks are on the average less efficient than banks from old EU countries.

<Insert Table 2>

Next, I Table 3 we list bank efficiency scores over the observed time period. We see that the global financial crisis had a negative impact on bank efficiency. We may trace up that the efficiency levels started dropping in 2009-2010. These results are in line with our expectations.

<Insert Table 3>

Furthermore, our methodological approach allows us to open the black-box and examine the individual drivers behind bank inefficiency. In Table 4, we report the inefficiency levels of individual inputs/outputs. We see that the inefficiency scores for deposits are very low over the observed period. The inefficiency score of other input –

personal expenses - has gradually increased with a peak level of 44.7% in 2008. This was then followed by a decrease in efficiency in 2010 and 2011. This can be seen as a positive sign that indicates the successful implementation of bank restructuring policies. As for physical capital the inefficiency levels remain relatively high that means that banks did not utilize their physical capital in more efficient ways.

On the other hand, the inefficiency levels of individual outputs are rather high but customer loans. This is particularly evident for the categories of other earning assets (OEA) and NPLs. The contribution of NPLs on bank inefficiency is also quite volatile. The inefficiency levels of NPLs have however improved in 2010 -2011. This deterioration corresponds with the current situation in the European Banking sector when NPLs become a problem particularly for a large number of commercial banks. Our results further indicate that banks have a large scope for an improvement by expanding their business activities in the segment of OEA. The estimated inefficiency levels for OEA remain very high. This might be improved by a further deregulation process that would allow bank to be involved also in other business activities apart from providing standard lending.

<Insert Table 4>

The second part of the Table 4 displays the results for banks from old EU countries and the last part of Table 4 then summarises the results for new EU countries. We examine whether the average inefficiency scores are statistically different among the three analysed group of banks. We apply the Kruskal-Wallis test that is a general alternative nonparametric method of two-sample t-test. Based on the results of the test we reject the null hypothesis of equal inefficiency across these two groups of banks. The results of show that inefficiency scores are statistically different across the bank groups.

5.2 Convergence

The convergence results on efficiency and productivity are very revealing (see Table 5). For the whole sample of 147 banks from the EU27 countries, we find weak convergence for TFP and efficiency change. However, there is evidence of strong convergence for technical change (γ =3.41). For the sample of banks from the old EU countries, we obtain weak convergence for TFP (γ =-4.75), slow convergence for technical change (γ =0.85) and no convergence for efficiency change. For the new EU countries, there is weak convergence for both TFP and efficiency change but very strong convergence for technical change (γ =4.44). The results clearly suggest that the convergence in EU 27 in technical change is being predominantly driven by the new EU countries. These results tally with those of Kasman et al (2013)[6] who find evidence of convergence among the 22 EU member countries plus 3 candidate countries over an earlier period; 1995-2006.

<Insert Table 5>

The convergence results on the inefficiency scores (see Table 6) for the individual inputs show that across the EU27 banks, there is no evidence of convergence for personal expenses (x1), and total fixed assets (x2) while we find weak convergence for total deposits (x3) (γ =-0.07). When we split the sample into banks from the old EU and from the new EU, the picture changes slightly. For the banks from the EU15 countries, slow convergence is detected only for total deposits (x3) while for the banks from the new EU countries, we find evidence of slow convergence for both total fixed assets (γ =-0.66) and for total deposits (γ =-0.06).

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[6] Kasman et al (2013) apply a different convergence methodology (the beta and sigma convergence method) and do not split their sample between the old and new EU member countries.

<Insert Table 6>

We also plot the transition paths, for 1) TFP, efficiency change and technical change and 2) the individual inputs[7] i.e x1, and x2, for the banks from the EU15 and new EU countries. Each transition path illustrates the behaviour of the transition coefficients vis-à-vis the panel average for each variable over the time period 2005-2010. Convergence is detected if the transition paths move asymptotically towards one. This procedure is insightful as it provides a visual image of the convergence or divergence process underway and also allows inferences to be drawn with regards to each variable's transition path.

Figure 3 illustrates the paths of the transition parameters for TFP, efficiency change and technical change and we find that their trajectories underpin the log$t$ results. Overall, we can observe that the path for technical change exhibits strong convergence behaviour as it moves close to the cross-section average. The other striking observation is the clear divergence observed in the paths for TFP for both EU15 and new EU countries around the period 2009. We attribute this bulge to the severe impact of the global financial crisis.

