THE INCIDENCE OF FUEL TAXATION IN INDIA*

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ABSTRACT

Fuel taxes have returned to centre stage as a potential policy instrument for greenhouse gas abatement. However critics have complained that a fuel tax is regressive. Such claims are based on few studies conducted in developed countries. This paper tests the validity of this claim for India. It uses data from a representative household survey covering more than 124 thousand Indian households. The study finds that a fuel tax is progressive. Using an input-output approach, this paper tries to study the distributional effect, once price change in non fuel goods (arising out of fuel tax) is considered. The progressivity result holds good even when one considers indirect consumption of fuel through its use as an intermediate input.

Keywords: carbon emission, tax burden, regressivity.

JEL Classification: Q48, Q52, Q53.

1. Introduction

The problem of climate change is increasingly being accepted as a major problem by policy makers round the world. Not only in Europe (where environmental issues have for long attracted the required attention of policy people) but even in countries like China, India and USA, there is a growing realization that the problem of global warming has reached an alarming stage and something needs to be done about it. Even to achieve modest targets like 550ppm by 2050, radical measures are required. Fossil fuels are the most important sources of carbon emissions and their use will have to be controlled to achieve any meaningful reduction in CO_2 emissions.

India is the fourth largest emitters of CO_2 worldwide. It is next only to United States, China and Russia in this respect. It accounts for about 4 percent of world CO_2 emissions. With India growing at a rate of 8% per annum compared to the world GDP growth rate of 5%, this share is expected to increase in future. Fossils fuels account for more than 95 percent of the CO_2 emissions in India. Solid Fuels (mainly coal) contributes more than two third of the emissions from fossil fuels.

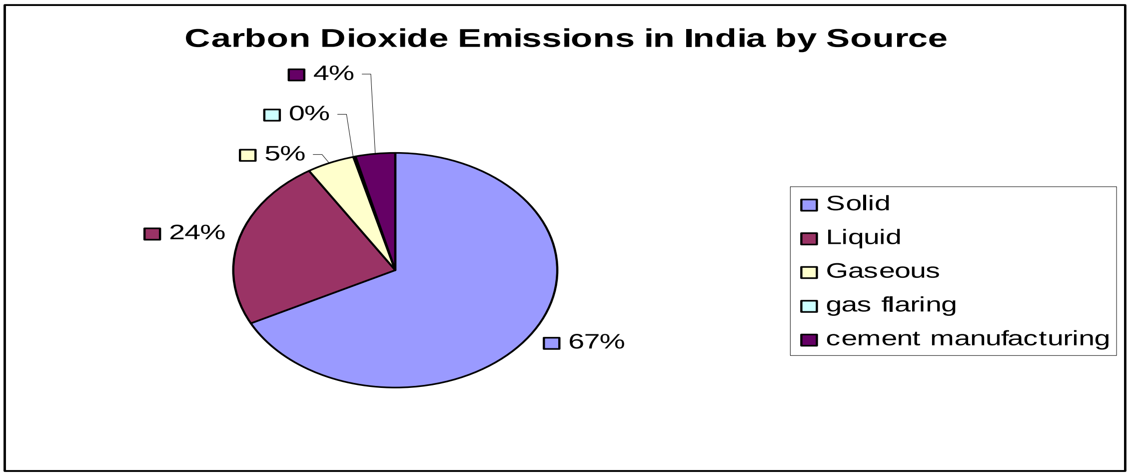

Figure1: CO_2 emissions in India by Sectors (Source: http://earthtrends.wri.org)

2. Fuel Taxes as an Policy Instrument

Although policy makers in United States and the developing world have often considered environmental taxes to be politically infeasible, Western Europe has for long experimented with environmental taxes: directly in the form of carbon taxes in 1990s (which was prematurely discarded) and indirectly in the form of fuel taxes. Though fuel taxes in many of these Western European countries were designed for non environmental reasons, it has been shown that they did have a significant environmental impact. Sterner (2007) reviews several studies and concludes "Had Europe not followed a policy of high fuel taxation but had low U.S. taxes, then fuel demand would have been twice as large". Having calculated the hypothetical transport demand for the whole OECD area, Sterner concludes that fuel taxes are the single most powerful climate policy instrument implemented to date.

However, fuel taxes have sometimes been criticized on distributional grounds. This has generated a popular perception that fuel taxes are regressive. The balance of academic evidence does not favour this view. It was in early 90's that the question of regressivity in fuel taxation made it appearance. A large number of people argued against fuel taxation on the ground that it imposes a larger burden on poor people. Such claims were based on studies that used the US data on petroleum consumption (KPMG Peat Marwick 1990). Santos and Catchesides

(2005) found similar regressivity, but only among car users in United Kingdom. However, United States is hardly a representative country in this regard. USA is a county with very high incomes where even the poor households have cars-In fact it is the poor who own old, energy inefficient cars. Besides they live far away from urban areas and thus have to travel long distances to work in a country where there is very little public transport. Thus it is expected that fuel taxes will be regressive in United States. Regressivity in these initial studies is also conditioned by the fact that such studies are based on current income rather than current expenditure. Poterba (1990), Kasten and Sammartino (1988) suggested that the extent of regressivity of fuel taxation in USA was exaggerated by the year to year fluctuations in income among households at the bottom of the annual income distribution. Poterba (1990) argues that consumption expenditure is a better indicator of a household's long run economic well being as it is less susceptible to shocks and hence incidence measures should be based on expenditure. Once that is done, gasoline tax ceases to be regressive. Poterba shows that when expenditure based measures are used the maximum incidence of gasoline tax is on middle income deciles.

Recently West (2004) showed that gasoline taxes in USA are regressive across higher income households only. For low levels of income it is progressive. Karl Steinger (2006) develops a computable general equilibrium model and finds that gasoline tax is progressive in Austria. Santos and Catchesides (2005) show that if all households (both with and without cars) are considered then the maximum burden of a gasoline tax is on the middle income households. Even this study is based on income and not on expenditure levels and thus their results might be biased in a way similar to the bias found in early studies in USA.

Only a few papers on distributional effects of fuel taxation are based on data from developing countries. This is rather surprising because developing countries (especially countries making rapid progress like India, China and Brazil) are some of the largest emitter of CO_2 in the world. Some work on the distributional impacts of fuel taxation has done on developing countries like South Africa and Mexico. Working with the Mexican data, Sterner and Lozada (2007) find that fuel taxation is strongly progressive if one takes only direct consumption of gasoline into account. However in poor countries, poor people generally use public transport more often than the rich. An increase in fuel prices is expected to change price of public transport significantly. This puts an indirect burden on users of public transport. If this is taken into account while calculating incidence of fuel taxation across expenditure deciles, fuel tax becomes neutral in Mexico. Ziramba shows that fuel taxation is progressive in South Africa independent of whether we consider indirect consumption through public transport.

3. Carbon Emissions and Fuel Pricing Policy in India:

Although Administered Price Mechanism (APM) was abolished in India in 2002, the Indian government continues intervention in the petroleum sector by absorbing state owned oil company losses. Thus the government provides subsidy to transport fuels in an indirect manner.

Given that the government considers cooking fuels as an important social instrument to help poorer households shift from biomass to modern fuel, the government continued to provide subsidies for Liquid Petroleum Gas and Kerosene ex-ante in the budget. However subsidies were expected not to exceed 15% of the Gas-Import Parity Price and 33% of the kerosene-Import Parity Price. The government had even thought of abolishing all budget subsidies within 5 years from 2002. However, five years have passed but abolition of cooking fuel subsidy doesn't seem to be on the government's agenda. According to a UNDP-ESMAP report titled "Access of the Poor to Clean Household Fuels in India", without price subsidies, a LPG cylinder would have cost Rs469 and a litre of kerosene would have cost Rs. 16.54 in February 2003. The prices in presence of subsidies were Rs. 241 for 14.2 kg cylinder and Rs. 9 per litre of kerosene.

However, contrary to popular belief, the fuel sector is not a story of one way flow of subsidies. While on the one hand subsidies are in place, the same commodities are subjected to various taxes. Both the Central Government and the state government impose taxes which pull up retail prices. While on one hand Oil PSU s are advised not to revise prices in conformity with crude rates, the government imposes excise duties and a plethora on other taxes on these items. The result is the Indian retail prices for petroleum and Diesel are the highest in South East Asia. For cooking fuels, Budget subsidies are coupled with various central and state level taxes. For cooking fuels the subsidies outweigh the taxes and the retail prices are lower than what they would have been in absence of any intervention. The same cannot be said about the transport fuels.

Thus we see that even after abolition of APM, there has been substantial government intervention in the fuel sector. The imposing a fuel tax is not an administrative problem in this context. Such taxes are will in turn be helpful in reducing emission externalities.

4. Data

Data on consumer expenditure on fuel and other commodities is obtained from the consumption schedule of the 61st round of the National Sample Survey conducted by the National Sample Survey Organization of the Government of India during the period July 2004- June 2005. This is one of the thick quinquennial rounds which have consumption expenditure information on more than 100,000 households.

The sample for the 61st round consists of 124584 households. The rural sample consists of 79258 households and corresponding figures for the urban sample are 45326 households. Since NSS data does not have information on household income, we measure incidence across expenditure classes. Expenditure, in any case, is a better measure of long term economic welfare than income. In this paper, we use consumption figures based on 30 day recall for both non-durables and durables.

In order to take into account the indirect consumption of fuels through its use as an intermediate input in the production of final goods, we use the Input-Output Tables of India prepared by the Central Statistical Organization of the Ministry of Statistics and Planning Implementation. We use two tables prepared at two different time points: 1998-1999 and 2003-2004. The 1998-1999 tables are used as it provides information for the energy sectors at a more disaggregated level. The table for the period 2003-04 includes transport fuels, kerosene, gas etc under the category " petroleum products", while the 1998-1999 tables has a separate category called "Gas" which includes Liquefied Petroleum Gas and Gobar gas. The table for 1998-1999 provides disaggregated information on input output transaction of 115 sectors .However in order to make it compatible with the NSSO data; we have created an aggregated input output matrix which has information on 47 broad sectors (Details in Appendix A). This obviously introduces an element of error, but compatibility between NSSO data and CSO data demands such aggregation. The table for 2003-2004 has information for 130 sectors from which we have created an aggregated matrix of 46 sectors.

5. Direct Effects:

- ### Methodology

An ideal measure of tax incidence should take into account all general equilibrium effects of a tax rise and then measure the impact of such changes on the household's welfare. A tax leads to a shift in the supply curve of the commodity on which the tax is imposed. Unless we have a situation of perfect elasticity or inelasticity, the burden is shared between producers and sellers. A fall in producer price implies that factor demands and factor prices change. An increase in consumer price implies that the prices of goods which use the taxed commodity as an intermediate input rise in proportion to the cost share of the taxed commodity. This is just the beginning of several rounds of feedbacks. However to calculate incidence taking all general equilibrium effects into account, requires a great deal of information. Knowledge of the demand and supply elasticities of different industries and the distribution of ownership of firms in those industries is necessary. Most consumer expenditure surveys don't provide us with such detailed information. Most measurements of tax incidence make simplifying assumptions. We start with the simplest of the measures.

Let us consider a situation where the following conditions hold:

(1) We assume that the production function of the taxed commodity shows fixed coefficient technology. Thus the supply curve of the taxed commodity is perfectly elastic. Consumers bear the entire burden of tax.

(2) The taxed commodity is not an intermediate input and so does not change the price of any other commodity in the economy. This assumption will be relaxed later.

(3) We assume that the own price elasticity of fuel is the same across all income quintiles. Or price elasticity of fuel is independent of income. Thus our assumption will ensure that we will over state the incidence on income groups with a more elastic demand but ,a priori, we do not know whether this will over or understate progressivity.

Under assumptions (1), (2) and (3), we can comment on the progressivity or regressivety of tax just by looking at the budget share of the taxed commodity across income levels.

Let $P = (P_1 , P_2 , \ldots\ldots P_n)$ be the before tax price of the n commodities in the economy. Let there be an advalorem tax at rate t on the current price of commodity i.

The new prices are $P' = (P'_1 , P'_2 , \ldots, P'_i = (1+t)P_i , \ldots P'_n)$.

The pre-tax budget share of i[th] commodity for j[th] household is $\theta_{ij} = \frac{Pi\, Xij(P)}{M_j}$ where Xij(P) is the commodity demand of commodity i for j[th] household and M_j is the income for j[th] household.

Let α be the own price elasticity of the i[th] commodity for all households, then $X_{ij}(P') = (1+t\alpha)\, X_{ij}(P)$.

