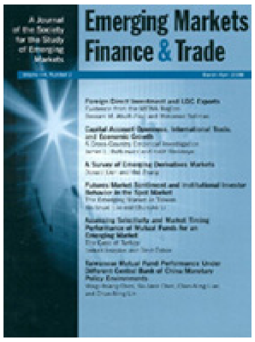

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Turkish Banking Recapitalization and the Financial Crisis: An Efficiency and Productivity Analysis

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ABSTRACT: This paper describes procedures in panel data econometrics for efficiency measurement and productivity decomposition in the banking system of an emerging economy with a special focus on the period following a financial crisis. In the recovery from a banking crisis, policymakers attempt to recapitalize the banking system, but this has the potential to impose significant costs. Turkey has restructured the banking system through recapitalization, and this has directly caused the shadow return on equity to turn negative. This negative shadow return on equity is an offset to total factor productivity change, and there is an important policy lesson that a successful recapitalization has a cost in restricting the banking system's overall productivity growth.

KEY WORDS: banking, cost function, panel data, stochastic frontier analysis.

When a banking system has gone through a financial crisis, there are important lessons to learn from how it emerges and recovers. An example is Turkey, which experienced major financial disruption in 2000–2001 both through severe recession—gross domestic product (GDP) fell by more than 5 percent—and through the rescue of a large part of the banking system by injecting public sector capital and the consequent expansion of public debt as a percentage of GDP (Akin et al. 2008, 2011). Since 2005 Turkey has made a remarkable recovery, with consumer price inflation below 10 percent per year, reemergence of strong GDP growth, and a decrease in public debt as a percentage of GDP. According to Akin et al. (2010) and Al and Aysan (2006), the tight fiscal policy that was implemented after the financial crisis in 2001 and the International Monetary Fund (IMF) stabilization programs were effective in establishing economic stability in Turkey.

During this period, the banking system in Turkey has been restructured with fewer but stronger banks and strongly recapitalized with higher capital ratios. Capital ratios have at one point reached almost double of those of European and U.S. banks. In 2007, the IMF concluded that the financial system in Turkey had been transformed since the 2001 crisis. It noted progress in modernizing the institutional framework for bank supervision and that the massive rise in foreign direct investment had been led by the banking industry (IMF 2007).

Three years later, following the global financial crisis, the IMF felt that the banking sector in Turkey had shown greater resilience than in its 2000–2001 crisis and stated that the factors contributing to this included large capital and liquidity buffers, and reliance on deposit-based funding. These actions protected the banks in Turkey from the global

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debt reductions, and the IMF observed that the already strong capital adequacy ratios rose even higher, to around 20 percent (IMF 2010).

In the aftermath of the 2007–8 financial crisis, the monetary authorities in Switzerland required their major banks to aim for equity-capital ratios far in excess of Basel requirements—approaching 19 percent to 20 percent (King 2010)—just as the banking system in Turkey did after the financial crisis of 2001 (Abbasoglu et al. 2007; Akyurek 2006). In the United Kingdom, King's broad answer to the banking crisis was very simple: "much, much more equity; much, much less short term debt" (King 2010, p. 18). However, as King (2010) points out, major recapitalization of the banking systems around the world must impose resource costs both on the wider economy and on the banking system in particular.

One focus of our research therefore will be on measuring the shadow return on equity when a banking system is recapitalized, examining the experience of Turkey over the period 2006–9. The core objective is to measure the efficiency and productivity analysis of the banking system during this recovery phase of the recapitalization process. We believe this is a significant contribution to the vast literature on bank performance studies (see the recent survey by Fethi and Pasiouras (2010)).

Furthermore, on bank-specific basis, we decompose productivity change into scale efficiency change, allocative efficiency change, technological change, technical efficiency change, and the impact of recapitalization. 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 recapitalization process act as an offset to the total factor productivity growth of the banking system, then it may be possible to estimate the costs of the recapitalization policy.

