

Environmental Policies- A Problem of Strategic and Coordinated Implementation

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Global warming and greenhouse gases are terms familiar to almost everyone living in this century. South Asia is no exception to that. In fact, South Asia has been a major contributor to these problems. The total amount of carbon dioxide emitted by South Asia has almost doubled from 735 million tons in 1990 to 1264 million tons in 2002. This increase can be attributed to increasing energy demands, especially by thermal power plants and the automobile sectors as well as industrial emissions. Industries in South Asia have paid negligible attention to the latter while taking measures against pollution. At the same time, the contribution from individual households, arising particularly from the use of wood, charcoal and kerosene oil as household fuels coupled with inadequate ventilation, has had a detrimental impact on the air quality that surrounds us. The resultant highly contaminated indoor air is

The model builds a skeleton of an international economy, denoted by E . The total number of agents in the economy is given by i . The agents are partitioned into the K countries, with i_k denoting the number of agents living in country k . Thus, it follows that $\sum i_k = I$. Each country k produces some amount of private goods, $y_k = g_k(p_k, k_k)$ using the inputs capital (k_k) and a pollution emitting input (p_k). The accumulation of capital is given by the standard equation $k_k = (1 - \mu)k_0 + e_k$; where e_k is the investment in each country, k_0 is the initial stock of capital which is given for

often a more severe health hazard than outdoor air pollution. High levels of urban air pollution have attracted growing attention from the government, civil society, and industry in South Asian countries. In India, the Environment Protection Act of 1986 clearly jots down the rules and regulations that are to be followed in order to prevent the pollution of the ecological system. It provides for the Environmental Impact Assessment to ratify a project before its implementation. Similar laws regulate the pollution levels of all the member states of South Asia. However, all these countries have a high pollution level. When one starts tracing the roots of this paradox, we see most of the aforementioned environmental legislations having analogous geographic restrictions. This myopic behaviour on the part of the countries' policy makers have often led to the age of the economic problem of "the tragedy of commons". Natural resources like air and water cannot be confined to a particular country and with the current policy framework; each country would try to benefit from the hard work of the other countries without paying for it, thereby leading to the tragedy of commons.

This article thus shows that a grand coalition of the entire member states working together to solve the problem of air pollution or any form of air pollution will lead to a socially desirable equilibrium.

$$G_{kk} < 0, g_{pp} < 0, g_{kk}g_{pp} - g_{pk}g_{kp} > 0$$

From the National Income Identity $C = Y - I$, Consumption in country k would be given by $x_k = g_k(p_k, k_k) - e_k$. The countries in the economy E would therefore have a social preference ordering described by the utility function $u_i = v(z) \cdot (g_k(p_k, k_k) - e_k)$, where

$$z = -(1 - \varphi)z_0 - \sum p_k$$

denotes the overall ambient pollution level in the economy, z_0 being the initial pollution stock and φ being the natural rate of degradation of the pollutants. $v(z)$ denotes the valuation of the environmental quality by the agents in the economy E . We

maintain the standard assumptions of a neoclassical type utility function.

A feasible set in the international economy is a vector $(x, p, z) \in R^x R^k \times R^z$ such that $\sum_k (g_k(p_k, k_k) - e_k) \geq \sum x_i$ and $z = -(1-\varphi)z_0 - \sum p_k$.

A feasible set basically implies that the supply of private goods must not be less than the demand for the private good by the agents in the international economy and that the ecological damage function incorporates the pollutants emitted from all the countries that make up the international economy.

A Pareto optimum of the international economy E is a feasible state (x, p, z) such that there exists no other feasible state (x^*, p^*, z^*) for which agents attain a higher utility.

Mathematically, the Pareto optimum feasible state of the economy can be solved by maximizing the joint utility function of all the agents in the countries that make up .

