

Gupta, Manish

**Working Paper**

## Costs of Reducing Greenhouse Gas Emissions: A Case Study of India's Power Generation Sector

Nota di Lavoro, No. 147.2006

**Provided in Cooperation with:**

Fondazione Eni Enrico Mattei (FEEM)

*Suggested Citation:* Gupta, Manish (2006) : Costs of Reducing Greenhouse Gas Emissions: A Case Study of India's Power Generation Sector, Nota di Lavoro, No. 147.2006, Fondazione Eni Enrico Mattei (FEEM), Milano

This Version is available at:

<https://hdl.handle.net/10419/74110>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*

**Costs of Reducing Greenhouse Gas  
Emissions: A Case Study of  
India's Power Generation Sector**

Manish Gupta

NOTA DI LAVORO 147.2006

**DECEMBER 2006**

CCMP – Climate Change Modelling and Policy

Manish Gupta, *National Institute of Public Finance and Policy*

This paper can be downloaded without charge at:

The Fondazione Eni Enrico Mattei Note di Lavoro Series Index:  
<http://www.feem.it/Feem/Pub/Publications/WPapers/default.htm>

Social Science Research Network Electronic Paper Collection:  
<http://ssrn.com/abstract=951455>

# **Costs of Reducing Greenhouse Gas Emissions: A Case Study of India's Power Generation Sector**

## **Summary**

If India were to participate in any international effort towards mitigating CO<sub>2</sub> emissions, the power sector which is one of the largest emitters of CO<sub>2</sub> in the country would be required to play a major role. In this context the study estimates the marginal abatement costs, which correspond to the costs incurred by the power plants to reduce one unit of CO<sub>2</sub> from the current level. The study uses an output distance function approach and its duality with the revenue function to derive these costs for a sample of thermal plants in India. Two sets of exercises have been undertaken. The average shadow prices of CO<sub>2</sub> for the sample of thermal plants for the period 1991-92 to 1999-2000 was estimated to be respectively Rs.3380.59 and Rs.2401.99 per ton for the two models. These shadow prices can be used for designing environmental policies and market-based instruments for controlling pollution in the power sector in India.

**Keywords:** Marginal Abatement Costs, Distance Function, CO<sub>2</sub> Emissions, Shadow Prices, Power Generation Sector

**JEL Classification:** Q40

*Address for correspondence:*

Manish Gupta  
National Institute of Public Finance and Policy  
18/2 Satsang Vihar Marg  
Special Institutional Area (Near JNU)  
New Delhi 110 067  
India  
Phone: 011 26563305, 011 26569303 (Office)  
E-mail: manish@nipfp.org.in

## 1. Introduction

Issues concerning greenhouse gas (GHG) emission and global warming have received a great deal of attention in the recent years. As per the Kyoto Protocol signed in 1997, the industrialised countries, which have historically been mostly responsible for increase in GHG concentration, agreed to reduce the flow of their GHG emission by 5.2 percent below the level prevailing in 1990. While the developing countries do not yet have any binding commitment, there is a realization that large developing countries such as China and India need to take some action in this regard since they are among the large contributors to incremental emissions. Any commitment by India towards reducing emissions would mean that all the sectors in the economy would have to make efforts for reducing their respective GHG emissions so that the national emission targets are met.

Power sector in India is one of the largest emitters of carbon dioxide (CO<sub>2</sub>) in the country accounting for about 35.53 percent of the total CO<sub>2</sub> emissions in the year 2001-02 (see Table 1). The main reason for such a high share is its heavy reliance upon coal. About 81.7 percent of the total power generation by the utilities in the country in the year 2000-01 was from coal (GOI, 2002). In addition, the coal burnt in the thermal power plants in the country is of inferior quality thereby resulting in an even higher level of emissions.<sup>1</sup> Thus, in near future if India were to participate in any international effort towards mitigating CO<sub>2</sub> emissions, the power sector, which is one of the largest emitter of carbon dioxide in the country, would be required to play a major role.

In this context the present study analyses the potential costs imposed on the coal fired thermal power plants, one of the main sources of CO<sub>2</sub> emissions in India, by the implementation of environmental regulation. More specifically the study aims to estimate the marginal abatement costs, which corresponds to the costs incurred by the power plants to reduce one unit of carbon dioxide from the current level. The present exercise, therefore, seeks to derive the 'shadow prices' of reducing carbon dioxide emissions generated by the thermal plants in India. It thus attempts to provide an answer to the question: how much does it cost the thermal plants in India to reduce CO<sub>2</sub> emission in terms of foregone output or revenue? These estimates are expected to help in formulating environmental policies. The marginal abatement costs thus obtained would

---

<sup>1</sup> Coal used in coal-fired power plants in India has a low calorific value (around 3,500 Kcal/kg) and a high ash content (as high as 45%).

provide guidance on whether the current regulation on pollution satisfies the cost-effectiveness criterion which is based on the principle of marginal abatement costs be equal across individual power plants (Baumol and Oates, 1988). It is being recognized by the developed world that the marketable emission permit system is a more efficient way of regulating pollution. The unit price of a marketable emission permit would be equivalent to the derived marginal abatement costs (Baumol and Oates, 1988; Titenberg, 1985). Consequently, these estimates of marginal abatement cost could be used to predict the price level of emission permits to be introduced.

**Table 1: Carbon dioxide Emissions in India (mn t CO<sub>2</sub>)**

<b>Year</b>	<b>Aggregate Emissions</b>	<b>Power Sector Emissions</b>	<b>Share of Power Sector in Total Emission (%)</b>
<b>80-81</b>	244.71	68.06	27.81
<b>85-86</b>	342.22	105.09	30.71
<b>90-91</b>	481.70	170.42	35.38
<b>95-96</b>	632.08	237.98	37.65
<b>96-97</b>	676.80	250.49	37.01
<b>97-98</b>	704.05	269.81	38.32
<b>98-99</b>	632.41	185.33	29.31
<b>99-00</b>	682.78	219.98	32.22
<b>00-01</b>	736.49	242.98	32.99
<b>01-02</b>	698.76	248.24	35.53

**Source:** Derived from Energy Balance Table using TEDDY (various years) and IPCC (1995).

Theoretical framework of the study is based on production theory and in particular on the distance function approach. The distance function (also known as the gauge function, transformation function, or deflation function) identifies a boundary or a frontier technology, which contains all observation on one side of the frontier and minimises a suitable measure of the total distance of all observations from the frontier. Although the basic ingredients of the theoretical framework on which the distance function is based was known long ago owing to the works of Debreu (1951), Malmquist (1953), and Shephard (1953, 1970), its application became popular only in the recent years by the works of Rolf Färe, Shawna Grosskopf and others. The methodology based on distance function framework was first developed by Färe et al.(1993) and applied by Coggins and Swinton (1996) to the US coal burning utilities. Hetemäki (1996), Kwon

and Yun (1999), Murty and Kumar (2002) etc. have also used the technique to derive the shadow prices of reducing the undesirable outputs. The main advantage of using the distance function approach over the conventional ones i.e., the production, cost, revenue and profit function is its computation requiring only quantity data. This feature is of particular importance in the field of environment economics since price data related to environmental compliance costs are often not available or are unreliable.

The present study uses the output distance function and its duality with the revenue function to derive the marginal abatement costs or the shadow prices of reducing CO<sub>2</sub> emissions for a sample of coal fired thermal power plants in India. The remainder of the paper is organized as follows: the next section provides a theoretical model for estimating the marginal abatement costs. It also describes the methodology for deriving marginal abatement costs using an output distance function approach. Section 3 highlights the procedure for the empirical estimation of the model while Section 4 provides information on the data used and also discusses the estimation procedure. The estimated results are presented in Section 5. The final Section 6 concludes by summarizing the main results of the study.

## 2. Theoretical Model

The conventional production function is defined as the maximum output that can be produced from a given vector of inputs. The distance function generalizes this concept to a multi-output case and describes how far an output vector is from the boundary of the representative output set. We can define the output distance function in terms of the output set  $P(x)$ . Suppose that a producer employs the vector of inputs  $x \in R_+^N$  to produce the vector of outputs  $y \in R_+^M$ , where  $R_+^N, R_+^M$  are non-negative  $N$  and  $M$  dimensional Euclidean spaces, respectively. The plant technology captures the relationship between the inputs and outputs and is described by the output set  $P(x)$ . The output set  $P(x)$  denotes all output vectors that are technically feasible for any given input vector  $x$ , i.e.,

$$(i) \dots P(x) = \{y \in R_+^M : x \text{ can produce } y\}$$

The output set is assumed to satisfy certain axioms, the details of which can be seen in Färe (1988). The output distance function is defined on the output set  $P(x)$  as

$$(ii) \dots D_o(x, y) = \min_{\theta} \{\theta > 0 : (y/\theta) \in P(x)\} \forall x \in R_+^N$$

The above equation measures the largest radial expansion of the output vector  $y$ , for a given input vector  $x$ , that is consistent with  $y$  belonging to  $P(x)$ . The value of the output distance function must be less than or equal to one for any feasible output. The axioms regarding the output set  $P(x)$  impose a set of properties<sup>2</sup> on the output distance function some of which are as follows:

1.  $D_o(0, y) = +\infty$  for  $y \geq 0$ , i.e., there is no free lunch. To produce outputs one requires inputs.
2.  $D_o(x, 0) = 0$  for all  $x$  in  $R_+^N$ , i.e., inaction is possible. No output is possible from positive inputs.
3.  $x' \geq x$  implies that  $D_o(x', y) \leq D_o(x, y)$ , i.e., more the inputs the less efficient would the production be.
4.  $D_o(x, \mu y) = \mu D_o(x, y)$  for  $\mu > 0$ , i.e., positive linear homogeneity.
5.  $D_o(x, y)$  is convex in  $y$ .

Of particular interest for our purpose is the disposability properties of the technology with respect to the output, especially the undesirable outputs. We assume that such outputs are *weakly disposable* i.e., a reduction in the undesirable outputs can only be achieved by simultaneously reducing some of the desirable outputs. We also assume that the desirable outputs are *strongly disposable* i.e., it is possible to reduce the desirable outputs without actually reducing the undesirable outputs. In other words the outputs are weakly disposable if  $y \in P(x)$  and  $\theta \in [0, 1]$ , then  $\theta y \in P(x)$ ; and strongly disposable if we have  $v \leq y \in P(x)$  implies  $v \in P(x)$ .

