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Energy Intensity and Structural Change in Indian Industries: a Decomposition Analysis

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Energy planning interventions is often made using integrated approaches that consider both the provision of energy supplies and the role of energy efficiency in reducing demands. This has two aspects – first is, supply-side energy efficiency i.e. efficiency in energy extraction, conversion, transportation, and distribution and second one, being end-use (or demand side) energy efficiency i.e. more efficient use of final energy in industry, services, agriculture, households, transportation, and other areas. Supply – side efficiency has been the focus of energy investment and research and development but not much work and research has been done on end-use energy efficiency.

Trends in energy intensity indicators increasingly serve not just as a monitoring tool, but as a basis for energy efficiency policies and regulations aimed at achieving greater energy conservation. Consequently, many believe that measuring changes in energy intensity can provide both international and national policy-makers with the information needed to design appropriate policies to improve energy efficiencies and also design greenhouse gas mitigation strategies.

The results of the study show that Indian industries have become more energy efficient over the years especially post 1992-93, which also coincides with the liberalisation policy turnaround of the government. This validates India's stand that the growth of the country is not as energy intensive as is made out by the western world.

Keywords: energy planning, energy efficiency, the use of energy products, energy monitoring.

Introduction

Energy policy has traditionally underestimated the benefits of end-use efficiency for society, the environment and employment. Achievable levels of economic efficiency depend on a country's stage of industrialization, motorization, electrification, human capital and policies. But the pace of realization can be slowed by sector and technology specific obstacles – including lack of knowledge, legal and administrative obstacles, and the market power of energy industries. Government and companies should recognize innovations that can remove or minimize these obstacles. The external costs of energy use can be covered by energy taxes, environmental legislation, and green house gas emissions trading. There is also an important role for international harmonization of regulations for efficiency of traded products. Rapid growth in demand provides especially favourable conditions

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for innovations in developing countries – enabling these countries to leapfrog stages of development if market reforms are also in place.

Dematerialization further reduces the use of energy in the countries, but much also depends on the level of industrialization and income of those countries. Dematerialization means covering the absolute or relative reduction in the quantity of material used to produce a unit of economic output. In its relative definition of tonnes or volumes of material used per unit of GDP, dematerialization has occurred over several decades in many countries. This shift has contributed to structural changes in industry-particularly in energy-intensive areas such as chemicals and construction materials.

A number of forces that drive dematerialization are:

- As incomes rise, consumer preferences shift towards services with lower ratios of material content to price.
- As economies mature, there is less demand for new infrastructure (buildings, bridges, roads, railways, factories), reducing the need for steel, cement, non-ferrous metals, and other basic materials.
- Material use is more efficient-as with thinner car sheets, thinner tin cans, and lighter paper for print media.
- Cheaper, lighter, more durable, and sometimes more desirable materials are substituted-as with the substitution of plastics for metal and glass, and fibre optics for copper.
- Recycling of energy-intensive materials (steel, aluminium, glass, paper, plastics, asphalt) contributes to less energy-intensive production. Recycling may be supported by environmental regulation and taxes.
- Reuse of products, longer lifetimes of products, and intensified use decrease new material requirements per unit of service.
- Countries with high energy imports and energy prices tend to decrease their domestic production of bulk materials, whereas resource-rich countries try to integrate the first and second production steps of bulk materials into their domestic industries. However this case is more evident in industrialized countries.

But most developing countries, like India, are also experiencing some of the drivers of increased material use per capita. Increasing urbanisation, mobility, and per capita incomes increase the demand for material-intensive infrastructure, buildings, and products. Smaller households, the increasing importance of suburban communities and shopping centres, and second homes create additional mobility (Kundu 2001). The move from repair to replacement of products and trends towards throwaway products and packaging work against higher material efficiencies and hence, against energy efficiency and sustainable development.

In many developing countries energy use is driven by industrialisation, urbanisation, increasing road transportation, and increasing personal incomes. Wide income disparities in many developing countries are also reflected in energy consumption patterns. Often a small portion of the population accounts for most commercial energy demand.