We proceed to describe the building blocks of the international economy E- the individual countries. These countries can be considered to be a sub-economy of E, formally denoted by, $E_k(p_{-k})$, and are obtained by restricting the set of agents to and for a given vector of polluting inputs other than the country k itself, i.e., $p_{-k} = (p_1, p_2, \dots, p_{k-1}, p_{k+1}, \dots, p_k)$. It is natural to believe that, by itself, India will have no control over the amount of pollutants released into the environment by Bangladesh or Pakistan. In what follows, we will use the term individual country k and sub-economy $E_k(p_{-k})$ interchangeably.

A feasible state in the country k, is a vector (x, p, z) such that, $(g_k(p_k, k_k) - e_k) \geq \sum_i x_i$ where $i \in i_k$ $p_{-k} = p_k = (p_1, p_2, \dots, p_k)$ i.e. pollution levels of other countries are given and, $z = -(1-\varphi)z_0 - \sum_j p_j - p_k$ for $j \neq k$ and $j \in I$.

The feasible state of a country is again simply the fact that the supply of the private good in the country is never less than the

demand of the private good by agents living in country k .

Now we proceed to find the Pareto optimal solutions to both these cases. For the international economy, the Pareto optimal solution is obtained by maximizing the joint utility of all the individuals that live in all the countries that comprise the international economy. Mathematically, it can be shown as follows:

$$\text{Max} \sum_i u_i = \sum_i [v(z)(g_k(p_k, k_k) - e_k)]$$

where $i \in \{1, \dots, i\}$ subject to $z = -(1-\varphi)z_0 - \sum p_k$

$$\& k_k = (1-\mu)k_0 + e_k$$

Solving the first order conditions, we get the Pareto optimal levels of investment and pollution emitting input,

$$\begin{aligned} p_z^0 &= p_z^0 \quad (.) \\ t_z^0 &= t_z^0 \quad (.) \end{aligned}$$

It is quite easy to show that the Pareto optimal allocation of the international economy E (x^0, p^0, z^0) exists and is unique.

As for the domestic economy or the sub-economy, the Pareto optimal solution is obtained by maximizing the joint utility of all the agents living in that country. It is formally shown as below:

$$\text{Max} \sum_i u_i = \sum_i [v(z)(g_k(p_k, k_k) - e_k)] \text{ where } i \in \{1, \dots, i\}$$

Subject to $z = -(1-\varphi)z_0 - \sum_j p_j - p_k$ for $j \neq k$ and $j \in i_k$ & $k_k = (1-\mu)k_0 + e_k$.

Solving the first order conditions, we get,

$$\begin{aligned} p_z^* &= p_z^* \quad (.) \\ t_z^* &= t_z^* \quad (.) \end{aligned}$$

Analogous to the case of the international economy E, we can conclude that the optimal solution to the maximization problem for the sub-economy exists and is unique due to the neoclassical assumptions.

The feasible state of the sub economy E_k ($(p_i(-k)^{1*})$) induced by the Pareto efficient allocation (x^*, y^*, z^*) is called the political equilibrium of the sub economy.

Once the political equilibrium for the sub-economies are determined given the vector of external emissions, we can indeed find the state of the international economy E that can occur in the absence of any form of international co-ordination. An international noncooperation equilibrium is defined as a state of the economy (z, p, x) , such that for all k in the state, (x^*, y^*, z^*) is a political equilibrium of the sub-economy $E_k(p''-k)$.

In this case, each country acts as benevolent social utility maximizers and maximizes the utility of the agents living in their respective countries. This can be explained in the form of a non-cooperative game with the countries acting as players in the game. The strategy of country k is a vector $T_k = \{(p_i, x_i) \mid 0 \leq p_i \leq p^*, 0 \leq x_i \leq x^*\}$, for $i \in i_k$. Thus $T = \prod_k T_k$ denotes the joint strategy space of the entire k -person game. The payoffs of the players can be the joint utilities of all the agents living in that country. Hence, the payoffs of each country k is given $u_k = \sum_i u_i$ for $i \in i_k$ and for all $k \in K$, $U = \prod_k u_k$ denotes the joint payoff space of the game. This completes the structure of the k -person non-cooperative game defined in its characteristic form by $[k, T, U]$.

