Emerging Economies and the re-capitalization of the banking systems

Meryem Duygun Fethi
m.fethi@leicester.ac.uk
School of Management, University of Leicester, UK

Mohamed Shaban
m.shaban@leicester.ac.uk
School of Management, University of Leicester, UK

Thomas Weyman-Jones
t.g.weyman-jones@lboro.ac.uk
School of Business and Economics, Loughborough University, UK

JEL classification: C23, D24, G21

Keywords: banking, stochastic frontier analysis, cost function, panel data.

Abstract: This paper describes procedures in panel data econometrics for efficiency measurement and productivity decomposition in the banking systems of emerging economies with a special focus on the re-capitalization process. In a banking crisis, policy makers may attempt to re-capitalize the banking system, but this has the potential to impose significant costs. We develop an analytical framework that models the re-capitalization process as a requirement to hold levels of a fixed input, i.e. equity, above the long run equilibrium level, or alternatively to achieve a target equity to asset ratio. To capture the effect of this under-leveraging, we adopt a model that allows the banking system to operate in an uneconomic region of the banking technology. Panel data methods then allow a productivity decomposition to be developed that can distinguish between technical change, efficiency change, scale change and exogenous factors such as policy constraints. This paper uses a panel data set of banks in emerging economies during the financial upheaval period of 2005-2008 to analyse these ideas.

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1. Introduction

When a banking system has gone through a financial crisis, there are important lessons to learn from how it emerges and recovers and these lessons have particularly strong policy implications at the beginning of the second decade of this century when most the of the developed world is recovering from the financial crisis of 2007-2008. Many emerging economies experienced financial crisis in the years before the major financial shock of 2007-2008 and some of these began to recover ahead of the developed economies. As a consequence, there are considerable lessons to be learned from the banking systems in emerging economies during these years and these lessons have implications for other economies where there are two major stresses: emerging market impacts and financial liberalisation on the one hand and banking system re-capitalization on the other. Banking system re-capitalization, i.e. a greater reliance on equity capital rather than short term borrowing as a means of providing full loss absorbing capacity for problem loans, is a major preoccupation of policy makers around the world.

However, major re-capitalization of the banking systems around the world must impose resource costs both on the wider economy and on the banking system in particular, and this is an issue that has pre-occupied regulators[1]. This paper attempts to measure some of these costs as they impact on the banking system. One focus of the research therefore will be on measuring the shadow return on equity when a banking system is re-capitalized. This shadow return is calculated from the negative of the

[1] For example a member of the US Senate Banking Committee asks: "What is the true cost to national economies of higher capital requirements for banks?" Senator Kay Hargan, letter to *The Economist*, June 4, 2010.

elasticity of a bank's cost function with respect to the level of equity capital[2]. There is considerable evidence that the shadow return on equity is strongly positive prior to financial crisis. Among the first papers to measure this is Hughes, Mester and Moon (2001), who noted that the shadow return on equity of US banks in the 1990s averaged around 15 percent with larger banks having considerably higher values, suggesting that larger banks used their market power to increase leveraging. More recent research confirms this finding of buoyant shadow rates of return on equity during periods when the banking system is unstressed. Liao et al (2009) confirm positive shadow returns on equity capital with higher values for relatively over-leveraged larger banks in a cross country comparison of banking system cost behaviour, and Boucinha et al (2009) demonstrate the same results for Portugal in the years following its entry to the Eurozone. What happens when the banking system is reversing the previous over-leveraging and how does this relate to the costs of re-capitalization? To discover this, the situation of the banking systems in emerging economies provides critical and important evidence.

This paper has several primary purposes. The core objective is to measure the efficiency and productivity analysis of the banking system during this recovery phase by constructing and analysing a model of the banking technology that takes account of the recapitalization process; for this we develop an econometric specification of cost minimizing intermediation behaviour subject to a capitalization constraint. A second objective is to analyse key factors associated with different levels of efficient performance by banks by incorporating variables that represent both banking system characteristics and the macroeconomic environment. A third objective is to use this

[2] This result is derived below.

analysis to develop bank specific decompositions of productivity change during the period into scale efficiency change, allocative efficiency change, technological change, technical efficiency change, and the impact of re-capitalization. This decomposition may permit the measurement of the impact of holding higher levels of equity on the productivity recovery of the banking system. If the higher levels of equity required by the re-capitalization process act as an offset to the total factor productivity growth of the banking system, then it may be possible to gauge the size of the costs of the re-capitalization policy.

2. Modelling the technology and relative efficiency

In this section, we develop a model of banking system activity that takes account of the equity capital requirements that must be met by banks, in particular, how increased capital requirements may impose additional costs on the efficient allocation of resources. The starting point is the definition of the production technology in terms of the input requirement set for a sample of multi-product firms producing *R* outputs from *K* inputs:

$$I(\mathbf{y},t) = \{\mathbf{x} : \mathbf{x}\ \textit{can make}\ \mathbf{y}\ \textit{at time}\ t, \mathbf{x} \in R_+^K, \mathbf{y} \in R_+^R\} \qquad [1]$$

We assume that this production technology has the properties of convexity, and weak disposability. It is the weak disposability assumption that is critical to our analysis. Formally this is represented as:

$$\mathbf{x}^0 \in I(\mathbf{y},t) \Rightarrow \lambda\mathbf{x}^0 \in I(\mathbf{y},t)\ \text{for some but not all}\ \lambda \geq 1 \qquad [2]$$

If the efficient boundary of the input requirement set is represented by a transformation function: $F(\mathbf{x},\mathbf{y},t)=0$ then weak disposability implies that the first derivatives, $F_k \equiv \partial F/\partial x_k$, $F_r \equiv \partial F/\partial y_r$ are not restricted in sign. This will permit the model to accommodate both positive and negative shadow prices in the dual cost function. The parametric frontier dual cost function that we will use is based on K variable inputs: $\mathbf{x}=(x_1,\ldots,x_K)$ with input prices: $\mathbf{w}=(w_1,\ldots,w_K)$ and R outputs: $\mathbf{y}=(y_1,\ldots,y_R)$, and an additional input which may be either a fixed input in the short run, or required in a fixed ratio to output, but this input is variable in the long run; for clarity, we symbolise this particular input as z_0, with input price: w_0. The interpretation of this fixed input will be critical in the analysis of a banking industry sample since it captures the importance of the level of equity capital. Following the arguments in Braeutigam and Daughety (1984) and Hughes, Mester and Moon (2001), we write the long run cost function, with all inputs including z_0 treated as variable, in the form:

$$c(\mathbf{y},\mathbf{w},w_0,t)=\min_{\mathbf{x},z_0}\{\mathbf{w}'\mathbf{x}+w_0 z_0 : (\mathbf{x},z_0,\mathbf{y}\in I)\} \qquad [3]$$