When disposable income increases, energy consumption by house-holds in developing countries, like India, shifts from traditional to commercial fuels. This trend has significant implications for energy efficiency in households. Since the technical efficiencies of cooking appliances using commercial fuels are higher than those of biomass, composite energy consumption per household tends to fall. A typical example is the move from a fuel wood stove with a technical efficiency of 12-18 percent to a kerosene stove with an efficiency of 48 percent, or to a liquefied petroleum gas stove with an efficiency of 60 percent. On the other hand, the substitution of commercial for traditional fuels raises ratios of commercial energy to GDP, because traditional energy is typically not included when such ratios are calculated. In addition, electrification in rural areas and increasing income and mobility in urbanising areas increase energy use. Developing countries also suffer due to the use of obsolete and energy inefficient technology which further spark the increase in energy usage.

End Use efficiency: Major Issues

As the present work focuses on demand-side or end-use energy efficiency hence it is pertinent to discuss some of the aspects related to it in detail.

Quantitatively assessing the factors that contribute to changes in energy consumption has been important for understanding past trends in energy use, measuring the performance of energy-related policies, forecasting future energy demand and improving the overall efficiency of energy use (Park 1992; Farla et al. 1996). Literature on the subject reveals that three main factors determine the level of energy consumption in an economy: the level of overall activity or production, the composition or structure of the economy, and the output or activity per unit of energy consumed. This last component is referred to as energy efficiency, and improvements in it occur when the level of service / activity / output are enhanced for a given amount of energy inputs.

The term energy intensity is often used interchangeably with the term energy efficiency. Energy intensity refers to the energy used per unit of output or activity. Total energy consumed in a sector, for example, is a product of energy intensity per unit of output and the total amount of output provided. When output is measured in physical units, an estimate of physical energy intensity is obtained (e.g., TJ / tonne). Economic energy intensity, on the other hand, is calculated using money value of output measures (e.g., TJ / Gross Domestic Product in Rs.). Energy intensity is the most commonly used basis for assessing trends in energy efficiency since a truly technical definition of energy efficiency can only be obtained through measurements at the level of a particular process or plant. Energy intensity is thought to be inversely related to efficiency, the less energy required to produce a unit of output or service, the greater the efficiency. A logical conclusion, then, is that declining energy intensities over time may be indicators of improvements in energy efficiencies.

For the last decade, indicators that reflect changes in energy intensity have been used to monitor efficiency progress and identify market trends and efficiency improvement opportunities. Governments routinely produce documents displaying trends in these indicators, and cross-country comparisons of energy intensity abound in energy policy literature. Trends in energy intensity indicators increasingly serve not just as a monitoring tool, but as a basis for energy efficiency policies and regulations aimed at achieving greater energy conservation.

Before the mid-eighties, however, policy-makers were primarily concerned with the effect of shifting energy consumption on economic growth. As a result, energy policies were often coupled with economic policies that were typically implemented to boost a nation’s economic performance. Although the maintenance of economic growth is still a priority for governments, the policy focus has shifted to capitalizing on the environmental benefits associated with more efficient energy use rather than just the economic benefits of conservation (Golove and Schipper 1997; Bosseboeuf et al. 1997). The current international debate on greenhouse gas emissions (GHGs) and their role in stimulating global climate change is concerned, in part, with how efficiently various countries use energy. This is because using fossil fuels (such as coal and oil) to create energy is directly related to the level of carbon dioxide emissions (CO2, the major greenhouse gas) in the atmosphere. The more fossil fuels are burned, the greater the level of CO2 emissions. The amount of energy consumed by a country that uses fossil fuels, and the efficiency of that energy use, therefore, are two of the major factors determining a country's overall level of CO2 emissions (Schipper et al. 1997). In other words, policy-makers are growing increasingly concerned with the physical rather than economic repercussions of energy use.

Consequently, many believe that measuring changes in energy intensity can provide both international and national policy-makers with the information needed to design appropriate policies to improve energy efficiencies and also design greenhouse gas mitigation strategies. Through the use of energy intensity indicators, governments may be able to identify which industries need to be targeted for mitigation strategies. Indeed, a special issue of the journal Energy Policy was devoted entirely to studies which examined the use of energy intensity and their implications for energy efficiency.