The tax burden of j[th] household is $TBj = \frac{t\, Xij(P')}{M_j} = \frac{t(1+t\alpha)}{P_i} \times \frac{Pi\, Xij(P)}{M_j} = \frac{t(1+t\alpha)}{P_i}\, \theta_{ij}$

Thus if elasticity is same across income groups then, the first term is the same across all households. Then the tax burden of a household due to a tax on commodity i depends on the share of commodity i in its budget. Under the stronger assumption that the volume of demand is constant, budget share have an interesting interpretation. It is the fist-order indication of the magnitude of income effects resulting from price changes. For a given product, its budget share corresponds to the price elasticity of total spending, assuming volume of demand constant.

$$\theta_{ij} = \frac{\partial \log M_j}{\partial \log P_i}$$

Similarly assuming volume of demand to be constant, the direct effect of taxes on fuels can be expressed as a function of budget shares.

$$\partial \log M_{direct} = \sum_{t=1}^{m} \theta_t * \partial \log P_t = \left(\sum_{t=1}^{m} \theta_t \right) \partial \log P \text{ , assuming } \partial \log P_t = \partial \log P \forall t$$

where t denotes a generic fuel product, θ_t represents the budget share of the fuel product t and m is the total number of fuel products.

Thus, under assumptions (1)-(3), we can test whether a tax on a particular fuel is regressive, simply by comparing the budget share of that fuel across different expenditure deciles. If the budget shares of the poor are higher than that of the rich, then we can conclude that a fuel tax is regressive.

- **Results**

In a low income country, we may expect transport fuel taxes to be progressive since poor people don't own cars. This is especially true for India were per capita income is just $620 and 75% of the population lives on less than two dollars a day. If domestic fuel use for cooking and lighting is also taken into account, the incidence results might not be progressive. However in India a large fraction of rural households use bio-fuels and does use fossil fuels for cooking purposes. However kerosene –an important petroleum product is widely used as lighting fuels. Thus it cannot be said for sure if cooking and lighting fuels will have distributional impacts different from that of transport fuels.

The figure below shows the budget shares of major cooking, lighting and transport fuels for different income classes:

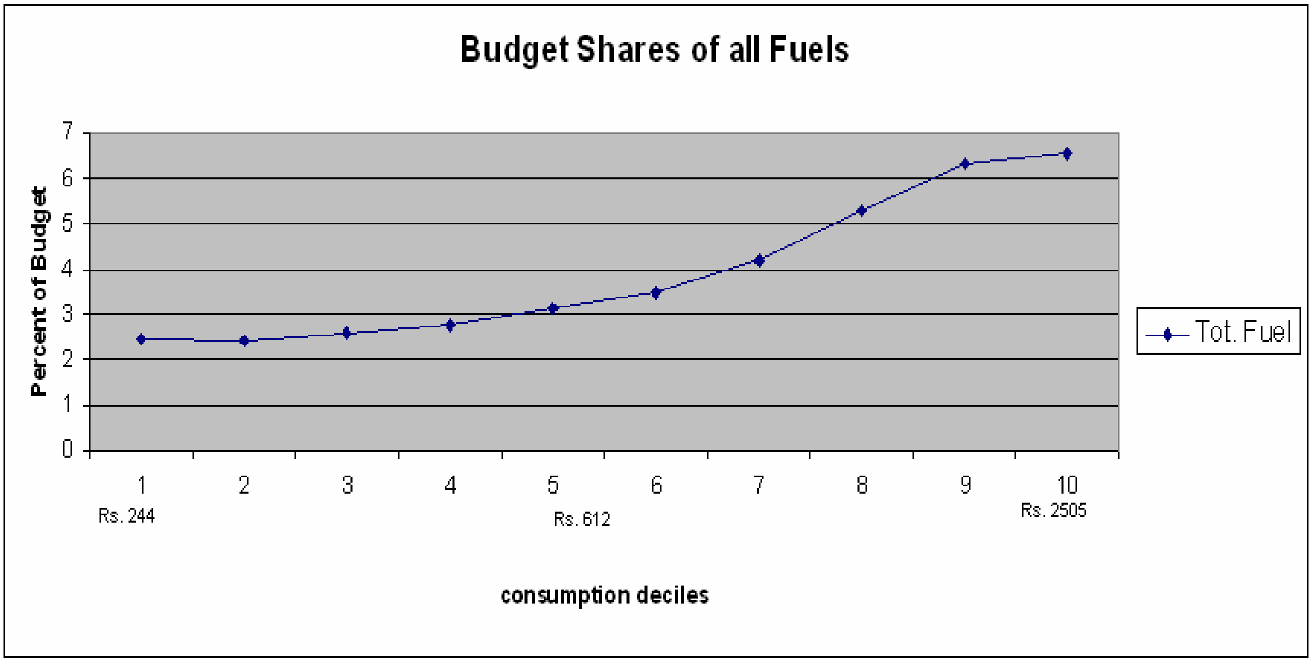

Figure 2: Budget shares of fuels (Transport + Cooking and Lighting Fuels) not taking into account indirect consumption through their use as intermediate inputs[1]

The combined budget share of all fuel products (Coke-Coal, Petrol, Diesel, Kerosene, Gas etc) is seen to be higher for higher consumption deciles. The budget share of fuels stay constant for the first three deciles, but increases thereafter, indicating that an overall fuel tax would be strongly progressive.

It will be interesting to see what is going on behind these figures. To see that we calculate the incidence results separately for transport fuels and cooking-lighting fuels.

From figure3, it is seen that the budget share of all cooking fuels stay unchanged for low levels, but starts increasing after the third decile. It falls substantially for the highest decile. If we consider kerosene and Liquefied Petroleum Gas, then the kerosene's budget decreases with income while Budget shares of LPG increases with consumption. The budget share for gas falls substantially for the last decile. This is expected because in India only the urban non poor use gas as a cooking fuel

[1] The market exchange rate of the Indian Rupee is 1 US dollar=Rs.40.42 (March 07,2008)Based on new statistical calculations of purchasing power parity (PPP) exchange rates published in 2005 by the International Comparison Program (ICP) of the IMF, the PPP adjusted exchange for India Rs14.7 / PPP adjusted US dollar

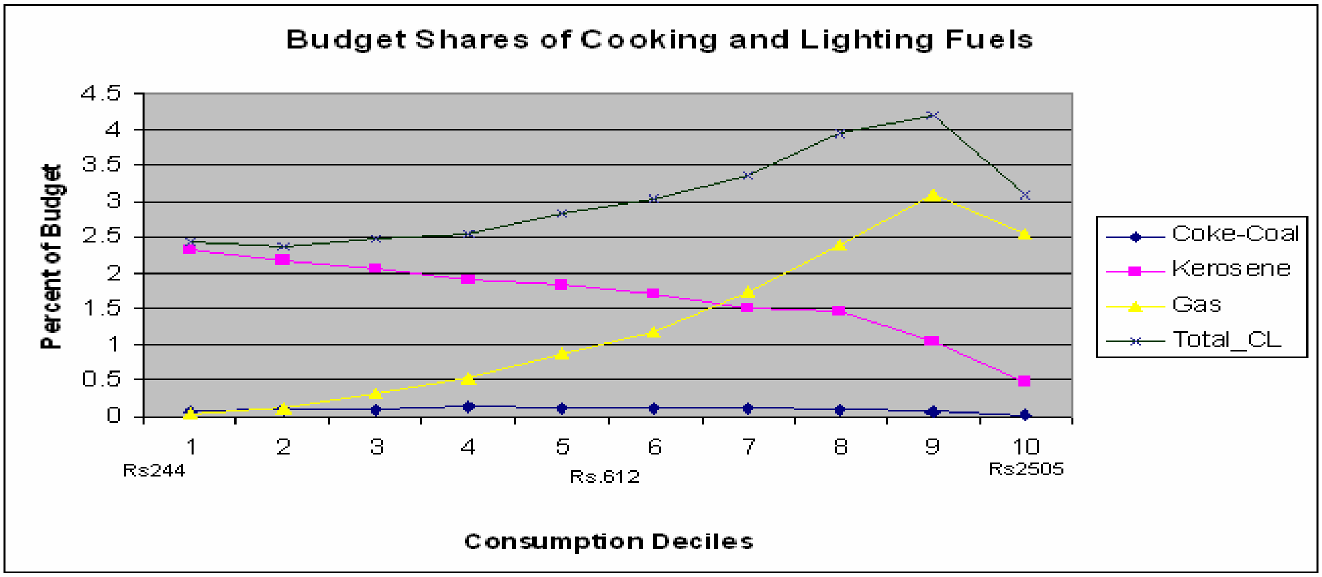

Figure 3: Budget shares of cooking and lighting fuels, not taking into account indirect consumption through their use as intermediate inputs

The budget share of all cooking fuels stay unchanged for low levels, but starts increasing after the third decile. It falls substantially for the highest decile. If we consider kerosene and Liquefied Petroleum Gas, then the kerosene's budget decreases with income while Budget shares of LPG increases with consumption. The budget share for gas falls substantially for the last decile. This is expected because in India only the urban non poor use gas as a cooking fuel.

It will be interesting to note the differences between the urban and the rural sector as the two sectors have very different patterns of fuel use. Figure 4 and 5 separately show the incidence results for rural and urban sectors. In rural India, very few households use gas. (Only 2 percent of the poorest 25 percent households use gas as their main cooking fuel, the figure increases to 30percent for the last quartile). Only people in the upper end of expenditure distribution use gas. The budget shares increase with the level of expenditure. Kerosene is the popular lighting fuel in rural areas, especially for the poor. As consumption increases people move towards electricity, subject to it's availability in villages. For cooking purposes bio-fuels are generally used. With an increase in income people start shifting towards more convenient fuels like kerosene and gas. However substitution towards LPG is low as availability of LPG is a problem. Thus the budget shares of kerosene fall with income.

In the urban sector electricity is used for lighting, almost universally. Only 10% of urban Indian households do not state electricity to be their main lighting fuel. This ten percent of urban households (the majority of whom come from the lowest decile) use kerosene.

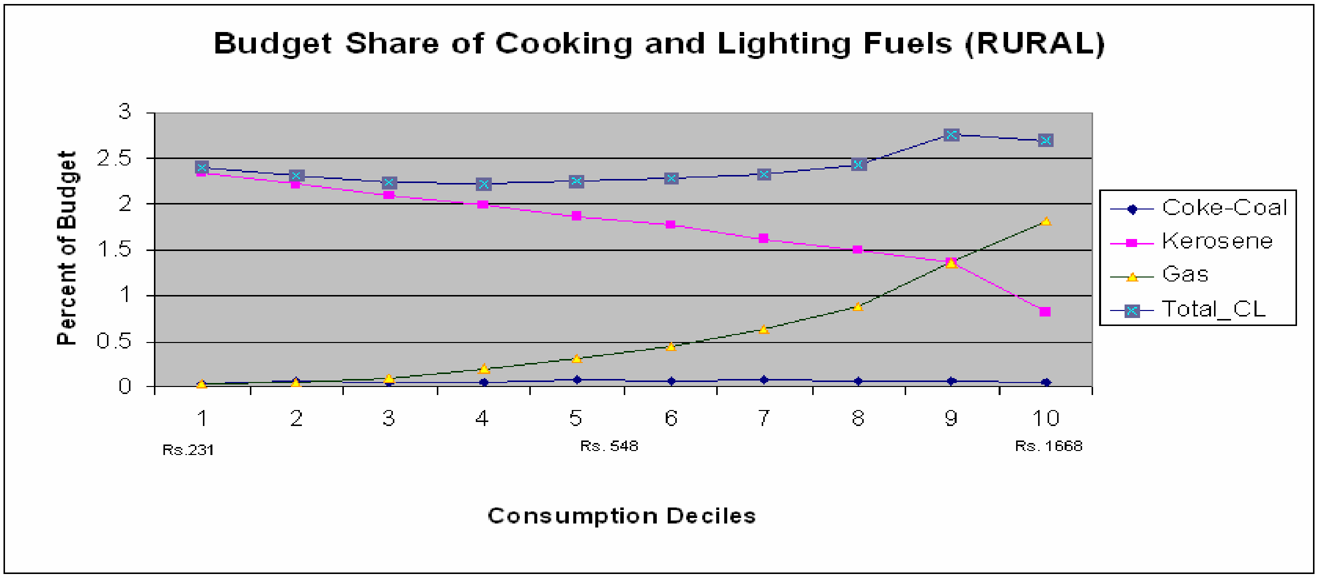

Figure 4: Budget shares of cooking and lighting fuels for the rural sector, not taking into account indirect consumption through their use as intermediate inputs