In the banking industry the regulated short run cost function can be modelled in two ways: either by *specifying a fixed level of the critical input equity capital*: z_0 is fixed; or, alternatively, by *specifying a fixed ratio of the critical input equity capital to a single dimension of output measured as total assets*, $r_0 = z_0/\mathbf{i}'\mathbf{y} = z_0/y$. Although most of the literature develops the envelope theorem application to banking costs through the short run cost function with a fixed equity level, here, we show the relationship between the long run total cost and the short run total cost expressed in regulated equity-asset ratio form. In this case, where the equity capital input z_0 must be held in a regulated or target ratio with output measured as total assets, r_0, the short run cost function is:

$$c(\mathbf{y}, \mathbf{w}, r_0, t) + w_0 z_0 = \min_{\mathbf{x}} \{\mathbf{w}'\mathbf{x} + w_0 z_0 : (\mathbf{x}, z_0, \mathbf{y} \in I); z_0 = r_0 \mathbf{i}'\mathbf{y} = r_0 y\} \quad [4]$$

The envelope theorem confirms that long run total cost defines the envelope of short run total cost:

$$c(\mathbf{y}, \mathbf{w}, w_0, t) = \min_{z_0} \{c(\mathbf{y}, \mathbf{w}, r_0, t) + w_0 z_0\} \quad [5]$$

Therefore the envelope theorem implies that for any slight deviation of the level of the fixed input above or below the optimal level, $z^*_0 = z^*(\mathbf{y}, \mathbf{w}, w_0, t)$, there will be no reduction in total cost and the long run total cost function is tangential to the short run total cost function:

$$c(\mathbf{y}, \mathbf{w}, w_0, t) = c(\mathbf{y}, \mathbf{w}, r_0^*, t) + w_0 z_0^* \quad [6]$$

Consequently, the following derivative result holds in the neighbourhood of the optimal ratio of the fixed input: $z_0 = r_0 y$:

$$\partial c(\mathbf{y}, \mathbf{w}, w_0, t)/\partial r_0 = 0 = [\partial c(\mathbf{y}, \mathbf{w}, r_0^*, t)/\partial r_0] + w_0 y \quad [7]$$

Rearranging this last result and expressing it in elasticity form, gives the critical interpretation of the shadow price of the target equity capital ratio:

$$-[\partial \ln c(\mathbf{y}, \mathbf{w}, r_0^*, t)/\partial \ln r_0] = (w_0 y)(r_0/C) = (w_0 z_0/C) \quad [8]$$

In words, the negative log derivative of the short run cost function expresses the shadow share of equity costs to total expenses[3].

There are two implications that are particularly important in the analysis of banking systems, and these concern the measurement of the shadow price away from equilibrium and the measurement of returns to scale. The fixed input in our model of

[3] In the case where a fixed level of input is the constraint, the corresponding result is that the negative of the derivative of the variable cost function with respect to this fixed input is the input's shadow price.

the banking system technology is the level of equity capital, held for both prudential and regulatory reasons.

The analysis above confirms that close to equilibrium, when the short run cost function is expressed in log form as a function of the outputs, input prices and the equity asset ratio, we interpret the negative of the derivative of short run total cost with respect to the equity-asset ratio as the shadow ratio of equity expenses to total expenses. This can be negative or positive in value depending on whether the shadow price of equity is negative or positive.

Consequently, by including the equity-asset or capital ratio as an explanatory variable in the cost function we are able to examine several possible outcomes. Banks which are over-leveraged or reliant on debt and under-use equity capital can be expected to show a relatively *low* ratio of equity expenses to total expenses (but with a negative sign on the measured elasticity in the cost function – see equation [8] above); banks which are engaged in active re-capitalization will show a relatively *high* ratio of equity expenses to total expenses, but still with a negative sign in [8]. Banks which are far from long run cost minimising equilibrium, for example because they are undergoing major re-capitalization with current equity capital levels well above the long run equilibrium, i.e. $z_0 > z^*(\mathbf{y}, \mathbf{w}, w_0, t)$ may be expected to show a significant rise in the ratio of equity expenses to total expenses compared with the long run average when the fitted cost function includes the equity-asset ratio. In the case where the fitted cost function is conditioned on the level of equity capital instead of the equity asset ratio, we will observe a very low possibly severely negative shadow return on equity in the recovery phase from financial crisis. Negative values of the shadow input price or return on the fixed input equity level (corresponding to above average ratio of equity to total expenses) would arise if, for example, the firm was operating in the uneconomic region of the production function[4]. We summarize these arguments in the twin proposition:

- *Specify short run total cost as a function of outputs, input prices and the equity asset ratio: during re-capitalization, the negative log derivative of cost with respect to the equity asset ratio increases above the long run average*
- *Specify short run total cost as a function of outputs, input prices and the equity level: during re-capitalization, the negative log derivative of cost with respect to the equity level falls and may turn negative if the production set is weakly disposable..*

The proof of the first part is given in equation [8]; the second part is proved in Fethi, Shaban and Weyman-Jones (2011).

The second implication of the analysis concerns the measurement of returns to scale. Panzar and Willig (1977) derive the following result concerning the inverse of the elasticity of cost with respect to output:

$$E_{\mathrm{cy}}^{-1} = c \Big/ \sum_{r=1}^{r=R} \left(y_r \left(\partial c / \partial y_r \right) \right) = 1 \Big/ \sum_{r=1}^{r=R} \left(\partial \ln c / \partial \ln y_r \right) \qquad [9]$$

Then $E_{\mathrm{cy}}^{-1} < 1$ implies diseconomies of scale (decreasing returns), $E_{\mathrm{cy}}^{-1} = 1$ implies constant returns to scale and $E_{\mathrm{cy}}^{-1} > 1$ implies economies of scale (increasing returns). The definition of cost used here is the long run total cost: $c(\mathbf{y}, \mathbf{w}, w_0, t)$, but as Braeutigam and Daughety (1983) demonstrate, close to the optimum level of the fixed input, the short run total cost can be used instead. Braeutigam and Daughety , (see also Caves, Christensen and Swanson (1980)) develop the adjusted elasticity of scale measure in terms of the shadow price of the fixed input, but we can adapt their derivation to use the shadow share of the input's cost to total cost. Specifically, where

[4] The translog specification used in this paper was developed in order to allow operation in the uneconomic region of the technology, see Kumbhakar and Lovell (2000: 45).