Let  $r = (r_1, r_2, \dots, r_M)$  denote the output price vector. Using the output set concept we can now define the revenue function in the lines of Shephard (1970), and Färe and Primont (1995) as

$$(iii) \dots R(x, r) = \max_y [ry : y \in P(x)]$$

The revenue function describes the maximum revenue that can be obtained from a given technology at the output price  $r$ . The revenue function, like the distance function, completely describes the production technology. Shephard (1970) showed that the revenue function and the output distance function are dual to one another. So,

---

<sup>2</sup> For detailed descriptions of these properties refer to Färe (1988).

$$(iv) \dots\dots R(x, r) = \max_y [ry : D_o(x, y) \leq 1]$$

$$(v) \dots\dots D_o(x, y) = \max_r [ry : R(x, r) \leq 1]$$

Thus the revenue function can be derived from the output distance function by maximising revenue over output quantities, and the output distance function can be derived by maximising the revenue function over output prices. This duality between the output distance function and the revenue function can be used to derive the shadow prices of the outputs. These are relative output shadow prices and in order to obtain absolute shadow prices additional information regarding the revenue is required (Färe et al 1993). In order to derive the shadow prices of outputs we assume that both the revenue and distance functions are differentiable. We follow the methodology used by Färe et al (1993) to derive the shadow price of the undesirable output. Let  $m'$  output be the undesirable output. In order to derive the shadow price of the undesirable output it is assumed that the price of at least one of the desirable output (say, the  $m^{\text{th}}$  output) is known and is equal to its shadow price,  $r_m^o$ . Then the absolute shadow price  $r_{m'}$  of the  $m'$  output can be computed as

$$(vi) \dots\dots r_{m'} = r_m^o * \frac{\partial D_o(x, y) / \partial y_{m'}}{\partial D_o(x, y) / \partial y_m}$$

As can be seen from equation (vi), the shadow price of the  $m'$  output (the undesirable output) is given by the product of the market price of the  $m^{\text{th}}$  output (the desirable output) and the marginal rate of transformation. This, in turn, is equivalent to the value of the foregone desirable output associated with the reduction in one unit of the undesirable output. In the above equation the ratio of the output shadow prices reflects the relative opportunity cost of the output in terms of the revenue foregone. In other words, it is equivalent to the marginal rate of transformation between the outputs. Thus the shadow prices reflect the trade-off between the desirable and undesirable outputs at the actual mix of outputs. Derivation of the shadow prices of undesirable output as given by equation (vi) is based on the assumption that the production is occurring at the frontier of the output set. But if the production firms lie within the output set and not on the frontier (i.e., for such firms the value of the output distance function is less than one) then there might be some problem in estimating the shadow prices. To resolve the problem of estimating



the shadow prices for such inefficient firms one can proportionately increase all the outputs so that they are on the frontier. Such proportionate scaling of the outputs will have no effect on the shadow prices as the output distance function is homogeneous of degree one in outputs and therefore its derivatives with respect to the outputs as shown in equation (vi) are homogeneous of degree zero. Thus, regardless of the location of the observed production combinations, the shadow prices can be derived through an estimated output distance function by using the actual data of the inputs and outputs - both desirable and undesirable (Kwon and Yun, 1999).

### 3. The Empirical Model

The present study uses the deterministic parametric method<sup>3</sup> for estimating the output distance function. The objective of such an exercise is to analyse the potential cost, if any, imposed on the coal fired thermal power plants in India by the implementation of environmental regulation. Thus, the objective is to estimate the shadow price of reducing CO<sub>2</sub> emissions (the undesirable output) expressed in terms of the value of electricity generation (the desirable output) foregone for a sample of coal fired thermal power plants in India by using the output distance function and its duality with the revenue function.

In order to derive the shadow prices by estimating the deterministic parametric output distance function we have to initially define its functional form. We choose to parameterise the output distance function  $D_o(x, y)$  as a translog function, as has been followed in the literature (see studies by Althin, 1994; Färe et al, 1993). Thus,

$$\begin{aligned}
 (vii) \dots \ln D_o(x, y) = & \alpha_o + \sum_{n=1}^N \beta_n \ln x_n + \sum_{m=1}^M \alpha_m \ln y_m + 0.5 * \sum_{n=1}^N \sum_{n'=1}^N \beta_{nn'} \ln x_n \ln x_{n'} \\
 & + 0.5 * \sum_{m=1}^M \sum_{m'=1}^M \alpha_{mm'} \ln y_m \ln y_{m'} + \sum_{n=1}^N \sum_{m=1}^M \gamma_{nm} \ln x_n \ln y_m \\
 & + \gamma_t t + 0.5 * \gamma_{tt} t^2
 \end{aligned}$$

In the above equation (vii),  $x = (x_1, x_2, \dots, x_N)$  denotes the inputs, and  $y = (y_1, y_2, \dots, y_M)$  corresponds to both the desirable and undesirable outputs. In the model  $y = (y_1, y_2, \dots, y_i)$  are the desirable outputs while  $y = (y_{i+1}, \dots, y_M)$  represent the undesirable outputs. In our empirical

---

<sup>3</sup> The advantage of using the deterministic parametric method for estimating the output distance function is that it is easy to use and allows computation of a large number of parameters even with a small number of observations.

model fuel (F), capital (K) and labour (L) are the three inputs while the outputs consists of desirable output, electricity (Y) and undesirable output, CO<sub>2</sub> emitted by the power plants. We introduce a time variable  $t$  in the model to reflect technical change. In order to reduce the number of parameters to be estimated the terms of the products of time variable and logarithms of other variables are excluded by assuming a neutral technical change.

The parameters of the equation (vii) are computed by using the linear programming technique as suggested by Aigner and Chu (1968). Theoretically the value of the output distance function  $D_o(x, y)$  cannot exceed unity and it must be less than or equal to one (assuming there are no measurement errors). Formally,

$$(viii) \dots \ln D_o^k(x, y) \leq 0 \quad \forall k = 1, 2, \dots, K.$$

where  $k = (1, 2, \dots, K)$  indexes individual observation. By adding a non-negative error term, one can write equation (viii) as

$$(ix) \dots \ln D_o^k(x, y) + \varepsilon^k = 0$$

where  $\varepsilon$ , ( $\varepsilon \geq 0$ ) denotes the non-negative residual or the error term.<sup>4</sup> Next we choose the ‘fitting’

criterion to be the *minimum absolute error* (MAE), i.e.,  $\sum_{k=1}^K |\varepsilon^k|$ ,  $\varepsilon^k \geq 0$ . The MAE fits

$\ln D_o(x, y)$  so that the sum of errors is as small as possible (Hetemäki, 1996). The parameters of the translog output distance function can be obtained by solving the following problem:

$$(x) \dots \max \sum_{k=1}^K [\ln D_o(x^k, y^k) - \ln 1]$$

where  $k = (1, 2, \dots, K)$  indexes individual observation.  $\ln D_o(x, y)$  has an explicit functional form as given by equation (vii). We assume that the first  $i$  outputs are desirable while the remaining  $(M - i)$  outputs are undesirable or bad outputs. The objective function minimises the sum of deviations of individual observations from the frontier of the technology. We know that the distance function takes a value less than equal to unity, therefore the natural logarithm of it i.e.,  $\ln D_o(x^k, y^k)$  will be less than or equal to zero and the expression  $[\ln D_o(x^k, y^k) - \ln 1]$ , which denotes the deviation from the frontier for observation  $k$  will be less than or equal to zero.

---

<sup>4</sup> It may be noted that in the literature the non-negative error term is interpreted as the reciprocal of Farrell output based technical efficiency index.

Our objective is to maximise the expression in equation (x) subject to the following constraints

$$(xi) \dots \ln D_o(x^k, y^k) \leq 0, \quad k=1, \dots, K$$

This constraint restricts the individual observations to be either on or below the frontier of the technology i.e., there are no outputs outside the frontier of the technology, given the set of inputs.

Desirable outputs are assumed to be strongly disposable, which implies that the output distance function should be increasing in desirable outputs. The strong disposability condition can be represented by the following inequality:

$$(xii) \dots \frac{\partial \ln D_o(x^k, y^k)}{\partial \ln y_m^k} \geq 0, \quad m = 1, \dots, i; \quad k = 1, \dots, K$$

The constraint above ensures that the shadow prices of the desirable outputs are non-negative. In addition it is assumed that both the outputs are weakly disposable. This weak disposability is always satisfied for the output distance function specified as the translog form when linear homogeneity condition represented by equation (xiv) and the symmetry conditions represented by equation (xv) are being imposed. Therefore, one requires no additional constraints when the restrictions denoted by equations (xiv) and (xv) are imposed (Kwon and Yun, 1999).

The weak disposability of undesirable outputs implies that the desirable output decreases when the emission of the pollutants or the undesirable outputs is reduced. The following assumption satisfies the criterion of weak disposability of the undesirable output:

$$(xiii) \dots \frac{\partial \ln D_o(x^k, y^k)}{\partial \ln y_m^k} \leq 0, \quad m = i+1, \dots, M; \quad k = 1, \dots, K$$

In addition to the above constraints we also impose the homogeneity and symmetry constraints into the model which can be represented as

$$(xiv) \dots \sum_{m=1}^M \alpha_m = 1, \quad \sum_{m=1}^M \gamma_{nm} = \sum_{m'=1}^M \alpha_{mm'} = 0, \quad \text{for all } m, n \text{ and}$$

$$(xv) \dots \alpha_{mm'} = \alpha_{m'm}, \quad \beta_{nn'} = \beta_{n'n}, \quad \text{for all } m, m', n \text{ and } n'$$

Equations (x)-(xv) represent the model we shall use to derive the shadow prices of the undesirable output. The model is solved using the GAMS programming tool.

