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Published in:
Economic Modelling

DOI:
10.1016/j.econmod.2016.08.015

Publication date:
2017

Document Version
Peer reviewed version

Investigating bank efficiency in transition economies: A window-based weight assurance region approach

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Abstract

This paper examines the efficiency of 116 banks for 9 new EU members in Central and Eastern European (CEE) countries over the period 2004-2015. We employ the Weight Assurance Region (WAR) and we treat deposits as an intermediate variable in a two-stage data-envelopment analysis model. We then expand the WAR model by including a window-based approach to take into account the patterns of efficiency over time. The results indicate a low level of efficiency over the entire period of analysis, especially for Eastern European and Balkan countries rather than Central European countries. Overall, we find that inefficiency in CEE countries is mainly driven by the *profitability* stage rather than the *value added activity* stage.

Keywords: Banking, efficiency, transition economies, data envelopment analysis, two-stage, window analysis.

JEL codes: C61, C67, G21, P20.

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1. Introduction

In the last two decades, Central and Eastern European (CEE) countries have gone through an important liberalization and privatization process, and have adopted important structural changes that substantially reformed the banking system. This intensive restructuring period characterized by relevant regulatory changes has sparked the interest of researchers and has been the subject of several studies. Whereas the reform of the banking system takes a similar form, the speed of adoption and the effect of such changes among CEE countries was different. Overall, the results show that the regulatory changes have been beneficial for the efficiency of CEE countries. In particular, several studies demonstrate that the privatization of state-owned commercial banks and a more liberal policy towards foreign banks enhanced the efficiency of the banking system in CEE countries (Bonin et al. 2005, a,b; Fries and Taci, 2005; Hasan and Marton, 2003; Matousek and Taci, 2004; Weill, 2003).

The financing sector in the transition region has gone through important changes since the 2008-09 crisis. Prior to the crisis, the banking system played a key role in supporting the investment and growth in transaction credit. Especially cross-border capital flows covered a pivotal role in spurring the growth in emerging Europe during the 2000s. Starting in 2009, transaction countries experienced a sharper drop in the rate of the investment and a consistent deleverage process in the banking system (EBRD, 2015), which have contributed to a widening of the credit crunch of small and medium-sized enterprises (SMEs). In addition, there was a decline in net capital flows from advanced European economies and in the percentage of total assets held by foreign banks. While this has worked as an external adjustment mechanism between domestic investments and levels of domestic savings (with the last one traditionally lower than the first one), the sudden decline of financial sources has however contributed to an enlargement of the investment shortfall (there was a drop by 20 per cent of GDP since 2008, EBRD, 2015). In this context, the large overhang of NPLs has also contributed to exacerbate the drop for investments. The rise of NPLs has in fact harmed the banking lending activities, increased funding costs and overall decreased operational efficiency. Before, despite the fact that Western countries were affected more by the global financial crisis and sovereign debt, transaction countries were weakened as well[1]. Correa and Sapriza (2014) show that sovereign debt problems can be transmitted to other countries through global banks that can be either directly or indirectly exposed to countries in distress. Further, as explained by Makin and Narayan (2011), an economy's net foreign borrowing is driven not only by domestic saving and investment behaviours, but also by foreign saving and investment strategies. In general, the financial crisis has harmed banking activities from both the funding side and the lending side. In fact, banks reduced their lending activities (e.g. De Haas and Van Horen, 2013), while at the same time suffering from pressure due to the freezing of the European Interbank market and the risk of withdrawal of deposits from customers (Iyer et al., 2014). All these negative events suggest that the recent financial crisis could have exerted a negative impact on the efficiency of banks in transaction economies. This could lead to a drop of competitiveness of the banking system in these regions with a negative impact on their integration process with Western European countries as a consequence.

In this context, this paper aims to underline banks' efficiency dynamics to provide new insights on the speed and recovery process patterns in transaction economies. In

[1]http://www.ebrd.com/downloads/research/REP/regional-economic-prospects1210.pdf, 01/10/2015.

particular, we aim to examine to what extent the financial crisis affected the efficiency of banks in transaction economies. We further investigate whether and to what extent the Global Financial Crisis (GFC) slowed down the recovery after the 2008-2009 financial crisis. Finally, we provide new insights on how and to what extent the GFC affected different stages of bank production processes. Our contribution consist of providing new insights of how and to what extent the financial crisis affected the different stages of production of banking activities. In this way, we can better investigate the source of transmission of inefficiency in the banking system during the financial crisis. This issue is of great concern to policy makers who need to assess and monitor the stability and competitiveness of the European banking system in order to intervene with prompt, corrective actions. In particular, we contribute to the existing literature on efficiency in transactions countries in different way. First, while previous papers have in fact examined the banks' efficiency of the whole process in transaction economies before the financial crisis (e.g. Brissimis et al., 2008; Delis et al., 2011; Havrylchyk, 2006; Koutsomanoli-Filippaki et al., 2009; Yildirim and Philippatos, 2007), we provide novel evidence on how and to what extent the GFC affected banks in these countries. Second, we use a two-stage DEA model that treats deposits as an intermediate variable in a two-stage DEA model (Fukuyama and Matousek, 2011; Fukuyama and Weber, 2010; Holod and Lewis, 2011). From an empirical viewpoint, this allows us to disentangle the production process of a bank into separate stages by focusing on the lending and funding activities. This is important given the changes that occurred in the period of analysis. The boost of credit supply from the banking sector, drop of loans to deposits by 120% in 2008 (EBRD, 2015), and limited expansion of the domestic deposit base could have indeed affected both the lending and funding side.

In particular, we make use of the Weight Assurance Region (WAR) model, recently developed by Halkos et al. (2015). This new framework combines the two-stage data envelopment analysis (DEA) model introduced by Chen et al. (2009) and the assurance region approach proposed by Thompson et al. (1990). The additive two-stage DEA model of Chen et al. (2009) calculates the contribution of each stage inside the model, in order to avoid any bias. However, Halkos et al. (2015) notified an extreme case where the contribution of one stage is zero. As explained by Thanassoulis et al. (2004) this may not be reasonable. Halkos et al. (2015) proposed the weight assurance region (WAR) model to overcome this problem. In addition, the WAR model allows for the incorporating *a priori* value judgements into the model, such as known information and/or widely accepted beliefs or preferences, and other types of information as described by Thanassoulis et al. (2004). The WAR model is an advancement of the original additive two-stage DEA model which can be considered as a special case of the WAR model with no additional information. We adapt this model to the banking case. The advantage of this model is twofold. Primarily, in the presence of *a priori* information or prior assumptions, the model allows the incorporation of assurance region-based weights regarding the contribution of each stage to the overall process. Further, this model has the advantage of being flexible and solves the infeasibility problem of the original additive model. Secondly, the paper extends the WAR model by including the dimension of time through a window-analysis approach. This allows us to include the effects of macroeconomic and structural changes in our measures of inefficiencies.

The paper presents the following structure: Section 2 briefly discuss the main changes in the CEE banking system and recent economic trend; Section 3 presents the deposit dilemma and the two-stage DEA models; Section 4 provides the framework and the mathematical formulation of the model; Section 5 discusses the results; finally, Section 6 concludes the paper.

