Productivity and Environmental Performance in Marketing Cooperatives: Incentive Schemes on the Horticultural Sector

Emilio Galdeano-Gómez*, José Céspedes-Lorente and Manuel Rodríguez-Rodríguez***

***Universidad de Almería, Departamento de Economía Aplicada, Spain**

****Universidad de Almería, Departamento de Dirección y Gestión de Empresas, Spain**

Contact: galdeano@ual.es , jcespede@ual.es , mancrd@ual.es

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1. Introduction

Environmental management in horticultural sector was intensified by the Common Agrarian Policy (CAP) through the so-called Operative Programs (OP) of the farming/marketing cooperatives (which are considered as key entities for the sustainable European agriculture).

The present study investigates the impact of environmental performance on total factor productivity (TFP) using a panel data of Spanish horticultural cooperatives for the period 1994-2002. Analyses of productivity have been applied to cooperative entities previously (e.g. Ferrier and Porter, 1991; Kondo and Yamamoto, 2002) considering different aspects of TFP and its components in terms of efficiency and technology, but without taking into account aspects related to environmental factors. We use a translog multi-input multi-output specification to estimate the Malmquist productivity index applying parametric-stochastic frontier approaches (Fuentes *et al*., 2001) and deriving a productivity environmental index (Kaneko and Managi, 2004; Managi and Karemera, 2005). We also analyze the determinants of productivity environmental changes and highlight the main conclusions and policy implications.

2. Productivity and Environmental Performance: Literature review

The evaluation of the relationship between companies' adoption of environmental practices and their economic performance constitutes one of the major lines of research within environmental management literature. Nevertheless, environmental performance in agriculture has received scant attention (Carpentier and Ervin, 2002). The scale of firms, the nature of operations (diffuse pollution in comparison with larger industries), the recent application of environmental regulations and the voluntary character of the programs, among others factors, may explain the lack of studies on this topic.

Carpentier and Ervin (2002) show the improvement of productivity as an important driver to environmental performance. The creation of integrated production and marketing systems and other tasks which are necessary to implement a environmental management program, such as environmental audits, can lead to cost reductions and/or opportunities for new products (Esty and Porter, 1998; Reinhard *et al*., 1999).

In the context of the productivity approach, the measurement of environmental performance of firms has received increasing attention in the recent years. Environmental performance indices can be grouped into two categories (Reinhard *et al*., 1999): those that adjust conventional indices of productivity change, and those, which adjust conventional measures of technical efficiency (usually related to the term “eco-efficiency”). In both cases the adjustment has involved incorporating quantifiable environmental effects (pollution, waste, etc.) usually as undesirable output into the output or input vector (e.g. Tyteca, 1997). Several authors use a non-parametric mathematical programming technique to construct their best-practice frontier (e.g. Ball *et al*., 1994). Mathematical programming techniques are also used (e.g. Färe *et al*., 1993). Several studies also use econometric methods (e.g. Reinhard *et al.*, 2002), whose main difference with respect to the former is the stochastic approach. The advantages or disadvantages of these different methods have been widely discussed (e.g. Lovell, 1993). Hjalmarson *et al.* (1996) argue that one of the main appeals of the stochastic frontier approach is the possibility it offers for a specification in the case of panel data.

On the incorporation of environmental effects, Tyteca (1997) and Reinhard *et al.* (1999) suggest that an environmental performance indicator can be derived as the ratio between the overall productivity measure (using both desirable and undesirable output), and the gross productivity index where undesirable output is ignored. Kaneko and Managi (2004) and Managi and Karemera (2005) derive environmental indices as the ratio of a total productivity index and a market productivity index. In the present study we follow this approach using econometric methods in order to estimate productivity environmental indices and test the effects of several management factors.

Another important issue is the diversity of environmental performance measurement. Tyteca *et al.* (2002) show the difficulty standardizing measures and tries to synthesize the recent procedures. These authors suggest that six distinct frameworks can be identified for environmental performance measurement: production, auditing, ecological, accounting, economic and quality. The quality measurement is related to the adoption by the firm of certified environmental management systems and environmental targets (Tyteca *et al.*, 2002). In the present analysis we use environmental indicators related to quality measurement in terms which are particularly useful in the case of horticultural cooperatives (Céspedes and Galdeano, 2004).

