An Input-Output Model For Energy Analysis: A Case Study of India

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Abstract

Energy is one of the most significant strategic resources around the world. Apart from this, energy resources and air pollutants from energy are responsible for global climate change. The changes in industrial and energy structure have a strong influence on energy absorption. The input-output model is useful because it recognizes the interdependence of all sectors of the economy and their consumption to the energy embodied in the sectoral output. With regard to pollution generation, several studies have used the input-output model to analyse the pattern that explain the levels of emission and how these relate to production process Further this technique proved to be very useful for the development of energy analysis.

The main objective of this study is to examine the three air pollutants CO_2, SO_2, and NO_2 from fossil fuel combustion. This study applies Input-Output model in a commodity - by- industry approach to estimate total energy and the three air pollutants CO_2, SO_2 and NO_2 emissions from fossil fuel combustion. The Input-Output tables of 2003-04, 2006-07 are used to analyse this. These results show that, in the process of development, though energy is important, it provides healthier economy and environment because the emission in certain sector has declined when compared to the earlier period.

KEYWORDS: Energy Analysis, Input-Output, Environment, Air pollutants

Introduction:

In recent years, the increase in the economic activity of modern societies has led to an increase in the standard of living and welfare. This development is linked to growing pressure on the environment, mainly as the result of the exploitation and use of energy and natural resources, but also as the result of an increase in population, vehicle transportation, and new techniques for making agriculture more productive or industry to probe more output. In the past decades the Input-Output analysis has been successfully applied to many energy issues, internationally by Proops, (1984) estimated energy-output ratio; Miller and Blair (1985); Machado, et al (2001) applied to the Brazilian economy to evaluate the total impacts of international trade on its energy use and CO_2 emissions.

In India, this technique was used by Murthy, etal (1997) to carry out an alternative scenarios for poverty reduction and energy efficiency; Mukhopadhyay, (2001); (2005). The environmental input-output framework integrates the economic and ecological relations that take place within the production system. In recent decades, the input-output model has become a useful tool for calculating environmental burdens such as energy consumption and pollution generation, caused by normal activity of productive sectors (Llop, 2007).

Objective:

The main objective of this study is to examine the levels of direct emission by different sectors by using oil and gas as an input. The three air pollutants CO_2, SO_2, and NO_2 from fossil fuel combustion are analysed with the help of Input-Output table of the Indian economy.

Methodology:

This study uses the Input-Output model in a commodity-by-industry approach to estimate total energy and the three pollutants (CO_2, SO_2, and NO_2) coefficients for the Indian economy in 2003-2004 and 2006-2007. Assuming that overall economic activity can be disaggregated into 'n' different producing sectors, input-output analysis decomposes total output of the economy into final and intermediate demands, thus explicitly dealing with inter industry trading.

Mathematically, the basic equation is expressed as

$$X= Ax+ Y \qquad .. (1)$$

With X as the n-vector of goods required for total output. Y as the n-vector of goods that satisfies the final demand and Ax is the n-vector of intermediate demand. A is the n×n matrix of technical coefficients, on a fixed ratio (constant), that reflect the inputs required (from all sectors) for the production of each particular sector.

Reorganization of expression (1) yields

$$X= (I-A)^{-1} Y \qquad .. (2)$$

Where I is a unit matrix of order n and $((I-A)^{-1}$ is the Leontief inverse, which converts final demand into total output. It is well known that, the inverse $(I-A^{-1})$ of (I-A). Where A represents the structural (input coefficient) matrix of a given economy, describes the total, that is, direct and indirect effects of Rupees 1 million worth increase in the final demand for the products of any given industry on the total output of this and every other industry. The amounts of each one of the three different kinds of pollutant generated in connection with the increase in level of all outputs contributing to final users of Re1 million worth of each particular kind of good are represented accordingly by the matrix product

As far as 2006-2007, I-O data are concerned only Input and output table of commodity-by- industry information exist. Hence by using the software MATLAB, the coefficients are obtained by the following formula

$$aij = Xij / Xj \qquad (3)$$

where Xij is the monetary input coming from sector i and used by sector j, while Xj is the total output of sector j. The input coefficient aij thus indicates in Million Rupees (mrs) of commodity i per Million Rupees (mrs) of output of commodity j. Further the (I-A), $(I-A)^{-1}$ are also calculated to arrive at direct and indirect energy consumption.