2. The CEE banking system and recent economic trend

Starting from the early 1990s, the majority of CEE countries have dismantled the mono-bank structure and moved to a two-tiered banking system by separating the policy-oriented activities of the central bank authorities from business-oriented activities of commercial banks. The majority of CEE countries also allowed for the privatization of state-owned banks and opened up the frontier to new players, either private banks or foreign banking institutions. However, at the beginning of the transaction period, all CEE countries experienced a period of instability and underwent a crisis period. Both a liberal licensing policy and low minimum capital requirements allowed a high number of new domestic commercial banks to enter the markets. These new players, however, started to engage in harsh price competition with state-owned banks and aggressive lending strategies (Matousek and Sarantis, 2009). This attitude was supported by weaknesses in the legal prudential system. In this context, several of these new commercial banks, in general small in size, were forced to exit the market or to merge with other banks (Bonin and Wachtel, 2002). At the same time, state-owned banks suffered consistent losses due to bad loans. As pointed out by Koutsomanoli-Filippaki et al. (2009), such a phenomenon was intensified by bad management, and inadequate banking skills and systems to properly assess credit risks. These unsound practices, combined with structural reforms not efficiently supported by a solid regulatory framework, speed and amount of monetary policy interventions, are all factors that have contributed to the economic and banking instability of CEE countries in the early 1990s. In response to this crisis period, CEE countries launched a restructuring program though a massive privatization process of the state-owned banks, and opened up the frontier to foreign banks. The presence of both private and foreign banks started to enhance the efficiency of banking system. However, as pointed out by Matousek and Sergi (2005) the process of consolidation, privatisation and re-capitalisation of commercial banks was not the same across all CEE countries. Baltic countries in particular sped up the process of privatization from the first stage of the transaction period, and exhibited the highest financial deepening compared to other CEE countries (Matousek and Sarantis, 2009). In addition to the growth of foreign investment, reduction of import barriers and development of a tax policy, also the globalization was an important growth factor of CEE economies from 1990 to 2009 (Gurgul and Lach, 2014).

In the period before the crisis, back in 2006, financial sectors were booming and economies were catching up with the more advanced economies in the European Union in terms of rates of growth and income. In particular, foreign direct investment (FDI) and cross-border capital flows have played an important role in speeding up the growth process of especially Central and South-Eastern Europe during the 2000s (EBRD, 2009).

Following the 2008-09 crisis, there was, however, a drop in net capital flows from advanced European economies, while the FDI remained more stable during the crisis. Among the CEB and SEE countries, EU regions in particular have put forward a strong deleverage process of the banks, that have led to a decrease of credits granted to the industrial sector. Consequently, especially small and medium-sized enterprises (SMEs) have been affected by the credit crunch in those regions. At the same time, there was an increase of debt to GDP ratio by 17 % from 2007 to 2014 (Lo and Rogoff, 2015) in all the areas (EBRD, 2015). The high rise of debt can be explained by: i) revaluations of the stock of debt when denominated in foreign currency; ii) use of public debt and external borrowing by larger companies; iii) increase of NPLs that have contributed to an inflation of the debt to GDP ratio (EBRD, 2015). All these figures together explain the slow recovery process of the area after the financial crisis 2008-2009.

3. A brief overview of "deposit dilemma" and DEA two-stage network model

Starting with Greenbaum, 1967 and Benston, 1965's work, there has been a proliferation of studies on efficiency and productivity on banks. In these studies, it is essential to correctly specify the inputs and outputs of a banking organization in order to get consistent efficient estimates. Despite the large amount of research produced on this theme, the definition of inputs and outputs for banks is still controversial. There is in fact an ongoing debate on whether deposits should be treated as input or an output in a production function. As discussed by Berger and Humphrey (1992), there are three main approaches that a researcher can adopt in the choice of bank outputs: the *asset or intermediation approach*, *value added or production approach* and the *cost approach*. The first approach treats deposits and other liabilities as inputs to produce the earning assets (such as loans and securities) of a bank. Instead, *the value added or production approach* considers every financial product with value added activity for the bank, including deposits, as output. Finally, the *cost approach* is a case-sensitive approach that evaluates the relative net contribution of each financial product to the bank revenue. In this formulation, deposits are treated as outputs unless their costs are higher than their opportunity costs (otherwise they are defined as inputs). Although Berger and Humphrey (1992) express a preference for the value-added approach that identifies deposits as bank outputs, how, they also state that deposits can be correctly used as inputs in a production function.

Starting with the work of Fukuyama and Weber (2010), there have been an increasing number of studies in the banking field (Akther et al., 2013; Fukuyama and Matousek, 2011; Lin and Chiu, 2013; Mukherjee et al. 2003; Yang and Liu, 2012; Wang et al. 2014a,b; Wanke and Barros, 2014; Wu et al., 2016) using the two stage- DEA model. The general concept of two-stage DEA models is based on the pioneering work of Färe and Grosskopf (1996a), who were the first to analyze the sources of efficiency. The two-stage DEA models can also be considered as a special case of network DEA models. 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. The two-stage DEA model requires the definition of intermediate variables to link different stage of production. Differently from the traditional DEA as formulated by Charnes et al. (1978), the two-stage DEA model disentangles the internal processes through which inputs are transformed in outputs. This model can therefore overcome the deposit dilemma by modelling the dual role of deposits through two stages of estimations. Specifically, deposits are the outputs of the first stage, while in the second stage they are modeled as inputs to be invested in earning assets (Fukuyama and Matousek, 2011; Fukuyama and Weber, 2010; Holod and Lewis, 2011). By revising the literature[2], we can identify four specifications of the two-stage

[2] For a detailed review of two-stage DEA models see Cook et al. (2010) and Halkos et al. (2014).

network DEA models: independent, connected, relational and game theoretic (Kao and Hwang, 2010; Halkos et al., 2014). These models differ from each other in the definition of the relationship between the two stages of the production process. While independent models apply the traditional DEA approach (Seiford and Zhu, 1999; Wang et al., 1997), the others models instead take into account the interactions between the two stages. For example, the assumption of a correlation or an additive or multiplicative relationship (Chen et al., 2009; Kao and Hwang, 2008) between the overall and the stage efficiencies in the relational model or following a game theoretic approach (Liang et al., 2006, 2008). In this paper we use the additive efficiency decomposition approach in two stage DEA model proposed by Chen et al. (2009).

4. Methodology

4.1 Weight Assurance Region (WAR) model

The assurance region approach in traditional single-stage DEA models imposes bounds on the ratios of multipliers (Thompson et al., 1990). In the literature, there are also alternative approaches that restrict DEA models through the introduction of additional constraints on multipliers such as regression analysis (Dsyon and Thanassoulis, 1988), inequalities (Wong and Beasley, 1990; Beasley, 1990, 1995) and absolute weight restrictions (Podinovski and Athanassopoulos, 1998). In addition, Charnes et al. (1989) restricted multipliers in a closed cone and Zhu (1996) used assurance region to restrict the weights of Analytic Hierarchy Process.