3. Methodology

3.1. Malmquist TFP indices and parametric distance functions

The Malmquist productivity indices are specific output-based measures of Total Factor Productivity (TFP). It measures the TFP change between two data points by calculating the ratio of two associated distance functions (Caves *et al.*, 1982).

In order to estimate a parametric distance function, the translog function is chosen because, among other advantages, it offers flexibility, is easy to derive and permits the imposition of homogeneity (Lovell *et al.*, 1994; Grosskopf *et al.*, 1997). This function to estimate a parametric distance function corresponds to a multi-output/multi-input technology with technological progress defined in the usual way as a trend variable (Grosskopf *et al.*, 1997; Fuentes *et al.*, 2001) and can be expressed (for firm i at time t) as:

$$\begin{aligned} \ln D_0^t (x^{i,t}, y^{i,t}) = {} & \alpha_0 + \Sigma_k \alpha_k \ln x_k^{i,t} + 1/2 \ \Sigma_k \Sigma_l \alpha_{kl} \ln x_k^{i,t} \ln x_l^{i,t} \\ & + \Sigma_k \Sigma_m \delta_{km} \ln x_k^{i,t} \ln y_m^{i,t} + \Sigma_m \beta_m \ln y_m^{i,t} + 1/2 \ \Sigma_m \Sigma_n \beta_{mn} \ln y_m^{i,t} \ln y_n^{i,t} \\ & + \gamma_1 t + 1/2 \ \gamma_2 t^2 + \Sigma_k \eta_k \ln x_k^{i,t} t + \Sigma_m \mu_m \ln y_m^{i,t} t \qquad (1) \end{aligned}$$

$i = 1, ..., I; t = 1, ..., T$

where $k, l \in \{1, ..., K\}$ are index inputs and $m, n \in \{1, ..., M\}$ index outputs.

The usual restrictions for symmetry and linear homogeneity of degree +1 are applied:

$$\alpha_{kl} = \alpha_{lk} \text{ and } \beta_{mn} = \beta_{nm} \quad \forall \text{ k, l, m, n} \qquad (2)$$

$$\Sigma_m \beta_m = 1, \Sigma_n \beta_{mn} = 0, m = 1, ..., M; \ \Sigma_m \delta_{km} = 0, k = 1, ..., K; \text{ and } \Sigma_m \mu_m = 0 \qquad (3)$$

We define the estimated translog distance function [ln D_0^t ($x^{i,t}$, $y^{i,t}$)] as ln TL($x^{i,t}$, $y^{i,t}$, t: θ), where θ is a vector of estimated parameters (α, β, δ, γ, η, μ). We obtain the following frontier model stochastic by choosing one of the outputs arbitrarily (e.g. $y_M^{i,t}$; see Lovell *et al*., 1994; Fuentes *et al*., 2001)

$$-\ln y_M^{i,t} = \ln TL(x^{i,t}, y^{i,t} / y_M^{i,t}, t: \theta) + \varepsilon^{i,t}, \quad \varepsilon^{i,t} = \nu^{i,t} + u^{i,t} \qquad (4)$$

where $\varepsilon^{i,t}$ is the composed error; $\nu^{i,t}$ is the random error term, independently and identically distributed as $N(0,\sigma_v^2)$; $u^{i,t}$ accounts for inefficiency in production and is assumed to be a non-negative random term truncated at 0, and independently and identically distributed as $N(\varphi,\sigma_u^2)$. Given the stochastic nature of the production frontier [TL + $\nu^{i,t}$], the predicted value of the output distance function for firm i at time t can be estimated as a conditional expectation (Batesse and Coelli, 1995) expressing its reduced form as follows: D_0^t ($x^{i,t}$, $y^{i,t}$) = E [exp ($-\nu^{i,t}$) | $\varepsilon^{i,t}$]. The parameters of the translog distance function (1) are estimated simultaneously with three other parameters, σ^2, ψ and φ (being: $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\psi = \sigma_u^2/\sigma^2$).

