Environmental Life Cycle Analysis: Measuring Consumer and Manufacturers' Response to Environmental Pricing of Automotive Gadgets

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Introduction

Sustainability is the key area of focus in the 21st century. Measures are to be developed to combat environmental degradation to ensure a sustainable future. Correction and prevention are the techniques adopted in such issues. As the adage goes, prevention is better than cure, and therefore, the present work has been initiated to provide a preventive measure for environmental degradation caused by the automobile sector. A method to levy environmental tax is analysed in this work that would be acceptable to public, manufacturers as well as the government. It is hoped that the results of this work will help in the formulation of environmental taxes in India.

Objectives

The main objectives of the study are to:

- Conduct Life Cycle Analysis (LCA) of an automobile air conditioner.
- Develop a data base for LCA calculations.
- Formulate a methodology for Entropy Added Taxing based on environmental damage.
- Simulate the response of automobile consumers and manufacturers to environmental taxing.
- Recommend a policy framework for implementation.

Life Cycle Assessment Based Tax

In Life Cycle Assessment (LCA), the environmental effects of processes and products are evaluated from raw material extraction through post use of disposition. It is also referred to as the "cradle to grave" approach or "womb to tomb" approach. The comprehensive environmental impact of a product or process can be assessed only by the LCA method.

The Life Cycle Assessment method has four components:

- Definition of system boundaries
- Inventory analysis
- Impact analysis
- Improvement analysis

The system boundaries can be fixed depending upon the accuracy one needs. The boundary can be extended to any limit, but beyond a certain level the incremental environmental effects are very marginal. One of the advantages of the LCA methodology is that it incorporates improvement analysis, which makes the process of making systems environment friendly possible.

In LCA of any equipment, the following phases are considered:

- Raw material acquisition
- Processing of materials
- Manufacturing and/ or assemble
- Use or service
- Re-use
- Re-manufacturing
- Material recycling
- Treatment and disposal

For each of these phases, the direct and indirect environmental effects need to be estimated. The energy consumption details are also to be collected. This will be helpful in finding the indirect environmental impact. The LCA results can be used as the base for levying environmental tax.

Entropy Added Tax

In every process of a system, entropy is added i.e., exergy or useful energy is lost. We cannot go for complete elimination of exergy loss. We have to reduce the exergy loss to the maximum extent, so that better utilisation of energy can be achieved. Further, energy is conserved by identifying and correcting the process that unnecessarily destroys exergy. To reduce exergy loss we should go for complete analysis of exergy in the system.

The exergy analysis is based on evaluating the work that is available at every point in the system. From the analysis of available work throughout the system, the quantity and location of lost work and useful work can be determined. This is the information required to make the complete exergy analysis of the system and to locate inefficient processes, equipment and operating procedures.

Exergy is calculated on the basis of the final temperature reference that is taken as the surrounding environment. In an energy analysis, based on the first law of thermodynamics, all forms of energy are considered to be equivalent. The loss of quality of energy is not taken into account. For example, the change in the quality of thermal energy as it is transferred from a higher to a lower temperature cannot be continuous. An exergy analysis, based on the first and second law of thermodynamics, shows the thermodynamic imperfection of a process, including all quality losses of materials and energy.

An energy balance is always closed as stated in the first law of thermodynamics. There can never be an energy loss; however, energy transfer to the environment amounts to irreversible loss of useful energy. In order to pinpoint and quantify the irreversibilities, an exergy analysis is performed. This can be used as the basis for Entropy Added Tax.

Study Area

Various industries in Tamil Nadu and Andhra Pradesh producing automobile air conditioners were contacted to collect data on energy consumption and effluent release for different processes. For conducting the Delphi study, the consumers and manufacturers in and around Chennai were contacted.