The WAR model has recently been developed by Halkos et al. (2015). This model combines a modified version of the relational two-stage DEA model of Chen et al. (2009)

and the assurance region concept introduced by Thompson et al. (1990). In particular, it assigns assurance region-based weights to determine the contribution of each stage to the overall production process. As pointed out by Halkos et al. (2015), the advantage of this model consists of including any *a priori* information available and solves a possible infeasibility problem of the original additive model. Specifically, the WAR model is appropriate for policy making in the presence of a priori information such as expert opinion, known information and/or widely accepted beliefs or preferences and other type of information. Furthermore, there is an extreme case of the two-stage additive model where the weight of a stage takes the zero value and as a result the individual efficiencies cannot be defined. Conceptually, assigning a zero weight to one stage and a unity weight in to the other stage has no meaning because there would be no need for a two-stage model. Furthermore, from a computational viewpoint there is an infeasibility problem where the efficiencies cannot be defined. The WAR model is not affected by the aforementioned problem of infeasibility because by construction it restricts the relative weights of each stage to be a non-zero number.

The WAR model follows the additive efficiency decomposition approach proposed by Chen et al. (2009). 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 *i*th input, the *d*th intermediate variable, and the *r*th output respectively of the *j*th DMU $(j = 1, \dots, n)$. Moreover, v_i, w_d and y_r are the multipliers of the model. The overall efficiency E_0 presents the following form:

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

The relative contribution of each stage to the whole process is represented by ξ_1 and ξ_2. These are proxied for the size of each stage. Drawing on Chen et al. (2009)'s definition, we define the overall size of the DMU as $\sum_{i=1}^{m} v_i x_{i_0} + \sum_{d=1}^{D} w_d z_{d_0}$ which is the sum of the first stage size $\sum_{i=1}^{m} v_i x_{i_0}$ and the second stage size $\sum_{d=1}^{D} w_d z_{d_0}$. Consequently, the relative contribution of each stage to the whole process can be written as:

$$\xi_1 = \frac{\sum_{i=1}^{m} v_i x_{i_0}}{\sum_{i=1}^{m} v_i x_{i_0} + \sum_{d=1}^{D} w_d z_{d_0}} \quad and \quad \xi_2 = \frac{\sum_{d=1}^{D} w_d z_{d_0}}{\sum_{i=1}^{m} v_i x_{i_0} + \sum_{d=1}^{D} w_d z_{d_0}} \tag{2}$$

where $0 \leq \xi_1, \xi_2 \leq 1$ and $\xi_1 + \xi_2 = 1$. Weights ξ_1 and ξ_2 follow the denominator rule of Färe and Karagiannis (2013) who have proved that when we aggregate ratio-type performance measures we can achieve consistency if we define the weights in terms of the denominator.

Zero value of ξ_1 or ξ_2 means that a stage does not contribute to the overall process at all. Instead, a value equal to the unity means that the overall process is entirely based on that stage. Assigning zero values to one of the stages leads to an infeasible and conceptual problem (Halkos et al., 2015). On one hand, it is not in fact possible to calculate both the overall efficiency and the efficiency for each separate stage. On the other hand, it is not reasonable to use a two-stage model when one of the stages does not contribute to the whole process at all. The WAR model restricts the ratio of weights ξ_1 and ξ_2 to be inside a region defined by two positive scalars, β and δ:

$$\beta \leq \frac{\xi_1}{\xi_2} \leq \delta \tag{3}$$

Note that β and δ represent the prior information and they cannot become zero. This ensures that neither ξ_1 nor ξ_2 are zero.

The VRS version[3] of the WAR model proposed by Halkos et al. (2015) is as follows:

$$E_0 = max \sum_{d=1}^{D} \mu_d z_{d_0} + \sum_{r=1}^{s} \gamma_r y_{r_0} + u^1 + u^2 \tag{4}$$

s.t.

$$\sum_{i=1}^{m} \omega_i x_{i_0} + \sum_{d=1}^{D} \mu_d z_{d_0} = 1$$

$$\sum_{d=1}^{D} \mu_d z_{d_j} - \sum_{i=1}^{m} \omega_i x_{i_j} + u^1 \leq 0,$$

$$\sum_{r=1}^{s} \gamma_r y_{r_j} - \sum_{d=1}^{D} \mu_d z_{d_j} + u^2 \leq 0,$$

$$-\sum_{i=1}^{m} \omega_i x_{i_0} + \beta \sum_{d=1}^{D} \mu_d z_{d_0} \leq 0$$

$$\sum_{i=1}^{m} \omega_i x_{i_0} - \delta \sum_{d=1}^{D} \mu_d z_{d_0} \leq 0$$

$$\gamma_r, \mu_d, \omega_i \geq 0$$

$$j = 1, \ldots, n;\ i = 1, \ldots, m; d = 1, \ldots, D; r = 1, \ldots, s$$

β and δ are user specified and ($0<\beta\leq\delta$)

u^1 and u^2 are free in sign

Note that the fourth and the fifth constraints in model (4) are the advancement of the WAR model. They are derived from inequality (3). They ensure that the ratio of the weights ξ_1 and ξ_2 is between β and δ.

The WAR model does not modify the stages' efficiency. They are defined as in the original model of Chen et al. (2009). There may be more than one optimal solution in (4).

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[3] We use the variable returns to scale version in order to capture any scale effects. Ang and Chen (2016) find 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 for larger weights in the second stage, and it is therefore better suited for our case.

The authors 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 first stage as depicted in the next section.

$$E_0^1 = max \sum_{d=1}^{D} \mu_d z_{d_0} + u^1 \tag{5}$$

s.t.

$$\sum_{i=1}^{m} \omega_i x_{i_0} = 1$$

$$(1 - E_0) \sum_{d=1}^{D} \mu_d z_{d_0} + \sum_{r=1}^{s} \gamma_r y_{r_0} + u^1 + u^2 = E_0,$$

$$\sum_{d=1}^{D} \mu_d z_{d_j} - \sum_{i=1}^{m} \omega_i x_{i_j} + u^1 \leq 0,$$

$$\sum_{r=1}^{s} \gamma_r y_{r_j} - \sum_{d=1}^{D} \mu_d z_{d_j} + u^2 \leq 0$$

$$\gamma_r, \mu_d, \omega_i \geq 0$$

$$j = 1, \dots, n;\ i = 1, \dots, m; d = 1, \dots, D; r = 1, \dots, s$$

Finally, the second stage efficiency E_0^2 based on (4) and (5) is calculated as:

$$E_0^2 = \frac{E_0 - \xi_1^* E_0^1}{\xi_2^*} \tag{6}$$

4.2 Window analysis of the WAR model

We extend the WAR model into a window-based approach in order to incorporate the dimension of time in our analysis (see Matousek and Tzeremes, 2015 and Tzeremes, 2015 for an explanation of the importance of time effects in the efficiency analysis). Charnes and Cooper (1985) have introduced the window analysis in order to apply DEA models to a panel data context. This technique is based on the principal of moving averages.

Essentially, it compares the performance of a DMU not only to the performance of other DMUs, but also to its own performance over time. As pointed out by Asmild et al. (2004), the window analysis is a useful tool to detect patterns of efficiency over time. The first step consists of defining a sliding window to determine the number of periods to include in the analysis. In particular, Asmild et al. (2004) suggest to use a narrow window (for example three periods to yield credible results).