The Malmquist TFP index can be decomposed into measures associated with technological change (TEC) and efficiency change (EFC) under constant returns to scale (Färe *et al*., 1994):

$$TFP(x^{i,t}, y^{i,t}, x^{i,t+1}, y^{i,t+1}) = TEC(x^{i,t}, y^{i,t}, x^{i,t+1}, y^{i,t+1}) \times EFC(x^{i,t}, y^{i,t}, x^{i,t+1}, y^{i,t+1}) \qquad (5)$$

Technological change measures shifts in the production frontier. Efficiency change measures changes in the position of a production unit relative to the frontier, also known as "catching up" (Färe *et al*., 1994). The parametric distance functions can be employed for Malmquist productivity measurements and its decomposition as (Fuentes *et al*., 2001):

$$TEC(x^{i,t}, y^{i,t}, x^{i,t+1}, y^{i,t+1})$$

$$= \exp \left\{ \Sigma_m \mu_m (\ln y_m^{i,t+1} - 2 \ln y_m^{i,t}) + \Sigma_k \eta_k (\ln x_k^{i,t+1} - 2 \ln x_k^{i,t}) - [\gamma_1 + \gamma_2 (t + 1/2)] \right\} \qquad (6)$$

and

$$EFC(x^{i,t}, y^{i,t}, x^{i,t+1}, y^{i,t+1}) = \exp \left[TL(x^{i,t+1}, y^{i,t+1} / y_M^{i,t+1}, t+1: \theta) - TL(x^{i,t}, y^{i,t} / y_M^{i,t}, t: \theta) \right] \qquad (7)$$

Thus, the estimation of parameters (by equation 1) is used to evaluate the technological change, and the efficiency change is determined by the ratio of two successive distance functions.

The Malmquist index formalism can be extended to take into account environmental factors. In this case, we introduce an output associated with waste production (undesirable output) and an input related to environmental effort.

We estimate productivity improvement associated with the efficient use of environmental effort or the efficient reduction of waste (Kaneko and Managi, 2004; Managi and Karemera, 2005). This environment productivity is obtained as the ratio between the overall productivity measure (including ordinary and environmental inputs/outputs) and the gross productivity index (including only ordinary inputs/outputs). We then use two versions of the models to measure and decompose productivity changes. First, a basic model is used to calculate total productivity of market output, TFP_{market}, using usual production input and output. Second, a joint model, TFP_{total}, which measures the total effect of increases in productivity due to improvements in technology and efficiency for the multi-production of marketable and undesirable outputs. Increases in market output, and/or reduction in undesirable output, given input level, will increase the TFP_{total}. Thus, the residual effects of two factors explain the changes in productivity related to the environmental factors given by,

$$TFP_{environment} = TFP_{total} / TFP_{market} \quad (8)$$

where increase in $TFP_{environment}$ implies productivity improvements related to environmental variables. These might be more reduction of undesirable output given the same level of environmental effort (input) or reduction of this input given the same level of undesirable output, or both (Kaneko and Managi, 2004).

3.2. Analysis of determinants on Malmquist TFP environment indices

The econometric approach allows us to estimate the effect of cooperative management attributes on productivity environmental indices. In most cases these variables are related to inefficiency and are estimated simultaneously in the translog function (single-stage approach) or by a two-stage approach (see Battese and Coelli, 1995, Söderbom and Teal, 2002, and Reinhard *et al*., 2002 for a general discussion about advantages and disadvantages of each method).

Following a two-stage approach, the incidence of several economic characteristics of cooperatives in productivity indices is estimated as a fixed effects model using our panel of data (Söderbom and Teal, 2002). This model is given by $Y^{i,t} = \alpha + \beta\, Z^{i,t} + \gamma\, t + \varepsilon^{i,t}$, where Y is the log of dependent variable ($TFP_{environment}$, and its decomposition in TEC and EFC), α is the intercept, Z is the vector of the log of explanatory variables, β is the vector of coefficients associated with the explanatory variables, γ is the time effect, and ε is a random disturbance term.

4. Application: Data and Specification of Variables

The present analysis has been based on a balanced panel data using the financial reports and surveys from 51 marketing cooperatives over the period 1994-2002. These cooperatives are located in Andalusia (South of Spain) and represent 18-20% of Spanish vegetable production. These cooperatives have taken advantage of different CAP incentive programs (OP) for the improvement of environmental quality management since the 1990s. European Commission (EC) Regulation 2078/92 and in a wider sense EC Regulation 2200/96 are particularly noteworthy. In general, these are traduced in the application of several environmental quality certifications, such as the EUREP-GAP (Good Agricultural Practices) code or others which specialize more in the horticultural sector, such as the UNE-155 and the Integrated Production Certificates.