$C = \mathbf{w}'\mathbf{x} + w_0 z_0$, i.e. expenditure on variable inputs plus actual fixed cost, we have the following proposition:

The elasticity of scale is measured by adjusting the long run Panzar-Willig estimate by the shadow ratio of equity expenses to total expenses

$$E_{\mathbf{cy}}^{-1} \approx \left(1 - \partial \ln C / \partial \ln r_0\right) \Big/ \sum_{r=1}^{r=R} \left(\partial \ln C / \partial \ln y_r\right) \qquad [10]$$

This measures returns to scale at the observed sub-optimal level of the fixed input. Braeutigam and Daughety note that this measure may be more appropriate if the industry is expected to remain at a sub-optimal allocation of inputs. The derivation of [10] uses the following steps. From the Panzar-Willig definition:

$$E_{\mathbf{cy}}^{-1} = C \Big/ \sum_{r=1}^{r=R} \left(y_r \left(\partial C / \partial y_r\right)\right) = \left(C^V + w_0 z_0\right) \Big/ \sum_{r=1}^{r=R} \left(y_r \left(\partial \ln c(\mathbf{y}, \mathbf{w}, r_0 *, t) / \partial y_r\right)\right)$$

Re-arranging this expression we obtain first:

$$E_{\mathbf{cy}}^{-1} = C^V \left(1 + \left(w_0 z_0 / C^V\right)\right) \Big/ \sum_{r=1}^{r=R} \left(y_r \left(\partial \ln c(\mathbf{y}, \mathbf{w}, r_0 *, t) / \partial y_r\right)\right)$$

then replacing the possibly unknown market equity expense to total expense ratio by its shadow value from equation [8], we have equation [10] above.

We therefore have two possible specifications of the short run total cost function, one using the equity-asset ratio and one using the equity level. We proceed at this point using the equity-asset ratio, but both forms are fitted in the estimation results. The actual cost experienced by the firm is by definition:

$$C_t \equiv \mathbf{w}'\mathbf{x} + \alpha_0 \qquad [11]$$

where α_0 is expenditure on the fixed input. Consequently, cost efficiency at time *t* is:

$$CE_t = \{c(\mathbf{y}, \mathbf{w}, r_0, t)/C_t\} \in (0,1] \qquad [12]$$

Using $\exp(-u), u \geq 0$ to transform the measure of cost efficiency from the interval: $(0,1]$ into a non-negative random variable with support on the non-negative real line: $[0,+\infty)$, yields:

$$\ln C_t = \ln c(\mathbf{y}, \mathbf{w}, r_0, t) + u \qquad [13]$$

This function should be homogeneous of degree +1 and concave in input prices, Diewert and Wales (1987). An econometric approach may be adopted by replacing the deterministic kernel of [13] by a fully flexible functional form such as the translog function with an additive idiosyncratic error term, v to capture sampling, measurement and specification error. Homogeneity is imposed by dividing through by one of the input prices, e.g. w_K . Express the variables in vector form as:

$$\begin{aligned} \mathbf{l\tilde{w}} &= \left(ln(w_1/w_K) \quad \ldots \quad ln(w_{K-1}/w_K) \right) \\ \mathbf{ly} &= \left(ln\, y_1 \quad \ldots \quad ln\, y_R \right) \end{aligned}$$

Write the translog approximation with additive error term as $TL(\mathbf{y}, \mathbf{\tilde{w}}, r_0, t) + v$. In the equity-asset ratio specification, these steps give us the result:

$$\begin{aligned} \ln(C/w_K) = {} & \alpha_0 + \boldsymbol{\alpha}'\mathbf{ly} + \boldsymbol{\beta}'\mathbf{l\tilde{w}} + \tfrac{1}{2}\mathbf{ly}'\mathbf{A}\,\mathbf{ly} + \tfrac{1}{2}\mathbf{l\tilde{w}}'\mathbf{B}\,\mathbf{l\tilde{w}} + \mathbf{ly}'\boldsymbol{\Gamma}\,\mathbf{l\tilde{w}} + \delta_1 t + \tfrac{1}{2}\delta_2 t^2 + \boldsymbol{\mu}'\mathbf{ly}\,t + \boldsymbol{\eta}'\mathbf{l\tilde{w}}\,t \\ & + \rho_1 \ln r_0 + \tfrac{1}{2}\rho_2 (\ln r_0)^2 + \boldsymbol{\theta}'\mathbf{ly} \ln r_0 + \boldsymbol{\xi}'\mathbf{l\tilde{w}} \ln r_0 + \omega \ln r_0 t + v + u \end{aligned} \qquad [14]$$

The vectors of elasticity functions (equivalent in the case of the input prices to the share equations by Shephard's lemma) are derived by differentiating the translog quadratic form:

$$\begin{bmatrix} \boldsymbol{\varepsilon}_y \\ \boldsymbol{\varepsilon}_{\tilde{w}} \\ \varepsilon_t \\ \varepsilon_{r0} \end{bmatrix} = \begin{bmatrix} \boldsymbol{\alpha} & \mathbf{A} & \boldsymbol{\Gamma} & \boldsymbol{\mu} & \boldsymbol{\theta} \\ \boldsymbol{\beta} & \boldsymbol{\Gamma}' & \mathbf{B} & \boldsymbol{\eta} & \boldsymbol{\xi} \\ \delta_1 & \boldsymbol{\mu}' & \boldsymbol{\eta}' & \delta_2 & \omega \\ \rho_1 & \boldsymbol{\theta}' & \boldsymbol{\xi}' & \omega & \rho_2 \end{bmatrix} \begin{bmatrix} 1 \\ \mathbf{ly} \\ \mathbf{l}\tilde{w} \\ t \\ \ln r_0 \end{bmatrix} \qquad [15]$$

This matrix derivative of the translog short run cost function can be used to generate a total factor productivity decomposition