Following the notation of Asmild et al. (2004), given *n* DMUs $(j = 1, \dots, n)$ for T periods $(t = 1, \dots, T)$, we consider $x_t^j = (x_{1t}^j, x_{2t}^j, \dots, x_{mt}^j)'$, $z_t^j = (z_{1t}^j, z_{2t}^j, \dots, z_{Dt}^j)'$ and $y_t^j = (y_{1t}^j, y_{2t}^j, \dots, y_{st}^j)'$ as respectively the *i*-dimensional input vector $(i = 1, \dots, m)$, the *d*-dimensional intermediate measure vector $(d = 1, \dots, D)$, and the *r*-dimensional output vector $(r = 1, \dots, s)$ respectively of the *j*th DMU at time *t*.

A window k_w with $n \times w$ observations is denoted starting at time k, $1 \leq k \leq T$ width *w*, $1 \leq w \leq T - k$. We define the matrix of inputs as follows:

$$X_{k_w} = (x_k^1, \dots, x_k^n, x_{k+1}^1, \dots, x_{k+1}^n, \dots, x_{k+w}^1, \dots, x_{k+w}^n)$$

the matrix of intermediate variables is given as:

$$Z_{k_w} = (z_k^1, \dots, z_k^n, z_{k+1}^1, \dots, z_{k+1}^n, \dots, z_{k+w}^1, \dots, z_{k+w}^n)$$

and the matrix of outputs as:

$$Y_{k_w} = (y_k^1, \dots, y_k^n, y_{k+1}^1, \dots, y_{k+1}^n, \dots, y_{k+w}^1, \dots, y_{k+w}^n)$$

The WAR model for the *j*th DMU at time *t* takes the following form:

$$E_{k_w t} = \max \mu \cdot z_t' + \gamma \cdot y_t' + U^1 + U^2 \quad (7)$$

s.t.

$$\omega \cdot x_t' + \mu \cdot z_t' = 1$$

$$M \cdot Z_{k_w} - \Omega \cdot X_{k_w} + U^1 \leq 0$$

$$\Gamma \cdot Y_{k_w} - M \cdot Z_{k_w} + U^2 \leq 0$$

$$-\omega \cdot x_t' + \beta \cdot \mu \cdot z_t' \leq 0$$
$$\omega \cdot x_t' - \delta \cdot \mu \cdot z_t' \leq 0$$
$$\gamma_r, \mu_d, \omega_i \geq 0$$
$$j = 1, \dots, n \times w;\ i = 1, \dots, m; d = 1, \dots, D; r = 1, \dots, s$$

the first stage efficiency is:

$$E_{k_w t}^1 = \max \mu \cdot z_t' + U^1$$

s.t.

$$\omega \cdot x_t' = 1$$
$$\left(1 - E_{k_w}\right) \cdot \mu \cdot z_{k_w} - \gamma \cdot y_{k_w} + U^1 + U^2 = E_{k_w}$$
$$M \cdot Z_{k_w} - \Omega \cdot X_{k_w} + U^1 \leq 0$$
$$\Gamma \cdot Y_{k_w} - M \cdot Z_{k_w} + U^2 \leq 0$$
$$\gamma_r, \mu_d, \omega_i \geq 0$$
$$j = 1, \dots, n \times w;\ i = 1, \dots, m; d = 1, \dots, D; r = 1, \dots, s$$

and then the second stage efficiency based on (7) and (8) is:

$$E_{k_w t}^2 = \frac{E_{k_w t} - \xi_1^* \cdot E_{k_w t}^1}{\xi_2^*} \tag{9}$$

5. Data and results

5.1. Data and model description

Our dataset comprises 116 commercial banks in nine transition economies of Central and Eastern Europe (Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania), the new EU countries, for the period from 2004 to 2015. We collected the data from Bankscope. We specify the inputs and outputs of the two-stage DEA model following Fukuyama and Matousek (2011) and Holod and Lewis (2011). In particular, we use the two-stage approach to overcome the deposits dilemma and ensure the dual role of deposits (Fig. 1). In the first stage we use total assets and personnel expenses as two inputs, while deposits function as the output. Deposits then enter the second stage as inputs, whereas loans and securities are the final outputs. Narayan and Sharma (2011) and Sharma et al. (2014) marked the significance to control for possible DMUs' size effects. In line with the above and following Mastromarco and Simar (2015) all variables are logged and normalized with respect to the median—to ensure homogeneity assumption in inputs and outputs—before estimation. Fig. 1 presents the framework of our model where the first stage measures the *value added activity* and the second stage measures the *profitability* of the bank.

<Insert Figure 1 about here>

Usually banks exert a greater control over their inputs compared to their outputs. Therefore, we assign a value to in the WAR model in order to ensure that the first stage will contribute at least the same as the second stage does to the whole process. Specifically, we set $\beta=1$ and $\delta=5$. In this way, the first stage contributes to 50%-80% to the whole process, while the second stage does so for 20%-50%. We assume that it is not reasonable for the second stage to contribute less than 20%. We also ensure that there are no infeasibility' problems[4]. In addition, we apply the variable returns to scale in order to capture scale effects among banks in different countries.

We choose a 3-year window for our analysis (Asmild et al., 2004). The first window includes 2004, 2005 and 2006. The second window moves one year forward omitting 2004

[4] Note that we can incorporate all available information regarding the contribution of the two stages to the whole process by adjusting the β and δ values in the WAR model.

and including 2007. Our analysis includes 10 windows and each window has 348 DMUs ($n \times w = 116 \times 3 = 348$). The total number of DMUs included in our analysis is 3480. Table 1 reports the descriptive statistics of the variables used in this study for the overall sample over the period 2004–2015. There are considerable variations across firms as concerns both the outputs and outputs and inputs as indicated by the large standard deviation.

<Insert Table 1 about here>

5.2. Empirical Results

Prior to discussing the efficiency scores at the country level, we provide an illustrative example[5] of the results for a single bank that we obtained by applying the window-based WAR model. We specifically discuss the case of ING Bank Śląski S.A.. The bank was established as Bank Śląski in 1988 as a result of the separation from the National Bank of Poland. NBP was a typical example of a *monobank* system in a planned economy (in fact there were two banks in Poland, PNB and PKO Bank Polski) and was specialized in currency, credits and savings. ING Bank Śląski S.A. was established in 1988 as a state bank and later, in 1994, was listed on the Warsaw Stock Exchange. Since the 1996, it is part of the Dutch ING Group.

Table 2 reports the efficiency scores of ING Bank Śląski. In particular, the rows indicate the trend across the same window, while the columns indicate the stability of the efficiency for a specific year across different windows. The overall efficiency scores seem

[5] The results for all banks are available upon request.

to increase from 2004 to 2008, they slightly decrease from 2008 to 2013 and then they increase again. The value added activity scores appear to be very high and stable across the years. The profitability efficiency scores significantly increase from 2004 to 2005 while they fluctuate in the following years following the trend of the overall efficiency scores.