Methodology

A literature survey on different environmental taxing methodologies was conducted. As LCA based taxing and entropy added taxing were found to be better methodologies in terms of sustainability, work was focused on these. Data on energy consumption and pollution levels of different processes involved in the making of an automobile air conditioner was taken. Detailed analysis was carried out and the pollution caused in three different phases was found out - raw material acquisition, manufacture and service or operation. Exergy analysis of an automobile air conditioner was then carried out to quantify the entropy addition. After establishing the fact that LCA based taxing and entropy added taxing are possible, computer programmes were written to carry out exergy loss calculation and LCA for auto air conditioners. Then a Delphi study was conducted among manufacturers and consumers of automobile gadgets to find out the response for environmental taxing in India. The survey was conducted to

- Study the environmental awareness among public.
- Seek the justification for environmental tax.
- Formulate the accepted method of levying environmental tax.

In the first round, 500 questionnaires were sent to consumers and manufacturers of automobiles to which 298 responses were received. The results were then analysed and a policy framework was drawn.

Data Analysis

In the first round the survey Delphi was administered to respondents and the feedback obtained was analysed. The analysis was performed to determine the level of confidence with which participants answered the questions. The characteristics of Delphi are anonymity, iteration, controlled feedback and statistical aggregation of group response. Two rounds of Delphi were conducted. The statistical analysis was performed which gives the mean, median and extent of spread of participant's opinion, helping to identify whether a consensus has been arrived at. The Delphi helps the participants to

come to a common understanding. Stability and consensus are achieved through the Delphi analysis, and hence can be used for policy decisions.

Stability

To check whether Delphi rounds and response categories are independent i.e., group stability, the two hypotheses used in the chi square ($\times^2$) test were as follows:

Ho: The Delphi rounds are independent of the responses obtained in them

H_1: The Delphi rounds are not independent of the responses obtained in them

The calculated and the Chi square (x^2) values along with their degrees of freedom (DOF) for group stability and individual stability were determined. It was found that the computed value was less than the critical value at the 0.05 level of significance in most of the cases. Hence, the null hypothesis was accepted, and group stability was present in almost all cases.

The individual stability was checked next. For individual stability to be present, the respondents who selected a certain option in the first round would have chosen the same option in the second round. The two hypothesis to test whether there were significant differences between individual responses in the different rounds were as follows:

Ho: Individual responses of rounds i and i+1 are independent

H_1: Individual responses of rounds i and i+1 are not independent

Comparing the calculated and the critical ($\times^2$) values, it was found that in almost all cases the calculated value was higher than the critical value. This indicated that the null hypothesis was rejected at 0.05 level of significance. The null hypothesis "that the individual responses in the two rounds were dependent" was rejected. We accept the alternative hypothesis, indicating the presence of individual stability in all cases. The reason why both individual and group stability were checked was because although individual stability implies group stability, group stability does not imply individual stability. The reason for this is that there may be major switching of individual responses with no significant variation in the overall group response.

Consensus

The variation of standard deviation and confidence in the two rounds were determined. The distance of the point from the origin indicates the amount of change in deviation and confidence.

Results

Life Cycle Assessment

The total pollution caused for the *ACQUISITION OF RAW MATERIAL* for an air conditioner is summarised below:

Carbon dioxide	1720.8 kg
Nitrogen dioxide	694.6 x 10-3 kg
Sulfur dioxide	1048.5 x 10-3 kg
Carbon monoxide	186.0 x 10-3 kg
Hydrocarbons	327.6 x 10-3 kg
Suspended particulate	538.7 x 10-3 kg
R12	30 gm

The total pollution causing emission due to the *MANUFACTURE AND ASSEMBLY* of an auto air conditioner was as follows:

Carbon dioxide	8.0 kg
Nitrogen dioxide	0.2 kg
Sulfur dioxide	0.2 kg
Carbon monoxide	0.01 kg
Hydrocarbons	0.007 kg
TSP	0.12 kg
R11	150gm
R12	650 gm

The total emissions caused during the lifetime *SERVICE* of an auto air conditioner.