<Insert Figure 3>

Figure 4 illustrates the paths for the inefficiency scores for the individual inputs. The interesting observation is that the paths for both the EU15 and new EU countries start away from the cross-section average, to then start clustering from 2006. However, the paths diverge again past 2009. Again, the impact of the crisis seems evident.

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[7] We omit the variable total deposits, x3, due to the values being close to 0.

<Insert Figure 4>

6. Conclusions

The aim of this paper is to conduct a thorough empirical investigation of the convergence process in European retail banking sector by analysing banking efficiency across the EU27 countries for the period 2005 to 2011. An important contribution of this paper is the construction of three types of banking efficiency scores for all members of the European Union and the application of the Phillips and Sul (2007) convergence methodology, which detects the presence of convergence and provides an estimate of the speed of convergence.

We may summarise our results and contributions as follows: Firstly, we show that bank efficiency has been undermined by the financial crisis in both groups, i.e new and old EU countries. Secondly, we find that the EU banking sector as a whole diverges across the EU countries. We observe some indications of the improvement in 2011 but we cannot confirm if this is an occasional event or trend. Therefore, further examinations are needed to confirm it. Thirdly, we argue that NPLs reduce bank efficiency and this issue has to be addressed by the EU Banks. This result is most probably due to the impact of the global financial crisis. The results show that EU banks have to continue in their restructuring policy in order to fully recover and improve their efficiency. We find that the inefficiency levels are significantly different among banks from old and new EU countries. In particular, management of labour forces, premises, other earning assets, and non-performing loans needs to be improved.

We extend the literature on European banking integration by not only testing for convergence in productivity and efficiency of European banks but by taking it a step further by investigating the convergence in banks' individual output. The use of the Phillips and Sul

(2007) regression-based test is a major contribution of this paper as this methodology not only detects the presence and degree of integration but also provides an estimate of the speed of convergence. It also provides a visual depiction of the integration process. Overall, the convergence results point to convergence in total factor productivity, which is clearly driven by strong technical change convergence from the new EU countries' banks. Convergence in the inefficiency of individual inputs is rather weak or non-existent. These results are underpinned by the divergent behaviour of the transition paths, especially post 2009.

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Table 1 Efficiency scores with bad outputs

			Allocative efficiency		Technical efficiency			Cost efficiency	
		dummy	# of bank	AEcrs	AEvrs	TEcrs	TEvrs	Scale efficiency	CEcrs	CEvrs
old	GERMANY	old	9	0.802	0.869	0.839	0.869	0.969	0.690	0.777
old	UNITED KINGDOM	old	23	0.657	0.767	0.835	0.900	0.932	0.564	0.713
old	FRANCE	old	41	0.563	0.615	0.842	0.876	0.962	0.477	0.548
old	SPAIN	old	14	0.763	0.788	0.855	0.897	0.956	0.665	0.722
old	NETHERLANDS	old	8	0.804	0.829	0.875	0.926	0.946	0.702	0.771
old	ITALY	old	36	0.593	0.609	0.855	0.891	0.961	0.507	0.545
old	SWEDEN	old	4	0.626	0.740	0.915	0.924	0.990	0.596	0.716
old	DENMARK	old	4	0.752	0.791	0.937	0.950	0.986	0.720	0.769
old	BELGIUM	old	4	0.867	0.887	0.873	0.900	0.970	0.763	0.806
old	FINLAND	old	2	0.856	0.907	0.955	0.969	0.985	0.817	0.880
old	AUSTRIA	old	7	0.809	0.796	0.839	0.877	0.956	0.685	0.702
old	IRELAND	old	4	0.846	0.868	0.911	0.932	0.978	0.788	0.828
old	GREECE	old	10	0.700	0.713	0.786	0.841	0.937	0.550	0.604
old	PORTUGAL	old	9	0.783	0.783	0.834	0.864	0.967	0.669	0.692
old	LUXEMBOURG	old	4	0.816	0.825	0.824	0.848	0.974	0.707	0.736
New	CZECH REPUBLIC	New	10	0.775	0.803	0.862	0.876	0.985	0.682	0.719
New	CYPRUS	New	4	0.672	0.727	0.747	0.794	0.947	0.513	0.600
New	POLAND	New	10	0.683	0.680	0.821	0.848	0.969	0.568	0.585
New	HUNGARY	New	5	0.749	0.735	0.759	0.805	0.946	0.575	0.599
New	ROMANIA	New	11	0.656	0.659	0.634	0.669	0.949	0.421	0.444
New	SLOVENIA	New	11	0.717	0.718	0.814	0.830	0.981	0.586	0.600
New	SLOVAKIA	New	7	0.569	0.585	0.782	0.800	0.979	0.452	0.478
New	LITHUANIA	New	7	0.692	0.710	0.784	0.811	0.968	0.552	0.584
New	MALTA	New	1	0.724	0.723	0.799	0.803	0.995	0.579	0.582
New	LATVIA	New	12	0.628	0.678	0.800	0.837	0.958	0.514	0.581
New	ESTONIA	New	2	0.504	0.849	0.934	0.992	0.942	0.479	0.843
New	BULGARIA	New	6	0.597	0.630	0.704	0.724	0.978	0.435	0.470