<Insert Table 2 about here>

Table 3 presents the results for the first top twenty banks[6] in terms of average efficiency values from all CEE countries and its decomposition into the *value added activity* scores and the *profitability* scores. We briefly recall that the *value added activity* scores are calculated in the first stage of two-stage DEA model where capital and employees are the inputs and deposits are the outputs. Instead, the *profitability* scores come from the second stage analysis where deposits are treated as inputs and loans and securities are considered as outputs.

Our findings indicate that there is still a wide heterogeneity among banks in terms of efficiency. The overall efficiency scores, for example, range from 0.198 for Porsche Bank Hungaria in 2013 to 1.000 for Estonian Credit Bank in 2004 and Czech Moravian Guarantee and Develpoment Bank in 2014 and 2015. Moreover, Československá Obchodní Banka appears to have the highest overall efficiency (0.951) and MBank Hipoteczny SA exhibits the highest average annual growth (3.6%).

<Insert Table 3 about here>

[6] We provide the results for the first twenty banks relative to the overall efficiency scores in order to preserve space. Table of the full results is available upon request.

Focusing on the single component of efficiency scores for *value added activity* scores they remain stable until 2012 and then they slightly decrease. By shifting our attention to the each single case, we observe that the *value added activity* scores range from 0.149 for Porsche Bank Hungaria in 2014 to 1.000 for sixteen banks. On average, Stavební Spořitelna achieved the highest efficiency (0.995) and HSBC Bank Polska SA the highest average annual growth (15.1%). Compared to the *value added activity* scores, the *profitability* scores show the largest discrepancies. The scores take the values from 0.05 in the case of AS Reverta in 2014 to 1.000 for fifteen banks. On average, Československá Obchodní Banka achieved the highest efficiency (0.970) and Credit Europe Bank (Romania the highest average annual growth (16.9%).

As discussed in the methodological section, the evaluation of the efficiencies for the first and the second stage is an important tool for the decision makers in order to identify the source of inefficiencies of the entire banking system (Wang et al., 2014a,b). As revealed by the results, the efficiency scores of the *value added activity* stage are significantly higher than the *profitability* scores. Therefore, the primary source of inefficiency can be found in the *profitability* stage. Consequently, the decision makers should aim to improve the second stage efficiency in order to enhance the overall efficiency.

As follow, we examine the trend of each country. In particular, we notice that Czech Republic and Poland has the largest number of efficiency banks (seven banks) in the group of top-20 banks. The average score for all the eleven Czech banks included in the dataset is 0.819, with Ceskoslovenska Obchodni Banka (0.951) and Ceska Sporitelna (0.936) to be the highest performers. The average score for all the twenty two Polish banks included in the dataset is 0.717, with Bank Pekao (0.932) and ING Bank Slaski (0.914) to achieve the heist scores. We also notice that three Hungarian banks[7], two Croatian and one Estonian banks are in the top 20. The average score for Hungarian banks is 0.703 (thirteen banks), for Croatian banks is 0.622 (twenty five banks) while that one of the Estonian banks is 0.648 (four banks)[8]. Bulgaria (0.596), Latvia (0.673), Lithuania (0.644) and Romania (0.613) have no bank in the top 20.

Fig. 2 presents more detailed information on the average efficiency score of the banking sector for the individual countries over time. Firstly, we notice different patterns in efficiency change across countries and over time. Our findings indicate relatively stable average efficiency from 2004 to 2010 for the overall sample (a number of countries such as Bulgaria and Czech Republic increased efficiency scores during this period). However, in correspondence with the financial crisis, we notice a decrease in efficiency during the period 2011-2014. In the years following 2011, there was a reversal trend for the majority of countries (e.g. Hungary, Lithuania). This decline in the efficiency of the banking system is partially caused by the macroeconomic and political instability of the area.

In order to examine the robustness of the results we also run a 5-year window. The overall efficiency estimates on average terms results are presented per country in Fig. 3. We notice that the 3-year window results (Fig. 2) and the 5-year window results (Fig. 3) are quite similar. Therefore we can deduce that the results are robust in respect to different window width.

[7] The best performer is OTP Bank with an average efficiency score equals to 0.901.
[8] The best performers in Czech Republic are Československá Obchodní Banka with ab average efficiency score of 0.957 and Česká spořitelna with an average efficiency score of 0.915.

<Insert Figures 2 and 3 about here>

We find that Romania exhibits a low efficiency scores over most of the period under investigation. As pointed out by Koutsomanoli-Filippaki et al. (2009), Romania started the reform process later compared to other countries in the same area and it was then hardly affected by the banking crisis in late 1990s. However, we notice that it managed to increase the efficiency of the banking system over the last few years. Starting from 2010, Romania has started to promote some enforcement actions to reduce abuse of market power and to promote a competitive environment[9]. In a more competitive environment, banks are pushed to improve their efficiency profile to preserve their market share and survive.

Poland, Hungary and Czech Republic display the highest efficiency compared to the other CEE countries. Both Hungary and Poland have promoted the government and restructuring actions to reinforce budget constraints and to promote corporate governance effectively (for example, privatization combined with tight credit and subsidy policies and/or enforcement of bankruptcy legislation)[10]. In addition, Hungary presents more than 75 per cent of enterprise assets in private ownership with effective corporate governance.

In line with previous studies (Bonin et al. 2005,a,b; Fries and Taci, 2005; Hasan and Marton, 2003; Matousek and Taci, 2004; Well, 2003), we support the view that the privatization of state-owned commercial banks can enhance the efficiency in the banking system of CCE countries).

Finally, we do not find a strong match between foreign market share percentage and

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[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, 01/10/2015.
10 See footnote 7.

overall efficiency scores (Table 4).

<Insert Table 4 about here>

One possible reason is that CEE countries benefited in terms of spillovers from an increase of foreign presence in the early stage of the liberalization process. Once the presence of foreign ownership share achieved a stable level, such positive effect results to be less relevant for bank efficiency. This can for example be the case for the Czech Republic. In particular, it presents a high percentage of market share of foreign banks, 85%, that is stable for the period of analysis. The Czech banking system can have presumably benefited from spillovers with foreign investors especially in the late 1990s and early 2000s when the foreign market share's percentage increased from 26% in 1998 to 89% in 2001 as maintained by Koutsomanoli-Filippaki et al. (2009).

To sum up, Central European countries present a more efficient banking system compared to eastern European and Balkan countries over the period analyzed.

5. Conclusions

This paper examines the sources of inefficiency for the banks of nine new EU members in CEE countries over the period 2004 to 2015. Differently from previous studies, we investigate the changes of sources of banks' inefficiency before and after the crisis, and the impact of the GFC on the functionality of the baking system. This is important because over this period of analysis, the banking system in transaction economies went through profound changes. Back in 2006, the banking sector was booming by strong rates of growth and income, and a converging process towards the western countries in the European Union. Following the 2008-09 crisis, the scenario changed profoundly. Several transaction countries experience a consistent investment shortfall, rise in indebtedness levels, and a large overhang of NPLs. In addition, there was a drop in the cross-border capital flows and assets owned by foreign banks, which have played a key role in spurring growth and promoting banking efficiency during the 2000s.