The productive activity of horticultural marketing cooperatives has been characterized by the consideration of a market, one undesirable output and three inputs: two traditional productive factors, labor and capital, and an environmental input.

Market output has been obtained from the gross value added of marketable production (value of sales minus purchases, i.e. mainly the farmers' production and packaging materials). A gross value added is considered instead of the usual accountable value added, which includes environmental incentives (e.g.

taxation or subsidies) from policy programs (Tyteca *et al.,* 2002).

The labor factor has been obtained from annual labor costs (Fuentes *et al*., 2001; Kondo and Yamamoto, 2002), and the capital factor from the depreciation expenditures of buildings, equipment and machinery (Martínez *et al*., 1999).

The environmental performance measures of cooperatives are related to the management of implementation of certified environmental systems (Tyteca *et al.,* 2002). Thus, undesirable output is measured by the waste production obtained from the farmer's produce which does not reach the minimum standards required by the environmental controls (involving an indirect measure of pesticide reduction, water and land contamination, etc.). The environment input is measured by the annual expenditure on the application of environmental certifications, since this expenditure is included in the annual OP of horticultural cooperatives. Due to the existence of incentives associated with these Programs, the subsidies have been subtracted from this annual expenditure.

Waste production is measured in thousands of kilograms of non-marketable produce. The monetary variables have been corrected for inflation (base year 1994). The descriptive statistics of said variables are shown in Table 1.

The vector of explanatory variables (Z) in the second step of analysis is constructed considering several cooperative attributes. We assume that any inefficiencies obtained are due in part to the omitted variables and related to productive capacities (Reinhard *et al*., 2002).[1] Labor quality may constitute a relevant variable and we consider two, the share of qualified staff (number of engineers, technicians and managers over total workers) and an accountable productivity (profit before interest and tax over labor costs). A specification variable of capital intensity can be obtained by the annual investment in new machinery and equipment over the total assets. We also take into account cooperative size (total assets) to measure the scale effect. The effect of policy incentives on environmental performance is measured by

[1] The choice of inefficiency effect variables always presents a certain degree or arbitrariness (Reinhard *et al*., 1999). In this case, we follow recent studies on this horticultural sector (e.g. Céspedes and Galdeano, 2004) and the consideration that these variables may not be strictly conventional inputs/outputs, but rather characteristics of these inputs/outputs

the annual subsidies over turnover (as calculated by the OP). The time dummy variables may also be indicative of these institutional effects and of the growth of productivity changes (Reinhard *et al.*, 2002). Additionally, we consider a *spillover* variable using environmental expenditures in other firms of the Andalusian horticultural sector as a proxy of spillover related to environmental innovation (considering that other production methods or environmental management techniques lead to more severe competition, Blomstrom and Kokko, 1998). These explanatory variables are expressed in first differences given the nature of our dependant variables. Since heteroscedascity is present, the method of generalized least squares (GLS) is used.

5. Analyses and Results

5.1. Results of Productivity Indices

We estimate the stochastic frontier model with two separate specifications. The first specification excludes undesirable output and environmental input, whereas the second specification includes them. We started with the full translog specification and tested previously whether some parameters could be deleted (considering the Cobb-Douglas or a restricted translog function). The full translog distance functions were found to be the most appropriate specification by the likelihood ratio test. Tables 2 and 3 report the results of maximum likelihood estimates[2].

All the variables have been normalized around their means and the first order parameters can be interpreted as the elasticities for average firm from the sample. In both tables most of the parameters appeared to be significant, and on the whole coefficients for most variables have the expected sign. The negative signs of inputs with respect to the output distance function indicate that the value of the function is non-increasing with respect to inputs, that is, as input-usage efficiency increases a cooperative becomes closer to the frontier. This may apply to the undesirable output in terms of efficiency improvement. Coefficients of the time variables indicate the presence of technological progress or regression. Negative parameters for all variables with time indicate positive changes in the technology. In both estimations

(Reinhard *et al*., 2002).

inefficiencies are identified within the composed error term. The LR test in the one-sided error is significant and the null hypothesis that $\varphi = 0$ is rejected and the high share of inefficiency in total variance (ψ) suggests that the role of statistical noise in explaining the efficiency scores is small.