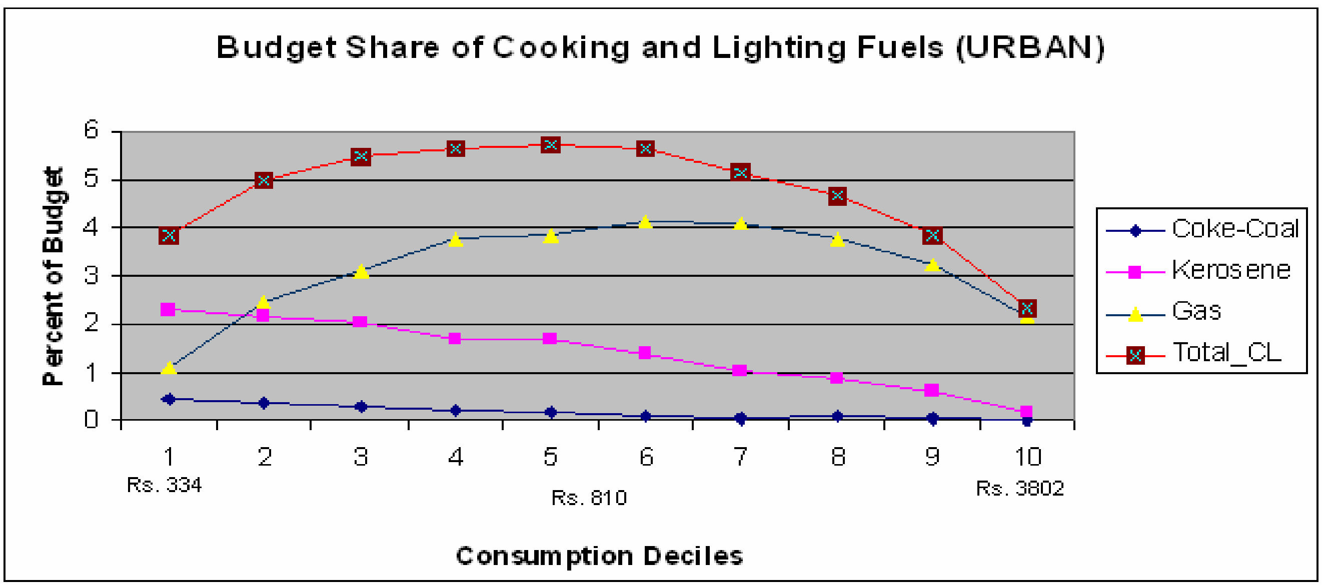

Figure 5: Budget shares of cooking and lighting fuels for the urban sector, not taking into account indirect consumption through their use as intermediate inputs

On the other hand poor urban households use firewood and chips or kerosene as their main cooking fuel. As income increases, a larger proportion of households use LPG. However the curve for LPG is inverted U shaped. It increases till the 6th decile but falls thereafter. Thus tax on LPG will be progressive initially, but becomes regressive for higher levels of income. The middle income group in urban areas bears the maximum burden of such a tax.

Now we look at transport fuels. Most of the literature on the distributional effects of "fuel tax" concentrates on transport fuels like gasoline. In the figure below we consider the two major transport fuels: Petrol (Gasoline) and Diesel. Other transport fuels are rarely used in India. It is only in cities like Delhi that the public transport fleet uses cleaner fuels like CNG.

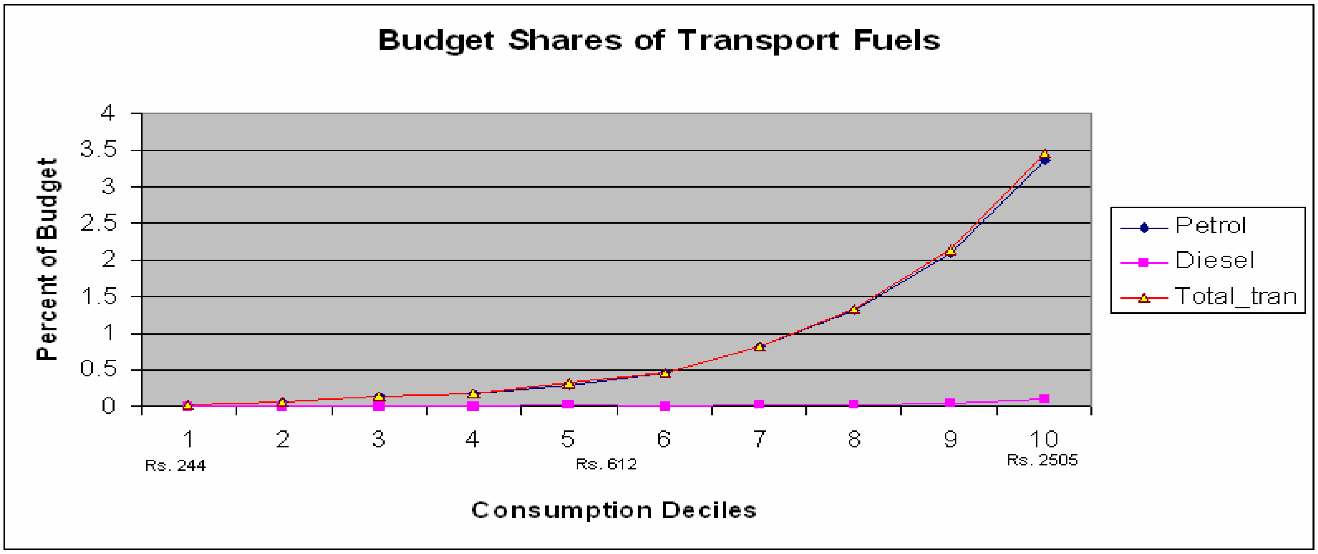

Figure 6: Budget shares of transport fuels, not taking into account indirect consumption through their use as intermediate inputs

As is evident from the figure above, the budget shares of transport fuels are strictly increasing with consumption. This is expected in a poor country like India (per capita income of $620 in 2004) as only the very rich can have access to transport fuels. A large majority of Indian households (more than 80% according to 61st round NSS data) do not buy either petrol or diesel.

The figures for the urban sector shows that progressivity is much greater the urban sector. This is expected as most households with access to private transport are situated in the urban sector. The curve for diesel is almost flat, showing some upward slope for top consumption deciles. It is very close to zero showing that a negligible amount of Indian households use diesel vehicles for private transport.

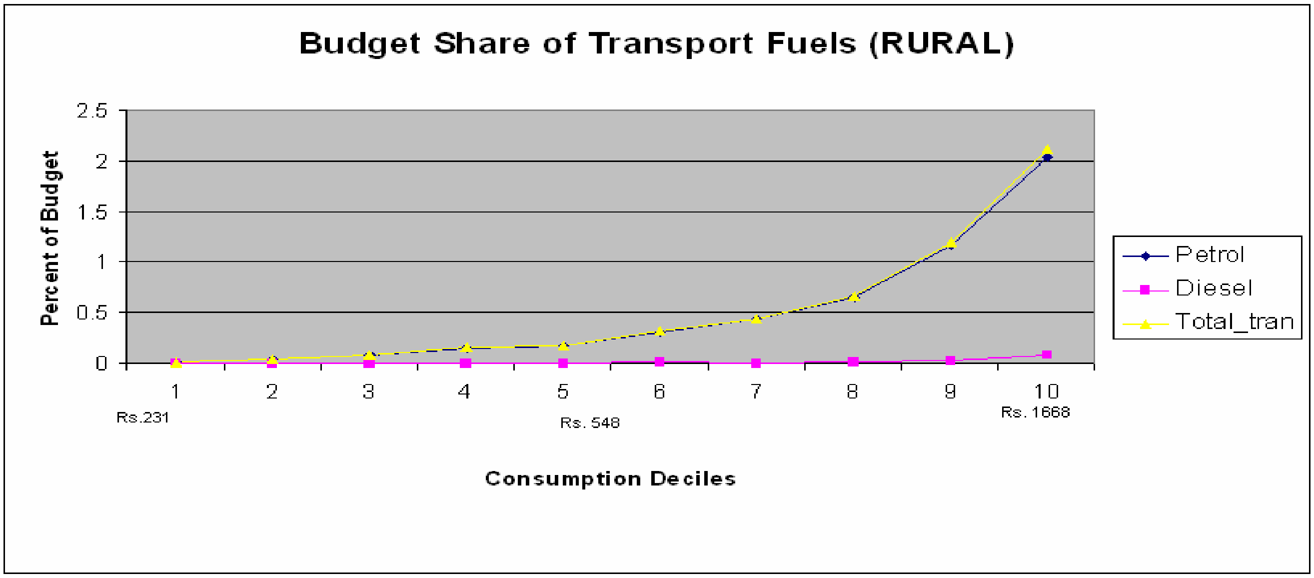

Figure 7: Budget shares of transport fuels for the rural sector, not taking into account indirect consumption through their use as intermediate inputs

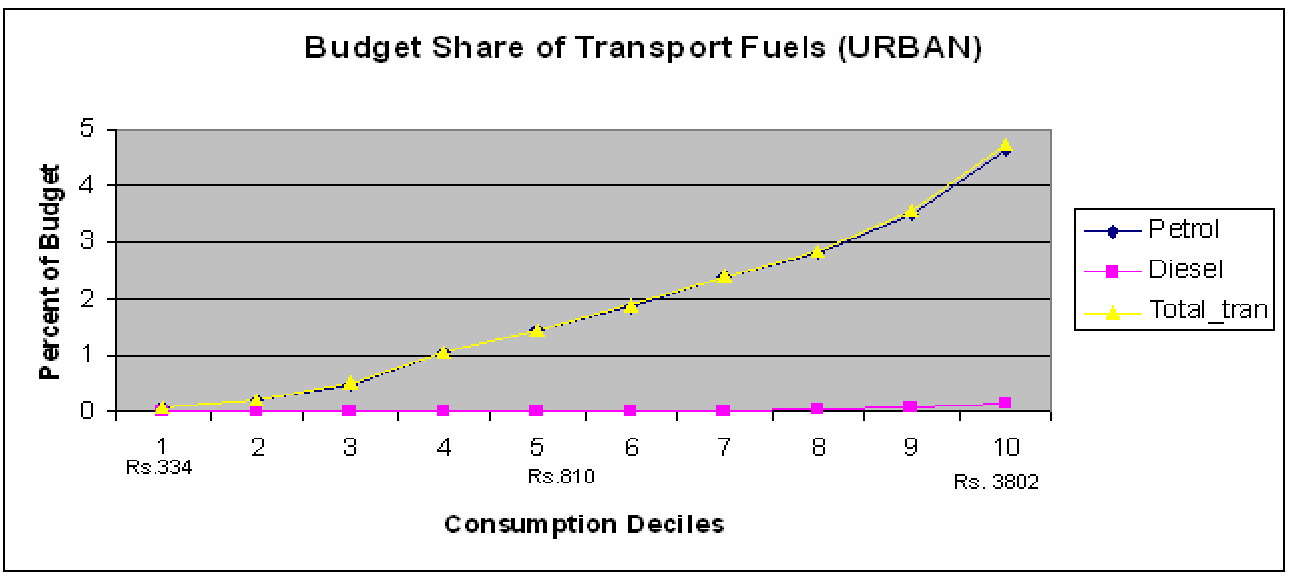

Figure 8: Budget shares of transport fuels for urban sector, not taking into account indirect consumption through their use as intermediate inputs

However it should be borne in mind that the results above are obtained when we assume the direct consumption of fuels by various households. Though such results are interesting they are only half of the entire stories. Transport Fuel is an important input in the production of most goods that are mechanically produced. When households consume good which use fuel as an input, they indirectly consume fuel. When such indirect consumption is taken into account, the regressivity or progressivity results might be overturned.