Modeling the Technology and Relative Efficiency

The parametric frontier dual cost function that we use is based on K variable inputs: $\mathbf{x} = (x_1, ..., x_K)$ with input prices of $\mathbf{w} = (w_1, ..., w_K)$ and R outputs of $\mathbf{y} = (y_1, ..., y_R)$, and an additional input that may be a fixed input in the short run, but which is variable in the long run. For clarity, we symbolize this particular input as z_0, with input price w_0. The envelope theorem confirms that long-run total cost defines the envelope of short-run total cost, written here as variable plus fixed cost:

$$c\left(\mathbf{y},\mathbf{w},w_0,t\right)=\min_{z_0}\left\{c\left(\mathbf{y},\mathbf{w},z_0,t\right)+w_0 z_0\right\} \tag{1}$$

Consequently, the following derivative result holds in the neighborhood of the optimal level of the fixed input, z_0^*:

$$\partial c\left(\mathbf{y},\mathbf{w},w_0,t\right)/\partial z_0 = 0 = \left[\partial c\left(\mathbf{y},\mathbf{w},z_0^*,t\right)/\partial z_0\right]+w_0. \tag{2}$$

Rearranging this last result gives the critical interpretation of the shadow price of the fixed input:

$$-\left[\partial c\left(\mathbf{y},\mathbf{w},z_0^*,t\right)/\partial z_0\right]=w_0. \tag{3}$$

This form of the envelope theorem is particularly useful when, in addition to an input being fixed, there is no explicit information on its price. The negative of the derivative of the variable cost function with respect to this fixed input is the input's shadow price.

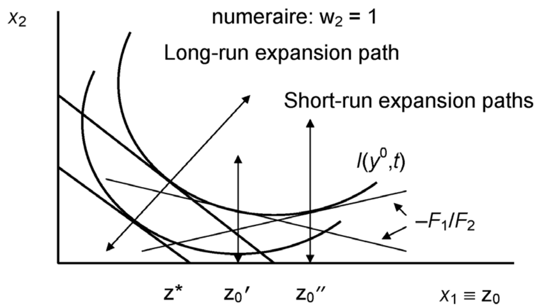

Figure 1. Long-run and short-run expansion paths with weak disposability

The fixed input in our model of the banking system technology is the level of equity capital held for both prudential and regulatory reasons. Negative values of the shadow input price of equity would arise if the firms were operating in the uneconomic region; thus we assume that the production technology has the properties of convexity and weak disposability so an uneconomic region is feasible. Figure 1 displays a diagrammatic representation of these arguments.

Figure 1 also shows an input requirement set as the area to the northwest of the isoquant boundary for the corresponding level of output. Weak disposability allows the isoquants to exhibit a positive slope for high values of one of the inputs, so that the marginal rate of technical substitution between inputs is allowed to be positive in the uneconomic region of the production function. The long-run expansion path of the firm is shown by the successive tangencies of isoquant and isocost lines and include the long-run equilibrium level of the input: $x_1 \equiv z_0^*$. Short-run fixed requirement levels of the input are shown as z_0' and z_0'' with corresponding short-run expansion paths. If the firm is constrained to hold a very high level of the input, for example z_0'', the short-run expansion path passes through an uneconomic region of the production function or input requirement set. The marginal rate of technical substitution becomes positive, implying that the marginal product of the fixed input has become negative. The shadow return on the fixed input in the cost function measures the value of this possibly negative marginal product. The second implication of the analysis concerns the measurement of returns to scale. Braeutigam and Daughety (1983) adapt the analysis in Panzar and Willig (1977) to derive the following result concerning the inverse of the elasticity of cost with respect to output:

$$E_{c\mathbf{y}}^{-1} \approx \left(1 - \partial \ln C / \partial \ln z_0\right) \Big/ \sum_{r=1}^{r=R} \left(\partial \ln C / \partial \ln y_r\right). \tag{4}$$

This measures returns to scale at the observed suboptimal level of the fixed input, which may be more appropriate if the industry is expected to remain at a suboptimal allocation of inputs. The actual cost experienced by the firm is by definition

$$C_t \equiv \mathbf{w}'\mathbf{x} + \alpha_0, \tag{5}$$

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

$$CE_t = \left\{c\left(\mathbf{y}, \mathbf{w}, z_0, t\right) / C_t\right\} \in \left(0,1\right]. \tag{6}$$

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

$$\ln C_t = \ln c\left(\mathbf{y}, \mathbf{w}, z_0, t\right) + u \tag{7}$$

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 $\ln(C/w_K) = \ln c(\mathbf{y}, \mathbf{w}], z_0, t) + u$ by a fully flexible functional form, such as the translog function with an additive idiosyncratic error term, ν, to capture sampling, measurement, and specification error.[1] Homogeneity is imposed by dividing through by one of the input prices, w_K. Therefore we redefine the variables in vector form as

$$\mathbf{l}\tilde{\mathbf{w}} = \left(\ln\left(w_1 / w_K\right) \ldots \ln\left(w_{K-1} / w_K\right)\right)$$
$$\mathbf{ly} = \left(\ln y_1 \ldots \ln y_R\right).$$