[Insert Tables 2 and 3 about here]

Graph 1 shows the changes in TFP indices for total outputs, and change in the TFP decomposed into the market and environmental outputs. The TFP_{total} shows an average annual growth of 2.9% over the period studied. This increase is explained by the growth in the TFP_{market} and in the $TFP_{environment}$ with an average growth per annum of 1.9% and 1% respectively. Inefficiencies in environment performance are observed for the three first periods, however, from 1997/8 these are turned into efficiency. Graph 2 represents the three indices for TEC, showing a similar evolution to changes in TFP. The TEC results of total outputs indicate an average annual change of 1.6%, and may explain approximately half the total TFP growth. The similar evolution of results in EFC (shown in Graph 3), with an average annual change of 1.3%, indicates that the increase in efficiency is almost as relevant as the increase in TEC to explain the TFP improvements. Efficiency in environmental variables shows an increase from –0.3% in 1994/5 to 1.5% in 2001/2.

[Insert Graphs 1, 2 and 3 about here]

5.2. Analysis of the Determinants of Productivity Environmental Changes

The GLS estimates of the fixed effect model are presented in Table 3.

[Insert Table 4 about here]

Labor quality shows parameters highly correlated with the productivity environmental indices suggesting the relative importance of qualified staff in this the environmental performance. Although to a lesser extent, labor productivity also shows significant parameters. The size variable has no significant parameters, even in the case of EFC the effect is negative. This may be due to the

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[2] The estimations are carried out using the Frontier Version 4.1 software (Coelli, 1994).

characteristics of the horticultural sector analyzed, since the grower-members tend to run relatively small family-owned businesses (other studies by Kondo *et al.* –1997- or Kondo and Yamamoto –2002- on Japanese agricultural cooperatives, obtain similar results). The spillover variable has a positive effect on productivity measures, and the parameters are significant for the EFC and TPF changes, indicating a relative transfer of management techniques in environmental performance in the sector, although this may be the result of an overall increase in environmental effort observed in horticultural firms (Céspedes and Galdeano, 2004). As expected, capital intensity shows positive significant coefficients for TEC and TFP. Policy incentives also show a positive effect, but the coefficients are only significant for TFP. This relatively low correlation may be a consequence of the low level of subsidies (approximately 2-4% over turnover) which was maintained over the analyzed period. The time dummy variables show significant parameters especially from the period 97/98, due to the intensification of environmental effort.

6. Conclusions and policy implications

The cooperatives analyzed show an average annual growth in total productivity of 2.9% over the period studied (increasing from 0.9% in 1994/5 to 5.3% in 2001/2). This growth is caused by the increase in technological (1.6%) and in efficiency change (1.3%). Environment variables have a positive impact on productivity, especially from 1997/8 onwards, reaching a similar impact to that of market variables.

From the second step of our analysis, we can deduce that these results are particularly motivated by the intensification of environmental performance in horticultural cooperatives, influenced to a great extent by improvements in labor quality and productivity, and the growth of capital intensity. We can also consider a positive spillover effect in this process. Policy incentives have probably played an important initial role in establishing environmental practices, but the low proportion of these incentives with respect to turnover may have caused their impact on environmental practices to decrease. On the whole productivity improvement can be a major motivation for environmental performance in this sector.

References

Ball, V.E., Lovell, C.A.K., Nehring, R.F., Somwaru, A., 1994. Incorporating undesirable outputs into models of production: an application to US agriculture, Cahiers d'Economique et Sociologie Rurales, 31, 59-73.

Battese, G.E., Coelli, T.J., 1995. A model for technical inefficiency effects in a stochastic frontier production function for panel data, Empirical Economics, 20, 325-332.

Blomstrom, M., Kokko, A., 1998. Multinational corporations and spillovers, Journal of Economic Surveys, 12, 247-277.

Carpentier, C.L., Ervin, D.E., 2002. Business approaches to agri-environmental management: incentives, constraints and policy issues. OECD, Paris.

Caves, D.W., Christensen, L.R., Diewert, W.E., 1982. The economic of index numbers and the measurement of input, output, and productivity, Econometrica, 50, 1393-1414.

Céspedes, J., Galdeano, E., 2004. Environmental practices and the value added of horticultural firms, Business Strategy and the Environment Journal, 13(3), 403-414.

Coelli, T.J., 1994. A guide to Frontier version 4.1: A computer program for stochastic frontier and cost function estimation. Department of Econometrics, University of New England, Armidale.

Esty, D., Porter, M., 1998. Industrial ecology and competitiveness: strategic implications for the firm, Journal of Industrial Ecology, 2(1), 35-43.