Table 2 Average Efficiency Levels with bad ouptuts

	dummy	# of bank	AEcrs	AEvrs	TEcrs	TEvrs	Scale efficiency	CEcrs	CEvrs
Old countries	old	179	0.676	0.716	0.849	0.888	0.958	0.582	0.649
New countries	New	86	0.672	0.697	0.779	0.807	0.967	0.533	0.574

Table 3 Average scores for individual years

		Allocative efficiency		Technical efficiency			Cost efficiency	
	# of bank	AEcrs	AEvrs	TEcrs	TEvrs	Scale efficiency	CEcrs	CEvrs
2005	173	0.687	0.715	0.867	0.894	0.971	0.600	0.647
2006	219	0.728	0.740	0.820	0.862	0.951	0.604	0.648
2007	245	0.745	0.772	0.866	0.886	0.978	0.650	0.693
2008	258	0.747	0.773	0.868	0.897	0.968	0.651	0.699
2009	255	0.675	0.714	0.847	0.875	0.969	0.572	0.630
2010	251	0.612	0.667	0.824	0.866	0.953	0.505	0.584
2011	242	0.607	0.673	0.827	0.858	0.966	0.503	0.585

Table 4. Disaggregated Inefficiency levels

All		Total inefficiency		personal expenses		total fixed assets		total deposits		Non-performing loan		Customer loan		Other earning assets
	# of bank	Total		x1		x2		x3		b1		y1		y2		
2005	173	0.347		0.397		0.436		0.003		0.604		0.017		0.297		
2006	219	0.897		0.325		0.439		0.002		0.568		0.019		3.718		
2007	245	0.470		0.327		0.503		0.001		0.590		0.004		1.083		
2008	258	0.664		0.447		0.493		0.000		0.638		0.005		2.075		
2009	255	0.498		0.443		0.455		0.000		0.635		0.010		1.111		
2010	251	0.494		0.324		0.466		0.001		0.538		0.011		1.353		
2011	242	0.590		0.379		0.561		0.002		0.524		0.022		1.843		

Old		Total inefficiency		personal expenses		total fixed assets		total deposits		Non-performing loan		Customer loan		Other earning assets
	# of bank	Total		x1		x2		x3		b1		y1		y2		
2005	124	0.303		0.360		0.355		0.004		0.542		0.009		0.243		
2006	152	0.321		0.318		0.378		0.003		0.518		0.005		0.420		
2007	167	0.331		0.303		0.458		0.001		0.550		0.002		0.377		
2008	177	0.408		0.433		0.442		0.000		0.597		0.007		0.665		
2009	173	0.404		0.433		0.415		0.000		0.573		0.001		0.710		
2010	169	0.399		0.337		0.388		0.001		0.478		0.007		0.945		
2011	167	0.510		0.359		0.508		0.003		0.481		0.013		1.505		

| **New** | # of bank | Total inefficiency | personal expenses | total fixed assets | total deposits | Non-performing loan | Customer loan | Other earning assets |
		Total	x1	x2	x3	b1	y1	y2
2005	49	0.458	0.493	0.643	0.000	0.762	0.035	0.434
2006	67	2.204	0.341	0.580	0.000	0.681	0.050	11.200
2007	78	0.767	0.379	0.598	0.000	0.675	0.009	2.594
2008	81	1.222	0.477	0.603	0.000	0.727	0.001	5.156
2009	82	0.698	0.463	0.541	0.000	0.767	0.030	1.958
2010	82	0.691	0.295	0.626	0.000	0.662	0.018	2.193
2011	75	0.769	0.424	0.680	0.000	0.622	0.040	2.596

Table 5: Phillips and Sul Log*t* convergence test on efficiency and productivity

Data sets	γ	t-stat		γ	t-stat		γ	t-stat
All EU27 banks			**Old EU banks**			**New EU banks**		
TFP	-7.12	-1.16	TFP	-4.75	-1.11	TFP	-4.20	-1.43
EFFCH	-5.10	-1.58	EFFCH	-5.11	-1.94*	EFFCH	-1.00	-0.90
TECHCH	3.41	1.18	TECHCH	0.85	0.40	TECHCH	4.44	2.01

Note:* Indicates rejection of the null hypothesis of convergence at the 5% significance level.