#### 4. Data and Estimation Procedure

The empirical analysis is based on primary data collected from the coal fired thermal plants under the Calcutta Electricity Supply Corporation (CESC), West Bengal Power Development Corporation Limited (WBPDCL) and Damodar Valley Corporation (DVC) in the Eastern region of India. These coal fired thermal plants are a part of the Eastern Grid.<sup>5</sup> We have collected detailed data on inputs and outputs for the years 1990-91 to 1999-2000 for all the thermal plants listed above. However, the data for the Mejia TPS and Budge-Budge TPS were available for the years 1997-98 to 1999-2000 as these thermal plants were commissioned in the year 1997 and had started commercial production only from the year 1997-98. A detailed table listing the various thermal power stations along with the year of commissioning of their respective units is presented in Table A1 in the appendix. An interesting feature worth mentioning about our sample of thermal plants is that these plants are of different vintages. On the one hand we have plants like Bokaro TPS 'A' which was commissioned in the decade of fifties, there are newer plants like Mejia TPS and Budge-Budge TPS which are still under construction and only some of their units have started commercial operations on the other. Moreover, there are also plants that were commissioned in the decades of eighties and nineties. So we have a whole spectrum of thermal plants in the analysis representing technologies of different vintages. The primary data pertaining to inputs and outputs were collected from the WBSEB, DVC and CESC for their respective thermal plants. Only plant level data on inputs, outputs and prices of one of the desirable output is needed for our analysis.

*Inputs:* The main inputs needed for generation of electricity by the thermal plants are fuel, capital and labour. The major fuel input needed by the power plants considered in the present study is coal. In addition, the coal fired thermal plants also require fuel oil or light diesel oil (LDO), as a secondary fuel to provide the necessary heat input as and when required to start-up the boiler or for stabilization of flame at low load. Coal consumption figures are given in metric tonnes while the fuel oil (or LDO) consumption is recorded in kilolitres. The data pertaining to coal and fuel oil consumed by the power plants are converted from their respective units to *tonnes of oil equivalent* (See Box 1 for conversion factors) and are then aggregated to get the total fuel consumption figure for the individual plants.

**Box 1: Conversion Factors**

1 Kilolitre of LDO	=	0.863 metric tonnes of LDO
1 Metric tonne of LDO	=	1.035 tonne of oil equivalent
1 Metric tonne of Coal	=	0.67 tonnes of oil equivalent

**Source:** India, Ministry of Petroleum and Natural Gas (MPNG), (various years), *Indian Petroleum and Natural Gas Statistics*, (New Delhi: MPNG, various years).

The other important inputs in the generation of electricity are capital and labour. In the present study we have used the plant capacity in megawatt (MW) as the capital variable following Kwon and Yun (1999). The data on labour input cover both production and non-production (white-collar) workers employed in the plant.

*Outputs:* The output variable consists of both desirable and undesirable outputs. While electricity generated by the thermal plant is the desirable output and is measured in Megawatt hours (Mwh), CO<sub>2</sub> emission is the bad output. We have used for the desirable output the plant-wise electricity generation data which was made available by the WBSEB, DVC and CESC for their respective thermal plants for the period 1990-91 to 1999-2000.

Coal is burnt to generate electricity in the thermal plants. Since in coal carbon is bundled with ash, carbon, sulfur etc., its burning results in the emission of carbon dioxide, particulate matters, NO<sub>x</sub>, etc., in the atmosphere as pollutants. The emission of these pollutants in the atmosphere can be regarded as the byproduct of electricity generation, and thus is considered as the undesirable output. The present study considers carbon dioxide as the only undesirable output. The data relating to the emission of CO<sub>2</sub> are not readily available, as most of the thermal plants in India still do not measure the emissions of CO<sub>2</sub>. As a result we have used the data on fuel consumption for generating the data on CO<sub>2</sub> emissions. Having obtained the plant wise data on the consumption of coal and fuel oil or LDO, the emission factors of various fuels given by IPCC (1995) was used to derive plant wise total CO<sub>2</sub> emissions. We also collected data on the calorific value of coal consumed by the thermal plants in the sample and found that the coal supplied to these thermal plants is of a higher grade and has a higher calorific value vis-à-vis those used in most thermal plants in India. In the present study while calculating plant-wise CO<sub>2</sub> emissions from burning of coal the calorific values of different grades of coal consumed by the

---

<sup>5</sup> The thermal plants included in the empirical model are Kolaghat Thermal Power Station (KTPS) under the WBPDC, Bokaro TPS 'A', Bokaro TPS 'B', Chandrapura TPS, Durgapur TPS, Mejia TPS under the DVC and

power plants were incorporated and the CO<sub>2</sub> emission factors for coal provided by the IPCC were adjusted accordingly.<sup>6</sup>

The descriptive data on the inputs and outputs are given in Table 2 below. The standard deviations for all the variables are less than their mean values, indicating that the plants are a relatively homogeneous group (Hetemäki, 1996).

**Table 2: Descriptive Statistics**

Variables	Unit	Mean	Std. Dev	Min	Max
Electricity (Y)	Mwh	1874281	1541744	141000	6686101
Capital (K)	MW	469.64	341.52	67.50	1260
Labour (L)	number	1308	792.48	104	2946
Fuel (F)	toe	887848.20	735710.10	68720.71	3197387
CO <sub>2</sub> (P)	tCO <sub>2</sub>	2413491	2182987	139013.60	9169197

**Note:** Sample size is 76; toe = tonnes of oil equivalent; t CO<sub>2</sub> = tonnes of carbon dioxide; Mwh = Megawatt hour; MW = Megawatt; Fuel comprises both coal and oil consumption.

*Electricity Prices:* In order to derive the shadow prices of the outputs, market price of at least one of the output is necessary. As there exists no market for the undesirable outputs we do not get the prices for these. Therefore, in order to derive the shadow prices of the undesirable outputs we need to know the price of the desirable output, which in the present case is electricity. The data on electricity tariffs i.e., the sale price of electricity is taken as the price of electricity and is obtained from CESC, DVC and WBPDC for their respective plants for the different years.

It should be noted here that as the data on CO<sub>2</sub> emission used in the present exercise is generated from the consumption of fossil fuels by the thermal plants it cannot be used for econometrically estimating the output distance function. Hence the present study uses the deterministic linear programming technique to derive the shadow prices of undesirable output.

As mentioned the sample consists of plants of different vintages, some are new and use relatively better and efficient technologies and thus emit less CO<sub>2</sub> than the plants which are very old and pollute more per unit of output. In order to differentiate plants that are old and have not

---

Titagarh TPS, Southern TPS and Budge-Budge TPS under the CESC.

<sup>6</sup> In India most of the coal that is consumed in the thermal plants is of a lower grade and has low calorific value in comparison the coal consumed by the plants under consideration. In order to capture the grade differential while

installed any equipment to control their emissions i.e., the dirty plants, from the plants that use new technology which is less polluting and plants which have old technology but have installed equipment or have taken additional measure to restrict emissions and hence pollute less i.e., the cleaner plants, a dummy variable<sup>7</sup> is introduced in the model. The output distance function is initially estimated without making any distinction between the dirty and cleaner plants. This is our Model-1. The estimation of the output distance function is again carried out, now by incorporating the dummy variable to distinguish the dirty plants from the cleaner ones. This is called Model-2.<sup>8</sup> The estimated parameters of both the models are presented in Table 3.

**Table 3: Estimated Parameters**

Parameter	Value		Parameter	Value	
	Model-1	Model-2		Model-1	Model-2
$\alpha_o$	5.713907	8.265383	$\alpha_{YY}$	-0.073590	-0.069163
$\beta_L$	-0.756283	-0.168085	$\alpha_{YP}$	0.073590	0.069163
$\beta_K$	0.526069	0.947600	$\alpha_{PP}$	-0.073590	-0.069163
$\beta_F$	-1.875104	-2.727518	$\gamma_{LY}$	-0.253212	-0.306170
$\alpha_Y$	-0.892840	-0.409482	$\gamma_{LP}$	0.253212	0.306170
$\alpha_P$	1.892840	1.409482	$\gamma_{KY}$	-0.103620	-0.017939
$\beta_{LL}$	-0.005172	-0.100494	$\gamma_{KP}$	0.103620	0.017939
$\beta_{LK}$	0.148123	0.205437	$\gamma_{FY}$	0.261308	0.220088
$\beta_{LF}$	-0.013652	-0.036834	$\gamma_{FP}$	-0.261308	-0.220088
$\beta_{KK}$	0.126568	0.060381	$\gamma_t$	-0.010469	-0.007900
$\beta_{KF}$	-0.181760	-0.210416	$\gamma_{tt}$	0.002092	0.001522
$\beta_{FF}$	0.163526	0.250791	Dummy	-	0.051274

**Note:** In Model 2 we have used Dummy  $D = 1$  for plants which are dirty and used dated technology and  $D = 0$  for plants which are clean.

estimating CO<sub>2</sub> emissions from the burning of coal the emission factors provided in the IPCC reference manual are adjusted accordingly.

<sup>7</sup> A Dummy Variable assuming values  $D = 1$  for dirty plants and  $D = 0$  for plants which are cleaner is incorporated in Model-2

<sup>8</sup> In Model-2, as per our formulation, Titagarh TPS, Bokaro TPS 'A', Durgapur TPS, and Chandrapura TPS fall under the category of dirty plants while the remaining thermal plants are considered as cleaner plants.

## 5. Results

Having estimated the parameters of the distance function we now substitute their values in equation (vii) to get the estimated value of the output distance function. Substituting the estimated output distance function in equation (vi) and simplifying we get the marginal cost of abating CO<sub>2</sub> expressed in terms of the value of electricity foregone.