Färe, R., Grosskopf, S., Lovell, C.A.K., Yaisawarng, S., 1993. Derivation of shadow prices for undesirable outputs: a distance function approach, Review of Economics and Statistics, 75(2), 374-380.

Färe, R., Grosskopf, S., Norris, M., Zang, Z., 1994. Productivity growth, technical progress, and efficiency change in industrialized countries, American Economic Review, 84, 66-83.

Ferrier, G.D., Porter, P.K., 1991. The productive efficiency of US milk processing cooperatives, Journal of Agricultural Economics, 42, 161-173.

Fuentes, H.J., Grifell-Tatje, E., Parelman, S., 2001. A parametric distance function approach for Malmquist productivity index estimation, Journal of Productivity Analysis, 15(2), 79-94.

Grosskopf, S., Hayes, K.J., Taylor, L.L., Weber, W.L., 1997. Budget-constrained frontier measures of fiscal equality and efficiency in schooling, Review of Economics and Statistics, 79(1), 116-124.

Hjalmarsson, L., Kumbhakar, S.C., Heshmati, A., 1996. DEA, DFA and SFA: a comparison, Journal of Productivity Analysis, 7(2/3), 303-327.

Kaneko, S., Managi, S., 2004. Environmental productivity in China, Economics Bulletin, 17(2): 1-10.

Kondo, K., Demura, K, Yamamoto, Y., 1997. The technical efficiency of agricultural cooperatives Hokkaido's dairy-farming region, Review of Agricultural Economic, 53, 55-59.

Kondo, K., Yamamoto, Y., 2002. Technical change and technical efficiency of agricultural cooperatives in Japan: a nonparametric Malmquist approach. Proceedings in Second North American Productivity Workshop, Union College, Schenectady, USA, 20-22 June 2002, pp. 1-20.

Lovell, C.A.K., 1993. Production Frontiers and Productive Efficiency. In: Fried, H.O., C.A.K. Lovell and S.S. Schmidt (Eds.), The Measurement of Productive Efficiency: Techniques and Applications, New York, Oxford University Press, pp. 3-67.

Lovell, C.A.K., Richardson, P., Travers, P., Wood, L.L., 1994. Resources and functionings: a new view of inequality in Australia. In: Eichhorn, W. (Ed.) Models and Measurements of Welfare and Inequality, Berlin, Springer-Verlag.

Managi, S., Karemera, D., 2005. Trade and environmental damage in US agriculture, World Review of Science, Technology and Sustainable Development, 2(2), 168-190.

Martínez, E., Díaz, R., Navarro, M., Ravelo, T., 1999. A study of the efficiency of Spanish port authorities using Data Envelopment Analysis, International Journal of Transport Economics, 2, 237-253.

Reinhard, S., Lovell, C.A.K., Thijssen, G., 1999. Econometric estimation of technical and environmental efficiency, American Journal of Agricultural Economics, 81(1), 44-60.

Reinhard, S., Lovell, C.A.K., Thijssen, G., 2002. Analysis of environmental efficiency variation, American Journal of Agricultural Economics, 84(4), 1054-1065.

Söderbom, M., Teal, F., 2004. Size and efficiency in African manufacturing firms: evidence from firm-level panel data, Working Paper WPS2002-07, Centre for the Study of African Economies (CSAE), University of Oxford.

Tyteca, D., 1997. Linear programming models for the measurement of environmental performance of firms – Concepts and empirical results, Journal of Productivity Analysis, 8(2), 183-197.

Tyteca, D., Carlens, J., Berkhout, F., Hertin, J., Wehrmeyer, W., Wagner, M., 2002. Corporate environmental performance evaluation: evidence from the MEPI report, Business Strategy and the Environment, 11, 1-13.

Tables

Table 1. Descriptive statistics of the sample variables (average of the period 1994-2002).

Type	Variable	Average	Standard deviation	Maximum	Minimum
Outputs and inputs	Value added	515.36	297.56	1,002.05	192.51
	Undesirable output	283.25	102.13	485.62	109.17
	Capital	217.79	135.04	431.13	59.48
	Labor	173.74	102.48	364.18	40.21
	Environmental input	108.38	33.04	146.10	88.23
Attribute variables	Size	1,208.04	421.22	1,860.12	598.74
	Labor quality	7.91	2.46	11.19	5.03
	Labor productivity	4.75	2.13	6.31	2.18
	Spillover	11,633.02	6,221.63	18,650.34	6,402.081
	Capital intensity	11.07	4.15	15.23	6.83
	Policy incentives	2.81	0.97	3.58	1.96

Table 2. Estimations of the parametric output distance function without environmental variables.