We give an illustrative example to explain this. Let us consider the example of coal consumption. We have seen earlier that the budget shares of coke and coal are highest for middle consumption groups. However coal is an important input in the production of energy. If we consider the indirect consumption of coal through energy use, the distributional effects might change. We make calculations of incidence by incorporating the effects of indirect consumption into account. We make this calculation by making two assumptions: Firstly we assume that higher order effects are missing. An increase in coal price increases just the input cost of electricity. Any increase in the price of other inputs due to rise in price of coal is ignored. Secondly, we assume demand for coal and electricity to be inelastic (this assumption is sufficient but not necessary for our purpose). Under these assumptions, we calculate the indirect budget shares which are defined as follows:

Indirect Budget Share of Coal = Direct Budget Share of Coal +

Cost Share of Coal in the Production of Electricity × Direct Budget Share of Electricity…………………… (1)

Let the direct cost share of coal in production of electricity as reported by CSO input-output table is 10 percent. Even such a low value flips the results:

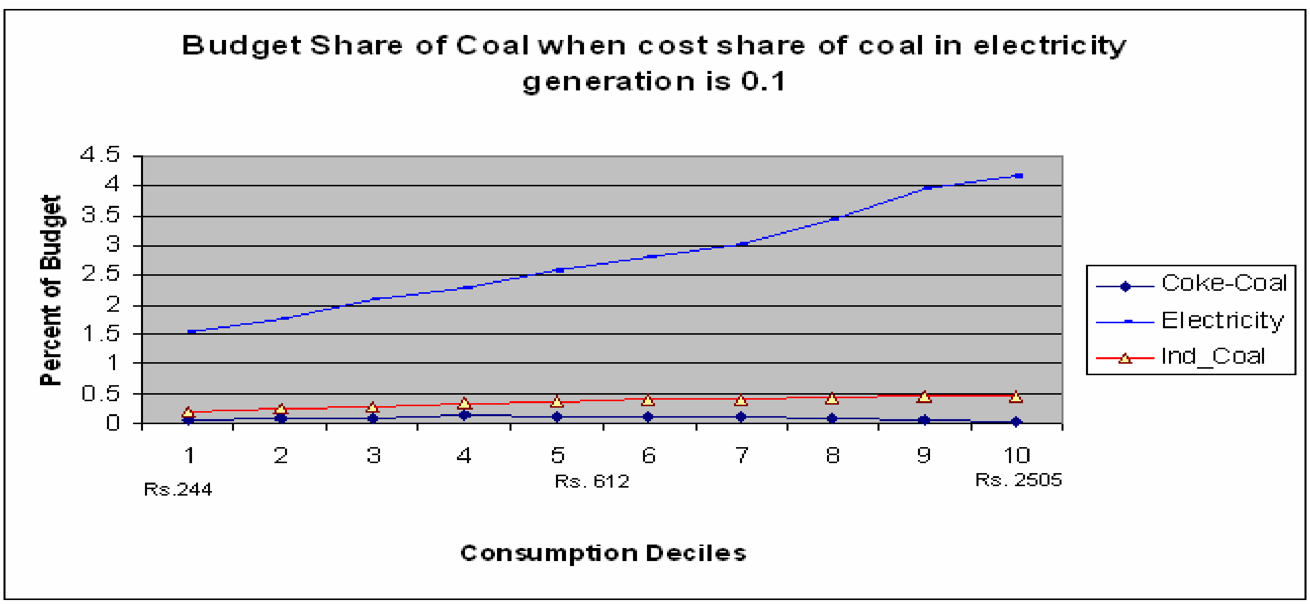

Figure9: Budget Shares of coal accounting for its use as an input in electricity generation when cost share in electricity generation is 0.4

Thus once indirect consumption of coal is included we get mild progressivity. For higher values, which are more realistic, we get strong progressivity.

6. Including Indirect Effects:

- **Methodology**

Thus indirect consumption can play an important role in determining distributional effects of fuel tax. Thus an appropriate measure should take into account the price changes happening in the various sectors happening in the economy, and calculate the tax burden arising from price changes for different consumption deciles. To calculate the economy wide price changes we at first use the Input Output Coefficient matrix 1998-99 published by the Central Statistical Organization. This is because compared to the latest 2003-2004 matrix; the 1998-99 matrix provides energy sector information at a more disaggregated level. The original matrix for 1998-1999 has disaggregated information on 115 sectors. We add a new sector called kerosene to these 115 sectors. We assume that kerosene input requirements of kerosene is similar to that of petroleum products. This is a reasonable assumption on the ground that the chemical composition of kerosene is similar to that of other petroleum products like transportation fuels. We also assume that kerosene does not enter into the production of any other commodity. The only conceivable intermediate use of kerosene is its use in adulterating transport diesel. According to a study carried out by the National Council of Applied Economic Research (NCAER) and commissioned by the petroleum and natural gas ministry, 35 percent of the total amount of kerosene distributed in the country through PDS is diverted. The study further found out that of the volume diverted, 18% is used to adulterate diesel. Thus around 6 percent of the total kerosene supply is diverted to adulterate diesel. Given that the price of diesel is almost thrice that of kerosene supplied through PDS, the cost share of kerosene in diesel is less than one percent, around 0.4 percent.[2] As kerosene is not used to adulterate non diesel transport fuels, the cost share of diesel in transport fuels will be even lower. Thus it is safe to make the assumption that kerosene is not used as an intermediate input. However for the 2003-04 matrix this paper don't make any such assumption and works with the aggregated sector called "Petroleum Products" which includes transport fuels, gas and kerosene.

In order to make it compatible with the 61st round NSS data we use an aggregated matrix. For the 1998-99 matrix the numbers of sectors have been reduced to 48, while for the 2003-04 matrix it is 46. The method and pattern of aggregation has been described in the Appendix A and B. Before describing the theoretical framework of calculating price changes we mention two things: Firstly, when we use the 1998-1999 matrix, there is a five year gap between the date of the input output table and consumption survey. But this is the best that can be done with the data currently available. We will later use the input-output table for 2003-2004 to show that the results do not

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[2] The total sales of diesel and kerosene in India are about 40milion tones and 9.5 million tones respectively. If 6 percent of kerosene is diverted to adulterate diesel and the price of diesel is thrice that of kerosene, then the cost share is
$((9.5 \times 0.06)/40) \times 0.33 = 0.004$

change appreciably, at least at an aggregative level. Secondly, the aggregation of sector also introduces an element of error. But the effect is expected to be marginal.

Now we develop the theoretical framework required to calculate tax burden taking price changes of all sectors into account. We work with two frameworks: one in which the economy is assumed to be closed and indirect taxes are advalorem and another in which the economy is assumed to be a small open economy with unit taxes.

When the closed economy assumption is made, the framework described below is used:

- Closed (Autarkic) Economy

Let A be the 48 X 48 input output matrix.

$$A \equiv \begin{bmatrix} a_{11} & . & . & . & a_{1n} \\ . & . & . & . & . \\ . & . & . & . & . \\ . & . & . & . & . \\ a_{n1} & . & . & . & a_{nn} \end{bmatrix}$$

where n = 48 and a_{ij} is the quantity of i^{th} sector output used to produce 1 unit of commodity j.

a_{ij} is the quantity of i^{th} sector output used to produce 1 unit of commodity j.

Let the price formation equation be

$$P_j = \sum_{i=1}^{47} a_{ij} P_i + VA_j + t_j P_j, \; i = 1 \; (1) \; 48 \ldots\ldots (1)$$

$$\text{or, } (I-A^T-T)_{n \times n} P_{n \times 1} = VA_{n \times 1} \ldots\ldots (2)$$

where

- n= 47
- I is a n×n identity matrix
- T is a n ×n diagonal matrix with tax rates in the diagonal
- P and VA are column vectors showing prices and value added of the 47 sectors.

Let us assume that the tax of the i^{th} commodity changes by dt_i. Then system of equations depicting price change is:

$$(I - A^T - T)_{n \times n} \, dP_{n \times 1} = P_i \, dt_i \, e_i \quad \text{(3)}$$

where e_i is a column vector with 1 in the i^{th} place and 0 in every other place

Taking inverse (assuming inverse exists) we have,

$$dP_{n \times 1} = P_i \, dt_i \, (I - A^T - T)^{-1} e_i \quad \text{(4)}$$

The tax burden of the k^{th} household is

$$TB_k = P_i \, dt_i \left[\frac{X_k (I - A^T - T)^{-1} e_i}{Y_k} \right] \quad \text{(5)}$$

where X_k is the $(1 \times n)$ vector of quantities purchased by household k and Y_k is consumption expenditure of household k. Denote the term within parenthesis by S_k. This can be interpreted as the share of commodity i in household k's expenditure taking all indirect effects into account.

Since the terms outside the parenthesis are same for all households, we only need to calculate the term within to comment of distribution of tax burden. Information on X_k and M_k is obtained from NSSO data while information about other matrices is obtained from CSO input output table. The CSO input output transaction matrix is actually the cost share matrix $\{C_{ij}\}_{n \times n}$ where $C_{ij} = a_{ij} \times (P_i / P_j)$. We chose physical units in such a way that initially (before tax) $P_1 = P_2 = \ldots\ldots = P_n = 1$ .Given this assumption $\{C_{ij}\}_{n \times n}$ is the same as $\{A_{ij}\}_{n \times n}$ and the tax burden can be easily calculated. We can calculate it for each household corresponding to tax changes in coal, natural gas, kerosene and petroleum products.

- Small Open Economy

Let A and M be the 48 X 48 input output matrix and 48×48 import matrix respectively:

$$A \equiv \begin{bmatrix} a_{11} & . & . & a_{1n} \\ . & . & . & . \\ . & . & . & . \\ a_{n1} & . & . & a_{nn} \end{bmatrix} \qquad M \equiv \begin{bmatrix} m_{11} & . & . & m_{1n} \\ . & . & . & . \\ . & . & . & . \\ m_{n1} & . & . & m_{nn} \end{bmatrix}$$

where a_{ij} is the amount of input i (both domestic and imported) used in production of commodity j and m_{ij} is the amount of imported input i used in production of commodity j. Now define a new matrix of domestic input use as:

D= $\{d_{ij}\}_{n\times n}$ = A- M where d_{ij} is the amount of domestically produced commodity i used in the production of output j. We assume that domestically produced input and imported input are imperfect substitutes .Each one of them is required in a fixed amount to produce one unit output i. They being differentiated commodities, prices difference between them can exist. The price of imported inputs is determined in the international markets, and are unaffected by domestic taxes. We also assume that the value added per unit of output is unchanged.

Let the price formation equation be

$$P_i = \sum_{j=1}^{n} d_{ji} P_j + \sum_{j=1}^{n} m_{ji} P_j^m + V_i + \sum_{j=1}^{n} t_j^m m_{ji} + t_i^d \text{ , } \forall i \text{ .... (6)}$$

where P_i is the domestic price of i th good , P_i^m is the international price of the imported version of good i , t_i^m is the import duty per unit of commodity i imported, and t_i^d is the domestic per unit tax on commodity i.

Taking total differential,

$$dP_i = \sum_{j=1}^{n} d_{ji} dP_j + dt_i^d \ \forall i \text{ .... (7)}$$

When only tax on commodity i is increased by dt_i , we get

$$dP = \left[I - D^T\right]^{-1} dt_i^d e_i \text{ .... (8)}$$

where e_i is a column vector with 1 at the i th row and 0 at every other row.

The tax burden of the k th household is

$$\text{TB}_k = \left[\frac{\text{X}_k (\text{I} - \text{D}^\text{T})^{-1} \text{e}_\text{i}}{\text{Y}_\text{k}}\right] dt_i^d \text{ .... (9)}$$

where X_k is the $(1\times n)$ vector of quantities purchased by household k and Y_k is consumption expenditure of household k. Denote the term within parenthesis by S_k.

Since the terms outside the parenthesis are same for all households, we only need to calculate the term within to comment of distribution of tax burden. Information on X_k and Y_k is obtained from NSSO data while information about other matrices is obtained from CSO input output table. The CSO input output transaction matrix is actually the cost share matrix $\{C_{ij}\}_{n \times n}$ where $C_{ij} = a_{ij} \times (P_i / P_j)$. We chose physical units in such a way that initially (before tax) $P_1 = P_2 = \ldots\ldots = P_n = 1$ .Given this assumption $\{C_{ij}\}_{n \times n}$ is the same as $\{A_{ij}\}_{n \times n}$. From this matrix we deduct the import matrix to obtain the domestic input use matrix. Once this information is available we can easily obtain the tax burden corresponding to increase in tax rate of different commodities.

- **Results**

<u>Results corresponding to closed economy model when 1998-1999 input output data is used:</u>

The indirect budget shares (S_k) of fuel for different consumption classes are as follows:

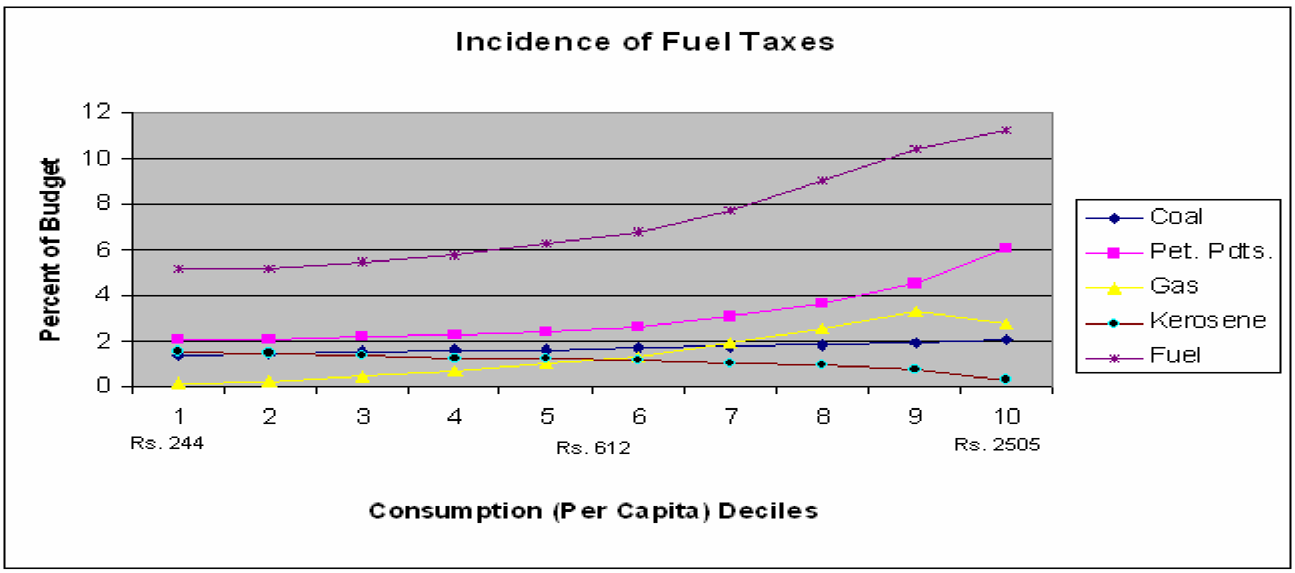

Figure 10: Tax incidence across consumption groups, taking indirect consumption of fuel into account.