As a further contribution, we make use of a two-stage DEA model where deposits are treated as an intermediate variable in the production function. This model allows us to overcome the classical dilemma on how to treat deposits in a production function: as either inputs or outputs. By disentangling the production function in two stages, we can better identify the sources of inefficiencies and provide further guidance to policy makers in promoting the development of the banking system in transaction countries. From a methodological viewpoint, we apply the WAR proposed by Halkos et al. (2015) to assign a weight to each stage of the production process. We expand this model by including a window-based approach to take into account the patterns of efficiency over time. This helps us to take into account the evolution of banks' efficiency for the effect of structural and macroeconomic changes.

We provide important new findings and policy implications. Our results reveal large discrepancies among CEE countries. In particular, banks in Central European countries (Poland, Hungary and Czech Republic) experience higher average efficiencies than banks in Eastern Europe and Balkan countries. Our findings also suggest that there has been a relative stable and slight increase of the overall efficiency over time until 2010 and then slightly decrease. Finally, our analysis shows that the *value added activity* stage exhibits significantly higher efficiency scores than the *profitability* stage.

Our findings indicate to policy makers that there are unexplored opportunities to enhance the banking efficiency by expanding for example credit supply and financial investments. In other words, there are margins to encourage investments in transaction countries by reducing inefficiency in loan allocation to create space for the growth of new credit. However, such changes should be supported by the improvement of managerial skills, adequate technical resources and banking supervision to control for the increase of non-performing loans, which have burden CEE countries over the last years. The overhang of NPLs has led to the application of restrictive credit constraints that have reduced the access to credit of firms and the efficiency of banks' production process. In line with previous studies (Bonin et al. 2005, a,b; Fries and Taci, 2005; Hasan and Marton, 2003; Matousek and Taci, 2004; Well, 2003) we argue that the privatization of state-owned commercial banks can be a possible solution to enhance the efficiency of the banking system of CCE countries. However, there is also need and room for the improvement of the legislation framework on supervision, insolvency and foreclosure, and banks' corporate governance. Several local authorities have moved in this direction by expressing the intention to improve the cooperation agreement with the European Central Bank toward the European Single Supervisory Mechanism, such as Bulgaria, and to promote a new regulatory framework in the banking sector (EBRD, 2015). Such initiatives and changes in the governance of Europe's banking sector require a coordinated and unified banking supervision system to be effective especially in the case of cross-border banks.

Acknowledgements

We would like to thank the Editor and the two anonymous reviewers for their helpful and constructive comments on an earlier version of our manuscript. Any remaining errors are solely the authors' responsibility.

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Table 1: Descriptive statistics

	Overheads		Fixed assets		Deposits		Loans		Securities	
	Mean	**Std. dev**	**Mean**	**Std. dev**	**Mean**	**Std. dev**	**Mean**	**Std. dev**	**Mean**	**Std. dev**
2004	77903	140369.5	2360047	4016570	1847928	3134603	1191649	1902939	911549	1944779
2005	84566	149259.4	2838447	4818622	2194133	3642495	1479034	2355910	1063632	2344513
2006	92988	161996.8	3482276	5819047	2701651	4440727	1948216	3130090	1149206	2451656
2007	112131	193983.3	4340404	7281295	3443306	5825678	2600760	4237421	1250902	2739747
2008	125866	227608.1	4728153	7427504	3735830	5893119	3016466	4711477	1216900	2505359
2009	118269	194961.2	4577301	7333737	3728173	5977733	2875545	4455340	1235835	2533198
2010	115520	198190.9	4703234	7659611	3785671	6221305	2917552	4583739	1325169	2794423
2011	112496	186192.4	4602434	7461423	3699038	6031279	2851557	4513581	1308723	2649172
2012	117842	195618.5	4863373	7945373	3875054	6322157	2942769	4744194	1424947	2790308
2013	121508	210015.8	5005600	8100357	4046433	6557222	2971046	4715994	1534794	2977487
2014	121577	207629.7	5156010	8287812	4137883	6590401	3012203	4906801	1512229	2566433
2015	128938	216991.9	5381753	8651703	4302169	6839932	3149994	5282563	1545482	2526695

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: A three-year window analysis for the ING Bank Śląski S.A.

Overall efficiencies	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
W1	0.873	0.940	0.924									
W2		0.923	0.916	0.872								
W3			0.967	0.925	0.949							
W4				0.964	0.986	0.915						
W5					0.987	0.913	0.922					
W6						0.910	0.919	0.911				
W7							0.908	0.895	0.890			
W8								0.887	0.889	0.882		
W9									0.889	0.881	0.914	
W10										0.870	0.899	0.931
Averages	**0.873**	**0.932**	**0.936**	**0.920**	**0.974**	**0.913**	**0.917**	**0.898**	**0.889**	**0.878**	**0.906**	**0.931**
Value added activity												
W1	0.983	0.949	0.991									
W2		0.899	0.935	1.000								
W3			0.935	1.000	0.988							
W4				1.000	0.975	0.977						
W5					0.981	0.990	0.987					
W6						0.989	0.987	0.973				
W7							0.995	0.981	0.954			
W8								0.982	0.955	0.982		
W9									0.955	0.985	0.949	
W10										0.985	0.949	0.980
Averages	**0.983**	**0.924**	**0.954**	**1.000**	**0.981**	**0.985**	**0.990**	**0.979**	**0.954**	**0.984**	**0.949**	**0.980**
Profitability												
W1	0.763	0.932	0.857									
W2		0.950	0.896	0.744								
W3			1.000	0.850	0.909							
W4				0.927	0.997	0.852						
W5					0.994	0.836	0.857					
W6						0.832	0.852	0.850				
W7							0.821	0.809	0.826			
W8								0.792	0.824	0.781		
W9									0.822	0.777	0.877	
W10										0.755	0.848	0.883
Averages	**0.763**	**0.941**	**0.918**	**0.840**	**0.966**	**0.840**	**0.843**	**0.817**	**0.824**	**0.771**	**0.862**	**0.883**

Note: The table presents a 3-year window analysis for the overall efficiency, the first and the second stage efficiencies for the case of ING Bank Śląski S.A.

