E C O N O M I C S   B U L L E T I N

Productivity and Environment in India

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Abstract

As a result of this India's extremely rapid economic growth, the scale of environmental problems is no longer in doubt. Whether pollution abatement managements are efficiently controlled is an empirical question. Using recently developed productivity measurement technique, we show that overall environmental productivity decreases over time in India. At present, the existing environmental management is not sufficient to bring about sustainable development in India.

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1. Introduction

It has been a tough trade-off decision between economic growth and environmental protection especially in developing countries. Tireless efforts to accelerate economic growth had kept environmental considerations as secondary objectives in policy making in these countries. This indifference towards environmental protection has led to serious environmental problems in the developing countries and has threatened their sustainable future[1]. For example, damage caused by pollution in India is estimated to cost $14 billion annually: amounting to close to 4.5% to 6% of GDP (Economic Survey of India, 1998-1999). In response, from the early 1970s India had begun implementation of environmental policies in relation to air and water pollution and solid waste disposal, and the stringency of these regulations has been increasing over years (CPCB, 2001).

It has been increasingly recognized that technological progress can play a key role in maintaining a high standard of living in the face of these increasingly stringent environmental regulations. However, the extent of the contribution of technological progress depends on how well environmental policies are designed and implemented. Successful environmental polices can contribute to technological innovation and diffusion (Jaffe et al., 2003) while poor policy designs can inhibit innovation.

This paper attempts to measure technological/productivity change for environmental (non-market) outputs in India using state-level industry data over the period 1991-2003. We intend to measure environmental productivity following the traditional productivity literature[2]. The regulations requiring more stringent pollution abatement do not necessarily change environmental productivity since the linear expansion of pollution abatement costs and pollution reduction does not necessarily change the pollution reduction per abatement cost.

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[1] For more information, see Annual Report, Ministry of Environment and Forest, Government of India (2001).

[2] There are several studies that measures market productivity in India. For example, Pallikara (2004) finds 2.8% annual increase of market TFP using Solow residual type total factor productivity over 1992 and 2001.

The more efficient utilization of pollution abatement technologies, at least in part, influences the cost of alternative production and pollution abatement technologies (e.g., Jaffe et al., 2003). An extensive body of theoretical literature examines the role of environmental policy in encouraging (or discouraging) productivity growth. On the one hand, abatement pressures may stimulate innovative responses that reduce the actual cost of compliance below those originally estimated. On the other, firms may be reluctant to innovate if they believe regulators will respond by 'ratcheting-up' standards even further. In addition to the changes in environmental regulations and technology, management levels also affect environmental productivity. Thus, whether environmental productivity increases over time is an empirical question[3].

This paper is structured as follows. Section 2 briefly reviews the environmental policies in India. The empirical model and data are explained in Section 3 while the results are presented at Section 4. The concluding remarks and further discussions are provided in the final section.

2. Environmental Policies in India

To combat the problem of environmental degradation, several environmental policies were initiated by the Government of India from late 1970s. India was the first country to insert an amendment into its Constitution allowing the State to protect and improve the environment for safeguarding public health, forests and wild life. The 42nd amendment was adopted in 1976 and went into effect January 3, 1977. The language of the *Directive Principles of State Policy (Article 47)* requires not only a protectionist stance by the state but also compels the state to seek the improvement of polluted environments.

The Air (Prevention and Control of Pollution) Act was passed in 1981 and the Parliament had passed the Environment (Protection) Act in 1986. The responsibility of administering new legislations fell on the central and state pollution control boards. The Department of Environment (DOE) was created in 1980, which was supposed to

[3] Most current empirical studies focus on developed countries (Managi et al., 2005). To the authors' knowledge, there are very few studies that have estimated the efficiency changes of environmental technology or management in the context of developing countries and this a first attempt in Indian case.

appraise the environmental aspects of development projects, to monitor air and water quality, to establish an environmental information system, to promote environmental research, and to coordinate activities between federal, state and local governments. The DOE was criticized, however, by environmental groups for its small political and financial base. Environmentalists recognized quickly that the DOE would essentially serve as an advisory body with few enforcement powers.

This deficiency was soon recognized and a Ministry of Environment and Forests (MoEF) was created in 1985. It continued the same functions that the DOE originally had, such as monitoring and enforcement, conducting environmental assessments and surveys, but also provided promotional work about the environment. The MoEF's implementation of a monitoring system was noteworthy. In 1984, there were 28 monitoring stations for air pollution in India. It had increased to 290 stations by 1994 including 51 stations from the Global Environmental Monitoring System (GEMS).