The figure shows that inclusion of indirect consumption hardly affects the progressivity results. For example, the progressivity of a gas tax remains unchanged (Figure 6). Inclusion of indirect consumption flips a few regressivity results that we had obtained earlier. Earlier the budget share of coal was highest for the middle deciles and was low at the two ends (Figure 3). However inclusion of indirect consumption yields progressivity. This result is quite intuitive. Coal is an important input in the production of energy and manufacturing sector. The rich spend a much bigger proportion of their total expenditure on energy and consumer goods. This in turn changes the earlier result. The shape of the gas curve is almost unchanged. It suggests strong progressivity till the ninth decile. The indirect budget shares drops abruptly for the topmost decile. The budget shares for petroleum products are almost unchanged for the first few deciles .They start increasing thereafter. Thus at an All India level, taxes on all the three items are progressive. However as kerosene is assumed not to enter into production of any other good, the total incidence curve mimics the earlier direct budget share curve. A combined tax on the four items yield strong progressivity as is evident from the topmost curve.

We now take a look at the rural and urban sector separately as the two sectors have very different patterns of fuel use.

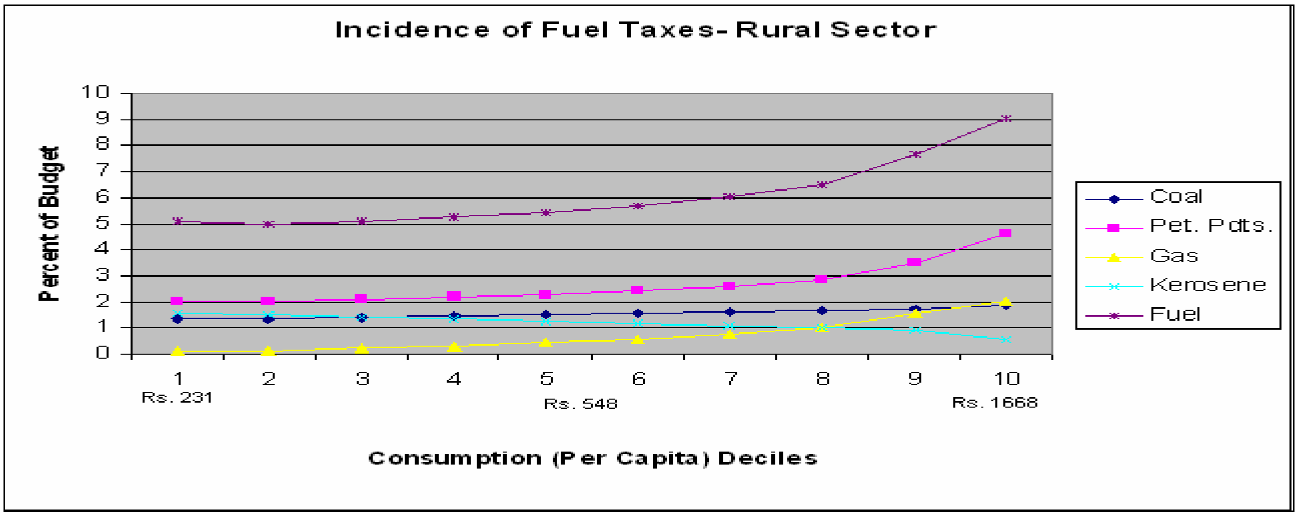

Figure 11: Incidence for rural sector, taking the impact through intermediate use of fuels into account

The results from the rural sector are quite straightforward. Taxes on Petroleum Products and Gas are strongly progressive, while taxes on coal are very weakly progressive.

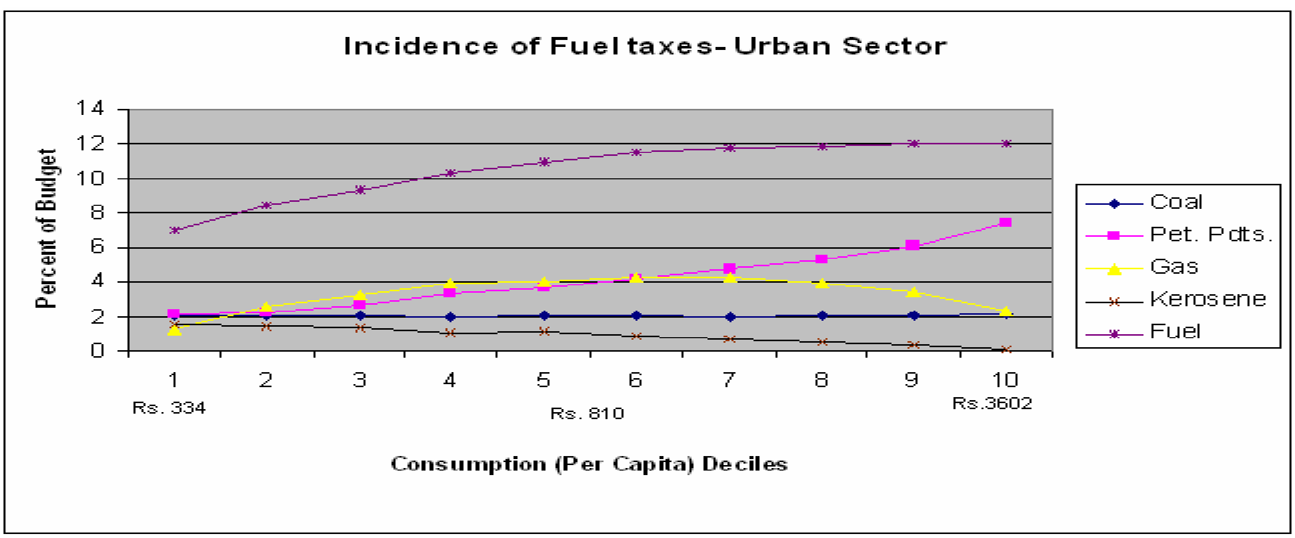

Figure 12: Incidence for urban sector, taking the impact through intermediate use of fuels into account

Tax on kerosene is regressive. The results from the urban sector are much more interesting. Budget Shares for petroleum products increase with consumption. Burden of a coal tax is constant (slightly increasing) across deciles, implying weak progressivity. The incidence curve for gas is inverted U shaped, implying highest tax burden on the middle expenditure groups.

<u>Results corresponding to closed economy model when 2003-2004 input output data is used:</u>

We now do similar calculations for tax incidence by using the 2003-2004 input output matrix. As noted earlier, the new table provides information about the energy sector at an aggregated level. Thus we have incidence results for coal, petroleum products (which includes gas, kerosene and transport fuels) and fuel as a whole.

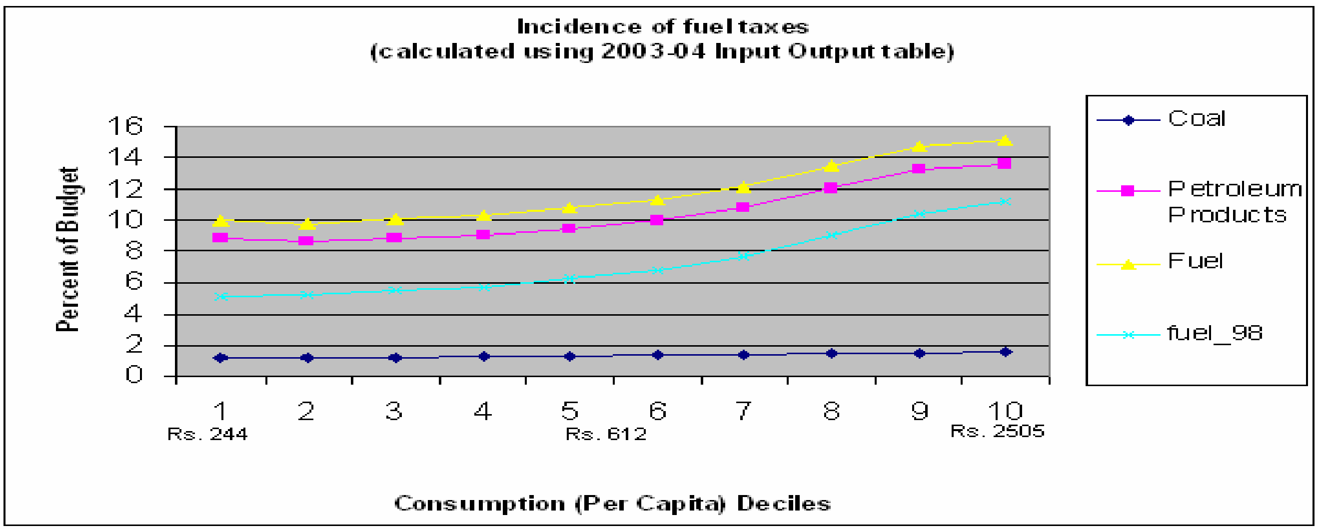

Figure 13: Incidence of Fuel Taxes, taking the impact through intermediate use of fuels into account

(Calculated using 2003-2004 Input Output Table)

The progressivity results remains unchanged when we use 2003-2004 input output data. A coal tax is still weakly progressive. The tax burden is now marginally lower than the figures obtained earlier. This might be a result of lowering of coal intensity of production or decrease in coal prices. Tax on petroleum products is strongly progressive. The magnitude of tax burden is much higher now. This might be the reflection of the steep increase in price of petroleum products since the abolition of administered price mechanism in the beginning of 21st century and the reduction of subsidies that followed it. The figures below show the incidence results separately for the rural and urban sector.

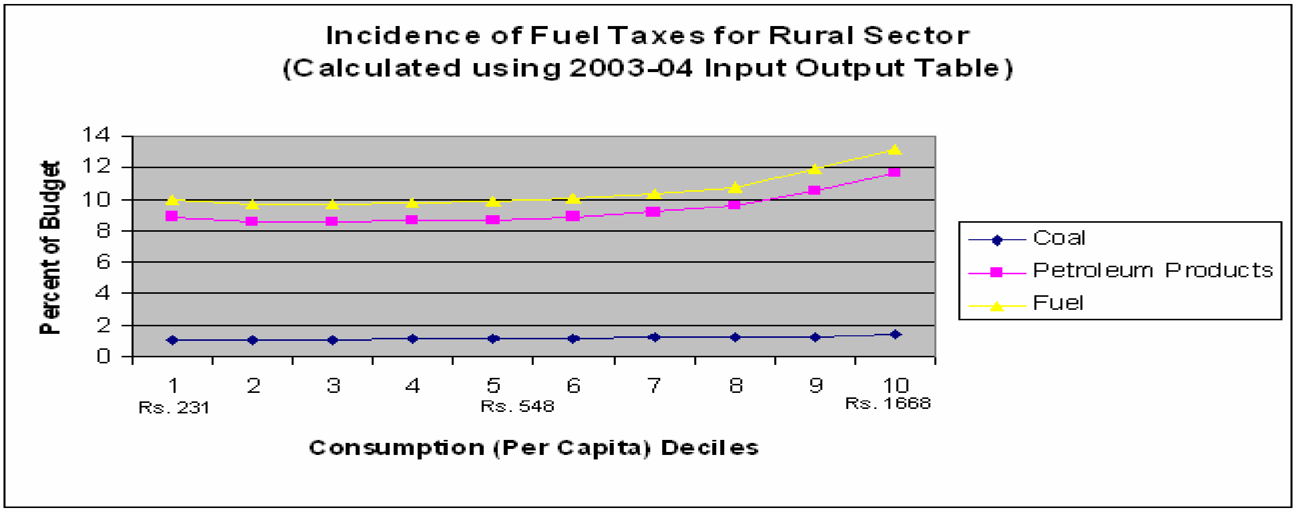

Figure 14: Incidence of fuel taxes for rural sector, taking the impact through intermediate use of fuels into account