and writing the translog approximation with additive error term as

$$\begin{aligned} \ln(C/w_K) = {} & \alpha_0 + \boldsymbol{\alpha}'\mathbf{ly} + \boldsymbol{\beta}'\mathbf{lw}] + (1/2)\mathbf{ly}'\mathbf{A}\mathbf{ly} + (1/2)\mathbf{lw}]'\mathbf{B}\mathbf{lw}] + \mathbf{ly}'\boldsymbol{\Gamma}\mathbf{lw}] \\ & + \delta_1 t + (1/2)\delta_2 t^2 + \boldsymbol{\mu}'\mathbf{ly}\, t + \boldsymbol{\eta}'\mathbf{lw}]\, t + \rho_1 \ln z_0 + (1/2)\rho_2(\ln z_0)^2 \\ & + \boldsymbol{\Psi}'\mathbf{ly} \ln z_0 + \boldsymbol{\xi}'\mathbf{lw}] \ln z_0 + \omega \ln z_0 t + \nu + u. \end{aligned} \tag{8}$$

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

$$\begin{bmatrix} \boldsymbol{\varepsilon}_y \\ \boldsymbol{\varepsilon}_{\tilde{w}} \\ \varepsilon_t \\ \varepsilon_{z0} \end{bmatrix} = \begin{bmatrix} \boldsymbol{\alpha} & \mathbf{A} & \boldsymbol{\Gamma} & \boldsymbol{\mu} & \boldsymbol{\Psi} \\ \boldsymbol{\beta} & \boldsymbol{\Gamma}' & \mathbf{B} & \boldsymbol{\eta} & \boldsymbol{\xi} \\ \delta_1 & \boldsymbol{\mu}' & \boldsymbol{\eta}' & \delta_2 & \omega \\ \rho_1 & \boldsymbol{\Psi}' & \boldsymbol{\xi}' & \omega & \rho_2 \end{bmatrix} \begin{bmatrix} 1 \\ \mathbf{ly} \\ \mathbf{l}\tilde{w} \\ t \\ \ln z_0 \end{bmatrix}. \tag{9}$$

We estimate this cost model using a stochastic frontier analysis approach.

Productivity Growth

Following Bauer (1990), Lovell (2003), and Orea (2002), we differentiate both sides of the cost equation with respect to t and obtain:

$$E^{-1}\boldsymbol{\varepsilon}_y'\dot{\mathbf{y}} - \mathbf{s}'\dot{\mathbf{x}} = (1 - E/E)\boldsymbol{\varepsilon}_y'\dot{\mathbf{y}} + (\mathbf{s} - \boldsymbol{\varepsilon}_{w]})'\dot{\mathbf{w}} - \varepsilon_t - (du/dt) - \varepsilon_{z0}\dot{z}_0. \tag{10}$$

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 $\varepsilon_{yr} = \partial \ln c(\mathbf{y}, \mathbf{w}], z_0, t)/\partial \ln y_r$; $\boldsymbol{\varepsilon}_{w]}$ is the vector of cost elasticity functions with respect to the input prices, with typical element $\boldsymbol{\varepsilon}_{w]k} = \partial \ln c(\mathbf{y}, \mathbf{w}], z_0, t)/\partial \ln w]_k$; ε_t is the cost elasticity function with respect to the time-based index of technological progress $\boldsymbol{\varepsilon}_t = \partial \ln c(\mathbf{y}, \mathbf{w}], z_0, t)/\partial lt$; (du/dt) is the rate of change in inefficiency; ε_{z0} is the cost elasticity with respect to the fixed input, that is, equity capital; and $\mathbf{s}$ is the vector of actual cost shares. The left-hand side of this expression is by definition a measure of total factor productivity change with weights that add up to unity, 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:

1. $(1 - E/E)\boldsymbol{\varepsilon}_y'\dot{\mathbf{y}}$, *scale efficiency change:* if $E = 1$, that is, constant returns to scale (CRS), there is zero scale efficiency change in the total factor productivity change (TFPC) decomposition.
2. $(\mathbf{s} - \boldsymbol{\varepsilon}_{w]})'\dot{\mathbf{w}}$, *allocative efficiency change:* if actual input cost shares and optimal input cost shares are equal, there is no potential for allocative efficiency change, that is, $\mathbf{s} - \boldsymbol{\varepsilon}_{w]} = 0$.
3. $-\varepsilon_t$, *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.
4. $-(du/dt)$, *cost efficiency change:* if this term, including the sign, is positive, then productivity is enhanced by improvements in technology.
5. $-\varepsilon_{z0}\dot{z}_0$, *fixed input productivity change:* if this term, including the sign, is positive, then productivity is enhanced by increased use of the fixed input.