Intercept	-1.284 (-3.42)***	Labor × Capital	0.032 (1.86)**
Labor	-0.567 (-2.35)**	Time	-0.121 (-2.85)***
Capital	-0.310 (-2.04)**	Time^2	-0.034 (-1.72)*
Labor^2	0.082 (0.62)	Time × Labor	-0.065 (-2.10)**
Capital^2	-0.123 (-1.77)*	Time × Capital	0.029 (1.32)
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.092 (3.08)***	φ	-0.822 (-4.31)***
$\Psi = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$	0.796 (17.30)***	LR test of the one-sided error	156.37
Log likelihood	-355.60		
Time period	1994-2002	Observations	408

Note: t-tests are reported in parentheses. *** Significant at 1%; ** significant at 5%; * significant at 10%. Value added is selected as the dependent variable and as the variable of normalization. All of the parameters are multiplied by –1.

Table 3. Estimations of the parametric output distance function with environmental variables

Intercept	1.021 (3.18)***	Value added × Labor	-0.153
Labor	-0.354 (-2.89)***	Value added × Capital	0.027
Capital	-0.310 (-2.15)**	Capital × Environmental input	-0.109 (-2.20)**
Environmental input	-0.135 (-1.71)*	Capital × Undesirable output	-0.027 (-0.48)
Value added	1.290	Value added × Environmental input	1.069
Undesirable output	-0.289 (-2.06)**	Undesirable output × Env. input	-1.069 (-1.93)**
Labor^2	0.102 (1.87)**	Value added × Undesirable output	-0.037
Capital^2	0.026 (0.83)	Time	-0.203 (-2.40)**
Environmental input^2	0.048 (1.66)*	Time^2	0.062 (1.71)*
Value added^2	-0.052	Time × Labor	-0.015 (1.98)**
Undesirable output^2	0.089 (1.07)	Time × Capital	0.005 (0.59)
Labor × Capital	-0.048 (-1.69)*	Time × Environmental input	-0.104 (2.10)**
Labor × Environmental input	-0.123 (-2.07)**	Time ×Undesirable output	-0.077 (-1.85)**
Labor × Undesirable output	0.152 (1.92)**	Time × Value added	0.077
$\sigma_v^2 + \sigma_u^2$	0.112 (1.97)**	φ	-0.774 (-1.94)**
$\Psi = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$	0.821 (14.55)***	LR test of the one-sided error	283.14
Log likelihood	-437.84		
Time period	1994-2002	Observations	408

Note: t-tests are reported in parentheses. *** Significant at 1%; ** significant at 5%; * significant at 10%. Value added is selected as the dependent variable and as the variable of normalisation. All of the parameters are multiplied by –1.

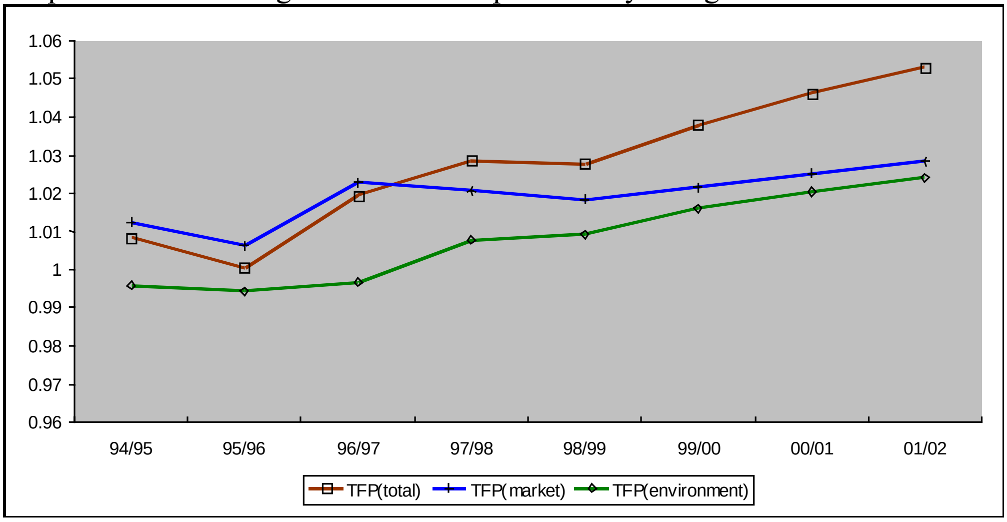
Table 4. GLS parameter estimates of the fixed effect model (time period1994-2002).