Out of a total 76 observations in Model-1, 15 observations are located on the frontier of the output set as the value of the output distance function for these observations is unity, while the remaining 61 observations, for which the value of the output distance function is less than one, lie inside it. Similarly, in Model-2, 17 observations lie on the frontier of the output set and have value of the distance function as unity and the remaining 59 observations lie inside the frontier. On an average the mean value of the output distance function for the sample of thermal plants in Model-1 is estimated to be 0.9669 with standard deviation 0.0356. This means that the electricity generation can be increased by 3.31 percent (with CO<sub>2</sub> emissions increasing in the same proportion) on an average by the thermal plants if they produce efficiently i.e. if they operate on the frontier of the output set. On the other hand, for Model-2, the mean value of the distance function is estimated to be 0.9722 with a standard deviation of 0.0275 implying that the electricity generation can be increased by 2.78 percent if the plants operate efficiently. But such increase in output will be accompanied by a proportionate increase in the emission of the pollutants. The mean value of the shadow price or the marginal cost of abatement of CO<sub>2</sub> for the power plants in the study is estimated to be Rs. 3380.59 per tonne in case of Model-1 and Rs. 2401.99 per tonne in case of Model-2. These shadow prices reflect the trade-off between the desirable and undesirable outputs at the actual mix of outputs. This means that if the plants were to reduce their CO<sub>2</sub> emission by one tonne, they will have to forego electricity output worth Rs. 3380.59 in Model-1 and Rs. 2401.99 in Model-2. It should be noted here that these shadow prices or the marginal abatement costs of CO<sub>2</sub> are at constant 1990-91 prices. There is a wide variation in the mean values of the output distance function and the marginal abatement cost across plants as is shown in Table A2 in the appendix. The mean value of the distance function varies, in case of Model-1, between 0.896814 (for Titagarh TPS) and 0.998510 (for Mejia TPS) and between 0.937319 (for Bokaro 'B' TPS) and 0.997814 (for Mejia TPS) in case of Model-2. Thus there is a considerable scope of increasing the electricity output if these plants were to



operate efficiently. Similarly, there is a wide variation in the mean value of the output distance function and the mean value of the marginal abatement costs of CO<sub>2</sub> across years as is seen in Table A3 in the appendix.

In both the models there is wide variation in the marginal abatement cost across plants. Even for a particular plant there are variations in the shadow prices across different years (Refer to Tables A4 and A5 in the Appendix). The wide variation in the marginal abatement costs or the shadow prices of CO<sub>2</sub> can be explained by the variation in the ratio of CO<sub>2</sub> emissions to electricity generation, the different vintages of capital used by the different plants for generation of power and the different measures adopted for abating or controlling pollution. The variations in the marginal abatement costs by plant have an important implication in evaluating the cost effectiveness of the current environmental policies in India. These differences in the marginal abatement costs across plants are important because of their policy implications. They suggest, per se, the current pollution control regulations in the country cause an inefficient allocation of abatement resources across plants and a market oriented system would potentially result in transfer of such resources across plants and this would lead to cost effectiveness.

It would be meaningful to statistically test whether the equi-marginal principle is satisfied for power generation sector in the country. To secure a minimum number of observations for a statistical test, we divide the sample into two periods of 1990-91 to 1994-95 and 1995-96 to 1999-00. The hypothesis to be tested is that the marginal abatement costs for CO<sub>2</sub> are same within the sub-samples. For this end, after ordering the marginal abatement costs for CO<sub>2</sub>, we separate each sub-sample into two groups of high and low marginal abatement costs. Using a *t*-test, we test whether the mean of high-cost group is different from that of low cost group. The results of the test are shown in Table 5. From Table 5 it is evident that for both the sub-samples, the hypothesis is rejected at 1 per cent level of significance, thereby implying that the equi-marginal principle does not hold for environmental regulations pertaining to CO<sub>2</sub> emission in the Indian power generation sector. Thus, the CO<sub>2</sub> emission reduction is not being achieved in the least cost way.

**Table 5: Test results for cost-effectiveness**

Period	<i>t</i> -value	
	Model-1	Model-2
1990-91 to 1994-95	4.280	4.017
1995-96 to 1999-00	6.339	7.030

We define the ratio of total CO<sub>2</sub> emissions to electricity generation as our index of efficiency. As per the definition an efficient plant is associated with a lower value of this ratio because it would emit less of CO<sub>2</sub> per unit of electricity output generated. In other words the higher the ratio the less efficient the plant is and vice-versa. On the basis of the index of efficiency and the estimated shadow prices, the present study gets the expected result that the higher efficiency is associated with a higher value of the shadow price of CO<sub>2</sub>. This means that the marginal cost of abating CO<sub>2</sub> emissions is high for a clean and efficient plant while for a dirty and inefficient plant it is low. The estimated relation between the estimated shadow prices and the efficiency index is given in Table 6.

**Table 6: Impact of Efficiency Index on Marginal Abatement Cost**

Variable	Model-1	Model-2
<b>Dependent Variable:</b> $\log(\text{shadow price of } CO_2)$		
<b>Explanatory Variables:</b>		
$\log(CO_2 \text{ emission/power generation})$	-1.379 (-7.16)	-3.689 (-8.34)
<i>constant</i>	7.758 (80.78)	5.232 (17.58)
<i>envt_dummy</i>		3.942 (9.02)
$R^2$	0.748	0.668
<i>Adjusted R</i> <sup>2</sup>	0.717	0.629
<i>N</i>	75	76

**Note:** Figures in parenthesis are t-values.

Plant dummies have been used in estimating both the regressions but are not reported while presenting the results.

From the estimated relationship between the marginal abatement costs and efficiency index one can infer that, for the sample of thermal plants, the marginal cost of abatement of CO<sub>2</sub> increases with the increase in the efficiency of the plant. That is, it becomes increasingly difficult

or expensive for a plant, which has invested in pollution abating technology or equipment and is emitting less of CO<sub>2</sub> per unit of output to reduce an additional unit of the pollutant vis-à-vis plants that emit more CO<sub>2</sub> per unit of electricity generation. Thus, for a given level of output the less one pollutes, the higher will be the cost of reducing an additional unit of the pollutant and vice-versa.

## **6. Conclusion**

There have been a number of studies for India, which have applied the output distance function approach to calculate the shadow prices of the undesirable outputs. These studies mainly relate to water pollutants like BOD (biological oxygen demand), COD (chemical oxygen demand), and SS (suspended solids) (Refer to studies by Murty and S. Kumar 2001, 2002). The present study is one of the few to use the output distance function technique for the coal fired thermal plants in India and perhaps the only one to calculate the shadow price of CO<sub>2</sub> emissions for the power sector India. The only other study that uses the output distance technique to calculate the shadow prices of the pollutants emitted by the power plants in India, is Kumar (1999) which uses both deterministic and stochastic output distance function technique to derive the shadow price of (PM<sub>10</sub>) for the power plants in India. Apart from the studies relating to India, numerous other studies have also been carried out worldwide to derive the shadow prices of the pollutants using the output distance technique. Appendix Table A6 displays the results of some of the studies that use the output distance function technique to derive the shadow price(s) of pollutant(s) for the power sector.

The present study uses the output distance function approach and its duality with the revenue function to calculate the plant specific shadow prices of CO<sub>2</sub>, for the coal fired thermal power plants in India. A distinguishing feature of this framework is that it provides a measure of productive efficiency for each producer. The output distance function technique, since it allows shadow prices to vary across producers, can reveal a pattern of variation by production techniques, by other plant characteristics like the age of the plant, volume of pollution etc. This type of information would be helpful for policy makers in designing or formulating policies to reduce carbon dioxide emissions.

Economic theory suggests that equalization of the marginal cost of abatement across the firms would minimise the total cost of abating the pollutants at an aggregate level. The results of

the study reveal that the estimated shadow prices of CO<sub>2</sub> vary across plants. The estimated mean values of the shadow price or the marginal abatement cost of CO<sub>2</sub> for the coal fired thermal plants in India for the period 1991-92 to 1999-2000 is Rs. 3380.59 per ton of CO<sub>2</sub> as per model-1 and Rs. 2401.99 per ton of CO<sub>2</sub> as per model-2. Considerable differences in the plant specific shadow prices point towards inefficient use of abatement technology by the thermal plants in the country. One can also infer from the study that the command and control measures are not successful in controlling pollution in this sector thereby building a case for consideration of various economic instruments like pollution taxes, input taxes or tradable pollution permits to control pollution. As the marginal abatement costs vary considerably across plants it implies that the current environmental regulations in India do not achieve cost minimisation condition. Therefore it would be expected that the introduction of environmental/pollution taxes, input taxes or tradable pollution permits which are highly market oriented and incentive-based would achieve reduction in social costs.<sup>9</sup>

As regards the relationship between efficiency of the power plants defined in terms of CO<sub>2</sub> emissions per unit of electricity output generated and marginal cost of abating CO<sub>2</sub> is concerned the results of the study indicate that there exists a direct correlation between the two. This implies that a relatively efficient plant is associated with a higher marginal cost of abating CO<sub>2</sub>. In other words, it becomes increasingly difficult for a plant, which emits less CO<sub>2</sub> per unit of its good output to reduce an additional unit of CO<sub>2</sub> vis-à-vis plants that are less efficient and hence emit more CO<sub>2</sub> per unit of good output. That is, the marginal abatement cost increases with the efficiency of the thermal plant.

---

<sup>9</sup> In order to predict the amount of cost savings by these market oriented policies, it would be necessary to analyse further the extent to which the costs related to reducing pollution emissions would be decreased compared to the current level due to the introduction of these policies.

## Appendix

**Table A1: Details of the Various Thermal Power Stations (TPS)**

<i>Thermal Power Stations</i>	<i>Units</i>	<i>Year of Commissioning</i>	<i>Thermal Power Stations</i>	<i>Units</i>	<i>Year of Commissioning</i>
<b>Calcutta Electric Supply Corporation</b>			<b>Damodar Valley Corporation</b>		
Titagarh TPS	Unit 1	1983	Bokaro TPS "A"	Unit 1	February 1953
	Unit 2	1983		Unit 2	August 1953
	Unit 3	1984		Unit 3	October 1953
	Unit 4	1985		Unit 4	1 April 1960
Southern TPS	Unit 1	1990	Bokaro TPS "B"	Unit 1	12 March 1987
	Unit 2	1991		Unit 2	15 December 1991
Budge-Budge TPS	Unit 1	1997	Chandrapura TPS	Unit 3	1 April 1968
	Unit 2	1999		Unit 1	November 1968
<b>West Bengal Power Development Corporation Ltd.</b>				Unit 2	April 1965
Kolaghat TPS	Unit 1	9 September 1990		Unit 3	1 August 1968
	Unit 2	9 March 1986		Unit 4	31 March 1975
	Unit 3	12 October 1984		Unit 5	1 April 1976
	Unit 4	1 April 1995	Unit 6	1 April 1980	
	Unit 5	14 May 1991	Durgapur TPS	Unit 1	December 1960
	Unit 6	1 January 1994		Unit 2 *	February 1961
			Mejia TPS	Unit 3 *	1 April 1967
				Unit 4	1 December 1982
				Unit 1	1 December 1997
			Unit 2	15 March 1999	
			Unit 3	28 September 1999	

Note: \* Decommissioned due to fire since 23 October 1985.