If the shadow price or rate of return on equity is positive, then holding higher levels of equity capital will move the banking system toward 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), then the requirement to hold higher than equilibrium levels of equity capital will impose a negative component on productivity growth. This allows us to measure the cost impact of recapitalization by the contribution (negative or positive) of the changes in the equity level to the measured total factor productivity growth. These components of total factor productivity change are shown in total differential form; however, by application of the quadratic lemma (Caves et al. 1982), we can use them in index number form:

1. $(1/2)\Sigma_r[((1 - E^{t+1})\varepsilon_{yrt+1}/E^{t+1}) + ((1 - E^t)\varepsilon_{yrt}/E^t)](\ln y_{rt+1} - \ln y_{rt})$ is the effect of scale efficiency change.
2. $(1/2)\Sigma_k[(s_{kt+1} - \varepsilon_{w]kt+1}) + (s_{kt} - \varepsilon_{w]kt})](\ln w_{kt+1} - \ln w_{kt})$ is the effect of the bias in using actual cost share weights instead of optimal cost shares based on shadow prices, that is, allocative efficiency change.
3. $-(1/2)[(\partial \ln c(\mathbf{y}, \mathbf{w}, z_0, t + 1)/\partial t) + (\partial \ln c(\mathbf{y}, \mathbf{w}, z_0 t)/\partial t)]$ is the effect of cost-reducing technical progress.
4. $[CE_{t+1} - CE_t]$ is the cost efficiency change.
5. $-(1/2)[\varepsilon_{z0t+1} + \varepsilon_{z0t}](\ln z_{0t+1} - \ln z_{0t+1})$ is the effect on productivity change of variation in the fixed input equity-level constraint.

Estimation

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

$$\ln(C/w_K)_{it} = \alpha_0 + \mathbf{x}_{it}'\boldsymbol{\theta} + \nu_{it} + u_{it} \quad i = 1, ..., N,\ t = 1, ..., T, \tag{11}$$

where $\mathbf{x}_{it}'$ is a $(K + R + 2)$ vector of explanatory variables representing the input prices, outputs, time, and the level of the fixed input equity capital. 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 to the data, we shall use a number of different types of these models.

As a benchmark starting point we use iterative, seemingly unrelated regression (SURE). This assumes a single-component error structure without an inefficiency element so that every firm is assumed to be on the frontier. It proceeds by replacing the left-hand side of the calculated input price elasticity functions by the actual input shares in total cost and estimating the cost equation and the $\boldsymbol{\varepsilon}_{w]}$ rows of the derivative matrix as a system of seemingly unrelated regressions with cross-equation parameter-equality constraints. Although this assumes a single error component, an inefficiency interpretation is possible by applying a corrected least squares approach based on the minimum residual, that is, corrected generalized least squares based on seemingly unrelated regressions, or SURE-CGLS.

The stochastic frontier analysis models all assume two component error terms, one to measure idiosyncratic error and one to measure inefficiency. One of these composed error models is due to Schmidt and Sickles (1984), who treated the inefficiency term as time invariant in a fixed effects (FE) formulation. Both Pitt and Lee (1981) and Schmidt-Sickles (1984) suggested random effects (RE) formulations as well, with time-invariant inefficiency; Pitt and Lee specify normal and half-normal distributions for the idiosyncratic and inefficiency components and use maximum likelihood estimation.

There are three time-varying efficiency models. The first is due to Cornwell et al. (1990) and is further developed in Sickles (2005). This is an FE model with firm-specific linear dependence on the time of the fixed effects representing the inefficiency component. The fixed effects used to measure inefficiency in Schmidt and Sickles (1984) are permitted to be time varying by using a polynomial function of time (Cornwell et al. 1990). Battese and Coelli (1992) extended the Pitt–Lee model to allow for time-varying inefficiency by combining a truncated normal distribution for the inefficiency component with a deterministic function of time incorporating a single parameter covering the whole sample. In a further development, Battese and Coelli (1995) suggested their technical efficiency effects model, in which the mean of the truncated distribution for inefficiency is a deterministic function of a number of exogenous variables, which may include time. The computation of the estimated inefficiency component varies among the different models, and is further described in Kumbhakar and Lovell (2000).

Data

The data are gathered from two major sources: Bankscope by Bureau Van Dijk (2010) and the European Commission's Annual Macro-Economic Database (2010), which is the annual macro-economic database of the European Commission's Directorate General for Economic and Financial Affairs. The bank data have been reported in millions of U.S. dollars at current prices and market exchange rates. We convert to constant price (2000) values by deflating the U.S. dollar–denominated data converted at market exchange rates by the U.S. GDP deflator reported by the European Commission (2010). Table 1 reports summary statistics for our sample of twenty-two banks over the period 2006–9, comprising a balanced panel of eighty-eight observations. The number of banks has changed significantly since the financial crises of the 1990s, and the data show less volatility since those times. Within sample variability is shown by the reported coefficients of variation in Table 1.