	Dependent variables		
Variable[(a) (b)]	TFP changes (environment)	TEC (environment)	EFC (environment)
Intercept	1.027 (5.08)***	0.836 (4.12)***	0.743 (2.35)**
Labor quality	0.331 (2.23)**	0.287 (2.11)**	0.402 (2.85)***
Labor productivity	0.092 (1.94)**	0.078 (1.82)**	0.037 (1.63)*
Size	0.009 (0.21)	0.015 (0.86)	-0.003 (-0.42)
Spillover	0.023 (1.80)**	0.007 (0.32)	0.016 (1.68)*
Capital intensity	0.191 (1.98)**	0.205 (2.33)**	0.089 (1.87)**
Policy incentives	0.015 (1.71)*	0.008 (1.03)	0.012 (1.29)
$\gamma^{95/96}$	-0.011 (-0.29)	0.000 (0.05)	-0.014 (-0.36)
$\gamma^{96/97}$	0.006 (0.18)	-0.039 (-1.72)*	0.021 (1.66)*
$\gamma^{97/98}$	0.048 (1.90)**	0.104 (2.06)**	0.032 (1.73)*
$\gamma^{98/99}$	0.039 (1.67)*	0.156 (2.26)**	0.112 (1.89)**
$\gamma^{99/00}$	0.268 (2.95)***	0.194 (2.38)**	0.049 (1.63)*
$\gamma^{00/01}$	0.052 (1.65)*	0.055 (1.71)*	0.155 (2.24)**
$\gamma^{01/02}$	0.176 (1.94)**	-0.017 (-0.59)	0.212 (2.78)***
R^2	0.765	0.669	0.708
F-test for no fixed effects	85.03***	58.41***	62.17***

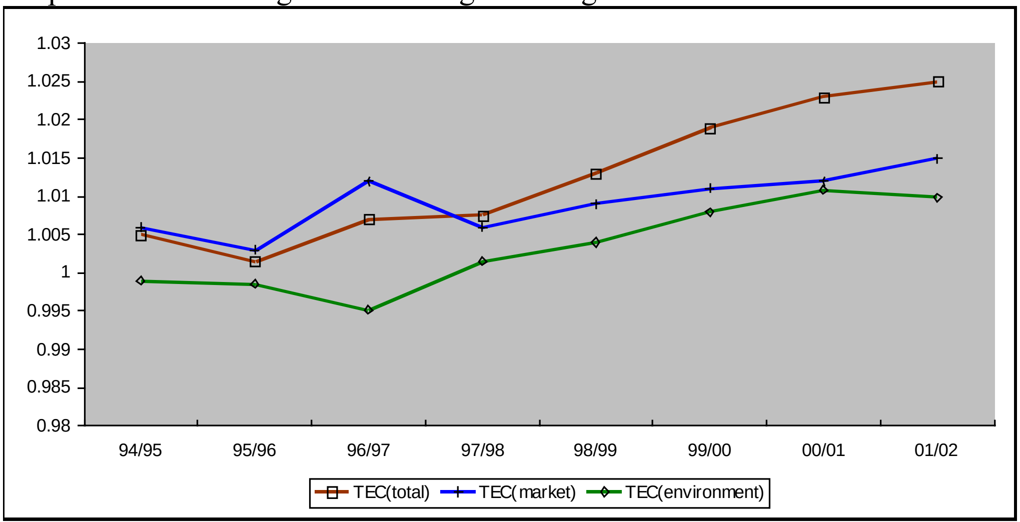
Note: t-tests are reported in parentheses. *** Significant at 1%; ** significant at 5%; * significant at 10%.
(a) Explanatory variables are measured in first differences. (b) The time dummy of 94/95 is omitted.

Figures

Graph 1. Annual averages of total factor productivity change.



Graph 2. Annual averages of technological change.



Graph 3. Annual averages of efficiency change.