**Table A2: Mean Values of Output Distance Function and Shadow Prices Across Plants**

Thermal Plants	Model-1		Model-2	
	Distance Function	Shadow Price (Rs. / tonne)	Distance Function	Shadow Price (Rs. / tonne)
Titagarh TPS	0.896814	3086.94	0.966136	2436.48
Southern TPS	0.964838	3709.37	0.965143	2715.56
Bokaro TPS 'A'	0.965746	939.31	0.976638	673.47
Bokaro TPS 'B'	0.977155	3418.66	0.937319	2453.95
Chandrapura TPS	0.984893	4760.05	0.984939	2679.60
Durgapur TPS	0.981496	7595.67	0.988897	5726.76
Kolaghat TPS	0.986287	1312.70	0.982368	909.74
Mejia TPS	0.998510	2587.78	0.997814	1567.78
Budge-Budge TPS	0.972593	1716.42	0.960523	630.81
<b>Overall</b>	<b>0.966916</b>	<b>3380.59</b>	<b>0.972229</b>	<b>2401.99</b>

**Note:** The values of the shadow price or marginal abatement costs of CO<sub>2</sub> abatement are at 1990-91 Prices; TPS = Thermal Power Station.

**Table A3: Mean Values of Output Distance Function and Shadow Prices Across Years**

Year	Model-1		Model-2	
	Distance Function	Shadow Price (Rs. / tonne)	Distance Function	Shadow Price (Rs. / tonne)
1990-91	0.961592	4492.213	0.973064	2788.97
1991-92	0.961590	4768.077	0.972118	2746.79
1992-93	0.961934	3357.720	0.973692	3679.13
1993-94	0.967121	2445.274	0.972898	1922.71
1994-95	0.971794	3091.220	0.976806	2213.27
1995-96	0.969427	3124.218	0.971137	2327.37
1996-97	0.959193	3714.176	0.961707	2535.19
1997-98	0.979707	3074.603	0.981455	2041.24
1998-99	0.968473	3313.584	0.971292	2187.87
1999-00	0.964824	2717.520	0.967193	1888.36
<b>Overall</b>	<b>0.966916</b>	<b>3380.59</b>	<b>0.972229</b>	<b>2401.99</b>

**Note:** The values of the shadow price or marginal abatement costs of CO<sub>2</sub> abatement are at 1990-91 prices; The numbers of plants in our study which were seven till 1996-97 increased to nine from the year 1997-98 with the commissioning of two new plants.

**Table A4: Shadow Price Of CO<sub>2</sub> (Rs. / tonne)***(Model-1)*

Year	Titagarh	Southern	Bokaro 'A'	Bokaro 'B'	Chandrapura	Durgapur	Kolaghat	Mejia	Budge-Budge
1990-91	3004.55	9788.45	720.96	2399.59	5329.14	7985.58	2217.22	-	-
1991-92	3580.52	3069.24	866.61	3594.23	4945.82	15652.64	1667.48	-	-
1992-93	3470.91	3087.15	675.99	6199.12	4757.24	-	1955.90	-	-
1993-94	2742.66	2727.92	826.29	3277.56	2740.97	3140.97	1660.54	-	-
1994-95	2926.60	2990.87	855.24	3565.90	5649.30	4372.71	1277.93	-	-
1995-96	3535.08	2912.66	872.74	4875.58	3858.90	4926.40	888.17	-	-
1996-97	2498.35	3316.50	947.68	3897.56	2987.34	11564.53	787.27	-	-
1997-98	2622.94	2443.97	627.65	2301.21	5400.80	6380.25	962.00	4120.71	2811.91
1998-99	2869.59	3152.50	1539.58	1995.88	6619.60	9302.76	901.01	2035.36	1405.98
1999-00	3618.20	3604.45	1460.34	2079.96	5311.41	5035.23	809.47	1607.27	931.36

**Note:** The shadow prices or the marginal abatement costs are at 1990-91 prices.

**Table A5: Shadow Price Of CO<sub>2</sub> (Rs. / tonne)***(Model-2)*

Year	Titagarh	Southern	Bokaro 'A'	Bokaro 'B'	Chandrapura	Durgapur	Kolaghat	Mejia	Budge-Budge
1990-91	2369.08	5415.70	558.19	1979.47	2883.03	4806.78	1510.57	-	-
1991-92	2733.01	2256.15	656.19	2428.11	2823.26	7148.74	1182.07	-	-
1992-93	2719.09	2397.26	534.72	4002.66	2741.40	12058.91	1299.88	-	-
1993-94	2161.01	2208.95	575.29	2961.04	1860.65	2599.88	1092.12	-	-
1994-95	2306.98	2431.92	615.41	2605.58	2780.10	3877.56	875.37	-	-
1995-96	2796.70	2414.38	563.99	3535.65	2241.55	4098.96	640.34	-	-
1996-97	2048.91	2666.44	562.14	2587.65	2047.18	7264.05	569.95	-	-
1997-98	2115.83	2037.96	440.12	1651.34	2991.31	4965.66	686.01	2413.82	1069.13
1998-99	2320.92	2516.58	1124.43	1398.27	3478.73	6422.47	653.19	1298.90	477.35
1999-00	2793.23	2810.25	1104.22	1389.69	2948.78	4024.56	587.94	990.61	345.96

**Note:** The shadow prices or the marginal abatement costs are at 1990-91 prices.

**Table A6: The Marginal Abatement Costs for Air-borne Pollutants from Various Studies**

Study	Period	Sample	CO <sub>2</sub>	SO <sub>x</sub>	NO <sub>x</sub>	TSP
Coggins and Swinton(1996)	1990-92	Coal Burning Utilities in Wisconsin	-	\$175.7 - \$326.7	-	-
Gollop and Roberts (1985)	1973-79	Fossil fueled electric generation in US	-	\$141 - \$1226	-	-
Kwon and Yun (1999)	1990-95	Bunker-C and coal power plants in Korea	\$2.38	\$194.1	\$91.69	\$ 9676.44
Kumar (1999)	1992-93	Coal burning utilities in India	-	-	-	Rs.326.18*
Our Study	1990-2000	Thermal power plants in eastern India	Rs.3380.59 # Rs.2401.99 @	-	-	-

**Note:** \* this shadow price value is for PM<sub>10</sub> and the unit is Rs. per kg.

# This pertains to Model-1 and @ for Model-2



## References:

- Government of India (1998), *Economic Survey 1997-98*, Economic Department, Ministry of Finance, Government of India, New Delhi.
- Baumol, W.J. and W. Oates (1988), *The Theory of Environmental Policy*, Cambridge University Press, Cambridge, United Kingdom.
- Tietenberg, T.H. (1985), *Emissions Trading: An Exercise in Reforming Pollution Policy*, Resources For the Future, Washington DC.
- Debreu, G. (1951), "The Coefficient of Resource Utilization", *Econometrica*, vol. 22, pp. 14-22.
- Malmquist, S. (1953), "Index Numbers and Indifference surfaces," *Trabajos de Estadística*, vol. 4, pp. 209-242.
- Shephard, Ronald W. (1953), *Cost and Production Functions*, Princeton University Press, Princeton.
- Shephard, Ronald W. (1970), *Theory of Cost and Production Functions*, Princeton University Press, Princeton.
- Färe, Rolf, S. Grosskopf, C.A.K. Lovell, and S. Yaisawarng (1993), "Derivation of Shadow Prices for Undesirable Outputs: A Distance Function Approach," *The Review of Economics and Statistics*, vol. 75, pp. 374-380.
- Coggins, J.S., and J.R. Swinton (1996), "The Price of Pollution: A Dual Approach to Valuing SO<sub>2</sub> Allowances," *Journal of Environmental Economics and Management*, vol. 30, pp. 58-72.
- Hetemäki L. (1996), "Essays on the Impact of Pollution Control on a Firm: A Distance Function Approach", Finnish Forest Research Institute Research Paper 609, Helsinki Research Centre, Helsinki.
- Kwon, O.S. and W.C. Yun (1999), "Estimation of the Marginal Abatement Costs of Airborne Pollutants in Korea's Power Generation Sector," *Energy Economics*, vol. 21, pp. 547-560.
- Murty, M.N. and S. Kumar (2002), "Measuring the Cost of Environmentally Sustainable Industrial development in India: A Distance Function Approach," *Environment and Development Economics*, vol. 17, No. 3, pp. 467-486.
- Färe, Rolf (1988), *Fundamentals of Production Theory*, Lecture Notes in Economics and Mathematical Systems, Springer Verlag, Berlin.
- Färe, Rolf and D. Primont (1995), *Multi-Output Production and Duality: Theory and Applications*, Kluwer Academic Publishers, Boston.
- Althin, R. (1994), "Shadow Pricing of Labor: A Translog Distance Function Approach," Department Of Economics, University of Lund Working Paper Series 33/94, Sweden.
- Aigner, D.J. and S.F. Chu (1968), "On Estimating the Industry Production Function," *American Economic Review*, vol. 58, pp. 826-839.
- Intergovernmental Panel on Climate Change (1995), *Greenhouse Gas Inventory Reference Manual: Guidelines for National Greenhouse Gas Inventories*, Vol. 3, IPCC, Geneva.

- Gollop, F.M. and M.J. Roberts (1985), "Cost-Minimizing Regulation of Sulfur Emissions: Regional Gains in Electric Power", *The Review of Economics and Statistics*, vol. 67, pp. 81-90.
- Murty, M. N. and S. Kumar (2001), "Environmental and Economic Accounting for Indian Industry", Institute of Economic Growth Working Paper Series No. E/212/2001, Delhi.
- Kumar, S. (1999), "Economic Evaluation of Development Projects: A Case Analysis of Environmental and Health Implications of Thermal Power Projects in India", Ph.D. Thesis, Jawaharlal Nehru University, New Delhi.
- The Energy and Resources Institute (various years), *TERI Energy Data Directory and Yearbook (TEDDY)*, TERI, New Delhi.