In December 1993, the MoEF completed its Environmental Action Plan to integrate environmental considerations into developmental strategies, which, among other priorities, included industrial pollution reduction. However, the control of environmental degradation had not been found to be satisfactory mostly because of the growth oriented policies of the government. Since the adoption of the reform policies in India in 1991, the economy has climbed upon a higher trajectory in its growth rate. Between 1993-1994 and 1997-1998, the Indian economy has averaged to more than 7% growth rate per annum (Economic Survey of India, 1998-1999). The growth of industrial production and manufacturing has averaged at 8.4% and 8.9% respectively during these years. This expansion of economic activities had a heavy toll on the environmental quality in the country. Further, lack of properly functioning markets for environmental goods and services and market distortions created by price controls and subsidies have aggravated the environmental problems.

The weakness of the existing system lies in the enforcement capabilities of the environmental institutions both at the center and the state. There is no effective coordination amongst various Ministries/institutions regarding integration of environmental concerns at the inception/planning stage of the project (Economic Survey, 1998-99). Further, it was analyzed that the current policies are also fragmented across several government agencies with differing policy mandates. Lack of trained personnel and comprehensive database delay many projects. Most of the state government institutions are relatively small suffering from inadequacy of technical staff and resources.

Although, it was claimed by the Central Pollution Control Board (CPCB) that the overall quality of Environmental Impact Assessment (EIA) process have improved over the years, little is known about how environmental productivity has changed over time in India. By considering the divergence of policy intention and actual implementation in each province/state, this study measures the efficiency of environmental management in India using two techniques explained in the following section.

3. Model

We measure productivity change in a joint production model, with a vector of market and nonmarket outputs using production frontier analysis. This approach uses the Luenberger productivity index, which is the dual to the profit function and does not require the choice of an input–output orientation (Chambers et al., 1996)[4]. In contrast, the more commonly used Malmquist productivity index requires the choice between of an output or input orientation corresponding to whether one assumes revenue maximization or cost minimization as the appropriate behavioral goal (Färe et al., 1985). Since the Luenberger productivity index can be applied with an output or input-oriented perspective, it is a generalization of, and superior to, the Malmquist productivity index (Luenberger, 1992a,b; Chambers *et al*., 1998; Boussemart *et al*., 2003). In this study, we estimate Luenberger productivity index.

Following Managi *et al.,* (2005), this study uses two datasets, of which one includes only market input/output, TFP_{Market}, and the other includes environmental input/output in addition to the market input/output, TFP_{Joint}, considering the maximum expansion of

[4] Though Luenberger Productivity is theoretically well developed, there is very little empirical work in the literature (Managi, 2004). A commonly used technique in productivity measurement is growth accounting, which forms a residual after taking the impact of changes in capital and labor inputs out of changes in real output. Compared with the approach used, however, this approach has a number of disadvantages, including an assumption of constant returns-to-scale and zero inefficiency.

good outputs and contraction of bad outputs. The total factor productivity (TFP) associated with environmental outputs, TFP_{Env} or environmental productivity, is then calculated as:

$$TFP_{Env} = TFP_{Joint} - TFP_{Market}. \quad (1)$$

where TFP is Luenberger indices, which takes the difference of the two models. This is because Luenberger indices employ the difference method (see Chambers *et al.*, 1998).

The TFP includes not only the change in technology, but also the effect of management-level changes in institutions, including environmental regulations. Thus, even though the technology level remains constant, there are cases where there are changes in TFP. Taking a simple example, assume there is a single plant with one end-of-pipe technology in a region. In the next year, the firm constructs another plant in the same region without end-of-pipe technology. In this case, we specify pollution discharge as the environmental output and the effort level of pollution abatement as the environmental input. Market inputs and outputs and environmental outputs then increase, but the environmental input remains constant since a single end-of-pipe technology is used over the two years. Although the environmental technology level in the first plant does not change in the second year, the environmental productivity of the firm decreases since inexistence of environmental technology in the new plant contributes to the overall ineffectiveness of environmental management in the firm.

Production frontier analysis yields the Luenberger index (e.g., Luenberger, 1992a), which can then be used to quantify productivity change. The index-based approach measures the TFP change between two data points by calculating the ratio or difference of two associated distance functions or shortage functions (e.g., Caves *et al.*, 1982; Luenberger, 1992a). This approach has several advantages. One advantage is the immediate compatibility with multiple inputs and outputs. This is important for environmental applications since pollutants, as the by-product of market outputs, can be multiple. This technique estimates the weight given to each observation, such as the weight or shadow price for each item of environmental pollution data, and implicitly combines these into the one index. In addition, this approach can incorporate the inefficient behavior of the decision maker and avoid the need for the explicit specification of the production function (see Managi (2004) and Managi *et al.*, (2004, 2005) for further details).