3. Productivity growth

We derive a total factor productivity decomposition as follows, see Bauer (1990), Orea (2002) and Lovell (2003). Differentiating both sides of the cost equation [13] with respect to *t* and rearranging the result, we obtain:

$$E^{-1}\boldsymbol{\varepsilon}_y'\dot{\mathbf{y}} - \mathbf{s}'\dot{\mathbf{x}} = (1 - E/E)\boldsymbol{\varepsilon}_y'\dot{\mathbf{y}} + (\mathbf{s} - \boldsymbol{\varepsilon}_w)'\,\dot{\mathbf{w}} - \varepsilon_t - (du/dt) - \varepsilon_{r0}\dot{r}_0 \qquad [16]$$

In this expression, E^{-1} is the elasticity of scale, $\boldsymbol{\varepsilon}_y$ is the vector of cost elasticity functions with respect to the outputs, with typical element: $\varepsilon_{yr} = \partial \ln c(\mathbf{y}, \mathbf{w}, r_0, t)/\partial \ln y_r$; $\boldsymbol{\varepsilon}_w$ is the vector of cost elasticity functions with respect to the input prices, with typical element: $\varepsilon_{wk} = \partial \ln c(\mathbf{y}, \mathbf{w}, r_0 t)/\partial \ln w_k$; ε_t is the cost elasticity function with respect to the time based index of technological progress: $\varepsilon_t = \partial \ln c(\mathbf{y}, \mathbf{w}, r_0, t)/\partial t$, (du/dt) is the rate of change of inefficiency and finally, ε_{r0} is the cost elasticity with respect to the target equity-asset ratio constraint. The left hand side of this expression is by definition a measure of total factor productivity change with weights that sum to unity: by construction in the case of outputs and by linear homogeneity in the case of inputs. Hence the right hand side is a complete decomposition of the total factor productivity index.

The five components of the total factor productivity change on the right hand side of the equation can therefore be interpreted as follows:

a) $(1 - E/E)\boldsymbol{\varepsilon}'_y \dot{\mathbf{y}}$: *scale efficiency change*; if $E = 1$ i.e. CRS, there is zero scale efficiency change in the total factor productivity change, *TFPC*, decomposition

b) $(\mathbf{s} - \boldsymbol{\varepsilon}_w)' \dot{\mathbf{w}}$: *allocative efficiency change*: if actual input cost shares and optimal input cost shares are equal, there is no potential for allocative efficiency change: $\mathbf{s} - \boldsymbol{\varepsilon}_w = \mathbf{0}$

c) $-\varepsilon_t$: *technological change*; if the elasticity of cost with respect to time as a proxy for the technological change is negative, $\varepsilon_t < 0$, then this term will raise productivity.

d) $-(du/dt)$: *cost efficiency change*: if this term, including the sign, is positive then productivity is enhanced by improvements in the technology

e) $\varepsilon_{r0}\dot{r}_0$: *regulated equity-asset ratio productivity change*; if this term, including the sign is positive then productivity is enhanced by relaxation of the equity-asset ratio constraint, and conversely productivity is reduced when the constraint becomes more strongly binding, for example in a re-capitalization phase.

It is the last component that allows us to compute the cost of re-capitalization of the banking system. If the shadow price or rate of return on equity is positive then, holding higher levels of equity capital or a higher target equity-assets ratio will move the banking system towards a long run equilibrium and will generate a positive impact on productivity growth. However, if the shadow price or rate of return on equity is negative (i.e. the equity level has a positive coefficient in the fitted cost function), or there is a requirement to hold higher than equilibrium levels of equity capital relative to assets, then this will impose a negative component on productivity growth. This allows us to measure the cost impact of re-capitalization by the contribution (negative or positive) of the changes in the equity level or the equity-assets ratio to the measured total factor productivity growth.

These components of total factor productivity change, $T\dot{F}P$, are shown in total differential form; however by application of the quadratic lemma, Caves, Christensen and Diewert (1982), we can use them in index number form, as follows:

a) $\frac{1}{2}\sum_r\left[\left(\left(1-E^{t+1}\right)\varepsilon_{yrt+1}/E^{t+1}\right)+\left(\left(1-E^{t}\right)\varepsilon_{yrt}/E^{t}\right)\right]\left(\ln y_{rt+1}-\ln y_{rt}\right)$ is the effect of scale efficiency change

b) $\frac{1}{2}\sum_k\left[\left(s_{kt+1}-\varepsilon_{wkt+1}\right)+\left(s_{kt}-\varepsilon_{wkt}\right)\right]\left(\ln w_{kt+1}-\ln w_{kt}\right)$ is the effect of the bias in using actual cost share weights instead of optimal cost shares based on shadow prices, i.e. allocative efficiency change.

c) $-\frac{1}{2}\left[\left(\partial\ln c\left(\mathbf{y},\mathbf{w},z_0,t+1\right)/\partial t\right)+\left(\partial\ln c\left(\mathbf{y},\mathbf{w},z_0 t\right)/\partial t\right)\right]$ is the effect of cost reducing technical progress

d) $\left[CE_{t+1}-CE_t\right]$ is cost efficiency change

e) $-\frac{1}{2}\left[\varepsilon_{r0t+1}+\varepsilon_{r0t}\right]\left(\ln r_{0t+1}-\ln r_{0t}\right)$ is the effect on productivity change of variation in the equity-asset ratio constraint.

4. Estimation

The stochastic frontier analysis regression to be estimated, with the error components: v representing idiosyncratic error and u representing inefficiency can be expressed succinctly as follows:

$$\ln(C/w_K)_{it} = \alpha_0 + \mathbf{x}'_{\mathbf{it}}\boldsymbol{\theta} + \varepsilon_{it} \quad ; \quad \varepsilon_{it} = v_{it} + u_{it} \quad i = 1 \ldots N, t = 1 \ldots T \qquad [17]$$

Here $\mathbf{x}'_{it}$ is a $(K + R + 2)$ vector of explanatory variables representing the input prices, outputs, time and the level of the fixed input equity capital including second order direct and cross product translog expressions. The range of panel data stochastic frontier analysis models reflects different assumptions about the nature of the composed error terms. Because experience suggests that parameter values can be sensitive to the form of the stochastic frontier analysis model that is fitted, we shall use a number of different types of these models. The literature here is immense but we can summarize it briefly as follows.