Despite increasing support for the use of energy intensity indicators as a basis for policy-making, numerous uncertainties and disagreements continue to surround the development, interpretation and application of these indicators. Thorny issues related to the development of the indicators tend to be methodological in nature. Specifically, disagreements exist as to the best method for constructing both physical and economic intensity indicators. Issues regarding the interpretation of trends depicted by the indicators also exist, since physical and economic energy intensity indicators sometimes show different trends. Lastly, uncertainties surround the application of these indicators. Are intensity indicators appropriate for all types of energy analyses? Are all types of indicators equally useful to policy-makers in terms of the information they provide? Until the issues associated with the development, interpretation and application of these indicators are formally addressed, their potential to act as policy-making tools will remain limited.

Methodology

Let E_0 and E_t denote the total energy consumption in all the sectors[1]in year 0 and t respectively. In the energy consumption approach the change in energy consumption between the two years, $(\Delta E_{tot})_{0,t}=E_t - E_0$ is split into the following components[2]:

$$(\Delta E_{tot})_{0,t}= (\Delta E_{pdn})_{0,t}+ (\Delta E_{str})_{0,t}+ + (\Delta E_{int})_{0,t}+ (\Delta E_{rsd})_{0,t} \quad (1)$$

Now, if

E = total industrial energy consumption in all the concerned sectors

E_i = energy consumption in the sector i

Y = total production of all the concerned sectors

Y_i = production of sector i

$S_i = Y_i/Y$ (production share of sector i)

$I = E/Y$ (aggregate energy intensity)

$I_i = E_i/Y_i$ (energy intensity of sector i)

Then the different effects are as follows:

$$(\Delta E_{pdn})_{0,t} = 0.5(E_0 + E_t)\ln(Y_t / Y_0) \quad (2)$$

$$(\Delta E_{str})_{0,t} = 0.5\sum(E_{i,0} + E_{i,t}) \ln(S_{i,t} / S_{i,0}) \quad (3)$$

$$(\Delta E_{int})_{0,t} = 0.5\sum(E_{i,0} + E_{i,t}) \ln(I_{i,t} / I_{i,0}) \quad (4)$$

where 0 and t are two time periods.

Results

The Indian industry shows an overall reduction in energy intensity ***(E/Y)*** after 1987-88. The break-up reveals that similar trend is evident in most of the subsectors, however beverages and wood show a reverse trend.

As far as structure of industry ***(Y_i/Y)*** is concern most of the subsectors remain same excepting food products, basic chemical and rubber, plastic & petrol have shown an increasing trend, and beverages basic metal, paper& print and others have shown a decreasing trend. Invariably most of the subsectors have been able to become energy efficient post 1990-91.

Those industries which are traditional have not been able to reduce the energy intensity however their share in the structural composition is getting reduced. Leather is an exception to this fact as in spite of becoming more energy intensive over the years it has been able to increase its sectoral share. Similarly metal products sector has become more energy intensive yet it has been able to maintain its sectoral share.

The story of basic metals has been just the reverse of leather, as it has become more energy efficient over the years yet its share has reduced in the overall composition. The figures of energy intensity and structural change respectively are given as under one after the other.

The change in energy consumption due to scale of production effect follows the trend of total consumption however the scale production effect becomes more than the total effect post 1993-94. As the change in total energy consumption is sum total of all the effects [eqn (1)] hence this can be explained, as the change in energy consumption due to structural effect and residual have remained very less as compared other effects however the change in energy consumption due to intensity effect has shown a downward trend and becomes negative after 1993-94. This interesting aspect means that overall Indian industry is becoming more energy efficient after 1991-92, as intensity effect is declining and in fact becomes negative after 1993-94.