For estimation of CO_2, SO_2 and NO_2 emissions, the above conventional method of input-output framework is extended to compute CO_2, SO_2 and NO_2 emission that takes place in the production of a commodity at various levels. The fuel specific carbon, sulphur and nitrogen emission factors to the row vector of fossil fuel sector (oil and gas and converted gas into oil equivalent) of the respective Input-Output table to estimate the total CO_2, SO_2 and NO_2 emitted by the oil sector.

The next step is to calculate the CO_2, SO_2 and NO_2 emissions, from fossil fuel combustion. This has been estimated by the Intergovernmental Panel on Climate Change (IPCC) guidelines (2006). It is assumed that all the oil and natural gas are combusted whenever they are used as an intermediate input, generating CO_2, SO_2 and NO_2 emissions. This methodology is based on the study undertaken by Mukhopadhyay (2005)

The inputs of the fossil fuels oil and gas (which are assumed to be combusted) in mrs have to be converted into the generation of emissions. The conversion factors have been estimated following the guidelines of IPCC. The amounts of oil in mrs (Million rupees) are translated first to MTOE (Metric tons of oil equivalent) which are then converted into metric tons of emissions (MT).

Sources Data:

This study uses the Indian I-O tables of 2003-2004 and 2006-2007. In case of 2003-2004, the Central Statistical Organisation has provided with the ready information on I-O coefficient matrix and Leontief inverse matrix.

Review of Literature:

Hoekstra and van den Bergh (2006) constructed physical input–output table (PIOT), which provided a framework in which all the physical flows associated with an economy can be recorded. This makes it a valuable tool for environmental–economic modeling and accounting. This paper elaborated these frameworks with packaging, residuals (wastes and emissions), recycling and stock changes, in order to create a ‘full’ PIOT. In the case of mined fossil fuel the composition should be corrected for a 10% metal packaging layer. In the case of machines and objects there a 5% metal packaging layer and a 10% plastic packaging layer.

Mongelli and Notarnicola (2006) findings reveal that during 1990s (1991–2001) the ratio between net exports (exp–imp) with developing countries and the domestic apparent consumption decreased only for the artificial and synthetic fibers and Iron, steel and other metals manufacturing sectors, while for the other energy and carbon intensive sectors the trends are quite constant and, above all, affected by conjectural factors. In particular, for these sectors, a country specific analysis reveals that the decrease of the net exports on apparent consumption occurs basically with Russia for Iron, steel and other metals manufacturing, while with China for Artificial and synthetic fibers.

Weisz and Duchin (2006) calculated the land appropriation of exports using input-output model. Demonstrated the equivalence between basic input-output models with the variables is measured in physical units on the assumption of unique unit price for the characteristic output of each sector. They found that the direct and indirect land appropriation gained from the monetary model, and the physical model, not only for exports but also for domestic final demand.

Xue et al. (2007) developed environmental input- output models at different spatial scales for entities such as manufacturing systems, manufacturing plants, and a company. For environmental input- output models developed at large spatial scales, e.g., at national or industry-wide level, these models are highly aggregated and lack spatial resolution, and cannot be decomposed or disaggregated to acquire information about the manufacturing systems, manufacturing plants, and companies.

Liang et al (2010) proposed a methodology named Hybrid Physical Input-Output Model for Energy Analysis (HPIOMEA) to study the energy metabolism, for Suzhou in China. The results show that the CO_2 , SO_2 and NO_2 are the main sources of climate change and acid rain. The water vapour has little effect on the atmospheric environment in Suzhou. Coal dominates the primary energy consumption.

Construction of the Energy Input-Output Tables

The original input-output table were aggregated into 60 sector tables in which 17 sectors from which most of the atmospheric pollution comes are described in a relatively detailed way by incorporating the 3 pollutants. In this analyses a comparative study of the emission status of these industries are done by using Input-output tables from the Central Statistical Organisation.