Within the strict panel data structure, many researchers have followed Schmidt and Sickles (1984) and Pitt and Lee (1981) in adopting a time-invariant model of inefficiency, which may not be too dangerous an assumption with a short panel; therefore the composed error term is written: $\varepsilon_{it} = v_{it} + u_i$. The model can be estimated by standard fixed effects using dummy variables, (FE-LSDV), standard random effects with generalised least squares (RE-GLS) or by random effects maximum likelihood estimation (RE-MLE) as suggested by Pitt and Lee (1981), if specific distributional assumptions are made, e.g. the truncated-normal distribution for the inefficiency term. The RE-GLS and RE-MLE models usually give very similar results. To incorporate the more general assumption of time-varying inefficiency two broad approaches are possible. The inefficiency component can be made an explicit function of time: $u_{it} = u_i h(t)$. Battese and Coelli (1992) use an exponential function which is the same across all producers and which can be estimated by maximum likelihood with the appropriate distributional assumptions, while Cornwell Schmidt and Sickles (1990) use a quadratic function of time which differs amongst producers and extends their previous fixed or random effects model to incorporate a time-varying fixed effect. These methods retain an explicit panel structure. An alternative approach to constructing time-varying inefficiency model is to maintain the error structure $\varepsilon_{it} = v_{it} + u_{it}$ and to estimate the time-varying inefficiency component explicitly without constraining it to have a particular dynamic pattern. The Greene (2005) true fixed effects model does this and additionally incorporates firm specific fixed effects for heterogeneity. Saal et al (2007) demonstrates the success of this model with a small number of firms and a large time-series dataset, but with a large number of producers and a short panel this model is more difficult to apply. Firm specific heterogeneity may be incorporated through additional conditioning variables, and a pooled estimation technique based on some form of modified least squares could also be adopted. For example, by making use of the seemingly unrelated regression estimator based on generalised least squares SURE-GLS, we can obtain estimators which are relatively efficient and permit the error terms in the cost hare equations to be related to the overall cost equation; this is a generalization which standard stochastic frontier analysis estimators are unable to provide, see Kumbhakar and Lovell (2000: 156-8). Finally, Battese and Coelli (1995) and Reifschneider and Stevenson (1991) suggested the strategy of making specific parameters of the inefficiency density function for u_{it} conditional on time-varying exogenous variables (i.e. conditional mean or conditional heteroscedasticity). Numerous other models in the literature develop variants of these general procedures; for example the ‘thick frontier' approach of Berger and Humphrey (1991) splits the sample into quantiles of the dependent variable and estimates average regressions for each quantile; the distribution-free approach of Berger (1993), which is similar in concept to RE-GLS uses seemingly unrelated regression with generalised least squares (SURE-GLS) applied to each time period separately.

Reflecting this discussion the empirical results in this paper are derived from five broad categories of model. Use the expression $TL(\mathbf{y}, \tilde{\mathbf{w}}, t, \mathit{capital})$ to denote a translog function of a vector of outputs, a vector of normalized input prices, time and a measure of capital. Capital can be measured either as the level of equity capital or the ratio of equity capital to total assets. Denote the exogenous bank characteristics and macroeconomic variables as: $\mathbf{z}$. The five model forms are:

i. Time-invariant fixed effects, (SSFE), Schmidt Sickles (1984)

$$\ln(C/w_K)_{it} = TL(\mathbf{y}, \tilde{\mathbf{w}}, t, \mathit{capital})_{it} + \mathbf{z}'_{\mathbf{it}}\boldsymbol{\pi} + v_{it} + u_i$$

$$v_{it} \sim iid\left(0, \sigma_v{}^2\right);\ u_i \sim \mathit{constant}$$

ii. Time-invariant random effects, (PL), Pitt-Lee (1981)

$$\ln(C/w_K)_{it} = TL(\mathbf{y}, \tilde{\mathbf{w}}, t, \mathit{capital})_{it} + \mathbf{z}'_{\mathbf{it}}\boldsymbol{\pi} + v_{it} + u_i$$

$$v_{it} \sim Nid\left(0, \sigma_v{}^2\right);\ u_i \sim Nid^+\left(\mu, \sigma_u{}^2\right)$$

iii. Time-varying panel, (BC92) Battese-Coelli (1992)

$$\ln(C/w_K)_{it} = TL(\mathbf{y}, \tilde{\mathbf{w}}, t, \mathit{capital})_{it} + \mathbf{z}'_{\mathbf{it}}\boldsymbol{\pi} + v_{it} + u_{it}$$

$$v_{it} \sim Nid\left(0, \sigma_v{}^2\right);\ u_{it} = u_i \exp(-\eta(t-T)) \quad u_i \sim Nid^+\left(\mu, \sigma_u{}^2\right)$$

iv. Time-varying conditional heteroscedasticity, (UHET) Reifschneider-Stevenson (1991)

$$\ln\left(C/w_K\right)_{it} = TL\left(\mathbf{y},\tilde{\mathbf{w}},t,capital\right)_{it} + v_{it} + u_{it}$$

$$v_{it} \sim Nid\left(0,\sigma_v{}^2\right);\ u_{it} \sim Nid^+\left(\mu,\sigma_{uit}{}^2\right);\ \sigma_{uit}{}^2 = \mathbf{z}'_{\mathbf{it}}\boldsymbol{\pi}$$

v. Time-varying seemingly unrelated system, (SURE-GLS)

$$\ln\left(C/w_K\right)_{it} = TL\left(\mathbf{y},\tilde{\mathbf{w}},t,capital\right)_{it} + \mathbf{z}'_{\mathbf{it}}\boldsymbol{\pi} + \varepsilon_{eit}$$

$$s_{kit} = s_{kit}\left(\mathbf{y},\tilde{\mathbf{w}},t,capital\right)_{it} + \varepsilon_{eit} \quad k = 1\ldots K-1$$

$$\varepsilon_{eit} \sim iid\left(0,\sigma_e{}^2\right) \quad e = C, s_1 \ldots s_{K-1}$$

We note that case iii has the conditioning heterogeneity variables determining the variance of the inefficiency component of the error term as suggested by Reifschneider and Stevenson (1991) and used with all dummy variables by Mester (1993), see also Kumbhakar and Lovell (2000: 272-3); consequently model iii incorporates the distinction between net and gross inefficiency suggested by Coelli and Perelman (1999).