Using the distance function specification, our problem can be formulated as follows. Let **x**, **b**, **y** be vectors of inputs, environmental output (or undesirable output) and market outputs, respectively, and then define the production possibilities set by;

$$\mathbf{P}^{t} \equiv \{(\mathbf{x}^{t}, \mathbf{b}^{t}, \mathbf{y}^{t}) : \mathbf{x}^{t} \text{ can produce } (\mathbf{y}^{t}, \mathbf{b}^{t})\}, \tag{2}$$

which is the set of all feasible production vectors. We assume that $\mathbf{P}^t$ satisfies standard axioms, which suffice to define meaningful output distance functions (see Fuss and McFadden 1978). The directional distance function is defined at t as;

$$\mathrm{D}^{t}(\mathbf{y}^{t}, \mathbf{x}^{t}, \mathbf{b}^{t}; \mathbf{g}^{t}) = \sup\{\delta : (\mathbf{y}^{t}, \mathbf{x}^{t}, \mathbf{b}^{t}) + \delta\, \mathbf{g}^{t} \in \mathrm{P}^{t}\}, \tag{3}$$

where **g** is the vector of directions which outputs are scaled. For this output oriented distance function, we define **g**=(**y**, **0**, **-b**), i.e. desirable outputs are proportionately increased, inputs are held fixed and environmental outputs (pollution) are proportionately decreased.

As in the Malmquist index, the DEA formulation calculates the Luenberger productivity index under variable returns-to-scale by solving the following optimization problem (Chambers *et al.*, 1996):

$$\begin{aligned}
& D^{t}(y^{t}, x^{t}, b^{t}) = \max_{\delta,\lambda} \delta \\
& s.t. \quad Y^{t}\lambda \geq (1+\delta)\, y_{i}^{t} \\
& \qquad\; B^{t}\lambda = (1-\delta)\, b_{i}^{t} \\
& \qquad\; X^{t}\lambda \leq (1-\delta)\, x_{i}^{t} \\
& \qquad\; N1'\lambda = 0 \\
& \qquad\; \lambda \geq 0
\end{aligned} \tag{4}$$

where N1 is an identity matrix, λ is a N×1 vector of weights, Y^t, X^t, B^t are the vectors of market output, y^t, inputs, x^t .and environmental outputs, b^t.

As in Malmquist indices, several different proportional distance functions are necessary to estimate the change in productivity over time. For the mixed period distance function, we have two years, *t* and *t+1*. For example, $D^{t}(y^{t+1}, x^{t+1}, b^{t+1})$ is the value of the distance function for the input–output vector of period *t+1* and technology at *t*. Luenberger productivity index defined by Chambers, Färe and Grosskopf (1996) and Chambers (2002) is as follows:

$$\mathrm{TFP} = \frac{1}{2}\Big[\Big(\mathrm{D}^{t}(\mathrm{y}^{t}, \mathrm{x}^{t}, \mathrm{b}^{t}) - \mathrm{D}^{t}(\mathrm{y}^{t+1}, \mathrm{x}^{t+1}, \mathrm{b}^{t+1})\Big) + \Big(\mathrm{D}^{t+1}(\mathrm{y}^{t}, \mathrm{x}^{t}, \mathrm{b}^{t}) - \mathrm{D}^{t+1}(\mathrm{y}^{t+1}, \mathrm{x}^{t+1}, \mathrm{b}^{t+1})\Big)\Big]. \tag{5}$$

This is an arithmetic mean of period *t* (the first difference) and period *t+1* (the second difference) Luenberger indices, as an effort once again to avoid any arbitrary selection of base years (e.g., Balk, 1998). This study measures the TFP index of market output (TFP_{Market}) and TFP of both market and environmental output (TFP_{Joint}) in a joint production analysis. These two TFP indices are then used to estimate the TFP of environmental output (TFP_{Env}).

TFP includes all categories of productivity change, which can be decomposed into two components including technological change and efficiency change. Technological Change (TC) and Efficiency Change (EC) have additive relations to compose TFP. TC measures shifts in the production frontier while EC measures changes in the position of a production unit relative to the frontier-so-called "catching up" (Färe et al. 1994).