To further enquire into the aspect the intensity effect for all the subsectors is seen. The intensity effect has shown a negative trend and

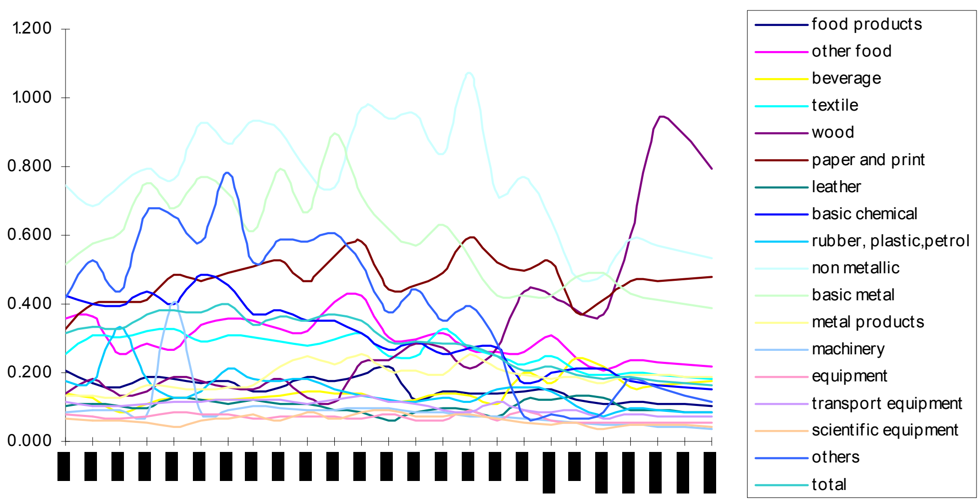

Fig. 1. Energy Intensity in Different Sectors

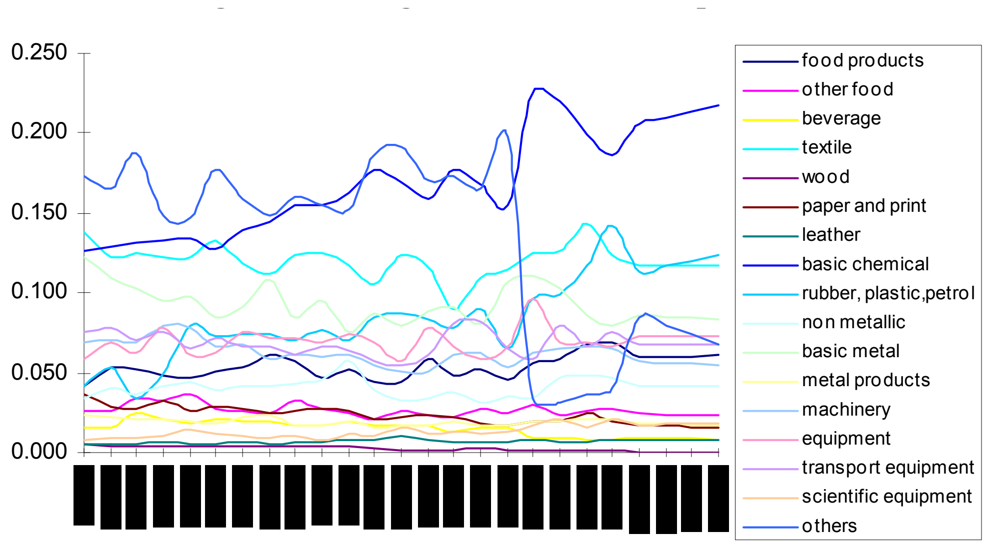

Fig. 2. Change in Structural Composition

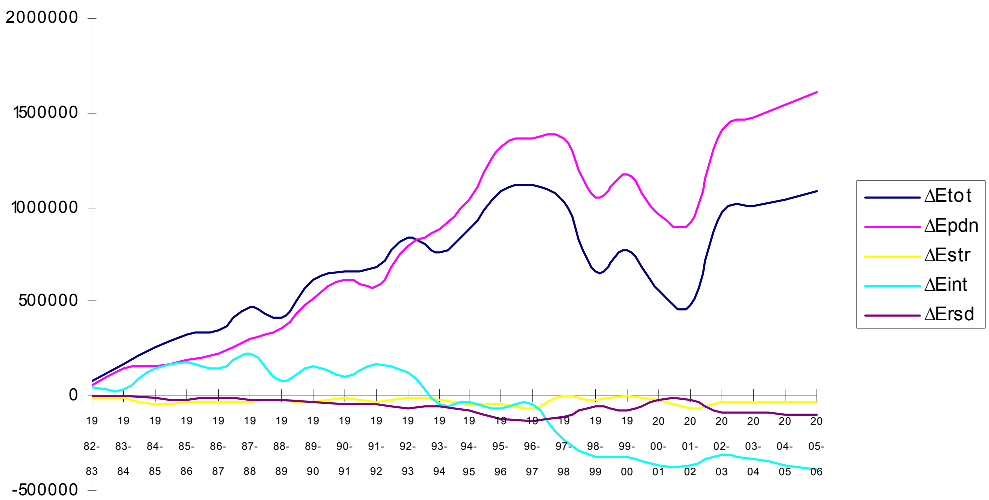

Fig. 3. Change in Energy Consumption based on Equation (1)