The estimated efficiency score differs in each model as follows, e.g.

i. SSFE : $CE_i = \exp\left(-\hat{u}_i\right) = \exp\left[-\left(\hat{\alpha}_i - \min\left(\hat{\alpha}_j\right)\right)\right]$

ii. PL : $CE_i = \exp\left(-\hat{u}_i\right) = E\left(\exp\left[-u_i \middle| \tilde{e}_{it}\right]\right)$

iii. BC92: $CE_{it} = \exp\left(-\hat{u}_{it}\right) = E\left(\exp\left[-u_i \exp\left(-\eta(t-T)\right) \middle| \tilde{e}_{it}\right]\right)$

iv. UHET: $CE_{it} = \exp\left(-\hat{u}_{it}\right) = E\left(\exp\left[-u_{it} \middle| \tilde{e}_{it}\right]\right)$

v. SURE-GLS: $CE_{it} = \exp\left(-\hat{u}_{it}\right) = \exp\left[-\left(e_{it} - \min\left(e_{jt}\right)\right)\right]$

In these expressions: $\hat{\alpha}_j$ is the estimated FE-LSDV intercept term,; e_{it} is the time varying SURE-GLS residual in the cost equation; $E\left(\exp\left[-u_{it} \middle| \tilde{e}_{it}\right]\right)$ is the expected value exponential derived from the conditional density function for the inefficiency component conditional on the corresponding MLE residual.

5. Data

The data are gathered from Bankscope by Bureau Van Dijk (2010) and OECD and World Bank databases. The bank data have been reported in $US millions at current prices and market exchange rates. We convert to constant price (year 2000) values by deflating the $US denominated data converted at market exchange rates by the US GDP deflator. Table 1 reports the range of countries and regions used in the sample, while summary statistics for our sample of 485 banks over the period 2005-2008 are reported in Table 2; these indicate the within sample variability of the pre-filtered raw data.

TABLE 1 HERE

TABLE 2 HERE

The definitions of the key variables in the cost function are standard in the current literature on bank performance, see for example Bikker and Bos (2008). They are calculated from the constant price data as follows. Cost, C, is total operating cost i.e. the sum of interest expenses, salaries and employee benefits and other operating costs. Outputs are: loans, y_1, securities investments, y_2, and off balance sheet total business volume, y_3. The loans variable used is *net loans* after allocating reserves for non-performing loans. Equity capital (z_0) is reported separately and the first two outputs, loans, y_1, securities investments, y_2 together account for total assets, (z_1). Input price indices are: the price of labour, w_1, computed as salaries and employee benefits relative to total assets, the price of physical capital, computed as other operating expenses divided by fixed assets, w_2, and the price of funds, computed as interest expenses relative to total assets, w_3. All of these industry variables are sourced from Bureau Van Dijk (2010) for each bank and period in the sample, and all have been deflated as above. In addition to these key variables banking system variables are used along with macroeconomic variables to condition the individual bank cost functions. Macroeconomic variables are collected from the OECD and World Bank data bases and vary through time but are constant across banks. They are measured as percentage rates of change. In this way the banking market is conditioned at the level of the macro-economy before the beginning of the sample period; then the relative changes in the macroeconomic environment are treated as exogenous shocks. They are measured in differenced form to avoid the spurious correlation problem of entering macroeconomic trending variables in the cost regression. The macroeconomic environmental shocks used in the analysis are as follows:

(a) change in Gross domestic product at 2000 market prices

(b) change in Gross domestic product at 2000 market prices per head of population;

These reflect the cyclical response to government macroeconomic policy as well as the impact of exogenous shocks from the external economy

Banking system variables are: Loan Loss Reserve / Gross Loans, net interest margin, return on assets, return on equity, Cost to Income Ratio, Net Loans / Total Assets, Net Loans / Customer and short term, Funding Reserves for Impaired Loans/ NPLs, Non-Interest Income/ Gross Revenues, Non-Interest Expense/ Gross expenses, NPL/ Gross

Loans, Reserves for NPL/ Gross loans, Reserves for NPL/ NPL, Interbank Assets/ Interbank Liabilities

All of the data in the fitted regressions are log-mean-corrected; i.e. expressed as deviations from the sample means after having been transformed to natural logarithms. This has three advantages: it ensures that the translog function which is an approximation to an arbitrary second order function (an element of class C^2 functions) has the point of approximation at the sample mean; it allows us to check the properties of the fitted translog function at the sample mean by examining the first order estimated coefficients; and it enables computation of the variance of linear functions of the estimated coefficients around the sample mean from the variance-covariance matrix of the regression coefficients.

6. Empirical results: parameter estimates and the shadow price of the equity-asset ratio

Prior to estimation of the models, the data were filtered using the financial ratio rules suggested by Bikker and Bos (2008) together with the addition of a statistical criterion in which we estimated a simple pooled OLS model for the whole sample and dropped observations with a standardised OLS residual exceeding 2 in absolute value. This rule of thumb is approximately equivalent to capturing outliers in the data by an instrumental dummy variable at the five percent level of significance. These filters resulted in reducing the sample from 1940 observations to 1869 observations.

Regression results for the first order coefficients in the cost function fitted under different models are shown in table 3. Table 3 presents: (i) the monotonicity effects, i.e. elasticity function estimates at the sample mean and (ii) measures of the presence of inefficiency as a component of the error term and whether the inefficiency is time varying.

TABLE 3

The regression coefficients on the first order terms[5], i.e. the cost function elasticities at the sample mean, are relatively consistent across the different econometric specifications. The models all fit will and there are no strong reasons to favour one over another. However, the SURE-GLS model which pools the data without a panel structure finds a negative effect from securities investment while at the same time suggesting that the shadow price of the equity-asset ratio constraint is higher than for other models. The four remaining stochastic frontier analysis models all find a very consistent negative shadow price of about -4.5 to -5 percent on the capital constraint. Interestingly when the equivalent models are estimated with the level of equity capital as the constraint, the shadow return on capital is consistently negative, confirming strongly that these emerging country banks experienced stringent re-capitalization during this period. Amongst the four stochastic frontier analysis models the Reifschneider-Stevenson UHET results indicate the significance of all of the output variables and have significant and theoretically correct first order elasticity estimates at the sample mean.

In interpreting this model in comparison to the others, it is important to remember that in the UHET specification, the additional z variables affect the variance of the estimated inefficiency whereas in the other models the z variables affect the position of the cost frontier-consequently the signs are not necessarily comparable.

[5] There are multiple second order and interaction coefficients too numerous to report here.

The Panzar-Willig estimate of the elasticity of scale at the sample mean, and the scale elasticity evaluated out of equilibrium, after adjusting for the regulated equity assets ratio are shown in table 4; they indicate a small degree of increasing returns suggesting the scope for some consolidation amongst the banking systems in emerging economies.