The dataset consists of annual data for the period 1991–2003 for 16 states in India. For conventional market output, state-wise manufacturing data are used from Annual Survey of Industries (ASI), by the central statistical organization (CSO) for industries in India**.** This study uses manufacturing output of the real gross output as market output in the model. Capital stock and labor as number of worker from ASI are used as inputs. On the other hand, environmental output is treated as a by-product from the industries in the production process in this study. We have used monitored air pollution data to account for environmental output in this study. This data are collected from the National Air Quality Monitoring Programme (NAMP)[5] reports of various years. Emission levels of SO_2, NO_2, and SPM are used in this study

4. Results

Separate frontiers are estimated for each year, and shifts in the frontiers over time are used to measure the technological change. The arithmetic mean of the Luenberger

[5] India has a well established air pollution monitoring network under the auspices of CPCB, which is the apex body for monitoring and control of pollution in the country. The National Air Quality Monitoring Programme (NAMP) network of CPCB was established in India during 1984-85 at the national level with 7 air quality monitoring stations. Since then, the number of stations has kept on expanding to reach 290 stations covering 90 cities/towns in 24 states and 5 UTs by 2002.

productivity indices for each state in each year[6] are estimated under the assumptions of both constant returns to scale (CRS) and variable returns to scale (VRS) production technologies.

Average values of TFP, TC and EC across the states for each periods are presented in Table 1 through Table 5. In these tables, the study period (1991-2002) is divided into three sub-periods of 1991 to 1994 (1st periods), 1995 to 1998 (2nd periods),

Table 1. Market Productivity Changes (Average Changes in Each Period)

	CRS			VRS		
Periods	TFP	EC	TC	TFP	EC	TC
1: 1991-1994	-0.011	0.006	-0.017	-0.022	0.007	-0.029
2: 1995-1998	0.019	-0.012	0.031	0.013	0.000	0.013
3: 1999-2002	0.013	-0.002	0.014	0.004	0.004	0.000
Mean	0.007	-0.002	0.009	-0.001	0.004	-0.005

and 1999 to 2002 (3rd periods). The purpose of this division is to compare productivity indices in these sub-periods to assess how changes in productivity have taken place vis-à-vis policy changes.

Market productivity

The results of market productivity are represented in Table 1. A perusal of the market productivity indices shows that there is a greater degree of similarity between the indices constructed under CRS and the corresponding indices constructed under VRS. Since VRS is a more realistic assumption in estimating the productivity indices, we mostly presente and discussed the indices estimated under this assumption. The results show that TFP_{Market} has gone through two phases. In the initial phase, the productivity change index has negative values showing a decline in the productivity from the base period. In the latter phase, TFP_{Market} change value has got positive values indicating a net productivity gain[7].

[6] See Balk (1998) for theoretical reasoning underlying the use of arithmetic means to average data.

[7] Note that the Luenberger TFP technique is difference based technique and therefore minus value implies that productivity decreases compared to base period. On the other hand, a plus value reflects a positive

Overall, the movement of the index suggests that the productivity of market has declined in the initial years of the economic reforms in India. In fact, the country was passing through a transition phase in the early 1990s following a massive policy change in 1991 that has resulted in a turbulent period in the industrial sector. The growth rates in both GDP and manufacturing output were abysmally low during 1991-1992 and 1992-1993. However, during mid-1990s, the industrial sector had recovered from the

Table 2. Joint Productivity Changes

	CRS			VRS		
Periods	TFP	EC	TC	TFP	EC	TC
1: 1991 - 1994	-0.022	-0.003	-0.019	-0.008	-0.003	-0.005
2: 1995 - 1998	-0.004	0.040	-0.043	-0.012	-0.001	-0.011
3: 1999 - 2002	-0.013	0.017	-0.030	-0.010	-0.003	-0.007
Mean	-0.013	0.018	-0.031	-0.010	-0.002	-0.008

early shocks of the reform process and registered reasonable growth rates. This is reflected in the positive TFP values later in the decade. The value of EC has decreased from 0.007 of first periods to 0 of the second periods while it increased to 0.004 of the third periods. On the other hand, the TC has increased from -0.029 of first periods to 0.013 of the second periods. Further, it has decreased to 0 of third periods.

Joint Output Productivity

Joint output productivity indices are constructed using a joint output production technology in which both desired output (conventional good) as well as undesired output (environmental pollution) of SO_2, NO_2, and SPM are jointly produced, the latter being the by-product. Luenberger productivity index uses output distance functions that attempt to maximize market output while minimizing the undesired by-products.