Table 6: Phillips and Sul Log*t* convergence test on inefficiency of individual inputs

Data sets	γ	t-stat		γ	t-stat		γ	t-stat
All EU27 banks			**Old EU**			**New EU banks**		
X1 -Personal expenses	-1.35	-30.21*	X1	-1.34	-30.18*	X1	-1.68	-2.71*
X2 -Total fixed assets	-1.10	-3.04*	X2	-1.22	-3.35*	X2	-0.662	-1.296
X3 - Total deposits	-0.07	-0.099	X3	-0.06	-0.087	X3	-0.06	-0.09

Note:* Indicates rejection of the null hypothesis of convergence at the 5% significance level.
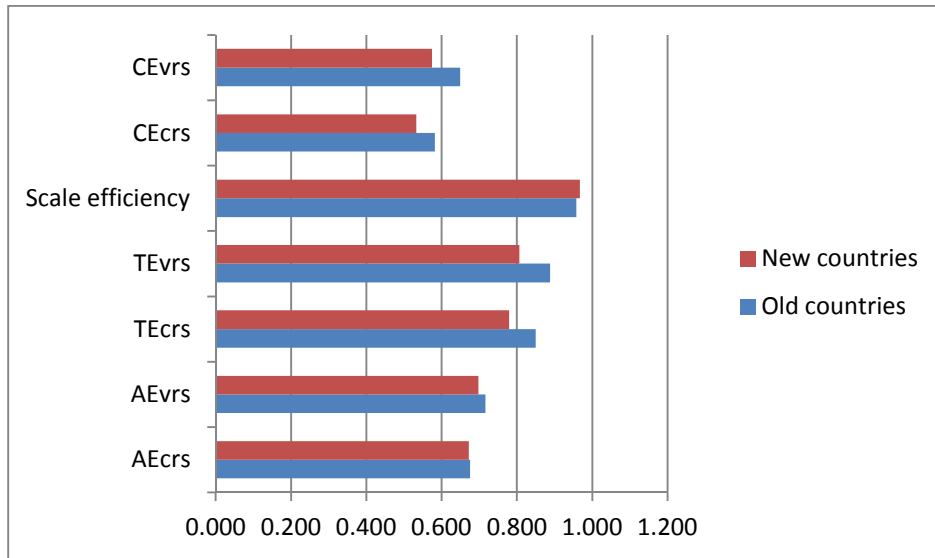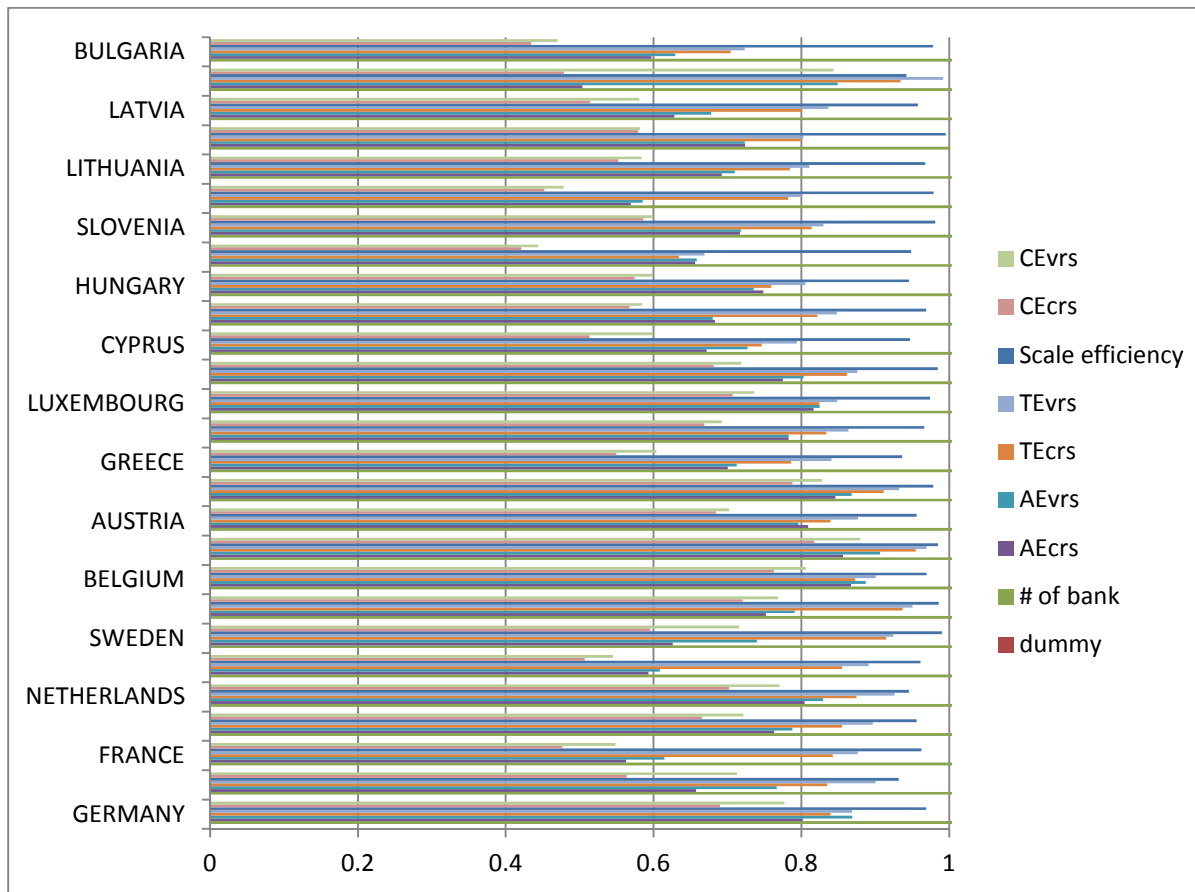
Figure 1