Table 1. Summary statistics for the sample of 22 banks 2006–2009

Variable	Mean	Standard deviation	Min	Max	Coefficient of variation
Total assets, USD billion at 2000 prices	15.200	18.700	0.293	69.800	1.230
Equity, USD billion at 2000 prices	1.782	2.189	0.070	8.531	1.228
Loans, USD billion at 2000 prices	8.062	9.180	0.169	30.300	1.139
Securities, USD billion at 2000 prices	4.317	6.630	0.001	26.100	1.536
Off–balance sheet business volume, USD billion at 2000 prices	22.200	26.500	0.293	105.000	1.194
Price index of funds, input cost relative to total assets	0.061	0.018	0.014	0.106	0.291
Price index of labor, input cost relative to total assets	0.018	0.006	0.006	0.035	0.351
Price index of physical capital, input cost relative to fixed assets	1.750	1.432	0.197	8.353	0.818
Cost, USD billion at 2000 prices	1.466	1.694	0.023	6.415	1.156

The definitions of the key variables in the cost function are standard in the current literature on bank performance (see, e.g., Bikker and Bos 2008). They are calculated from the constant price data as follows. Cost, C, is total operating cost, that is, 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 nonperforming loans. Equity capital (z_0) is reported separately and the first two outputs, loans, y_1, and securities investments, y_2, together account for total assets (z_1). Input price indices are: the price of funds, w_1, computed as interest expenses relative to total assets; the price of labor, w_2, computed as salaries and employee benefits relative to total assets; and the price of physical capital, w_3, computed as other operating expenses divided by fixed assets. 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, we investigated a number of macroeconomic variables to condition the regression estimation and the inefficiency scores. Macroeconomic variables are collected from the European Commission (2010) database and vary through time but are constant across banks. They are measured in differenced form to avoid the spurious correlation problem of entering macroeconomic trending variables in the cost regression, as follows:

1. change in GDP at 2000 market prices per capita, (z_3), which reflects the cyclical response to government macroeconomic policy as well as the impact of exogenous shocks from the external economy;
2. change in the price deflator for GDP at market prices, (z_4);
3. change in the harmonized consumer price index (all items), (z_5), the two price indices being alternative measures of the inflationary expectations during the emergence from financial crisis;

4. change in the unemployment rate, (z_6), which, like the change in the growth experience of national income, also reflects the general macroeconomic environment but also allows for the delayed impact of employment responses in conditioning the impact of loan behavior on cost;
5. change in general government consolidated gross debt, (z_7); and
6. change in the general government consolidated gross debt as a percentage of GDP at market prices, (z_8), these last two variables capturing the impact of the changes in government action to recapitalize the banking system during the emergence from financial crisis.

All the data in the fitted regressions are log mean corrected, that is, expressed as deviations from the sample means after having been transformed to natural logarithms.

Empirical Results

The estimation results across the different models are relatively stable. In all the regressions the macroeconomic exogenous variables failed to have any influence on the fitted equations, so we conclude that the specification based on the bank-specific variables captures all of the relevant variance in short-run costs.

Table 2 presents (1) the monotonicity effects,[2] that is, the elasticity function estimates at the sample mean, together with their asymptotic standard errors; (2) the tests for the presence of inefficiency as a component of the error term and whether the inefficiency is time varying; (3) the mean and standard deviation of the measured cost efficiency for each model; and (4) the Panzar-Willig (1977) estimate of the elasticity of scale at the sample mean, E(PW), and the scale elasticity evaluated out of equilibrium, after adjusting for the shadow return on the fixed input equity, E(SR).

As we noted earlier, previous research has demonstrated that similar models find a positive shadow return on equity prior to the financial crisis (e.g., Boucinha et al. 2009; Hughes et al. 2001; Shen et al. 2009), confirming that overleveraged banks display the highest positive shadow return on equity in the years preceding financial crisis. In strong contrast, the results for Turkey in the post–financial crisis period, when the banking system was being strongly recapitalized, show that the shadow return on equity is negative in all six of the models estimated (see Table 2). In other words, the massive recapitalization of the banks during the recovery from financial crisis drove them a long way from equilibrium, and the deleveraging involved has imposed significant costs.