Carbon dioxide	9070.5 kg
Nitrogen dioxide	22.00 kg
Sulfur dioxide	21.84 kg
Carbon monoxide	1.98 kg
Hydrocarbons	1.03 kg
TSP	11.9 kg
R12	110 gm

Exergy Analysis

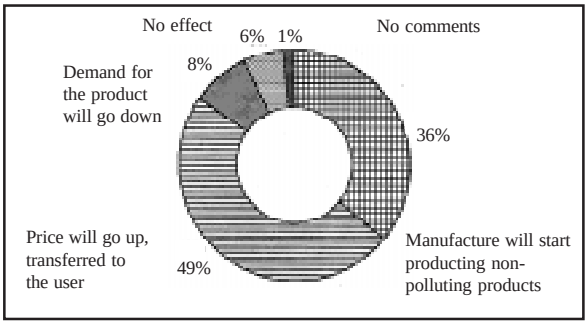
The Exergy loss values

Components	Exergy loss in kW	Exergy Destruction in kW	Total in kW	% of Loss
Compressor	0.0	0.5724	0.5724	9.2699
Condenser	45.7459	-41.8711	3.8748	62.7497
Throttling device	0.0	1.7771	1.7771	28.7783
Evaporator	-39.5709	39.5216	-0.0493	-0.7979

Survey Results

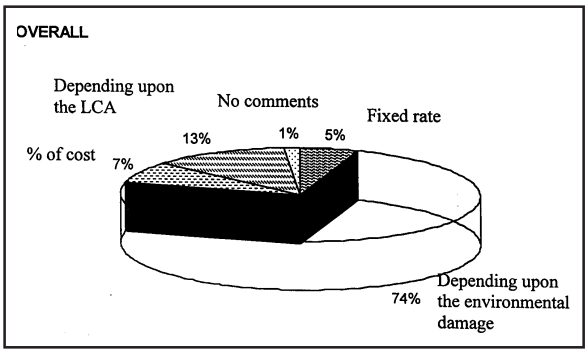
It is known that environmental taxing is followed in different countries to combat pollution. It is the experience of many nations that, in addition to fulfilling its prime objective of reducing pollution, levying environmental taxes also brings about side effects. As the environmental tax is levied, the demand for the product may go down. The manufacturer may either become environment friendly or the tax burden may be transferred to the public by way of higher prices. When asked to give their opinion about what will happen in India, majority of the consumers as well as the manufacturers (46% and 55% respectively) stated that the tax burden will be transferred to the users. This is not desirable. The government has to take steps to curb the habit of increasing the price by the manufacturers. Unless this is done the environmental tax will not do its job of abating pollution. Fig. 1 shows the responses of the consumers as well as the manufacturers.

Fig.1 Effect of Environmental Taxing



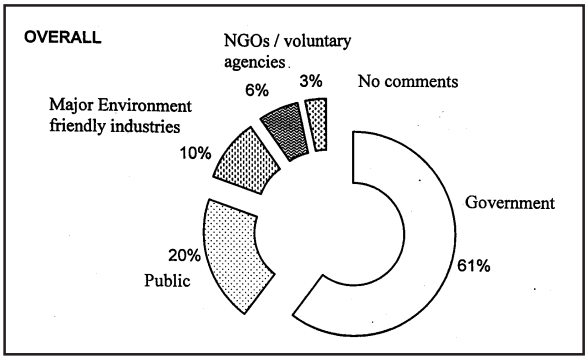
In the question related to the basis for environmental taxation, the focus was on either fixed rate or depending upon the environmental damage done. On an average, 74 percent of the respondents opted for damage based taxing. Only 5 percent of the respondents opted for fixed tax rate. Hence, it is concluded that some taxing methodology based on environmental damage has to be evolved. The responses are shown in Fig. 2.

Fig.2 Basis of Environmental Taxation



Having gone thus far in environment taxing, the next question is about who should play a major role in introducing environment tax. Majority of the respondents felt that the government should take the initiative. About 61 percent opted for this, followed by initiative taken by the public, as shown in Fig. 3.