Direct Emission from Fossil Fuel Combustion:

It examines the effect of green house gases CO_2, SO_2 and NO_2 by combusting fossil fuels (oil and gas) and compared the direct emission of CO_2, SO_2 and NO_2 in 2003-04 and 2006-07.

Table 1: Direct Emission CO_2 and SO_2

		CO_2 2003 MT	SO_2 2003 MT	CO_2 2007 MT	SO_2 2007 MT
1	Coal and lignite	0.001	0.001	0.017	0.002
2	Natural Gas	0.002	0.000	0.012	0.001
3	Textile products	0.023	0.002	0.262	0.027
4	Petroleum products	15.65	15.24	18.47	19.32
5	Coal and tar products	0.026	0.003	0.299	0.031
6	Inorganic heavy chemicals	0.002	0.004	0.017	0.002
7	Organic heavy chemicals	0.002	0.002	0.018	0.002
8	Fertilizers	0.409	0.042	4.267	0.446
9	Paints, varnishes and lacquers	0.014	0.002	0.151	0.016
10	Pesticides ,drugs and chemicals	0.157	0.016	1.635	0.171
11	Cement	0.029	0.003	0.329	0.034
12	Non metallic mineral products	0.001	0.000	0.015	0.002
13	Iron and steel industry	0.234	0.024	3.178	0.332
14	Other basic metal industry	0.040	0.004	0.089	0.009
15	Other machinery	0.024	0.003	0.321	0.034
16	Electrical electronic machinery & appliances	0.001	0.001	0.163	0.017
17	Electricity	0.445	0.046	3.964	0.415

	Total	17.06	15.39	33.21	20.86

Source: Calculated by the author by using the method described above.

The Table 1 shows that the CO_2 emissions from Petroleum product sector, Electricity, Fertilizers during 2003-04 are 15.65 MT, 0.44 MT, and 0.40 MT, respectively. In this category the Petroleum product sector emits high carbon dioxide. It is evident that, fossil fuels are diminishing due to extensive and continuous use by increasing population and rising level of development. Moreover, burning of fossil fuels (oil and gas) is the principal cause of CO_2 emissions leading to air pollution and environmental degradation. Further, it reveals that almost all industrial sectors the SO_2 emission trends are higher than the previous period. It can be seen that in case of, petroleum products the SO_2 emissions are very high, 16.2 MT in 2003 and it has increased to 19.32 MT in 2006-07, and Electricity sector 0.4 MT in 2003-04 and 0.41 MT in 2006-07 .