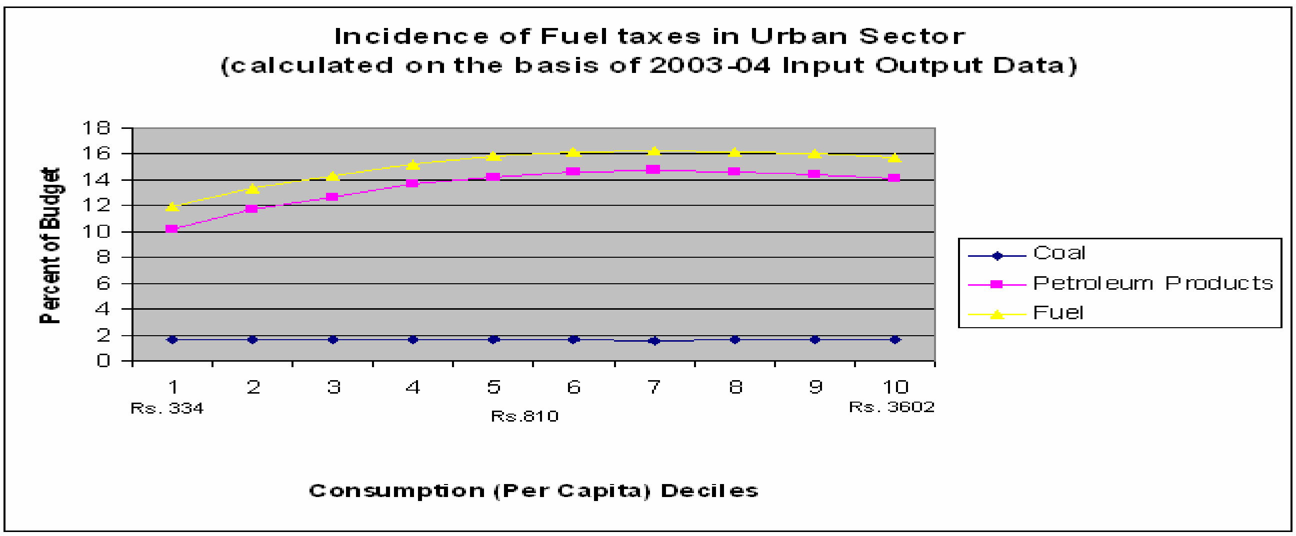

Figure 15: Incidence of fuel taxes for urban sector, taking the impact through intermediate use of fuels into account

In the rural sector tax burden due to a petroleum product tax increases with consumption level .The effect of a coal tax increases marginally with per capita consumption levels. In the urban sector, the coal tax is almost neutral but the curve depicting the burden of a tax on petroleum products is inverted U shaped, suggesting maximum burden at the middle levels of per capita expenditure. The results obtained from 1998-1999 input-output data suggested that the curve for gas is inverted U shaped. The curvature of the petroleum products curve might be due to this peculiar incidence pattern of a gas tax.

Results corresponding to open economy model when 2003-2004 input output data is used:

We now use the open economy framework and the data from 2003-04 Input-Output table and 61st round NSS to calculate incidence results. In this section the results are discussed in greater detail in order to decipher the story behind the incidence results. The poor have low budget shares for petroleum products (except kerosene) and high budget shares for coal, compared to the rich. In spite of that, the fact that fuel prices affect prices of other commodities and the possibility that the poor might have high budget shares for such commodities, may change the direction of the incidence results. For example, the poor might be affected adversely if food prices are highly sensitive to fuel prices. The fact that the budget share of food for the poor is high might depress the progressivity result obtained earlier. The table below gives the difference in the budget shares of the last and the first decile for some important sectors:

Sector	Budget Share of First Decile	Budget Share of tenth Decile	Difference in Shares
Major Food Crops and their products	33.17	7.15	-26.02
Other Crops	13.73	7.18	-6.55
Milk and Milk Products	3.01	7.13	4.12
Forestry and Logging	7.3	0.04	-7.26
Coal and Lignite	0.04	0.02	-0.02
Edible Oil	5.95	2.44	-3.51
Textiles	1.36	4.84	3.48
Petroleum Products	2.4	6.51	4.11
Health	2.46	7.32	4.86
Toiletries	6.19	3.38	-2.81
Electricity	1.53	4.14	2.61
Transport Services	1.82	4.01	2.19
Other Services and Communication	0.03	10.11	10.08
Hotels and restaurants	0.42	4.66	4.24
Ownership of Dwellings	0.11	6.91	6.8
Education	0.37	3.61	3.24

Table 1: Share of Consumption Expenditure of the two extreme deciles for some sectors

The table above shows that the "poor" have a higher budget share for food items, forestry and logging, coal and lignite, edible oil and toiletaries, compared to the rich. These sectors have the potential to depress the progressivity obtained earlier (by comparing direct budget shares), only if the products of these sectors are highly sensitive to fuel prices. On the other hand textiles, petroleum products, health, electricity, transport services, other services, education, Hotels and restaurants and education have lower budget shares for the poor, compared to the rich. The following figures show the price changes in all sectors in response to an increase in the unit tax on coal by one unit.

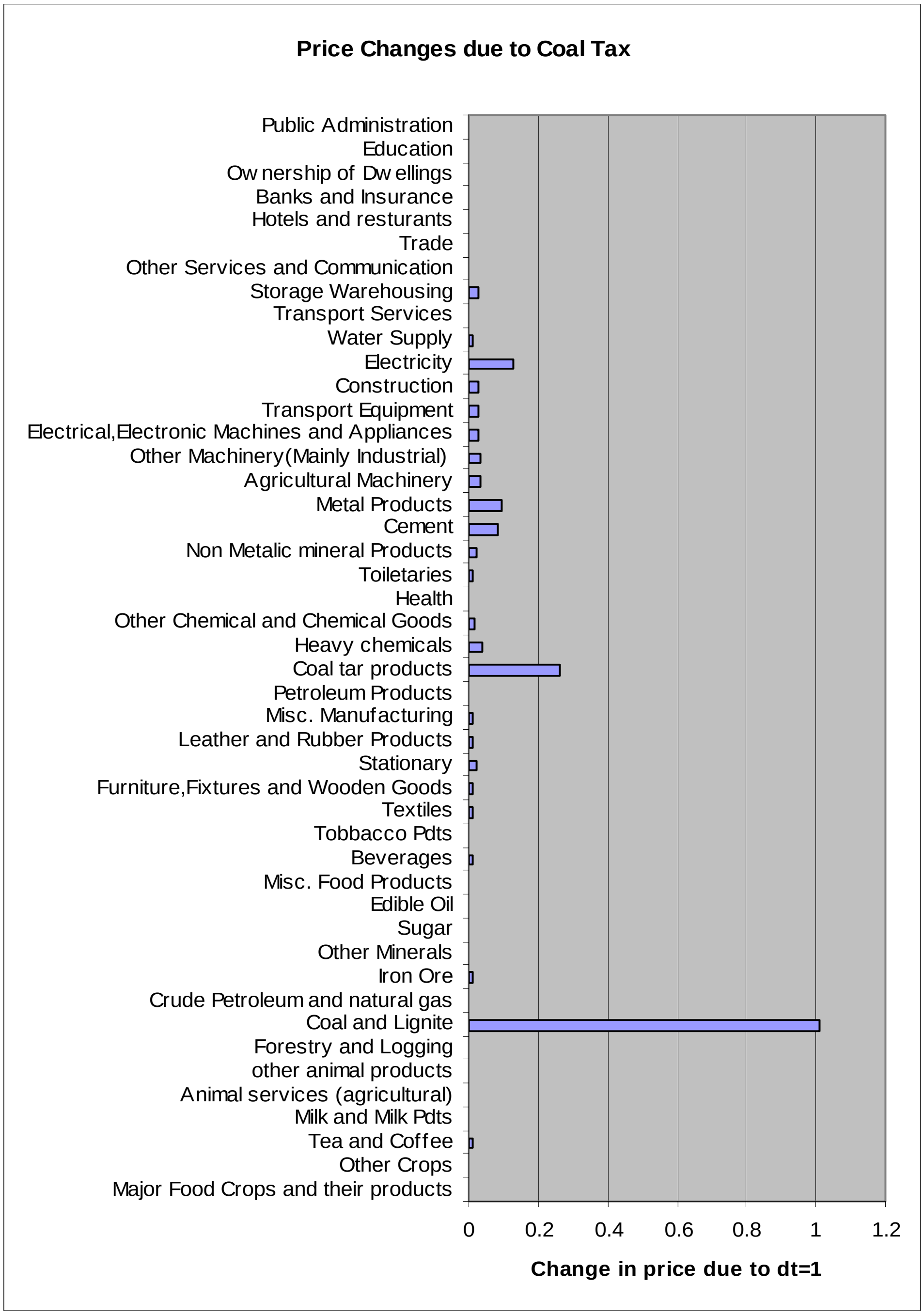

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Figure 16: Price Changes of Commodities in other Sectors due to coal tax

Source: Author's Calculation based on the 2003-2004 Input Output Matrix

We see that food items, forestry and logging, edible oil and toiletaries are not very responsive to a coal tax. On the other hand sectors like electricity are highly responsive to a coal tax. Thus electricity consumption can have an important role in determining the incidence of a coal tax. Now we look at the impact of a petroleum product tax on the prices across the economy.

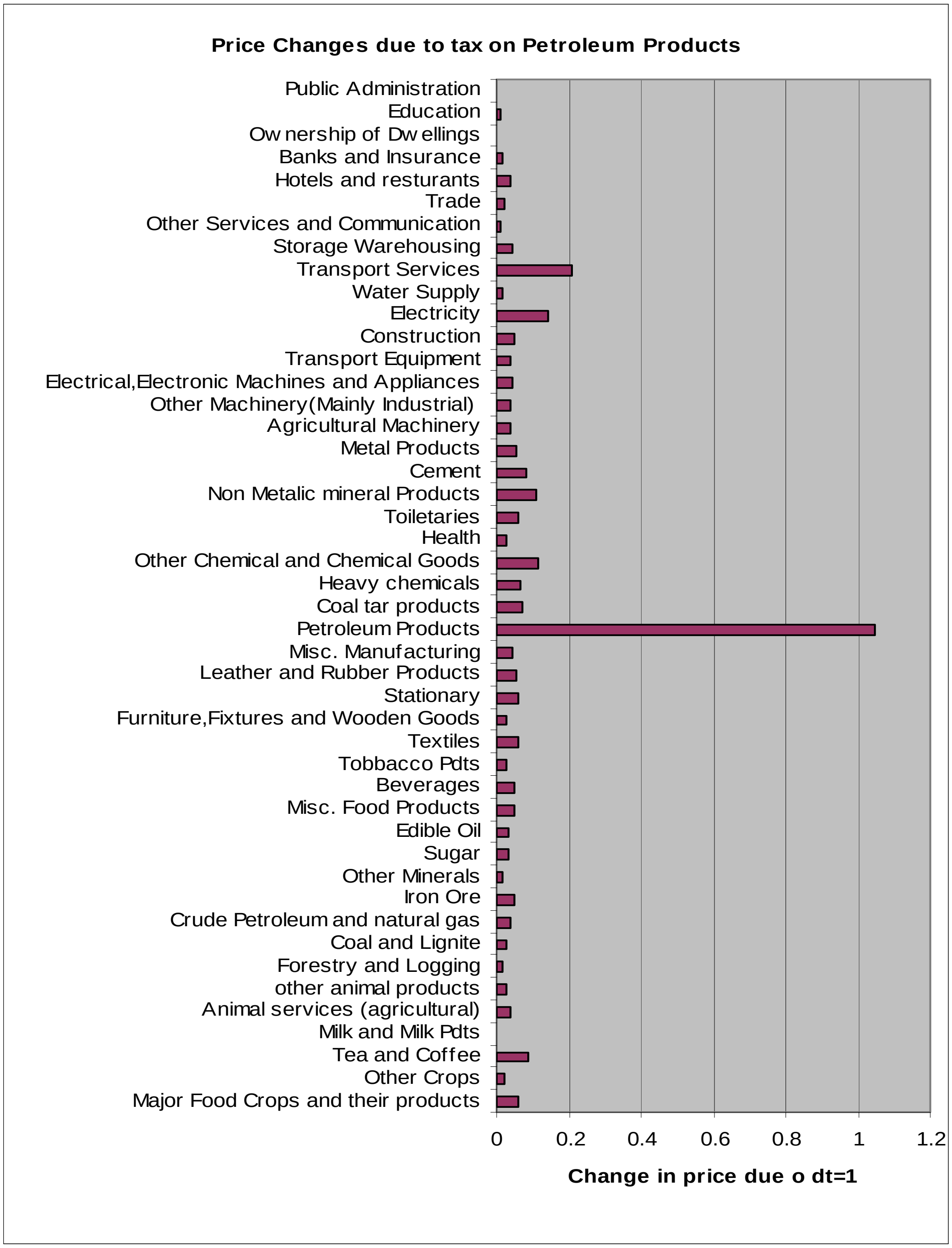

Figure: Price Changes of Commodities in other Sectors due to coal tax

Source: Author's Calculation based on the 2003-2004 Input Output Matrix

We see that cereals and non cereal food crops, forestry and logging, edible oil and toiletaries are not very responsive to a petroleum product tax. On the other hand sectors like electricity and transport services are highly responsive to such a tax. Thus electricity and transport services consumption can have an important role in determining the incidence of a petroleum products tax. The results from the analysis are as follows:

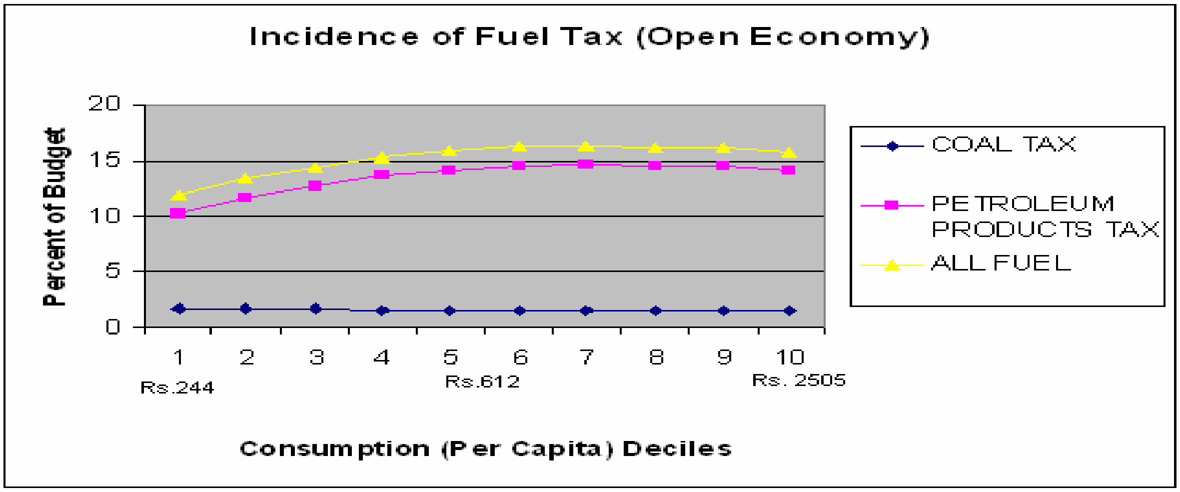

Figure 17: Incidence results from open economy model

The above figure shows that a coal tax is almost neutral. It shows no monotonic movement with increase in per capita consumption. Thus indirect effects are negligible or the positive and the negative effects cancel out each other. The bulk of indirect expenditure effect comes through increases in food expenditures. In spite of the food price hike being small, the huge budget share of food in the budget of poor depresses "progressivity gains" made from other commodities like electricity, textiles etc. The incidence curve of a petroleum tax is increasing at least for the first seven deciles. Then it dips a bit, but only marginally. As in the case of coal tax, food expenditure has a huge indirect effect. It depresses the progressivity result. However in the case of petroleum products, it is unable to wash away the positive contribution of transport, electricity, health, electronic goods towards progressivity. We now look at the rural and urban sector respectively:

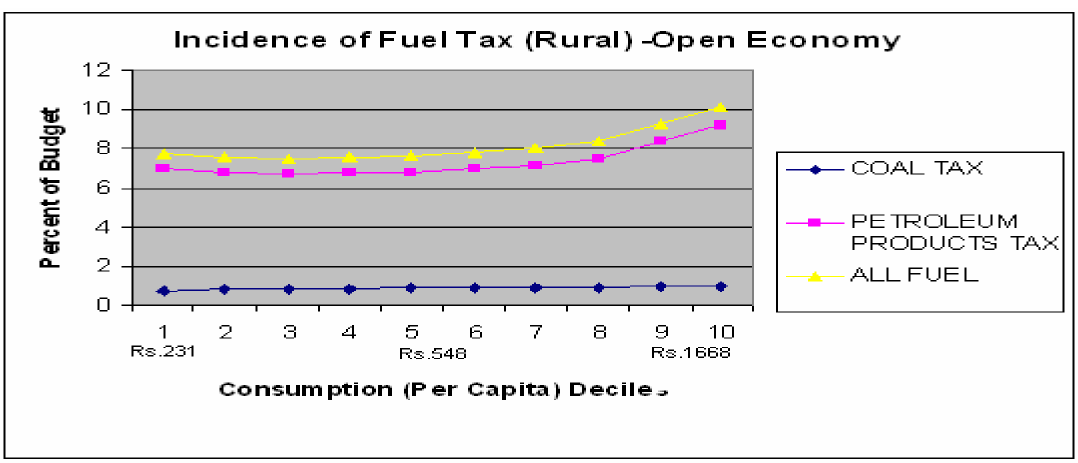

Figure 18: Incidence results for rural sector from open economy model

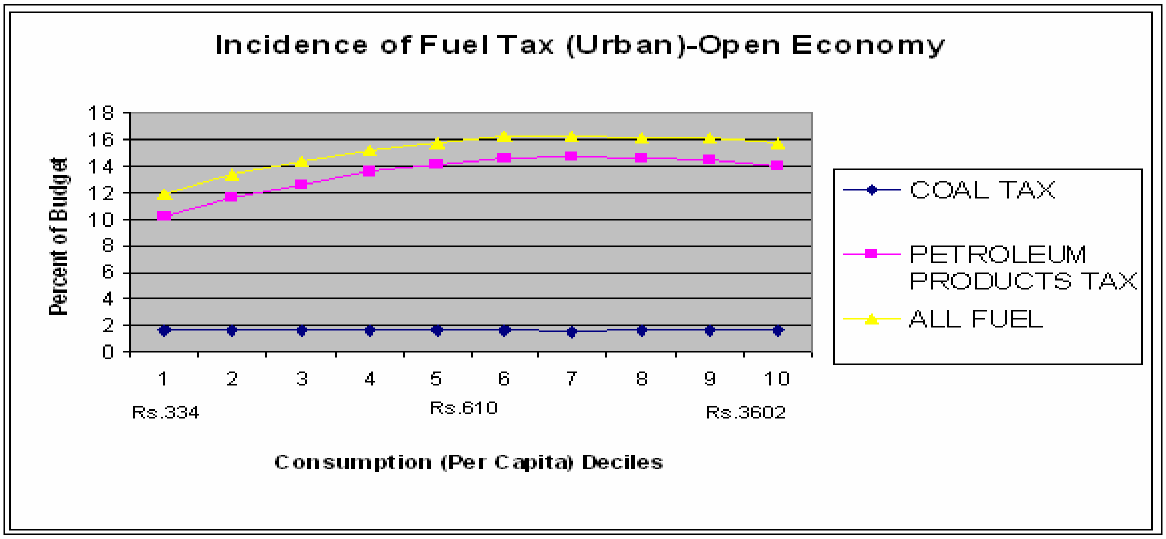

Figure 19: Incidence results for urban sector from open economy model

The results from the two sectors are in expected lines with a coal tax being almost neural in both cases and petroleum products tax being progressive. However in urban sector, at high levels of expenditure the burden of petroleum tax falls marginally.

Thus we see that inclusion of indirect consumption keep the major results of earlier analysis unchanged. However all our calculations are based on the assumption of perfectly elastic supply curves (arising out of the assumption of a Leontief fixed coefficient technology) and perfectly inelastic demand curves. Before making strong statements we need to check if demand responses change the strong progressivity results. The assumption of inelastic demand elasticity generally overstates the incidence results of groups with high elasticities. If one makes the reasonable assumption that the poor have higher price elasticity for energy and luxuries, which are fuel intensive, then any consideration of demand sensitivity will strengthen our progressivity results. On the supply side, substitution against fuel in response to a fuel price rise will reduce the burden on groups which have a higher indirect consumption of fuel.

6. Sensitivity Checks

Till now we have assumed that demand is inelastic. This is highly unrealistic but the strength of the progressivity results seem to suggest that the results will remain unaltered even when we allow for elastic demand. We carry out a sensitivity analysis using elasticity estimates from different studies to test if that is indeed the case. The estimates are obtained from different sources and are often not representative at an all India level. Thus they have problems of comparability. However the purpose of these checks is to show that the progressivity results don’t change for “reasonable” values of elasticity. One requires extreme values of elasticities to change the results.

Since it is not possible to obtain on price, cross price and income elasticity estimates for all the 48 commodities that we have considered earlier, we aggregate further and consider only 5 commodities: Coal, Gas, Petroleum Products, Kerosene and Others (Non Fuel Consumption).

Let the goods be X_1, X_2, X_3, X_4 and X_5. The demand functions are as follows:

$X_i = X_i (P_i, P_{-i}, M)$ for all i=1, 2, 3, 4, 5……………………………………………………………………….. . (6)

From the theory of demand we know that demand elasticities satisfy two conditions:

- $\sum_{j=1}^{5} e_{ji} + e_{mi} = 0$ for all i ……………………………………………………………………………(7)
- $\sum_{i=1}^{5} d_i \; e_{ji} = - \; d_j$ for all j (This is called the Cournot Aggregation Condition)…………………..(8)

Taking total differential of (6),

$$dX_i = \sum_j \frac{\partial X_i}{\partial P_j} \; dP_j + \frac{\partial X_i}{\partial M} \; dM$$

$= \sum_j e_{ji} \; \frac{X_i}{P_j} \; dP_j$ [The second term vanishes as dM is assumed to be zero)

$= \sum_j e_{ji} \; X_i \; dP_j$ [As we have set P_j =1 through appropriate choice of units]

Let there be a tax increase of magnitude dt_i = 1.This will result in price changes for all the commodities. Let X'_i be the new level of consumption after tax.

$$X'_i = X_i \; (1 + \sum_{j=1}^{5} e_{ji} \; dP_j)$$

Then the tax burden is

$$\text{TB} = \sum_{i=1}^{5} \frac{\left(1 + \sum_{j=1}^{5} e_{ji} dP_j\right) X_i dP_i}{M} \quad \text{...} (9)$$

Let there be two classes: Rich (R) and Poor (P). For a tax on commodity i to be progressive we require

$\text{TB}_R > \text{TB}_p$

$$\Rightarrow \sum_{i=1}^{5} \frac{\left(1 + \sum_{j=1}^{5} e_{ji}{}^{R} dP_j\right) X_i{}^{R} dP_i}{M^R} > \sum_{i=1}^{5} \frac{\left(1 + \sum_{j=1}^{5} e_{ji}{}^{P} dP_j\right) X_i{}^{P} dP_i}{M^P}$$

We assume $e_{ji}{}^{R} = e_{ji}{}^{P} = e_{ji}$ for all i, j. Then for progressivity we need,

$$\sum_{i=1}^{5} \left(1 + \sum_{j=1}^{5} e_{ji} dP_j\right) \left[D_i{}^{R} - D_i{}^{P}\right] dP_i > 0 \quad \text{...} (10)$$

where D_i^K is the budget share of the i[th] commodity in k's budget [k=R, P].Denote the expression on the LHS as FD_i

We already have budget shares for each decile. The two ends of the distribution are subject to volatility, so we consider second decile individuals to represent the poor and ninth decile individuals to represent the rich.

	2nd Decile	9th Decile	Difference
Coal	0.08301	0.06481	≈ -0.02
Petroleum Products	0.05766	2.1308	≈ 2.07
Gas	0.12100	3.087	≈ 2.97
Kerosene	2.1725	1.0528	≈ -1.12
Others	97.56583	93.66453	≈ -3.9

Table 2: Direct Budget Shares for the "Poor" and the "Rich"

The tables below shows the own price, cross price and income elasticities for different commodities. Information on the source of estimates is given in Appendix C.

		PRICES					
		COAL	PET.PDTS.	GAS	KEROSENE	OTHERS	INCOME
QUANTITY	COAL	0	0	0.07	0	-0.99	0.92
	PET.PDTS.	0	-0.42	0	0	-1.01	1.43
	GAS	-0.1	0	-0.99	0.1	0.29	0.7
	KEROSENE	-0.07	0	0.02	-0.5	-0.15	0.7
	OTHERS	0	-0.01	0	-0.01	-0.99	

Table 3: Uncompensated elasticity estimates of different commodities.

Using this value of elasticities we calculate the value of FD_i (refer to condition 10) for coal, petroleum products, gas and kerosene. The values are negative for coal and kerosene, for the rest it's positive. While Coal tax is weakly regressive, taxes on petroleum products and gas continue to be progressive. However the strength of progressivity falls a bit. However we have assumed that the poor and the rich have similar elasticities. To the extent that poor have a higher elasticity for fuels, these results understate the strength of progressivity.

7. Conclusion

Fuel taxes for environmental purposes have often faced skepticism and criticism on the grounds of regressivity. This paper shows that such criticisms do not apply to a low-income country like India. Here we find that taxes on fuels are on the whole progressive. Taxes on transport fuels (petrol and diesel) are highly progressive for both urban and rural sector. A tax on coal is also progressive, due to it's use as an intermediate input. However, cooking fuels like kerosene and gas show signs of non regressivity. While a tax on kerosene is regressive for both urban and rural sector, the results for gas differ within sectors. While a tax on gas is strongly progressive for the rural sector, it imposes maximum burden on the middle expenditure groups of the urban sector.