Table 3: Average efficiency score over time

Bank	Country	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average	Average annual growth
Overall efficiency												
Bank Handlowy w Warszawie	POLAND	0.806	0.833	0.855	0.822	0.832	0.804	0.836	0.871	0.854	0.848	0.009
Bank Millennium	POLAND	0.799	0.822	0.797	0.825	0.847	0.826	0.823	0.835	0.843	0.834	0.009
Bank Pekao	POLAND	0.863	0.867	0.873	0.960	0.918	0.927	0.938	0.946	0.952	0.932	0.012
Bank Zachodni	POLAND	0.797	0.821	0.819	0.850	0.867	0.858	0.847	0.853	0.828	0.861	0.017
Ceska Sporitelna	CZECH REPUBLIC	0.884	0.897	0.910	0.947	0.952	0.956	0.971	0.965	0.976	0.936	0.002
Czech Moravian Guarantee and Develpoment Bank	CZECH REPUBLIC	0.736	0.737	0.723	0.737	0.783	0.764	0.722	0.883	0.990	0.837	0.031
Ceskoslovenska Obchodni Banka	CZECH REPUBLIC	0.888	0.894	0.918	0.982	0.965	0.982	0.991	0.988	0.988	0.951	0.001
Deutsche Bank Polska	POLAND	0.928	0.929	0.875	0.775	0.710	0.742	0.768	0.914	0.925	0.822	-0.011
ING Bank Slaski	POLAND	0.873	0.932	0.936	0.920	0.974	0.913	0.917	0.898	0.889	0.914	0.007
K&H Bank Zrt	HUNGARY	0.820	0.829	0.836	0.829	0.874	0.871	0.880	0.802	0.795	0.832	0.002
Komercni Banka	CZECH REPUBLIC	0.887	0.888	0.904	0.928	0.944	0.952	0.958	0.960	0.955	0.926	0.002
MBank	POLAND	0.814	0.816	0.842	0.885	0.910	0.894	0.922	0.934	0.924	0.896	0.013
OTP Bank Plc	HUNGARY	0.884	0.891	0.899	0.913	0.914	0.938	0.926	0.927	0.926	0.903	-0.003
Primorska Banka	CROATIA	0.750	0.786	0.847	0.935	0.962	0.965	0.952	0.948	0.931	0.856	-0.008
Raiffeisen stavební sporitelna	CZECH REPUBLIC	0.854	0.854	0.804	0.754	0.784	0.798	0.803	0.816	0.813	0.804	-0.007
Stavební Sporitelna Ceské Sporitelny	CZECH REPUBLIC	0.871	0.873	0.850	0.824	0.803	0.816	0.848	0.864	0.869	0.845	-0.004
Swedbank	ESTONIA	0.851	0.911	0.952	0.947	0.941	0.897	0.885	0.757	0.654	0.823	-0.012
Unicredit Bank	CZECH REPUBLIC	0.795	0.805	0.822	0.847	0.867	0.859	0.841	0.825	0.845	0.851	0.013
UniCredit Bank Hungary Zrt	HUNGARY	0.756	0.743	0.784	0.794	0.804	0.815	0.754	0.758	0.778	0.793	0.012
Zagrebacka Banka	CROATIA	0.820	0.824	0.798	0.810	0.823	0.808	0.806	0.810	0.814	0.819	0.003
Value added activity												
Bank Handlowy w Warszawie	POLAND	0.662	0.757	0.779	0.760	0.719	0.765	0.797	0.763	0.740	0.772	0.030
Bank Millennium	POLAND	0.877	0.893	0.939	0.842	0.856	0.966	0.914	0.915	0.957	0.919	0.009
Bank Pekao	POLAND	0.978	0.949	0.956	1.000	0.970	0.970	0.953	0.939	0.939	0.970	0.002
Bank Zachodni	POLAND	0.869	0.895	0.907	0.921	0.942	0.971	0.948	0.936	0.920	0.922	0.005
Ceska Sporitelna	CZECH REPUBLIC	0.986	0.938	0.969	0.956	0.981	0.975	0.975	0.978	0.977	0.975	0.002
Czech Moravian Guarantee and Develpoment Bank	CZECH REPUBLIC	0.820	0.799	0.806	0.840	0.892	0.831	0.829	0.850	0.993	0.886	0.020
Ceskoslovenska Obchodni Banka	CZECH REPUBLIC	0.880	0.795	0.844	1.000	0.952	0.980	0.997	1.000	1.000	0.934	-0.005
Deutsche Bank Polska	POLAND	0.866	0.867	0.859	0.842	0.781	0.780	0.852	0.842	0.859	0.870	0.011
ING Bank Slaski	POLAND	0.983	0.924	0.954	1.000	0.981	0.985	0.990	0.979	0.954	0.972	0.000
K&H Bank Zrt	HUNGARY	0.858	0.864	0.867	0.937	0.975	0.981	0.955	0.927	0.794	0.894	0.002
Komercni Banka	CZECH REPUBLIC	0.992	0.960	0.984	0.995	0.962	0.962	0.952	0.930	0.926	0.966	-0.002
MBank	POLAND	0.830	0.840	0.869	0.904	0.929	1.000	0.989	0.967	0.918	0.861	0.030
OTP Bank Plc	HUNGARY	0.904	0.852	0.824	0.859	0.836	0.892	0.872	0.866	0.861	0.878	0.006
Primorska Banka	CROATIA	0.667	0.747	0.799	0.897	0.992	0.999	0.979	0.982	0.982	0.870	0.015
Raiffeisen stavební sporitelna	CZECH REPUBLIC	0.985	0.988	0.986	0.979	0.970	0.974	0.965	0.972	0.964	0.968	-0.004
Stavební Sporitelna Ceské Sporitelny	CZECH REPUBLIC	1.000	1.000	1.000	1.000	1.000	0.989	1.000	0.995	0.996	0.995	-0.002
Swedbank	ESTONIA	0.747	0.882	0.974	0.994	0.971	1.000	1.000	0.830	0.780	0.888	0.018
Unicredit Bank	CZECH REPUBLIC	0.838	0.812	0.811	0.790	0.791	0.826	0.849	0.850	0.829	0.837	0.005
UniCredit Bank Hungary Zrt	HUNGARY	0.840	0.813	0.872	0.887	0.908	0.911	0.870	0.894	0.882	0.887	0.009
Zagrebacka Banka	CROATIA	0.828	0.782	0.791	0.840	0.898	0.934	0.943	0.942	0.954	0.898	0.013

Profitability												
Bank Handlowy w Warszawie	POLAND	1.000	0.928	0.947	0.902	0.981	0.851	0.883	0.999	0.996	0.990	-0.010
Bank Millennium	POLAND	0.721	0.750	0.654	0.806	0.836	0.685	0.728	0.753	0.729	0.734	0.016
Bank Pekao	POLAND	0.749	0.783	0.790	0.920	0.867	0.884	0.924	0.954	0.965	0.972	0.025
Bank Zachodni	POLAND	0.722	0.745	0.726	0.776	0.790	0.745	0.746	0.769	0.732	0.880	0.032
Ceska Sporitelna	CZECH REPUBLIC	0.782	0.856	0.850	0.938	0.922	0.936	0.968	0.951	0.975	0.880	0.005
Czech Moravian Guarantee and Develpoment Bank	CZECH REPUBLIC	0.634	0.659	0.620	0.614	0.664	0.682	0.592	0.921	0.988	0.974	0.054
Ceskoslovenska Obchodni Banka	CZECH REPUBLIC	0.897	1.000	0.998	0.965	0.978	0.985	0.985	0.976	0.977	0.984	0.011
Deutsche Bank Polska	POLAND	1.000	1.000	0.893	0.694	0.619	0.693	0.668	1.000	0.998	0.540	-0.019
ING Bank Slaski	POLAND	0.763	0.941	0.918	0.840	0.966	0.840	0.843	0.817	0.824	0.771	0.018
K&H Bank Zrt	HUNGARY	0.779	0.792	0.802	0.718	0.773	0.761	0.805	0.673	0.796	0.764	0.008
Komercni Banka	CZECH REPUBLIC	0.782	0.815	0.825	0.860	0.927	0.943	0.965	0.991	0.986	0.927	0.009
MBank	POLAND	0.797	0.789	0.812	0.864	0.891	0.789	0.854	0.902	0.931	0.962	0.020
OTP Bank Plc	HUNGARY	0.864	0.933	0.980	0.972	1.000	0.987	0.986	0.995	1.000	0.954	-0.047
Primorska Banka	CROATIA	0.882	0.836	0.921	0.991	0.914	0.898	0.883	0.837	0.800	0.513	-0.101
Raiffeisen stavební sporitelna	CZECH REPUBLIC	0.720	0.719	0.618	0.522	0.595	0.622	0.636	0.656	0.659	0.639	-0.011
Stavební Sporitelna Ceské Sporitelny	CZECH REPUBLIC	0.741	0.746	0.699	0.647	0.597	0.636	0.686	0.731	0.741	0.723	-0.006
Swedbank	ESTONIA	0.976	0.941	0.930	0.901	0.911	0.794	0.769	0.673	0.500	0.547	-0.043
Unicredit Bank	CZECH REPUBLIC	0.752	0.798	0.834	0.915	0.957	0.896	0.832	0.797	0.863	0.895	0.023
UniCredit Bank Hungary Zrt	HUNGARY	0.659	0.659	0.693	0.695	0.696	0.717	0.626	0.612	0.669	0.709	0.019
Zagrebacka Banka	CROATIA	0.812	0.873	0.806	0.776	0.741	0.679	0.667	0.676	0.674	0.694	-0.007