## NOTE DI LAVORO DELLA FONDAZIONE ENI ENRICO MATTEI

### Fondazione Eni Enrico Mattei Working Paper Series

Our Note di Lavoro are available on the Internet at the following addresses:

<http://www.feem.it/Feem/Pub/Publications/WPapers/default.html>

<http://www.ssrn.com/link/feem.html>

<http://www.repec.org>

<http://agecon.lib.umn.edu>

### NOTE DI LAVORO PUBLISHED IN 2006

SIEV	1.2006	<i>Anna ALBERINI</i> : <u>Determinants and Effects on Property Values of Participation in Voluntary Cleanup Programs: The Case of Colorado</u>
CCMP	2.2006	<i>Valentina BOSETTI, Carlo CARRARO and Marzio GALEOTTI</i> : <u>Stabilisation Targets, Technical Change and the Macroeconomic Costs of Climate Change Control</u>
CCMP	3.2006	<i>Roberto ROSON</i> : <u>Introducing Imperfect Competition in CGE Models: Technical Aspects and Implications</u>
KTHC	4.2006	<i>Sergio VERGALLI</i> : <u>The Role of Community in Migration Dynamics</u>
SIEV	5.2006	<i>Fabio GRAZI, Jeroen C.J.M. van den BERGH and Piet RIETVELD</i> : <u>Modeling Spatial Sustainability: Spatial Welfare Economics versus Ecological Footprint</u>
CCMP	6.2006	<i>Olivier DESCHENES and Michael GREENSTONE</i> : <u>The Economic Impacts of Climate Change: Evidence from Agricultural Profits and Random Fluctuations in Weather</u>
PRCG	7.2006	<i>Michele MORETTO and Paola VALBONESE</i> : <u>Firm Regulation and Profit-Sharing: A Real Option Approach</u>
SIEV	8.2006	<i>Anna ALBERINI and Aline CHIABAI</i> : <u>Discount Rates in Risk v. Money and Money v. Money Tradeoffs</u>
CTN	9.2006	<i>Jon X. EGUIA</i> : <u>United We Vote</u>
CTN	10.2006	<i>Shao CHIN SUNG and Dinko DIMITRO</i> : <u>A Taxonomy of Myopic Stability Concepts for Hedonic Games</u>
NRM	11.2006	<i>Fabio CERINA</i> (lxxviii): <u>Tourism Specialization and Sustainability: A Long-Run Policy Analysis</u>
NRM	12.2006	<i>Valentina BOSETTI, Mariaester CASSINELLI and Alessandro LANZA</i> (lxxviii): <u>Benchmarking in Tourism Destination, Keeping in Mind the Sustainable Paradigm</u>
CCMP	13.2006	<i>Jens HORBACH</i> : <u>Determinants of Environmental Innovation – New Evidence from German Panel Data Sources</u>
KTHC	14.2006	<i>Fabio SABATINI</i> : <u>Social Capital, Public Spending and the Quality of Economic Development: The Case of Italy</u>
KTHC	15.2006	<i>Fabio SABATINI</i> : <u>The Empirics of Social Capital and Economic Development: A Critical Perspective</u>
CSRM	16.2006	<i>Giuseppe DI VITA</i> : <u>Corruption, Exogenous Changes in Incentives and Deterrence</u>
CCMP	17.2006	<i>Rob B. DELLINK and Marjan W. HOFKES</i> : <u>The Timing of National Greenhouse Gas Emission Reductions in the Presence of Other Environmental Policies</u>
IEM	18.2006	<i>Philippe QUIRION</i> : <u>Distributional Impacts of Energy-Efficiency Certificates Vs. Taxes and Standards</u>
CTN	19.2006	<i>Somdeb LAHIRI</i> : <u>A Weak Bargaining Set for Contract Choice Problems</u>
CCMP	20.2006	<i>Massimiliano MAZZANTI and Roberto ZOBOLI</i> : <u>Examining the Factors Influencing Environmental Innovations</u>
SIEV	21.2006	<i>Y. Hossein FARZIN and Ken-ICHI AKAO</i> : <u>Non-pecuniary Work Incentive and Labor Supply</u>
CCMP	22.2006	<i>Marzio GALEOTTI, Matteo MANERA and Alessandro LANZA</i> : <u>On the Robustness of Robustness Checks of the Environmental Kuznets Curve</u>
NRM	23.2006	<i>Y. Hossein FARZIN and Ken-ICHI AKAO</i> : <u>When is it Optimal to Exhaust a Resource in a Finite Time?</u>
NRM	24.2006	<i>Y. Hossein FARZIN and Ken-ICHI AKAO</i> : <u>Non-pecuniary Value of Employment and Natural Resource Extinction</u>
SIEV	25.2006	<i>Lucia VERGANO and Paulo A.L.D. NUNES</i> : <u>Analysis and Evaluation of Ecosystem Resilience: An Economic Perspective</u>
SIEV	26.2006	<i>Danny CAMPBELL, W. George HUTCHINSON and Riccardo SCARPA</i> : <u>Using Discrete Choice Experiments to Derive Individual-Specific WTP Estimates for Landscape Improvements under Agri-Environmental Schemes: Evidence from the Rural Environment Protection Scheme in Ireland</u>
KTHC	27.2006	<i>Vincent M. OTTO, Timo KUOSMANEN and Ekko C. van IERLAND</i> : <u>Estimating Feedback Effect in Technical Change: A Frontier Approach</u>
CCMP	28.2006	<i>Giovanni BELLA</i> : <u>Uniqueness and Indeterminacy of Equilibria in a Model with Polluting Emissions</u>
IEM	29.2006	<i>Alessandro COLOGNI and Matteo MANERA</i> : <u>The Asymmetric Effects of Oil Shocks on Output Growth: A Markov-Switching Analysis for the G-7 Countries</u>
KTHC	30.2006	<i>Fabio SABATINI</i> : <u>Social Capital and Labour Productivity in Italy</u>
ETA	31.2006	<i>Andrea GALLICE</i> (lxxix): <u>Predicting one Shot Play in 2x2 Games Using Beliefs Based on Minimax Regret</u>
IEM	32.2006	<i>Andrea BIGANO and Paul SHEEHAN</i> : <u>Assessing the Risk of Oil Spills in the Mediterranean: the Case of the Route from the Black Sea to Italy</u>
NRM	33.2006	<i>Rinaldo BRAU and Davide CAO</i> (lxxviii): <u>Uncovering the Macrostructure of Tourists' Preferences. A Choice Experiment Analysis of Tourism Demand to Sardinia</u>
CTN	34.2006	<i>Parkash CHANDER and Henry TULKENS</i> : <u>Cooperation, Stability and Self-Enforcement in International Environmental Agreements: A Conceptual Discussion</u>
IEM	35.2006	<i>Valeria COSTANTINI and Salvatore MONNI</i> : <u>Environment, Human Development and Economic Growth</u>
ETA	36.2006	<i>Ariel RUBINSTEIN</i> (lxxix): <u>Instinctive and Cognitive Reasoning: A Study of Response Times</u>