We concentrate our analysis on the five models that give largely consistent results: SURE-CGLS, SS(84), PL(81), BC(92) and BC(95). The results displayed in Table 2 confirm that the inefficiency measure is time varying. In particular, the Battese-Coelli (1992) and Battese-Coelli (1995) models show that inefficiency increased over the sample period for the group as a whole. The final two rows of Table 2 illustrate the computed elasticity of scale measures with and without adjustment for the shadow price of the fixed input. The long-run estimate of scale elasticity suggests strongly increasing returns to scale but the adjusted measure indicates that the banks are closer to constant returns.

Pulling all these results together, we conclude that (1) inefficiency fluctuated over the period of recovery from financial crisis; (2) there is some evidence of increasing returns to scale among these banks on the adjusted measure that allows for the shadow price of the fixed input; and (3) perhaps most significantly, the shadow return on equity appeared to become strongly negative during this period of significant recapitalization and

Table 2. Estimation results from six models

Dependent variable, ln(C/w_3)

	Model					
Elasticity of cost at sample mean with respect to:	**SURE-CGLS, pooled time varying**	**SS(84) FE, panel time invariant**	**PL(81) MLE-RE panel time invariant**	**CSS(90) panel time varying**	**BC(92) MLE panel time varying**	**BC(95) MLE pooled time varying**
Loans	0.185*	0.499*	0.380*	0.553*	0.534*	0.396*
	(0.055)	(0.084)	(0.049)	(0.134)	(0.051)	(0.058)
Securities	0.116*	0.149*	0.092*	0.071	0.124*	0.073*
	(0.019)	(0.039)	(0.020)	(0.059)	(0.018)	(0.018)
Off-balance sheet activity	0.240*	–0.014	0.183*	0.129	0.086*	0.203*
	(0.046)	(0.072)	(0.040)	(0.106)	(0.037)	(0.049)
Price of funds	0.623*	0.614*	0.740*	0.625*	0.742*	0.714*
	(0.010)	(0.082)	(0.046)	(0.114)	(0.042)	(0.078)
Price of labor	0.182*	0.181*	0.174*	0.269*	0.149*	0.204*
	(0.002)	(0.085)	(0.045)	(0.129)	(0.041)	(0.067)
Price of capital	0.195	0.205	0.086	0.105	0.109	0.082
	(n.a.)	(n.a)	(n.a)	(n.a)	(n.a)	(n.a)

Time	–0.048*	–0.003	–0.030*	0.398	–0.055*	–0.062*
	(0.013)	(0.016)	(0.009)	(0.232)	(0.008)	(0.012)
Equity capital	0.513*	0.227*	0.356*	0.063	0.230*	0.368*
	(0.052)	(0.083)	(0.044)	(0.162)	(0.044)	(0.039)
Test H_0: inefficiency error term is zero	n.a.	$F(21,31) = 5.93$**	$\chi^2(1)$ (LR) = 5.607**	$F(43,10) = 8.65$**	χ^2 (LR) = 21.974**	$\chi^2(3)$ (LR) = 22.08**
Test H_0: inefficiency error term is time-invariant	n.a.	n.a.	n.a.	H_0: $q_{il} = 0$ $F(21,10) = 2.79$**	H_0: $h = 0$ $t(48) = -6.54$**	H_0: $d = 0$ $t(48) = -2.34$**
Mean cost efficiency, CE	0.719	0.649	0.948	0.321	0.878	0.912
Standard deviation CE	0.104	0.197	0.035	0.199	0.133	0.069
E(PW)	1.846	1.577	1.526	1.328	1.344	1.489
E(SR)	0.899	1.219	0.983	1.244	1.035	0.941

Notes: Standard errors are in parentheses. n.a. = not applicable. * Coefficient significantly different from zero at the 5 percent significance level or less. Elasticity of price of capital is interpolated from the homogeneity condition. ** Reject null at the 5 percent significance level or less. E(PW) is the Panzar-Willig elasticity of scale measure at the sample mean. E(SR) is the elasticity of scale at the sample mean adjusted for the shadow return on equity as suggested by Braeutigam and Daughety (1983) and Caves et al. (1981).