These results of this paper can be used in different ways, depending on the policy objective of the government and tax authority. The objective of an environmental tax is to reduce emissions by reducing consumption of fuel. Thus, unlike a tax imposed for revenue purposes, an environmental tax should be imposed on fuels with elastic demand and on fuels with emission potential. Transport fuels satisfy these criteria and are thus an appropriate case for a fuel tax for environmental purposes. They have high mission potential with each litre of transport fuel emitting around 2.3 kilograms of carbon dioxide per litre of fuel. According Thomas Sterner (2007), while the elasticity of transport fuels are inelastic in the short run, they respond to price changes in the long run and have a long run elasticity of -0.84. However studies by Ramanathan and Geetha (1998) report a lower value of -0.42, still it is sensitive to price changes. In addition the results of this study show that a tax on transport fuel is progressive. The results holds good even when indirect consumption is considered. Thus a tax imposed on transport fuels achieves the desired objective of emission reduction without having any adverse distributional effects, thus making a strong case for transport fuel taxation.

The issue of taxing cooking and lighting fuel is a little more complex and it is difficult to make an unqualified recommendation for a tax. Contrary to popular perception, studies by Gundimeda and Kohlin (2006) show that elasticities of cooking and lighting fuels are not low for all sections of the society. According to their study, the elasticity of gas is close to unity for almost all sections of the society, ranging from -0.92 for the urban rich to-1.05 for the urban poor. However, gas is a cleaner fuel compared to its counterparts and thus the case for a gas tax (or equivalently, the case for a removal of gas subsidy) is not strong in spite of the fact that such a tax is progressive. The case for a gas tax becomes reasonable only when the government can couple it with incentives for using electricity for cooking purpose. At present, use of electricity for cooking purposes is rare and thus the case for a gas tax is not strong.

In India, kerosene is an important cooking and lighting fuel. While urban household use kerosene as a cooking fuel, rural households use it for lighting purposes. The demand for kerosene is responsive to prices especially in the rural sector. It ranges from -0.7 for the rural rich to -0.5 for he middle expenditure group. As a lighting source, kerosene is of poorer quality and is more expensive than electricity (Barnes, Plas and Floor, 1997). The results from this paper show that a tax on kerosene is regressive for both the sectors and a major reason for the observed regressivity in rural sector is that 35% of rural households use kerosene primarily to light their homes. Besides regressivity, a tax on kerosene has other aspects of concern. Any tax on kerosene causes the poor to substitute towards fuelwood, which has strong adverse health implications and can also lead to deforestation. According to Gundimeda and Kohlin (2006), a percent increase in kerosene price increases fuel wood use by 0.7 percent increase in fuelwood use for the rural poor and 0.4 percent for the urban poor. Thus, any tax proposal should be preceded by compensatory proposals for the poor. This can take the form of targeted electricity and LPG subsidy for the poor and should be coupled by a programme of rural electrification. The targeted gas subsidy might also help in forest conservation as has been pointed out by Baland et. al (2006).

It has now been well documented that the emission scenario of most developing countries reflects a sad state of climate injustice. “Hiding behind the poor”-A report by Greenpeace India show ,when it comes to CO_2 emissions, a relatively small wealthy class of 1% of the population in India is hiding behind a huge proportion of 823 million poor people. They go on to show that it is India’s poor who keep per capita CO_2 emissions really low. Thus it is natural that a policy designed to tackle GHG emission should impose a larger burden on the rich. The evidence from this study shows that an environmental fuel tax does just that. The progressivity result is robust to the inclusion of indirect fuel consumption. Thus it a bit surprising that people speaking for the Indian underclass in the polity often come down heavily on any proposal of fuel price hike, on the grounds that it imposes higher burden on the poor. While this is true for kerosene, it is not true for any other fuel.

One of the limitations of this paper is that we don't allow for dynamics in the supply side. If the supply curve is elastic a part of the tax burden will be transferred to the producers. This will in turn lead to adjustment in the factor market. Further research is required to take an entirely general equilibrium view of the regressivity debate.

Appendix A: Procedure for aggregating the (115 X 115) matrix of 1998-1999 into a 47 X 47 matrix.

The aggregation of 115 sectors into 47 broad sectors follows the following pattern:

FINAL SECTORS	FINAL SECTOR NAMES	COMPONENT SECTORS NUMBER from CSO 's original table
#1	FOOD CROPS and their products	1,2,3,4,5,6,7
#2	OTHER CROPS	8,9,10,11,14,15,16,17
#3	TEA AND COFFEE	12,13,37
#4	MILK AND MILK PRODUCTS	18
#5	ANIMAL SERVICES (AGRICULTURAL)	19
#6	OTHER LIVESTOCK PRODUCTS	20,22
#7	FORESTRY AND LOGGING	21
8	COAL AND LIGNITE	23
9	CRUDE PETROLEUM, NATURAL GAS	24
10	IRON ORE	25
11	OTHER MINERALS	26,27,28,29,30,31,32
#12	SUGAR	33,34
#13	EDIBLE OIL	35,36
#14	MISC. FOOD PRODUCTS	38
#15	BEVERAGES	39
#16	TOBACCO PRODUCTS	40
#17	TEXTILES	41,42,43,44,45,46,47,48,49
#18	FURNITURE AND FIXTURES AND WOODEN GOODS.	50,51
#19	STATIONARY	52,53
#20	LEATHER AND RUBBER PRODUCTS	54,55,56
#21	MISC. MANUFACTURING	57,97,98.
#22	PETRO PRODUCTS	58
23	COAL TAR PRODUCTS	59
24	HEAVY CHEMICALS	60,61
25	OTHER CHEMICALS AND CHEMICAL GOODS and CEMENT	.62,63,64,67,68
#26	HEALTH	113,65
#27	TOILETRIES	66
28	NON METALIC MINERAL PRODUCTS	69,71.
29	CEMENT	70
#30	METAL PRODUCTS	72,73,74,75,76,77.
31	AGRICULTURAL MACHINERY	78
32	OTHER MACHINERY (MAINLY INDUSTRIAL)	79-83
#33	ELECTRICAL,ELECTRONIC MACHINERY AND APPLIANCES	84,85,86,87,88,89,90.
#34	(PERSONAL) TRANSPORT EQUIPMENT	91,92,93,94,95,96.
35	CONSTRUCTION	99
#36	ELECTRICITY	100
#37	GAS	101
#38	WATER SUPPLY	102

#39	TRANSPORT SERVICES	103,104
40	STORAGE WAREHOUSING	105
41	OTHER SERVICES AND COMMUNICATION.	114,106
42	TRADE	107
#43	HOTELS AND RESTURANTS	108
44	BANKS AND INSURANCE	109,110
45	OWNERSHIP OF DWELLINGS	111
#46	EDUCATION	112
47	PUBLIC ADMINISTRATION	115

NB. # denotes categories for which NSS has household consumption information. For other categories, household consumption is zero.

Now, let small letters denote component sectors from the original 115 sectors and capital letters denote the aggregated sectors from final (47 X 47) matrix.

Let X_{ij} denote flows from sector i to sector j.

Y_i denote final demand for sector i

X_i denote total output of sector i

Thus, $X_i = \sum_{j=1}^{115} X_{ij} + Y_i$ for all i=1(1)115……………………………………………………………. (A1)

Let X_{IJ} denote flows from sector I to sector J

Y_I denote final demand for sector I

X_I denote total output of sector I

Thus, $X_I = \sum_{J=1}^{47} X_{IJ} + Y_I$ for all I=1(1)47……………………………………………………………. (A2)

Where $X_{IJ} = \sum_{i \in I} \sum_{j \in J} X_{ij}$, $Y_I = \sum_{i \in I} Y_i$ and $X_I = \sum_{i \in I} X_i$

Define,

a_{ij} = value of commodity i required to produce 1 rupee worth of output j = X_{ij} / X_j

a_{IJ} = value of commodity I required to produce 1 rupee worth of output J = $X_{IJ} / X_J = (\sum_{i \in I} \sum_{j \in J} X_{ij})/(\sum_{j \in J} X_j)$

Define, the semi–aggregate coefficient

$$A_{in} = \sum_{i \in I} a_{in} = \sum_{i \in I} (X_{in} / X_{j})$$

Finally, $a_{IJ} = (\sum_{j \in J} X_{j} \times a_{Ij}) / X_{J}$

Thus, the aggregate coefficient is a weighted average of the semi aggregate coefficients belonging to its large industry of destination, where the weights are the proportion of the small disaggregated sector in the production of the aggregated sector.

Appendix B: Procedure for aggregating the (130 X 130) matrix of 2003-2004 into a 46 X 46 matrix.

The aggregation of 130sectors into 46 broad sectors follows the following pattern:

FINAL SECTORS	FINAL SECTOR NAMES	COMPONENT SECTORS NUMBER from CSO 's original table
#1	Major Food Crops and their products	1,2,3,4,5,6,7
#2	Other Crops	8,9,10,11,12,13,16,17,18,19,20
#3	Tea and Coffee	14,15,42
#4	Milk and Milk Products	21
5	Animal services (agricultural)	22
#6	other animal products	23,24,26
#7	Forestry and Logging	25
#8	Coal and Lignite	27
9	Crude Petroleum and natural gas	28,29
10	Iron Ore	30
11	Other Minerals	31,32,33,34,35,36,37
#12	Sugar	38,39
#13	Edible Oil	40,41
#14	Misc. Food Products	43
#15	Beverages	44
#16	Tobacco Products	45
#17	Textiles	46,47,48,49,50,51,52,53
#18	Furniture, Fixtures and Wooden Goods	55,56
#19	Stationary	57,58
#20	Leather and Rubber Products	59,60,61
#21	Misc. Manufacturing	62,101,102,103,104,100
#22	Petroleum Products	63
23	Coal tar products	64
24	Heavy chemicals	65,66
25	Other Chemical and Chemical Goods	67,68,69,72,73
#26	Health	70,122
#27	Toiletries	71
28	Non Metallic mineral Products	74,76
29	Cement	75
#30	Metal Products	77,78,79,80,81,82
31	Agricultural Machinery	83
32	Other Machinery(Mainly Industrial)	84,85,86,87
33	Electrical, Electronic Machines and Appliances	88,89,90,91,92,93,94
#34	Transport Equipment	95,96,97,98,99,100
35	Construction	106
#36	Electricity	107
#37	Water Supply	108
#38	Transport Services	109,110,111,112,113
39	Storage Warehousing	114
40	Other Services and Communication	115,123,124,125,126,127,128,129
41	Trade	116
#42	Hotels and Restaurants	117
43	Banks and Insurance	118,119

44	Ownership of Dwellings	120
#45	Education	121
46	Public Administration	130

NB. # denotes categories for which NSS has household consumption information. For other categories, household consumption is zero. Aggregation is done using the procedure discussed in Appendix A.

Appendix C: Sources of Elasticity Estimates

Coal	Estimates in cell (1, 1) and (1, 4) - (table 18) are obtained from Gupta and Kohlin (2006). None of the estimates are significantly different from zero. This Paper is bases on preferences of domestic fuel in the Indian city of Kolkata. The cross price elasticity between coal and petroleum products is assumed to be zero. The elasticity of coal with respect to coal price and income elasticity of coal is not available. We assume that this relationship will be similar to the relationship between firewood and gas prices and firewood and income, as both this fuels are generally used by users with similar profiles. We obtain these estimates from Gundimeda and Kohlin (2006).This paper has estimates separately for lower, middle and upper classes of rural and urban India. We use the simple average of these 6 estimates. The estimate in cell (1, 5) is obtained from using condition (7).
Petroleum Products	The estimates of own price elasticity and income elasticity are obtained from Geetha and Ramanathan (1998). Cells (2, 1), (2, 3) and (2, 4) is assumed to be zero. The estimate in cell (2, 5) is obtained using condition (7).
Gas	The elasticity of gas with respect to coal price is not available. We assume that this relationship will be similar to the relationship between gas and firewood prices .We obtain this estimates from the paper by Gundimeda and Kohlin (2006).We take the average of the six estimates. The own price elasticity ,cross price elasticity with respect to kerosene and income elasticity of gas is also obtained from Gundimeda and Kohlin (2006).Gas is assumed to be inelastic with respect to petroleum prices. estimate in Cell(3,5) is obtained using condition (7)
Kerosene	All estimates other than those in cell (4, 2) and (4,5) are obtained from Gundimeda and Kohlin (2006).for first cell of this row ,we assume that this relationship will be similar to the relationship between kerosene and firewood prices. Kerosene is assumed to be inelastic with respect to petroleum prices. estimate in Cell(4,5) is obtained using condition (7)
Others	Estimates in these five cells are obtained using the Cournot Aggregation Rule. The budget shares used in the Cournot Aggregation conditions are the weighted average of individual budget shares. The vales obtained are 0.05, 0.89, 1.34, 1.65 and 96.03 percent for coal, petroleum, gas, kerosene and non fuels respectively.

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