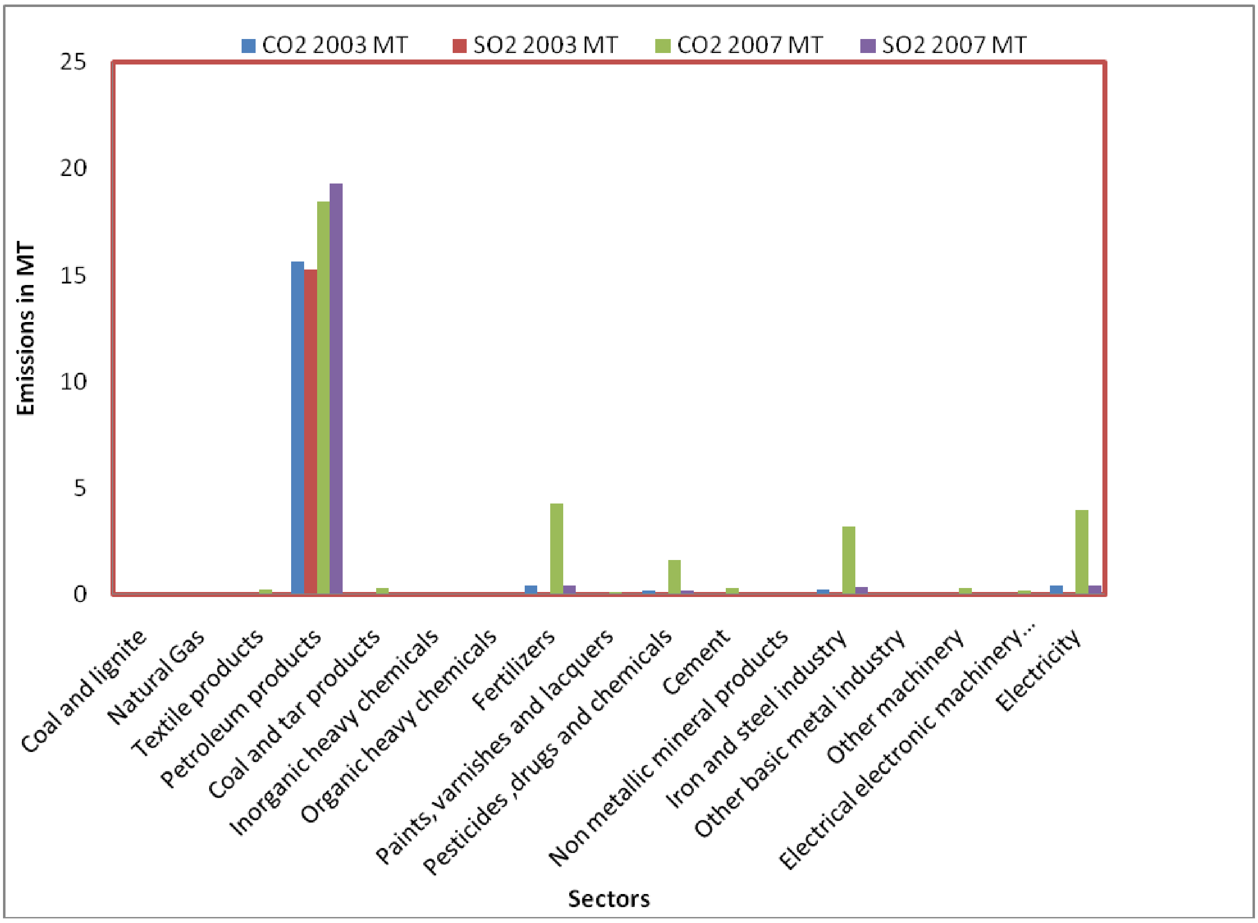

Figure 1 Direct emission of CO_2 and SO_2

The figure 1 displays that the direct emission of CO_2 and SO_2 in various sector. It shows that the Fertiliser, Iron and steel industry Pesticides and drugs, Electricity and Petroleum products emits higher CO_2 in 2007 when compared to 2003.

Findings:

a) CO_2 emission in the Petroleum products industry is very high at 91.7% in 2003-04 although in 2006-07 it has declined to 65.63%. Further the Electricity Sectors contribution to CO_2 in the environment is the second highest when compared to Fertilizer (2.39 % in 2003-04) and increased to 12.84% in 2006-07. For all the sectors, in 2006-07 there is a rise in the CO_2 emission except petroleum products. This may be because of the environmental regulations and the techniques used by petroleum product sector which may be due to pollution abatement techniques and stringency of environmental regulations.

b) Among SO_2 emission by top 5 industries, Petroleum product industries contribute more when compared to others. It is to be noticed from the data in the above figure the SO_2 in the Fertiliser sector has declined when compared to 2003 and in case of Pesticides, drugs and chemical industry the SO_2 emission has increased in 2007 when compared to 2003.

c) The NO_2 emission is very negligible in all the sectors. Even in the case of NO_2 emission the Petroleum Product sector contributes high source of emission when compared to other sectors. The petroleum product sector contributes nearly 91% of NO_2 emission, where as other top five polluting industries like Electricity sector, Fertilizer, Pesticides drugs and Chemicals and Iron and steel sectors contribute very less to the total NO_2 emission.

Conclusion:

To summarize, this study analysed the direct emission from fossil fuel combustion. The results derived from the study lead us to conclude that in India the direct CO_2 emission from the fossil fuel combustion is very high in five industries, which are Petroleum products, Electricity, Fertilizers, Iron and Steel industry and Pesticides and Drugs. From this, it is understood that environmental impacts of energy are enormous as an imbalance is created due to the fuel combustion by oil and gas.

Thus increasing levels of energy related environmental pollution in developing countries have led to a recognition of the need for improved energy options for sustainable development and also to find less material intensive development path. These results show that, in the process of development, though energy is important, it provides healthier economy and environment because the emission in certain sector has declined when compared to the earlier period.

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