Table 3. Components of the annual rate of productivity change in different frontier models

Component of productivity change	Year	SS(84)	PL(81)	BC(92)	BC(95)
Scale, SEC	2007	0.117	0.143	–0.075	0.075
	2008	–0.032	–0.017	–0.027	–0.013
	2009	0.039	0.024	0.062	–0.152
Allocative, AEC	2007	–0.002	–0.019	–0.012	–0.009
	2008	0.007	0.016	0.004	0.019
	2009	0.068	0.059	0.084	0.067
Technical, TC	2007	–0.035	0.057	0.060	0.118
	2008	–0.011	0.021	0.043	0.055
	2009	0.043	0.004	0.049	0.008
Exogenous (equity) EXC	2007	–0.074	–0.163	–0.111	–0.162
	2008	0.033	0.021	0.021	0.023
	2009	–0.067	–0.078	–0.051	–0.080
Efficiency, EC	2007	0	0	–0.032	–0.017
	2008	0	0	–0.044	–0.068
	2009	0	0	–0.060	0.003
Total factor productivity, TFPC	2007	0.006	0.018	–0.170	0.005
	2008	–0.003	0.041	–0.003	0.015
	2009	0.083	0.010	0.085	–0.155

deleveraging. This could be one of the most important considerations for policy makers in responding to financial crises. It is this last factor that will allow us to compute the cost of adjustment to the new regime of much higher equity capital ratios, which was regarded by the policy authorities and the IMF as critical to the recovery of the banking system from financial crisis.

We now use the discrete index number calculation to decompose productivity change during the period of recovery from the financial crisis. We illustrate the impacts by using the five models with consistent results described above. Table 3 reports the productivity estimates and the component factors for all four models under consideration.

There have been three positive aspects of productivity change: scale efficiency change, allocative efficiency change, and technical change are all broadly positive and suggest that the banks as a group have been expanding their loans more than proportionately to their use of inputs: they have been allocating resources more efficiently and the cost frontier has been shifting down. These are all signs of a banking system in the recovery phase after financial crisis. The major regressive factor is related to the extensive recapitalization process. We have already shown that this has resulted in a negative shadow return on equity, much of which may have a negative effect on the state if that is where the additional capital has to come from. The inefficiency in resource allocation implied by this massive reliance on an otherwise costly fixed input in order to repair the damage to the banking system from previous exposure to risk has been the major negative factor affecting productivity growth. Its impact has been sufficiently large to depress the overall composed sum of the total factor productivity components. We illustrate the combined results for all models by plotting the components of the total factor productivity decomposition averaged over all the frontier models in Figure 2.

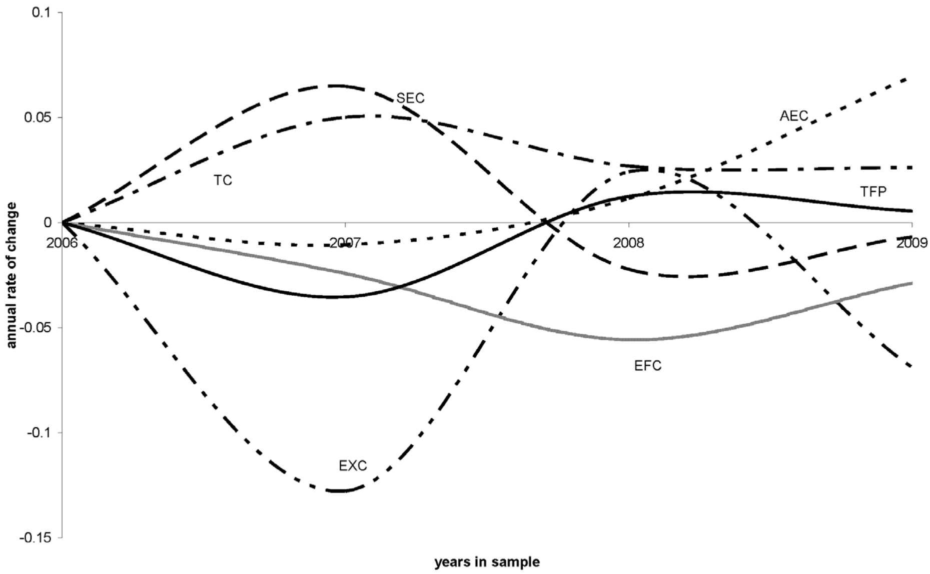

Figure 2. Productivity decomposition 2006–2009: average of four frontier models

Note: TC = technical change; SEC = scale efficiency change; AEC = allocative efficiency change; TFP = total factor productivity; EXC = fixed input productivity change; EFC = cost efficiency change.

Table 4. Components of total factor productivity annual percentage change averaged over sample period and all frontier models

SEC	AEC	TC	EXC	EFC	TFPC
1.20	2.34	3.44	–5.75	–3.62	–0.58

Note: SEC = scale efficiency change; AEC = allocative efficiency change; TC = technical change; EXC = fixed input productivity change; EFC = cost efficiency change; TFP = total factor productivity change.