has become negative in absolute terms for all the subsectors excepting wood, beverages, paper & print, leather and metal products. Even in case of paper & print and metal products the decline is visible after 1997-98.

The change in energy consumption due to structural effect which as was mentioned earlier is less as compared to other effects however is negative for most of the years. This means that the sectoral shift in the composition of industry is assisting in reducing the energy consumption per unit. At the subsectoral level food-products, leather, basic chemical, rubber plastic & petrol and scientific equipments have shown an upward trend. The other subsectors have either declined sharply or have remained negative there by compensating the effects of these. The subsectoral graph (figure 8.12) shows that there has been tremendous volatility as far as the structural effect is concern, this is because of the quick changes that occur in the sectoral share post liberalization moreover the change in energy consumption *vis-à-vis* base period by these subsectors has been fluctuating.

Conclusions

Energy intensities can serve as proxies for energy efficiency levels provided that factors not related to efficiency have been removed such as structural and production effects. The decomposition analysis fits the bill in this case as through this; one can isolate structure and pure intensity effects. Pure intensity is only a good measure of energy efficiency if the aggregate intensity from which it was derived was calculated using detailed and disaggregated data.

The overall improvement in energy efficiency and change in sectoral composition can be attributed to better utilization of inputs in most of the sectors of which energy is a major component to remain competitive in the market especially after liberalization. The other reason can be due to the proliferation of improved technology in these subsectors.

This however makes one thing clear that Indian industries have over the years have become extremely energy efficient and have bolstered the Indian case in the global energy and climate change discussions.

[1] Here sectors mean all the sectors given in ASI data at two digit level.

[2] See B.W. Ang and S.Y. Lee (1994), *'Decomposition of industrial energy consumption: Some methodological and application issues', 'Energy Economics'*, vol. 16, No. 2, p. 83-92; for detail on this type of analysis.

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Энергоемкость и структурные изменения в промышленности Индии: анализ распада

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При планировании энергопотребления часто применяют интегрированный подход, учитывающий как обеспечение энергоресурсами, так и энергоэффективность при снижении потребления. При этом энергоэффективность рассматривается с учетом двух аспектов: во-первых, с учетом энергоснабжения, т.е. эффективности добычи, преобразования, транспортировки и распределения энергии, во- вторых, с учетом конечного потребления (или энергоэффективность с учетом спроса), т.е. более эффективное использование конечного энергетического продукта в промышленности, сфере услуг, сельском хозяйстве, жилищно-коммунальном хозяйстве, транспортной и других отраслях. При планировании энергетических затрат основное внимание уделяется энергоэффективности с учетом энергоснабжения, в то время как энергоэффективность с учетом конечного потребления исследована недостаточно.

Индикаторы изменения энергоёмкости все чаще служат не только инструментом мониторинга, но и основой для политики и регулирования энергоэффективности, направленных на сохранение бóльшего количества энергии. Следовательно, распространено мнение, что измерение изменений энергоёмкости предоставит как международным, так и национальным политикам информацию, необходимую для разработки соответствующей политики по улучшению энергоэффективности и составления стратегии по сокращению выброса газов, создающих парниковый эффект.

Результаты данного исследования показывают, что промышленность Индии стала более энергоэффективной в последние годы, особенно после 1992-93 гг., что также совпадает с обращением правительства к политике либерализации. Это подтверждает представление Индии о том, что развитие страны требует не такого интенсивного энергопотребления, как принято считать на Западе.

Ключевые слова: планирование энергопотребления, энергоэффективность, использование энергетического продукта, мониторинг энергопотребления.