For this game $[k, T, U]$, the joint strategy choice $[(x_1, p_1), (x_2, p_2), \dots, (x_i, p_i)]$ for $i \in i_k$ is a Nash equilibrium for country k (or sub-economy $E_k(p''-k)$) if it maximizes the joint utility function of all the agents living in country k . The optimization problem can then be written as,

$$\begin{aligned} \text{Max } \sum_i u_i &= \sum_i [v(z)(g_k(p_k, k_k) - e_k)] \text{ where } i \in \{1, \dots, i\} \text{ for each } k \in K \\ \text{Subject to } z &= -(1-\phi)z_0 - \text{for } j \neq k \text{ and } j \in i_k \\ \text{and } k_k &= (1-\mu)k_0 + e_k \end{aligned}$$

It is worth noting that the above equations are identical to the solution of the Pareto optimal allocations of country k . So the solution to this problem is identical to the

Pareto optimal problem done before. Therefore the solution is:

$$\begin{aligned} p_z^* &= p_z^*(.) \\ i_z^* &= i_z^*(.) \end{aligned}$$

We can conclude by saying that the k -person non-cooperative game produces a Nash equilibrium where each country's strategy is to produce their Pareto optimal allocation, given the vector of emissions from the other countries. Although one might tend to conclude that this Nash equilibrium is a socially desirable equilibrium, we see that this Nash equilibrium is not compatible with the Pareto optimal equilibrium of the international economy E . Comparing the two cases, we can say that the net investment on capital goods is indeed the same in both the cases and thus the Nash equilibrium gives us an international political equilibrium for capital goods. But the same cannot be said about the pollutant emitting input. We first note that $i_k \ll i$. Hence from the well-known theory of diminishing marginal returns to inputs, we can say that the Nash equilibrium pollutant emitting input allocation is larger than the Pareto optimal level in the international economy E as a whole. Formally, this can be written as,

$$(p_z^* = p_z^*(.)) > (p_z^0 = p_z^0(.))$$

We can coin this apparently peculiar anomaly as the **Pinocchio Paradox**. This is a paradox that the famous character from English Literature called Pinocchio falls into. In terms of our paper, suppose the Environment Board announces that the pollution emitting level is more than the Pareto optimum level. The government, benevolent to its citizens, brings the allocation to its own Pareto optimum level. But because the government is not seeking to bring the allocation to the international Pareto level, the polluting input level is still higher than socially desirable. Hence a paradox – the government claims it has reached Pareto, yet the polluting input level is above Pareto optimal!

The inefficiency of the non-cooperative equilibrium gives us some incentive to look

into the matter of international cooperation in the form of international agreements to improve the allocation of polluting inputs in the international economy E. The basic aim of an international agreement, through a co-operative pan and contracts binding to the nations that agree to them, is to try and achieve the Pareto optimal allocation level of the international economy and share the costs involved in such a change in allocation between the countries involved. Formally, an international agreement among the countries K or a subset of it is a pair $(\Delta p, \alpha)$ consisting of a vector of emission changes $(\Delta p = (\Delta p_1, \Delta p_2, \dots, \Delta p_k))$ with respect to international non-cooperation levels such that $\Delta p_k \in [-p_z^* - (p_z^* - p_z^*), \forall k]$, and a total cost sharing rule $\alpha = (\alpha_1, \alpha_2, \dots, \alpha_k)$

such that $\alpha_k \in [0, 1] \forall k$ and $\sum_k \alpha_k = 1$.