Over all the models and years, the average annual percentage contributions to total factor productivity growth are shown in Table 4, and the overall total factor productivity change is the sum of the five component measures. The results indicate improved performance of the banking system in three critical areas: technical change (TC) captured by the frontier shift idea has been dominant at an average of 3.44 percent per year; allocative efficiency change (AEC), that is, the convergence of optimal and actual cost shares also being important, at an average of 2.34 percent per year; and scale efficiency change (SEC), that is, the expansion of outputs relative to input usage, has also been positive, at 1.20 percent per year. Overall, these three components—SEC, AEC, and TC—contributed 6.98 percent per year to productivity growth of the banking system during the recovery from financial crisis. This is clear evidence that the recapitalization and all of the other banking system policies have been working. This gives a picture of a banking system that is recovering strongly from crisis.

This progress however comes at a cost, and we have suggested that this cost can be measured by the offset to productivity growth embodied in the component associated with the high equity capital levels that have resulted in a negative shadow return on equity, indicating that the system is operating in an uneconomic region of the technology. In practice, this means that larger amounts of other inputs (e.g., deposit funding) and lower amounts of outputs (e.g., fewer and smaller loans) are needed than would be in long-run equilibrium. Our estimate averaged over all the models is that this offset is –5.7 percent of productivity growth per year, leaving overall productivity change at –0.58 percent per year on average. Without the impact of the negative shadow return on equity, the only offset to productivity growth has been efficiency change (i.e., the poor rate of catch up with respect to the frontier) and even then, excluding the impact of the equity constraint would have resulted in productivity growth of 3.36 percent per year.

In summary, the requirement to hold high equity levels during the recapitalization period has imposed costs that have almost completely offset the positive components of productivity change, contributing a negative productivity offset of up to 6 percent to an otherwise mostly positive contribution from more efficient performance by the banking system. The essential and widely welcomed recapitalization of this emerging economy banking system has inevitably come at a high cost.

Conclusions and Policy Lessons

Turkey is a major force among emerging economies and, significantly, it has recent experience of recovering from financial crisis by massively recapitalizing its banks, which have come through a difficult period of rationalization and restructuring. A critical factor in the development of the postcrisis banking system in Turkey has been the emphasis on rebuilding the equity-capital ratio. Therefore, there is a need to develop models of this recapitalization process. In this paper we have chosen a particular modeling route: the measurement of the efficiency and productivity of the banks through the estimation of the cost functions of banks. This has allowed us to treat the equity capital of the banks as a fixed or regulated input requirement and to derive insights from the implied estimates of the shadow return on equity.

We outlined two important results from the literature: the shadow return on equity (the fixed input) is the negative of the elasticity of cost with respect to the level of equity, and this elasticity in turn has an impact on the measured elasticity of scale; in addition, if the system is out of equilibrium and disposable technology is weak, there is nothing to prevent this shadow return from becoming negative, which would be expected when banks are required to hold larger levels of fixed input (equity capital) than they would choose in long-run equilibrium. Two empirical findings are of particular note. Turkey has restructured the banking system through recapitalization, and this has directly led to the shadow return on equity turning negative. This is an important lesson for both transition and postdevelopment economies, most of which experienced the onset of a banking crisis some years after Turkey started its recovery. The striking impact of this really appears when we examine the productivity changes in the sample of banks in Turkey as the banks move through the later stages of the emergence from crisis.

During the period under examination, the banking system in Turkey made significant technological progress (possibly due to the increased investment of foreign banks). It also demonstrated modest scale efficiency gains as the lending process expanded again in this growing economy. In addition, allocative efficiency change was positive, indicating the success of cost-cutting and resource reallocation strategies. The tougher financial environment also led to banking firms clustering more closely to the efficient frontier. All these are positive signs and must make regulators and policy authorities hopeful that policy is moving in the desired direction. However, this success comes at a cost; we have already noted that the large recapitalization has pushed the shadow return on equity into the negative region, so that the banks' ownership, including the state, is paying a high price in terms of foregone investment opportunity to ensure the banking recovery. In addition, this decreased return on equity is a drag on total factor productivity and has offset the gains elsewhere. The picture that emerges is of a banking system that has been vastly and successfully restructured at a cost in terms of large-scale recapitalization that has restricted the system's overall productivity growth until now. This may change in the future, but meanwhile there is a critical lesson for monetary authorities in the rest of the world. Saving the banking system from financial crisis is both possible and essential, but it brings economic pain for the policy makers and the industry.

Notes

1. 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, p. 45).
2. Second-order parameters are too numerous to present in detail but can be obtained from the authors.

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