TABLE 4

7. Empirical results: productivity measurement

In this section of the paper, we use the discrete index number calculation to decompose productivity change during the period encompassing the financial crisis. We could illustrate the impacts by using any of the four composed error stochastic frontier analysis models since their coefficients are relatively stable across different approaches. For a number of reasons described above, the Reifschneider Stevenson model seems to generate the most sensible results and we focus on that model to calculate the productivity decomposition. Table 5 reports the productivity estimates and the component factors for this model; the decomposition covers scale efficiency change, technical change, efficiency change, allocative efficiency change, and constraint relaxation change. The last component illustrates how the requirement to build up stronger equity asset ration during re-capitalization may enhance or offset total factor productivity change over the period.

TABLE 5 HERE

In table 5 we see that total factor productivity change in emerging economy banking systems averaged over the sample period has been very slightly negative. The forces driving total factor productivity up have originated in scale efficiency change and allocative efficiency change. Regressive factors have been an apparent loss of technological progress and the impact of the equity-asset constraint. In other words, the need to maintain capital structures has offset the positive forces on total factor productivity change during this critical period. We illustrate the overall trends of the frontier model in figure 1 for further clarity.

FIGURE 1 HERE

Figure 1 sketches the components of the asset weighted total factor productivity change for banking systems in emerging economies during this crucial period of re-capitalization. Consistently over the period allocative and scale efficiency change have contributed positively to the performance of banking systems in transition economies. Efficiency change has been improving after an initial negative start. Consequently the emerging economies' banking systems have shown signs of resilience while the international financial system has been coping with its recent problems. However, cost performance has been weakened by a failure to take advantage of technological progress and by the need to maintain acceptable equity capital ratios. The capital adequacy constraint has contributed to the weak overall productivity performance.

8. Conclusions and policy lessons

We have carried out an empirical analysis of the banking systems of a large number of emerging economies during a critical period for the international financial system. In doing this we focused on three aspects of the modelling problem. First we have chosen to construct short run constrained total cost functions for the emerging economy banks. Second we applied the stochastic frontier analysis to these in order to identify sources of variability in economic performance. Thirdly, we were able to derive from the estimated cost functions a decomposition of total factor productivity into: scale efficiency change, allocative efficiency change, technical change, efficiency change and the impact of the equity-capital constraint. This formulation can easily be generalised to investigate other policy related issues. We discovered that a variety of time-invariant and time-varying stochastic frontier analysis models gave consistent results for this relatively short period, but we were able to show that a time varying conditional heteroscedasticity model fitted the data particularly well.

Amongst the empirical results that we were able to uncover, we confirmed the importance of the equity capital ratio as a constraint on cost minimising behaviour. This has important policy implications. In the current state of worldwide recovery from the financial crisis, the issue of the re-capitalization of the banking system is dominating the policy debate. This has a long run dimension which is expressed in the question of whether greater reliance on equity capital will raise the long run funding costs of the banks. Policy makers seem relatively optimistic on this issue. However, the equity capital ratio also has a short run dimension: what are the adjustment costs that arise when a banking system recapitalizes? As we indicated at the beginning of the paper this is an important and unresolved policy problem. This paper has suggested a way of measuring these adjustment costs by examining the role of the equity capital constraint in the determination of total factor productivity of the banking system. Our results suggest that there is a positive adjustment cost. However it may be relatively small enough not to offset the recognised benefits of moving to a more securely based banking system that uses higher levels of equity capital.

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TABLES

Table 1

No	Country Name	2005	2006	2007	2008
1	ARGENTINA	14	14	14	14
2	BAHRAIN	6	6	6	6
3	BELARUS	10	10	10	10
4	BOLIVIA	8	8	8	8
5	BRAZIL	47	47	47	47
6	BULGARIA	12	12	12	12
7	CHINA-PEOPLE'S REP.	14	14	14	14
8	COSTA RICA	15	15	15	15
9	CROATIA	17	17	17	17
10	CZECH REPUBLIC	9	9	9	9
11	GEORGIA REP. OF	8	8	8	8
12	GREECE	13	13	13	13
13	HONG KONG	11	11	11	11
14	HUNGARY	7	7	7	7
15	INDIA	43	43	43	43
16	INDONESIA	6	6	6	6
17	ISRAEL	10	10	10	10
18	JORDAN	10	10	10	10
19	KOREA REP. OF	15	15	15	15
20	LATVIA	17	17	17	17
21	LITHUANIA	6	6	6	6
22	PERU	9	9	9	9
23	PHILIPPINES	20	20	20	20
24	POLAND	17	17	17	17
25	ROMANIA	17	17	17	17
26	SLOVAKIA	10	10	10	10
27	SLOVENIA	12	12	12	12
28	SOUTH AFRICA	8	8	8	8
29	TAIWAN	13	13	13	13
30	THAILAND	16	16	16	16
31	TURKEY	12	12	12	12
32	UKRAINE	26	26	26	26
33	UNITED ARAB EMIRATES	11	11	11	11
34	VENEZUELA	16	16	16	16
	Total	485	485	485	485

Table 2 Summary data on core variables prior to sample filtering: $US million at year 2000 prices except where otherwise stated

Variable	number in unfiltered sample	Mean	Std. Dev.	Min	Max
Loans	1940	89.88604	339.6181	0.0002287	5272.131
securities and investments	1940	40.29417	210.9409	0.000	3657.231
off balance sheet income	1940	57.23229	224.4006	0.000	3342.204
total assets	1940	161.4529	669.0114	0.1085498	11596.22
deposits and short term funding	1940	126.5258	576.3351	0.0176429	10547.89
interest expenses	1940	4.555784	14.12974	0.0003471	211
personnel expenses	1940	1.439621	4.573288	0.0022202	63.28918
other operating expenses	1940	1.496821	4.347391	0.0006781	46.88668
Equity-assets ratio (%)	1940	11.72962	8.703521	.102	86.24