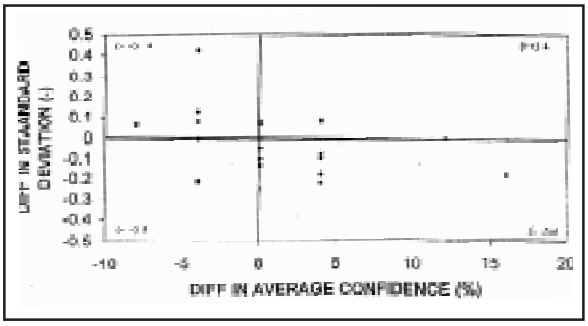
Fig.3. Major Player In Introducing Environmental Tax



The differences in standard deviation and confidence were determined, and the points are plotted in Fig.4. The distance of the point from the origin indicates the amount of change in deviation and confidence. It was found that a majority of the points lie in the fourth quadrant, which is that of increasing confidence and decreasing deviation. In total, 15 lie in the acceptable (+ -), 4 in the (+ +) quadrant, 2in the (- -) quadrant and 5 in the (- +) quadrant. It was

hence found that consensus has been achieved in a majority of cases.

Fig. 4. Confidence Level and Standard Deviation for Delphi



Overall Results and Outputs of the Study

- Environmental taxing is needed.
- If Carbon tax is sidelined, the other tax forms such as LCA based Tax and EAT (Entropy Added Tax) need to be investigated.
- EAT is the best in terms of sustainability. However, it is cumbersome, and would be difficult to introduce at present.
- LCA based tax is appropriate for the Indian context, and would also help industries to seriously adopt ISO 14000.
- The database for conducting LCA was collected in the study. A life cycle index was formulated that could be useful to compute tax, if such a decision was taken.
- The impact of different stages of the life cycle such as raw material acquisition, manufacture and assembly, service and maintenance and disposal on ozone depletion, acidification and green house gas accumulation for automobile air-conditioner were estimated.
- LCA for an automobile with the secondary data, for the different materials used in the car was done. It was found that the air-conditioner pollution is about 2 percent of the total pollution associated with the entire car.
- Exergy analysis was carried out for air-conditioners of different capacities that predict the percentage loss of exergy taking place in the air-conditioner. This percentage loss can be used directly to fix the EAT.
- The Delphi study revealed that there is a lack of awareness regarding the environmental degradation among people, both manufacturers and users. More than 60 percent of the people are aware of environmental degradation taking place in our country.
- The survey revealed that the best method to prevent pollution is to create greater awareness among the public. More than 50 percent of the people felt this way. About 25 percent of the respondents felt that heavy penalty for polluters would help prevent pollution.
- About 36 percent of the respondents felt that manufacturers would start producing non-polluting equipment if an environmental tax was levied.
- More than 46 percent of the respondents welcomed the idea of an environmental tax.
- According to 74 percent of the respondents, the basis for environmental taxation should be the environmental damage caused by the equipment.
- About 46 percent of the respondents felt that the taxes should be as low as 5 percent of the total cost.
- When asked about the choice between taxing the component and taxing the system, 36 percent of the respondents were in favour of taxing individual components, and 60 percent of the respondents favoured taxing the whole system.
- To prevent the transference of tax burden onto the public, the preferences of respondents for different options were:
  - Fixed pricing policy by 25 percent of the respondents.
  - Low tax with disincentives was suggested by 28 percent of the respondents.
  - Low tax was suggested by 30 percent of the respondents.

- A majority of the respondents felt that the major player in introducing environmental tax should be the government.
- The stability and consensus study conducted on the Delphi results revealed that around 2 results gave the accurate results.

Policy Recommendations

- To combat environmental degradation, Environmental Tax as a strategy is acceptable to the manufacturers and users of goods.
- Among the three different environmental taxes - Carbon tax, LCA based tax and Entropy Added Tax - it is recommended that the government enforce LCA based tax as Carbon tax has already been proved to be unacceptable, and Entropy Added Tax is quite cumbersome to calculate.
- Steps should be taken by the government to prevent the tax burden from being passed on to consumers by the manufacturers. In the present open economy, as the competition is high if 'low environmental tax with disincentives' for polluters is levied, then manufacturers will be forced to change this and go in for Environmentally Friendly Technologies.
- Life Cycle Assessment should be made mandatory for all products. Eco-labeling should be enforced and granted only for products for which LCA is done.