ETA	37.2006	<i>Maria SALGADEO</i> (lxxx): <u>Choosing to Have Less Choice</u>
ETA	38.2006	<i>Justina A.V. FISCHER and Benno TORGLER</i> : <u>Does Envy Destroy Social Fundamentals? The Impact of Relative Income Position on Social Capital</u>
ETA	39.2006	<i>Benno TORGLER, Sascha L. SCHMIDT and Bruno S. FREY</i> : <u>Relative Income Position and Performance: An Empirical Panel Analysis</u>
CCMP	40.2006	<i>Alberto GAGO, Xavier LABANDEIRA, Fidel PICOS And Miguel RODRÍGUEZ</i> : <u>Taxing Tourism In Spain: Results and Recommendations</u>
IEM	41.2006	<i>Karl van BIERVLIET, Dirk Le ROY and Paulo A.L.D. NUNES</i> : <u>An Accidental Oil Spill Along the Belgian Coast: Results from a CV Study</u>
CCMP	42.2006	<i>Rolf GOLOMBEK and Michael HOEL</i> : <u>Endogenous Technology and Tradable Emission Quotas</u>
KTHC	43.2006	<i>Giulio CAINELLI and Donato IACOBUCCI</i> : <u>The Role of Agglomeration and Technology in Shaping Firm Strategy and Organization</u>
CCMP	44.2006	<i>Alvaro CALZADILLA, Francesco PAULI and Roberto ROSON</i> : <u>Climate Change and Extreme Events: An Assessment of Economic Implications</u>
SIEV	45.2006	<i>M.E. KRAGT, P.C. ROEBELING and A. RUIJS</i> : <u>Effects of Great Barrier Reef Degradation on Recreational Demand: A Contingent Behaviour Approach</u>
NRM	46.2006	<i>C. GIUPPONI, R. CAMERA, A. FASSIO, A. LASUT, J. MYSLIAK and A. SGOBBI</i> : <u>Network Analysis, Creative System Modelling and DecisionSupport: The NetSyMoD Approach</u>
KTHC	47.2006	<i>Walter F. LALICH</i> (lxxx): <u>Measurement and Spatial Effects of the Immigrant Created Cultural Diversity in Sydney</u>
KTHC	48.2006	<i>Elena PASPALANOVA</i> (lxxx): <u>Cultural Diversity Determining the Memory of a Controversial Social Event</u>
KTHC	49.2006	<i>Ugo GASPARINO, Barbara DEL CORPO and Dino PINELLI</i> (lxxx): <u>Perceived Diversity of Complex Environmental Systems: Multidimensional Measurement and Synthetic Indicators</u>
KTHC	50.2006	<i>Aleksandra HAUKE</i> (lxxx): <u>Impact of Cultural Differences on Knowledge Transfer in British, Hungarian and Polish Enterprises</u>
KTHC	51.2006	<i>Katherine MARQUAND FORSYTH and Vanja M. K. STENIUS</i> (lxxx): <u>The Challenges of Data Comparison and Varied European Concepts of Diversity</u>
KTHC	52.2006	<i>Gianmarco I.P. OTTAVIANO and Giovanni PERI</i> (lxxx): <u>Rethinking the Gains from Immigration: Theory and Evidence from the U.S.</u>
KTHC	53.2006	<i>Monica BARNI</i> (lxxx): <u>From Statistical to Geolinguistic Data: Mapping and Measuring Linguistic Diversity</u>
KTHC	54.2006	<i>Lucia TAJOLI and Lucia DE BENEDETTIS</i> (lxxx): <u>Economic Integration and Similarity in Trade Structures</u>
KTHC	55.2006	<i>Suzanna CHAN</i> (lxxx): <u>“God’s Little Acre” and “Belfast Chinatown”: Diversity and Ethnic Place Identity in Belfast</u>
KTHC	56.2006	<i>Diana PETKOVA</i> (lxxx): <u>Cultural Diversity in People’s Attitudes and Perceptions</u>
KTHC	57.2006	<i>John J. BETANCUR</i> (lxxx): <u>From Outsiders to On-Paper Equals to Cultural Curiosities? The Trajectory of Diversity in the USA</u>
KTHC	58.2006	<i>Kiflemariam HAMDE</i> (lxxx): <u>Cultural Diversity A Glimpse Over the Current Debate in Sweden</u>
KTHC	59.2006	<i>Emilio GREGORI</i> (lxxx): <u>Indicators of Migrants’ Socio-Professional Integration</u>
KTHC	60.2006	<i>Christa-Maria LERM HAYES</i> (lxxx): <u>Unity in Diversity Through Art? Joseph Beuys’ Models of Cultural Dialogue</u>
KTHC	61.2006	<i>Sara VERTOMMEN and Albert MARTENS</i> (lxxx): <u>Ethnic Minorities Rewarded: Ethnostratification on the Wage Market in Belgium</u>
KTHC	62.2006	<i>Nicola GENOVESE and Maria Grazia LA SPADA</i> (lxxx): <u>Diversity and Pluralism: An Economist's View</u>
KTHC	63.2006	<i>Carla BAGNA</i> (lxxx): <u>Italian Schools and New Linguistic Minorities: Nationality Vs. Plurilingualism. Which Ways and Methodologies for Mapping these Contexts?</u>
KTHC	64.2006	<i>Vedran OMANOVIĆ</i> (lxxx): <u>Understanding “Diversity in Organizations” Paradigmatically and Methodologically</u>
KTHC	65.2006	<i>Mila PASPALANOVA</i> (lxxx): <u>Identifying and Assessing the Development of Populations of Undocumented Migrants: The Case of Undocumented Poles and Bulgarians in Brussels</u>
KTHC	66.2006	<i>Roberto ALZETTA</i> (lxxx): <u>Diversities in Diversity: Exploring Moroccan Migrants’ Livelihood in Genoa</u>
KTHC	67.2006	<i>Monika SEDENKOVA and Jiri HORAK</i> (lxxx): <u>Multivariate and Multicriteria Evaluation of Labour Market Situation</u>
KTHC	68.2006	<i>Dirk JACOBS and Andrea REA</i> (lxxx): <u>Construction and Import of Ethnic Categorisations: “Allochthones” in The Netherlands and Belgium</u>
KTHC	69.2006	<i>Eric M. USLANER</i> (lxxx): <u>Does Diversity Drive Down Trust?</u>
KTHC	70.2006	<i>Paula MOTA SANTOS and João BORGES DE SOUSA</i> (lxxx): <u>Visibility &amp; Invisibility of Communities in Urban Systems</u>
ETA	71.2006	<i>Rinaldo BRAU and Matteo LIPPI BRUNI</i> : <u>Eliciting the Demand for Long Term Care Coverage: A Discrete Choice Modelling Analysis</u>
CTN	72.2006	<i>Dinko DIMITROV and Claus-JOCHEN HAAKE</i> : <u>Coalition Formation in Simple Games: The Semistrict Core</u>
CTN	73.2006	<i>Ottorino CHILLEM, Benedetto GUI and Lorenzo ROCCO</i> : <u>On The Economic Value of Repeated Interactions Under Adverse Selection</u>
CTN	74.2006	<i>Sylvain BEAL and Nicolas QUÉROU</i> : <u>Bounded Rationality and Repeated Network Formation</u>
CTN	75.2006	<i>Sophie BADE, Guillaume HAERINGER and Ludovic RENO</i> : <u>Bilateral Commitment</u>
CTN	76.2006	<i>Andranik TANGIAN</i> : <u>Evaluation of Parties and Coalitions After Parliamentary Elections</u>
CTN	77.2006	<i>Rudolf BERGHAMMER, Agnieszka RUSINOWSKA and Harrie de SWART</i> : <u>Applications of Relations and Graphs to Coalition Formation</u>
CTN	78.2006	<i>Paolo PIN</i> : <u>Eight Degrees of Separation</u>
CTN	79.2006	<i>Roland AMANN and Thomas GALL</i> : <u>How (not) to Choose Peers in Studying Groups</u>

CTN	80.2006	<i>Maria MONTERO</i> : <u>Inequity Aversion May Increase Inequity</u>
CCMP	81.2006	<i>Vincent M. OTTO, Andreas LÖSCHEL and John REILLY</i> : <u>Directed Technical Change and Climate Policy</u>
CSRM	82.2006	<i>Nicoletta FERRO</i> : <u>Riding the Waves of Reforms in Corporate Law, an Overview of Recent Improvements in Italian Corporate Codes of Conduct</u>
CTN	83.2006	<i>Siddhartha BANDYOPADHYAY and Mandar OAK</i> : <u>Coalition Governments in a Model of Parliamentary Democracy</u>
PRCG	84.2006	<i>Raphaël SOUBEYRAN</i> : <u>Valence Advantages and Public Goods Consumption: Does a Disadvantaged Candidate Choose an Extremist Position?</u>
CCMP	85.2006	<i>Eduardo L. GIMÉNEZ and Miguel RODRÍGUEZ</i> : <u>Pigou's Dividend versus Ramsey's Dividend in the Double Dividend Literature</u>
CCMP	86.2006	<i>Andrea BIGANO, Jacqueline M. HAMILTON and Richard S.J. TOL</i> : <u>The Impact of Climate Change on Domestic and International Tourism: A Simulation Study</u>
KTHC	87.2006	<i>Fabio SABATINI</i> : <u>Educational Qualification, Work Status and Entrepreneurship in Italy an Exploratory Analysis</u>
CCMP	88.2006	<i>Richard S.J. TOL</i> : <u>The Polluter Pays Principle and Cost-Benefit Analysis of Climate Change: An Application of Fund</u>
CCMP	89.2006	<i>Philippe TULKENS and Henry TULKENS</i> : <u>The White House and The Kyoto Protocol: Double Standards on Uncertainties and Their Consequences</u>
SIEV	90.2006	<i>Andrea M. LEITER and Gerald J. PRUCKNER</i> : <u>Proportionality of Willingness to Pay to Small Risk Changes – The Impact of Attitudinal Factors in Scope Tests</u>
PRCG	91.2006	<i>Raphaël SOUBEYRAN</i> : <u>When Inertia Generates Political Cycles</u>
CCMP	92.2006	<i>Alireza NAGHAVI</i> : <u>Can R&amp;D-Inducing Green Tariffs Replace International Environmental Regulations?</u>
CCMP	93.2006	<i>Xavier PAUTREL</i> : <u>Reconsidering The Impact of Environment on Long-Run Growth When Pollution Influences Health and Agents Have Finite-Lifetime</u>
CCMP	94.2006	<i>Corrado Di MARIA and Edwin van der WERF</i> : <u>Carbon Leakage Revisited: Unilateral Climate Policy with Directed Technical Change</u>
CCMP	95.2006	<i>Paulo A.L.D. NUNES and Chiara M. TRAVISI</i> : <u>Comparing Tax and Tax Reallocations Payments in Financing Rail Noise Abatement Programs: Results from a CE valuation study in Italy</u>
CCMP	96.2006	<i>Timo KUOSMANEN and Mika KORTELAINEN</i> : <u>Valuing Environmental Factors in Cost-Benefit Analysis Using Data Envelopment Analysis</u>
KTHC	97.2006	<i>Dermot LEAHY and Alireza NAGHAVI</i> : <u>Intellectual Property Rights and Entry into a Foreign Market: FDI vs. Joint Ventures</u>
CCMP	98.2006	<i>Inmaculada MARTÍNEZ-ZARZOSO, Aurelia BENGOCHEA-MORANCHO and Rafael MORALES LAGE</i> : <u>The Impact of Population on CO2 Emissions: Evidence from European Countries</u>
PRCG	99.2006	<i>Alberto CAVALIERE and Simona SCABROSETTI</i> : <u>Privatization and Efficiency: From Principals and Agents to Political Economy</u>
NRM	100.2006	<i>Khaled ABU-ZEID and Sameh AFIFI</i> : <u>Multi-Sectoral Uses of Water &amp; Approaches to DSS in Water Management in the NOSTRUM Partner Countries of the Mediterranean</u>
NRM	101.2006	<i>Carlo GIUPPONI, Jaroslav MYSLAK and Jacopo CRIMI</i> : <u>Participatory Approach in Decision Making Processes for Water Resources Management in the Mediterranean Basin</u>
CCMP	102.2006	<i>Kerstin RONNEBERGER, Maria BERRITTELLA, Francesco BOSELLO and Richard S.J. TOL</i> : <u>Klum@Gtap: Introducing Biophysical Aspects of Land-Use Decisions Into a General Equilibrium Model A Coupling Experiment</u>
KTHC	103.2006	<i>Avner BEN-NER, Brian P. McCALL, Massoud STEPHANE, and Hua WANG</i> : <u>Identity and Self-Other Differentiation in Work and Giving Behaviors: Experimental Evidence</u>
SIEV	104.2006	<i>Aline CHIABAI and Paulo A.L.D. NUNES</i> : <u>Economic Valuation of Oceanographic Forecasting Services: A Cost-Benefit Exercise</u>
NRM	105.2006	<i>Paola MINOIA and Anna BRUSAROSCO</i> : <u>Water Infrastructures Facing Sustainable Development Challenges: Integrated Evaluation of Impacts of Dams on Regional Development in Morocco</u>
PRCG	106.2006	<i>Carmine GUERRIERO</i> : <u>Endogenous Price Mechanisms, Capture and Accountability Rules: Theory and Evidence</u>
CCMP	107.2006	<i>Richard S.J. TOL, Stephen W. PACALA and Robert SOCOLOW</i> : <u>Understanding Long-Term Energy Use and Carbon Dioxide Emissions in the Usa</u>
NRM	108.2006	<i>Carles MANERA and Jaume GARAU TABERNER</i> : <u>The Recent Evolution and Impact of Tourism in the Mediterranean: The Case of Island Regions, 1990-2002</u>
PRCG	109.2006	<i>Carmine GUERRIERO</i> : <u>Dependent Controllers and Regulation Policies: Theory and Evidence</u>
KTHC	110.2006	<i>John FOOT (lxxx)</i> : <u>Mapping Diversity in Milan. Historical Approaches to Urban Immigration</u>
KTHC	111.2006	<i>Donatella CALABI</i> : <u>Foreigners and the City: An Historiographical Exploration for the Early Modern Period</u>
IEM	112.2006	<i>Andrea BIGANO, Francesco BOSELLO and Giuseppe MARANO</i> : <u>Energy Demand and Temperature: A Dynamic Panel Analysis</u>
SIEV	113.2006	<i>Anna ALBERINI, Stefania TONIN, Margherita TURVANI and Aline CHIABAI</i> : <u>Paying for Permanence: Public Preferences for Contaminated Site Cleanup</u>
CCMP	114.2006	<i>Vivekananda MUKHERJEE and Dirk T.G. RÜBBELKE</i> : <u>Global Climate Change, Technology Transfer and Trade with Complete Specialization</u>
NRM	115.2006	<i>Clive LIPCHIN</i> : <u>A Future for the Dead Sea Basin: Water Culture among Israelis, Palestinians and Jordanians</u>
CCMP	116.2006	<i>Barbara BUCHNER, Carlo CARRARO and A. Denny ELLERMAN</i> : <u>The Allocation of European Union Allowances: Lessons, Unifying Themes and General Principles</u>
CCMP	117.2006	<i>Richard S.J. TOL</i> : <u>Carbon Dioxide Emission Scenarios for the Usa</u>