Figure 2

Figure 3: Transition paths for TFP and efficiency /technical change

Legend: EU15 TFP, New EU TFP, EU15 Efficiency change, New EU Efficiency change, EU15 Technical change, New EU Technical change
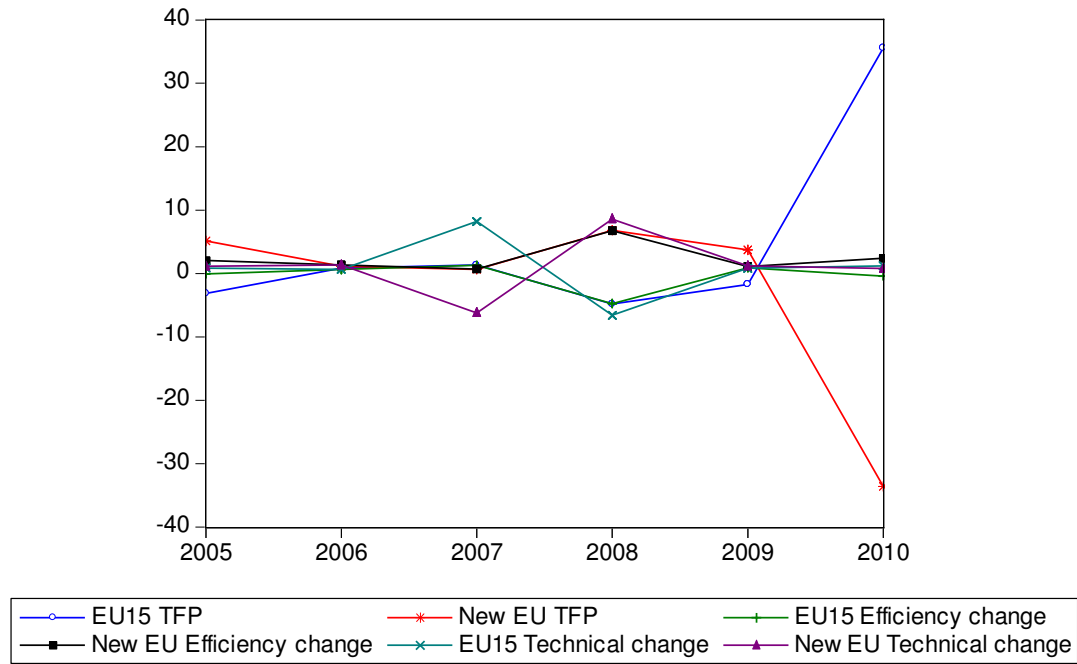
Figure 4: Transition paths for individual inputs x1, x2, x3

Legend:
- EU15 Personal expenses x1
- New EU Personal expenses x1
- EU15 Total fixed assets x2
- New EU Total fixed assets x2