In terms of foregone consumption, the total cost of allocation change is given by :

$$C(\Delta p) = \sum_k [g_k(p_z^*, k_k) - g_k(p_z^* + \Delta p_k k_k)]$$

The induced environment quality after the International Agreement will thus be

$$z(\Delta p) = -(1 - \varphi)z_0 - \sum_k [(p_k - \Delta p_k) D]$$

Thus, the utility of each country k in the international economy E becomes

$$u_k = \sum_i [u_i(z, x_i) = v(z(\Delta p))] \sum_i [g_k(p_z^*, k_k) - e_k - \alpha_k^i \left\{ \sum_k [g_k(p_z^*, k_k) - g_k(p_z^* + \Delta p_k k_k)] \right\}]$$

For an international agreement to come into existence, the countries must be involved in some collective decision making process. This can be done at two separate levels – the domestic level and the international level. In short, each country ratifies a particular international agreement by means of simple majority voting. In the simple majority voting games, there would be a winning coalition that which declares a particular vector of abatements and a cost sharing rule α which is its Nash Equilibrium. For any international agreement involving all countries, the co-operative game $[k, W_k, \alpha_k^*]$ is the ratification voting game bearing on the cost share α_k^* to country k.

with k denoting the number of countries in the international economy E. W_k simply denotes all the subsets that contain the majority of the countries forming the international economy.

The optimal value of the cost sharing rule given by the maximization of the game will be given by,

$$\frac{g_k(p_z^*, k_k) - e_k}{(\sum_k [g_k(p_z^* + \Delta p_k k_k)])}$$

This basically leads us to the conclusion that the international agreement ratified by the countries depends on the consumption pattern of the private good in each country. A country with more consumption of the private good requires a larger amount of pollution emitting inputs and consequently has to bear a larger cost to bear the damage to the environment. For at least one country, the cost of abating the pollution emitting input to the international Pareto optimal level must be positive. Thus there exists a country k (or sub-economy E_k ($p_k(-k)^{1*}$)) for which

$$[g_k(p_z^*, k_k) - g_k(p_z^* + \Delta p_k k_k)] > 0$$

For that country, the consumption of private good is obviously lower. Hence higher utility is reached at the Pareto optimal level only through improvement in environmental quality, i.e., through the function $(z(\Delta p))$.

With the knowledge of the international agreement ratified by the countries given to us, we proceed to see which winning coalition will ultimately be formed in the international economy. This leads us to the coalition formation game with the countries as players. The countries act simultaneously and announce a coalition to which they wish to belong. Any defection from a coalition induces the remaining players to split up as singletons. In the context of this coalition formation game, we may restrict our strategy choice to only those that will be ratified by the individual countries. Any other international agreement will not be ratified by the individual countries and thereby will not lead to a political equilibrium in the respective country. Once

a coalition is announced, ratified agreements are automatically generated by the majority voting game in each country. As a result, we associate with each coalition structure a series of international agreements with the property of being simultaneously ratified by the respective countries. For each coalition structure, there exists a unique ratified international agreement.

The strategy profile for which all the countries declare the grand coalition is a Nash equilibrium of the coalition formation game. Any country acting as a singleton would definitely be closer to the Pareto optimum of the international economy if it decides to become a member of the coalition. Similarly, there would be no incentive for a country within the coalition to deviate from it. Hence the grand coalition would ultimately lead to the Pareto efficient outcome of the international economy. the solution to the optimization problem of the coalition formation game would then be a replica of the Pareto optimum optimization problem for the international economy. Thus the cooperative game and the coalition formation game will ultimately lead to a political equilibrium in each country as well as a political equilibrium in the international economy.

The cost sharing ratio for the countries in the international economy would depend on the consumption pattern of private goods in the respective countries. While it is possible to transfer some amount of private good, a better way to bring about the sharing of costs is to issue pollution permits in proportion to the costs borne by each country. This would bring us to the topic of markets for pollution permits. It is worthwhile noting that implementing the Gale-Shapley algorithm of deferred acceptance would ultimately lead to efficient solutions. Following this algorithm, when polluting countries offer the non-polluting countries to buy pollution permits from them, through a proper mechanism design, none of the polluting countries will have to go for their least preferred choice,

leading to optimal strategies in the market for pollution permits.

Although some countries may refrain from revealing their true preferences, but Shapley has shown that there will exist a revelation principle in which showing the true preferences will be the optimal Bayesian strategy for every country.