The results in Table 2 show that TFP_{Joint} under VRS has negative values in almost all the years showing consistent decline in the productivity. The TFP_{Joint} has declined from -0.008 to -0.012, a 50% deceleration while moving from the first periods to the second periods and then it remained steady with a mean value of -0.010 of third

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increase.

periods. This shows that the productivity of joint output does not show any improvement in the post-reform periods in India. Further, computing the market output productivity has started increasing from the mid-1990s and joint output productivity indices has consistently declined throughout our study periods. This finding indicates that the productivity of environment have been declining continuously. However, we can not tell which pollution of SO_2, NO_2, and SPM are the main cause of the overall environmental productivity decrease from these results. Each specific environmental productivity is provided in the followings.

Table 3. SO_2 Productivity Changes

	CRS			VRS		
Periods	TFP	EC	TC	TFP	EC	TC
1: 1991 - 1994	-0.022	-0.003	-0.018	-0.028	-0.022	-0.005
2: 1995 - 1998	-0.003	0.036	-0.039	-0.007	0.003	-0.011
3: 1999 - 2002	-0.012	0.021	-0.032	0.005	0.012	-0.006
Mean	-0.012	0.018	-0.030	-0.010	-0.002	-0.007

Environmental Productivity

The environmental productivity indices in our study are calculated by taking the difference of joint productivity indices and market productivity indices. We have estimated separate productivity indices for the three pollution variables of SO_2, NO_2, and SPM, respectively. For example, environmental productivity of SO_2 is represented as TFP_{SO2}, *i.e.*, SO_2 pollution productivity. The TFP_{SO2} given in Table 3 shows that there are decline of the productivity from 1991 to 1999. Although the first two periods show negative sign, the deteriorating rate has been decrease. In the third periods, the index show positive sign Theses results indicate that the implementation of environmental regulations to control and prevent emissions of sulfur dioxide has been improving over the years in India and more particularly so in the recent years.

In contrast, the TFP_{NO2} of Table 4 has been monotonously negative over the whole study periods showing a continuous decline of the productivity. Moreover the alarming feature of the trend is that the rate of this decline is actually increasing over the years. The mean value of the index has declined from -0.011 in the first periods to -

0.017 in the second periods with a 55% decline in the productivity and it has further gone down to -0.031 in the third periods with a 82% decline in the productivity. This is quite significant and seriously questions the implementation process of the central and state pollution control boards in controlling the emission and concentration of nitrogen oxides in India. The CPCB annual report (2003-04) also raises concerns about the unabated spiraling of nitrogen oxide in industrial cities in the country

Finally, the estimated productivity indices of the third pollutant in our study, i.e. SPM show that the performance is not better than the NO_2 case (see Table 5). The index

Table 4. NO_2 Productivity Changes

	CRS			VRS		
Periods	TFP	EC	TC	TFP	EC	TC
1: 1991 - 1994	-0.021	-0.003	-0.018	-0.011	-0.006	-0.005
2: 1995 - 1998	-0.004	0.040	-0.044	-0.017	-0.005	-0.011
3: 1999 - 2002	-0.015	0.011	-0.025	-0.031	-0.022	-0.009
Mean	-0.013	0.016	-0.029	-0.020	-0.011	-0.009

Table 5. SPM Productivity Changes

	CRS			VRS		
Periods	TFP	EC	TC	TFP	EC	TC
1: 1991 - 1994	-0.021	-0.003	-0.019	-0.008	-0.002	-0.005
2: 1995 - 1998	-0.004	0.037	-0.040	-0.012	-0.001	-0.012
3: 1999 - 2002	-0.014	0.020	-0.034	-0.010	-0.003	-0.007
Mean	-0.013	0.018	-0.031	-0.010	-0.002	-0.008

has been negative in all the years indicating a net decrease in the productivity. The mean values show that the index has decreased from -0.008 of first periods to -0.012 of second periods, thus registering a 50% decline in the productivity. The rate of decrease in the third periods is smaller than that of NO_2. Nevertheless it raises serious concerns for the policy makers in the country.

5. Concluding Remarks

As a result of this India's extremely rapid economic growth, the scale and seriousness of environmental problems are no longer in doubt. Whether pollution abatement technologies are utilized more efficiently is crucial in the analysis of environmental management because it influences the cost of alternative production and pollution abatement technologies, at least in part (e.g., Jaffe et al., 2003). Using recently developed productivity measurement technique, we show that overall environmental productivity decreases over time in India. At present, the existing environmental management is not sufficient to bring about sustainable development in India. However, once we disaggregate the pollutants to specific pollution of SO_2, NO_2, and SPM, we find environmental productivity recently increased in SO_2. The results for NO_2 and SPM are the main causes of the productivity reduction over the study periods. In the future, more stringent comprehensive control strategies could be obtained by implementing new technologies and more effective managements. If the ongoing pace of industrialization is not met with effective environmental management then there would be untoward consequences in the country.

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