Table 3 First order regression coefficients of cost function variables

Variable	SSFE	PL	BC92	UHET	SURE_GLS
Core outputs, input prices, time and cost function constraint variables					
Loans	0.938***	0.957***	0.957***	0.805***	1.006***
Securities	0.005	0.001	0.003	0.145***	-0.035***
off balance sheet	0.007**	0.010***	0.008***	0.017***	0.011***
funding price	0.052***	0.059***	0.059***	0.064***	0.235***
capital price	0.571***	0.554***	0.555***	0.448***	0.543***
Time	0.025***	0.024***	0.054***	0.020***	0.011
equity-assets ratio	-0.049***	-0.049***	-0.041***	-0.044***	-0.099***
Z-variables used to condition the cost frontier or the inefficiency estimates					
net loans/total assets	-0.01422***	-0.01520***	-0.01460***	-0.00704	-0.01768***
net loans/deposits and short term funds	-0.00339***	-0.00360***	-0.00380***	-0.07951***	-0.00181***
liquid assets/deposits and short term funds	-0.00066***	-0.00084***	-0.00070***	0.01689***	-0.00015
reserves for impaired loans/ non-performing loans	-0.00001	-0.00002***	-0.00001**	-0.00003	0.00001
non-interest expenses/gross revenues	0.00028	0.00033*	0.00034*	-0.00114	0.00115***
non-performing loans/gross loans	0.00066	0.00049	0.00049	-0.00199	0.00150**
non-performing loans/gross loans relative to the average for the country	0.00196	0.00333***	0.00247*	0.11730***	0.00146
equity asset ratio relative to the average for the country	0.00384	0.00562***	0.00335*	0.10639***	0.00760***
per capita GDP growth rate	-0.00036	0.00004	-0.00068	0.02777	-0.00005
Mu		0.18958***	0.17306***		
Eta			0.14049***		
Time				0.29306**	
Model statistics					
F value	2150.00				
chi-square		272000.00	262000.00	200000.00	
sigma_u	0.15	0.12	0.09	* conditional on z-variables above	no u component
sigma_v	0.06	0.06	0.06	0.15	

Note: * p<0.05; ** p<0.01; *** p<0.001 where p = probability-value significance level

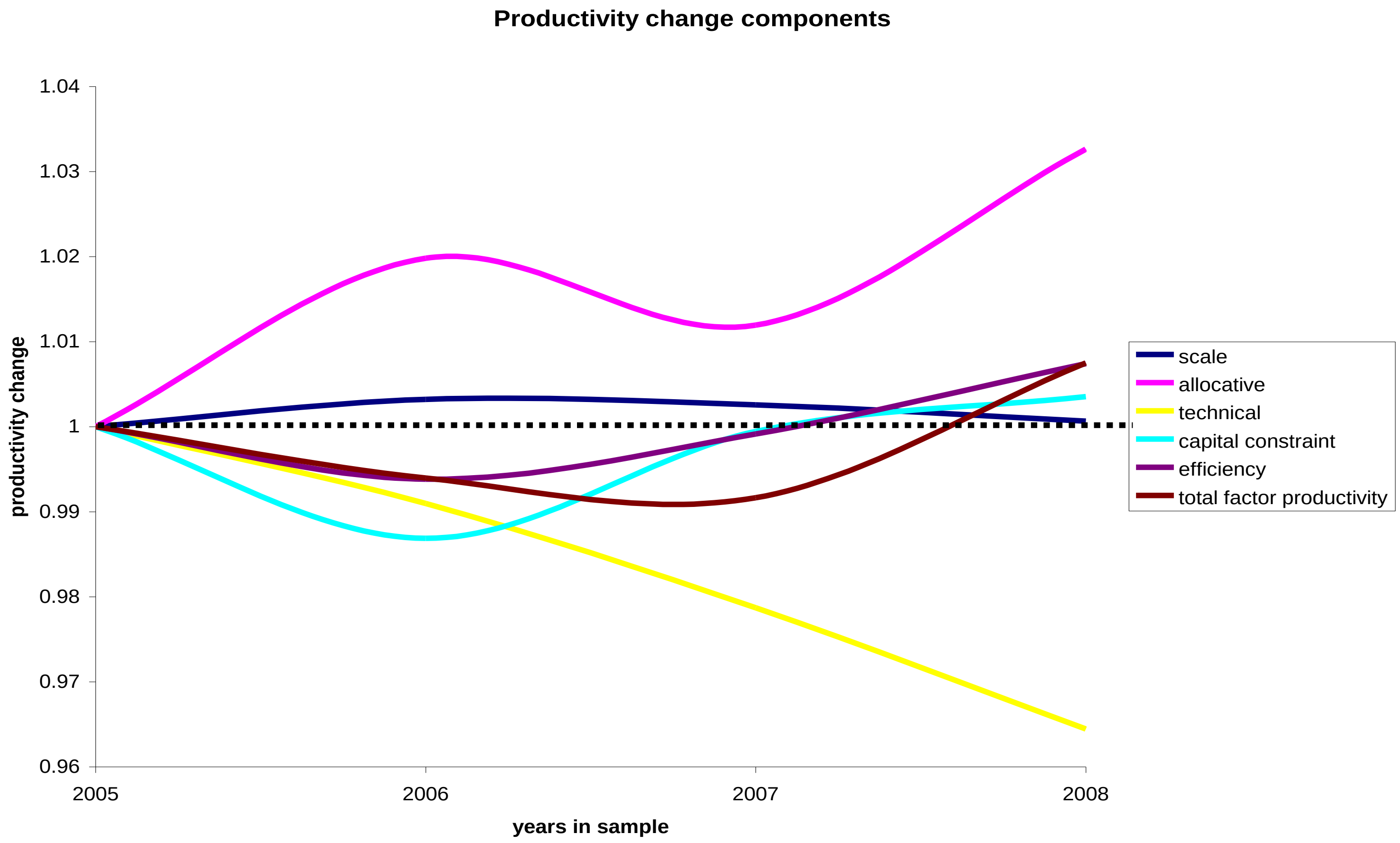
Table 4 Estimated elasticity of scale at the sample mean

Sample mean values	SSFE	PL	BC92	UHET	SURE_GLS
Panzar-Willig elasticity of scale	1.053	1.033	1.033	1.034	1.018
Adjusted elasticity of scale	1.105	1.084	1.075	1.079	1.120

Table 5 Total factor productivity change and its components

Year	scale	allocative	technical	capital constraint	efficiency	total factor productivity
2005	1.000	1.000	1.000	1.000	1.000	1.000
2006	1.003	1.020	0.991	0.987	0.994	0.994
2007	1.003	1.012	0.979	0.999	0.999	0.992
2008	1.001	1.033	0.964	1.004	1.007	1.007
mean over time	1.002	1.016	0.983	0.997	1.000	0.998

Figure 1


Productivity change components
1.04
1.03
1.02
1.01
1
0.99
0.98
0.97
0.96
productivity change
2005
2006
2007
2008
years in sample
scale
allocative
technical
capital constraint
efficiency
total factor productivity