Pollution regulation acts have been implemented in almost every country in the world and the list of pro-environment innovations is never-ending. However, we have been myopic in our behaviour. While we may be striving for Pareto optimal allocations within our country so as to maximize our own social welfare, we duly forget that we are part of a single planet called the Earth. The Pareto optimal allocation of many countries taken together will not coincide with the Pareto optimal allocation within individual countries. In the absence of international co-operation, the pollution levels in the economy will not be Pareto optimal for the international economy, even though each country individually attains Pareto efficiency. International cooperation in the form of a grand coalition of all the countries will induce the countries to produce at the Pareto efficient levels of the international economy. The international agreement reached by the countries in the coalition will be ratified by each individual country through majority voting, thereby leading to a political equilibrium in each country. The cost of abating pollution can also be efficiently shared through proper design mechanisms. What the countries need to pay attention to now is the development of appropriate mechanisms to ensure Pareto optimality.

References:

1. "Strategies for the protection of the environment", C. Carraro, and D. Siniscalco (1993), *Journal of Public Economics*.
2. "Stable international agreements on transfrontier pollution with ratification constraints", S. Currarini, H. Tulkens

3. *"Game theory and International Environmental Cooperation", M. Finus, New Horizons in Environmental Economics.*
4. *"Microeconomic Theory", A.Mascolell, M.D.Whinston, J.R.Green, Oxford University Press*
5. *"An introduction to Game theory", M.J.Osbourne, Oxford University Press*
6. *"Economic Growth", R.Barro, X.Sala-i-Martin, McGraw- Hill, Inc.*
7. *"ClimateChangeandGameTheory: A MathematicalSurvey", P.J.Wood*
8. *"South Asian Environment Outlook (2009)", UNEP, SAARC*
9. *"Thimpu Statement on Climate Change", Sixteenth SAARC Summit, April 2010.*
10. *"The Environment (Protection) Act 1986", India.*
11. *"Environment Protection Act 1997", Nepal.*

Plugging the Demand Supply Gap in the Power Sector- the 'Green Way'

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*"What gets us into trouble is not what we don't know,
 It's what we know for sure that just ain't so"*
 – Mark Twain

We live in a digital world. Everybody is so 'connected'. Power is the base for growth now. From homes to mills and from villages to megacities, people are heavily relying on 'power' to facilitate their needs and wants: politicians get the 'powerful' ticket by launching yet another promising village lighting project, women and children get 'empowered' by access to electricity, water,

proper sanitation etc, and countless businesses both big and small, feed on this most ubiquitous of modern resources to 'rise' higher and higher.

Power is like food, shelter and clothing. Inconspicuous? Maybe, but certainly not abundant. Mark Twain's quote eerily rings true. In the course of researching the electricity industry in India, I have come across a staggering demand supply gap which could have serious implications in the future. Sukhatme (2011) suggests a 'frugal' future annual per capita requirement of 2000 kWh for sustainable development. This, when multiplied by the population estimate of 1700 million, gives the value of 3400 TWh as the minimum requirement of the country by 2070. The electricity consumption p.a. per capita in India is not even 1/10th of that in developed countries. In the next 25 years, India's electricity demand is expected to grow at an annual average rate of 7.4% (World Bank, 2010). The total installed capacity of producing electricity as on 31st Dec '10 was 171,644 MW and electricity produced was 801,828 GWh or 801.8 TWh. We currently are and may continue to rely largely on fossil fuels (mainly coal) to meet our future power needs.

Clearly, the conventional source of power, i.e. coal or lignite based thermal plants cannot alone meet the projected demand in the long term. So can we plug this gap with renewable technology like solar, wind, biogas? It is a conscience clear, mess free way of growth, albeit expensive. A little bit of surveying of research in this direction revealed that if the full potential of all the renewable energy resources is exploited in India, this would generate 1229 TWh of electricity, which is hardly 36% of the projected requirement for 2070 i.e. 3400 TWh, Sukhatme (2011). So, howsoever sincere our effort towards greening the