NRM	118.2006	<i>Isabel CORTÉS-JIMÉNEZ and Manuela PULINA: <u>A further step into the ELGH and TLGH for Spain and Italy</u></i>
SIEV	119.2006	<i>Beat HINTERMANN, Anna ALBERINI and Anil MARKANDYA: <u>Estimating the Value of Safety with Labor Market Data: Are the Results Trustworthy?</u></i>
SIEV	120.2006	<i>Elena STRUKOVA, Alexander GOLUB and Anil MARKANDYA: <u>Air Pollution Costs in Ukraine</u></i>
CCMP	121.2006	<i>Massimiliano MAZZANTI, Antonio MUSOLESI and Roberto ZOBOLI: <u>A Bayesian Approach to the Estimation of Environmental Kuznets Curves for CO<sub>2</sub> Emissions</u></i>
ETA	122.2006	<i>Jean-Marie GREETHER, Nicole A. MATHYS, and Jaime DE MELO: <u>Unraveling the World-Wide Pollution Haven Effect</u></i>
KTHC	123.2006	<i>Sergio VERGALLI: <u>Entry and Exit Strategies in Migration Dynamics</u></i>
PRCG	124.2006	<i>Bernardo BORTOLOTTI and Valentina MILELLA: <u>Privatization in Western Europe Stylized Facts, Outcomes and Open Issues</u></i>
SIEV	125.2006	<i>Pietro CARATTI, Ludovico FERRAGUTO and Chiara RIBOLDI: <u>Sustainable Development Data Availability on the Internet</u></i>
SIEV	126.2006	<i>S. SILVESTRI, M PELLIZZATO and V. BOATTO: <u>Fishing Across the Centuries: What Prospects for the Venice Lagoon?</u></i>
CTN	127.2006	<i>Alison WATTS: <u>Formation of Segregated and Integrated Groups</u></i>
SIEV	128.2006	<i>Danny CAMPBELL, W. George HUTCHINSON and Riccardo SCARPA: <u>Lexicographic Preferences in Discrete Choice Experiments: Consequences on Individual-Specific Willingness to Pay Estimates</u></i>
CCMP	129.2006	<i>Giovanni BELLA: <u>Transitional Dynamics Towards Sustainability: Reconsidering the EKC Hypothesis</u></i>
IEM	130.2006	<i>Elisa SCARPA and Matteo MANERA: <u>Pricing and Hedging Illiquid Energy Derivatives: an Application to the JCC Index</u></i>
PRCG	131.2006	<i>Andrea BELTRATTI and Bernardo BORTOLOTTI: <u>The Nontradable Share Reform in the Chinese Stock Market</u></i>
IEM	132.2006	<i>Alberto LONGO, Anil MARKANDYA and Marta PETRUCCI: <u>The Internalization of Externalities in The Production of Electricity: Willingness to Pay for the Attributes of a Policy for Renewable Energy</u></i>
ETA	133.2006	<i>Brighta BERCEA and Sonia OREFFICE: <u>Quality of Available Mates, Education and Intra-Household Bargaining Power</u></i>
KTHC	134.2006	<i>Antonia R. GURRIERI and Luca PETRUZZELLIS: <u>Local Networks to Compete in the Global Era. The Italian SMEs Experience</u></i>
CCMP	135.2006	<i>Andrea BIGANO, Francesco BOSELLO, Roberto ROSON and Richard S.J. TOL: <u>Economy-Wide Estimates of the Implications of Climate Change: A Joint Analysis for Sea Level Rise and Tourism</u></i>
CCMP	136.2006	<i>Richard S.J. TOL: <u>Why Worry About Climate Change? A Research Agenda</u></i>
SIEV	137.2006	<i>Anna ALBERINI, Alberto LONGO and Patrizia RIGANTI: <u>Using Surveys to Compare the Public's and Decisionmakers' Preferences for Urban Regeneration: The Venice Arsenale</u></i>
ETA	138.2006	<i>Y. Hossein FARZIN and Ken-Ichi AKAO: <u>Environmental Quality in a Differentiated Duopoly</u></i>
CCMP	139.2006	<i>Denny ELLERMAN and Barbara BUCHNER: <u>Over-Allocation or Abatement? A Preliminary Analysis of the Eu Ets Based on the 2005 Emissions Data</u></i>
CCMP	140.2006	<i>Horățiu A. RUS (lxxx): <u>Renewable Resources, Pollution and Trade in a Small Open Economy</u></i>
CCMP	141.2006	<i>Enrica DE CIAN (lxxx): <u>International Technology Spillovers in Climate-Economy Models: Two Possible Approaches</u></i>
CCMP	142.2006	<i>Tao WANG (lxxx): <u>Cost Effectiveness in River Management: Evaluation of Integrated River Policy System in Tidal Ouse</u></i>
CCMP	143.2006	<i>Gregory F. NEMET (lxxx): <u>How well does Learning-by-doing Explain Cost Reductions in a Carbon-free Energy Technology?</u></i>
CCMP	144.2006	<i>Anne BRIAND (lxxx): <u>Marginal Cost Versus Average Cost Pricing with Climatic Shocks in Senegal: A Dynamic Computable General Equilibrium Model Applied to Water</u></i>
CCMP	145.2006	<i>Thomas ARONSSON, Kenneth BACKLUND and Linda SAHLÉN (lxxx): <u>Technology Transfers and the Clean Development Mechanism in a North-South General Equilibrium Model</u></i>
IEM	146.2006	<i>Theocharis N. GRIGORIADIS and Benno TORGLER: <u>Energy Regulation, Roll Call Votes and Regional Resources: Evidence from Russia</u></i>
CCMP	147.2006	<i>Manish GUPTA: <u>Costs of Reducing Greenhouse Gas Emissions: A Case Study of India's Power Generation Sector</u></i>

(lxxviii) This paper was presented at the Second International Conference on "Tourism and Sustainable Economic Development - Macro and Micro Economic Issues" jointly organised by CRENoS (Università di Cagliari and Sassari, Italy) and Fondazione Eni Enrico Mattei, Italy, and supported by the World Bank, Chia, Italy, 16-17 September 2005.

(lxxix) This paper was presented at the International Workshop on "Economic Theory and Experimental Economics" jointly organised by SET (Center for advanced Studies in Economic Theory, University of Milano-Bicocca) and Fondazione Eni Enrico Mattei, Italy, Milan, 20-23 November 2005. The Workshop was co-sponsored by CISEPS (Center for Interdisciplinary Studies in Economics and Social Sciences, University of Milan-Bicocca).

(lxxx) This paper was presented at the First EURODIV Conference "Understanding diversity: Mapping and measuring", held in Milan on 26-27 January 2006 and supported by the Marie Curie Series of Conferences "Cultural Diversity in Europe: a Series of Conferences.

(lxxxi) This paper was presented at the EAERE-FEEM-VIU Summer School on "Computable General Equilibrium Modeling in Environmental and Resource Economics", held in Venice from June 25th to July 1st, 2006 and supported by the Marie Curie Series of Conferences "European Summer School in Resource and Environmental Economics".

#### **2006 SERIES**

<b>CCMP</b>	<i>Climate Change Modelling and Policy</i> (Editor: Marzio Galeotti )
<b>SIEV</b>	<i>Sustainability Indicators and Environmental Valuation</i> (Editor: Anil Markandya)
<b>NRM</b>	<i>Natural Resources Management</i> (Editor: Carlo Giupponi)
<b>KTHC</b>	<i>Knowledge, Technology, Human Capital</i> (Editor: Gianmarco Ottaviano)
<b>IEM</b>	<i>International Energy Markets</i> (Editor: Matteo Manera)
<b>CSRМ</b>	<i>Corporate Social Responsibility and Sustainable Management</i> (Editor: Giulio Sapelli)
<b>PRCG</b>	<i>Privatisation Regulation Corporate Governance</i> (Editor: Bernardo Bortolotti)
<b>ETA</b>	<i>Economic Theory and Applications</i> (Editor: Carlo Carraro)
<b>CTN</b>	<i>Coalition Theory Network</i>