Note: The table presents the average overall and stage efficiency scores for the top 20 performers with respect to the overall efficiency.

Table 4: Percentage of foreign ownership share

Country	**2006**	**2011**
BULGARIA	80.1%	76.5%
CROATIA	90.8%	90.6%
CZECH REPUBLIC	84.7%	84.7% (*)
ESTONIA	99.1%	94.0%
HUNGARY	82.6% (**)	85.8%
LATVIA	63.3%	65.0%
LITHUANIA	91.8%	90.8% (+)
POLAND	74.2%	69.2%
ROMANIA	87.9%	81.8%

Source: EBRD, Share of foreign owned banks[11]. (*) 2008. Data is not available for later years. (+)Data is not available for 2011. (**) Data from 2005.

[11] Data retrieved from http://www.ebrd.com/what-we-do/economic-research-and-data/data/forecasts-macro-data-transition-indicators.html, 01/10/2015.

Figure 1: Two-stage bank process

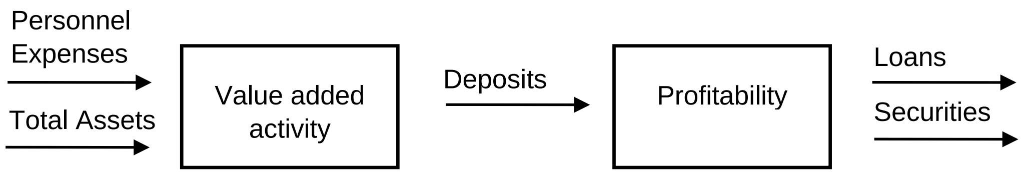

Figure 2: Average country scores over time 3-year window

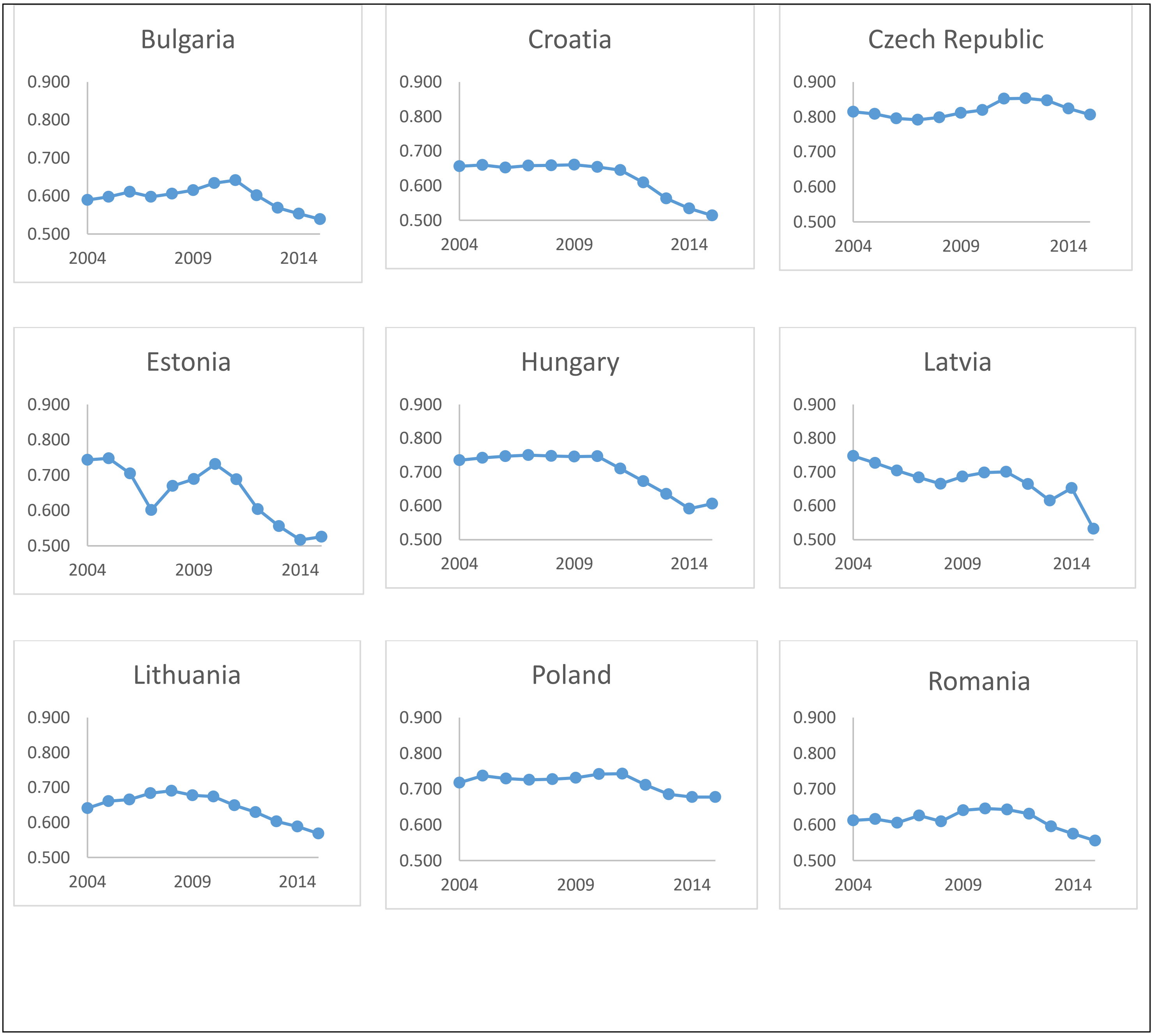

Figure 3: Average country scores over time 5-year window