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Management accounting approach to analyse energy related CO_2 emission: A variance analysis study of top 10 emitters of the world

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ABSTRACT

The paper undertakes a decomposition study of carbon dioxide emission of the top ten emitting countries over the period 1980–2007 using variance analysis method, with the objectives of examining the relative importance of the major determining factors, the role of energy structure and impact of liberalisation on emission and exploring the possibilities of arresting emission with simultaneous rise in population and income. The major findings indicate that although rising income and population are the main driving forces, they are neither necessary nor sufficient for increasing emission, rather energy structure and emission intensities are the crucial determinants, pointing towards the fact that a country with higher income and population with proper energy policy may be a low emitter and vice-versa. Since modern energy-intensive production limits the scope of reduction in total energy use, it is necessary to decouple the quantum of energy use from emission through technological upgradation. The results indicate that liberalisation resulted in higher emission. The paper attempts to illustrate the required adjustments in energy structure and suggests necessary policy prescriptions.

1. Introduction

Over the last few decades, the apprehensions regarding the impending global warming have heightened due to mounting emission of greenhouse gases, carbon dioxide (CO_2) being the foremost among them. "With the global economy set to quadruple by mid-century, energy related CO_2 emission would, on current trends, more than double, putting the world onto a potentially catastrophic trajectory" (World Development Report, 2010, pp. 189). Of late, there has been renewed interest to identify the forces that stimulate emission and search for appropriate measures for its mitigation.

The existing studies consider population and income alongwith technological factors to have crucial roles in emission. Bongaarts (1992), Dietz and Rosa (1994), Engleman (1998), O' Neill et al. (2001); Onozaki (2009) assert rising population to be a major driving force behind increasing CO_2 emission. Crowley (2000) precisely pointed out that about 3/4th of the global emission had been due to human influences. According to Dietz and Rosa (1997), the impact of population is roughly proportional to its size, while Shi (2001) finds it to be 1.28 times. Harte (2007) asserts that population growth has a disproportionately large effect on carbon emission as 'multiplier'. This view is substantiated by York (2007) who finds that a 1% growth in population increases energy consumption by 2.665%. However, different studies demonstrate that the impact is not uniform across the world. In the study of European Union (EU), Martínez-Zarzoso et al. (2006) find that the emission-population elasticity is lower than unity in case of the old members but it is 2.73 for the new members, while Shi (2003) finds the elasticity to be 1.58 and 0.83 in the developing and developed countries respectively.

However, a number of studies emphasise income level as the major determining factor of emission, although there exists considerable debate on their exact relationship. Hamilton and Turton (1999) and Shi (2001) associated rising income levels with a monotonically upward shift in emission; more precisely, Dinda (2004) pointed out that most of the earlier studies asserted the relationship to be largely unitary. On the contrary, the Environmental Kuznets Curve (EKC), demonstrated by an inverted U-shaped curve, postulates that as income rises, emission initially increases, reaches a maximum and finally declines. The rationales behind EKC are: first, in the initial phase of development, a hitherto unmechanised agrarian economy starts building up a very energy intensive industrial base, contributing hugely to emission. But with further development, attainment of a certain level of affluence leads to greater regulation of environmental pollutants and structural shift towards a less emission intensive economy. Secondly, an economically advanced country is more likely to value environmental quality,

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raise demand for environmental friendly goods and invest in energy efficiency (Dietz and Rosa, 1997 and Dinda, 2004). However, while the EKC hypothesis finds support in the empirical studies of Shafik and Bandyopadhyay (1992) and Grossman and Krueger (1995), the relationship does not hold strong in the studies of Shafik (1994) and Yandle et al. (2002).

Simon (1990) and Boserup (1998) pointed out to the crucial role of technology by showing that 1% increase in population may cause a lower than 1% increase in emission if population growth encourages technological innovation within a country and leads to the development of energy saving technologies. Development of various alternative and renewable energy sources can effectively reduce carbon emission. However, Brander (2007) notes that since most technological developments usually take place in information and communication technology and electronics, it might increase the energy efficiency but is unlikely to reduce the world emission. In fact, only few technological gains have been made in non-fossil fuel sources of energy like solar, wind and biomass, with the exception of nuclear power, which only makes up a relatively small percentage of total energy production. The role of technology in curbing emission is substantially undermined by Jiang and Hardee (2011) who assert that technological advances are likely to exacerbate emission, since they create new products that require more energy.

Ehrlich and Holdren (1972) were the first to argue that emission is determined collectively by population, income and technology. In the IPAT model, they suggested that the environmental impact (I) is the product of population (P), their affluence (A) and the implemented technology (T). The approach has been widely applied in a number of decomposition studies (Bruvoll and Medin, 2003; Lise, 2005). Decomposition analysis typically decouples emission into scale, composition and technological effects. While the scale effects are measured by changes in income and population, the composition effects capture the changes in the input or output mix, and the energy and emission intensities proxy the technological effects.

The alternative methods used in decomposition studies are regression method (Dietz and Rosa, 1997; Shi, 2001; Martínez-Zarzoso et al., 2006) and indexing method, of which log mean divisia index (LMDI) method developed by Ang (2005) is the most preferred and widely used one (Löfgren and Muller, 2008; World Bank, 2007; Pani and Mukhopadhyay, 2010). However, there exist different views regarding the selection of decomposition approach.

Zhou and Ang (2008) argue that although regression analysis is a superior approach since it can be used to investigate any well-defined factors associated with the change in one variable, it is not residual free. There are possibilities of interdependence among the explanatory variables (Gans and Jöst, 2005) that make the estimation procedure difficult. Although the interdependence can be captured by interaction terms, and the presence of multicollinearity can be dealt with by methods like dropping of variables, transformations of the variables and factor analysis, etc. to name a few, these methods are not without problems: interaction terms or dropping of variables may lead to specification error; transformation of the variables results in loss of degrees of freedom and the disturbance terms of the transformed model may suffer from autocorrelation or heteroscedasticity. Moreover, these remedies do not always guarantee that the problem has been solved (Farrar and Glauber, 1967).

On the other hand, Ang and Liu (2001) and Ang (2005) assert that the LMDI method has several advantages over other decomposition methods: it gives perfect decomposition, with almost no unexplained residual term; the results possess additive property in the sense that the change in total emission can be expressed as the sum of changes in emission due to its driving factors; there exists a simple relation between the multiplicative and additive decomposition so that separate decomposition using additive and multiplicative schemes are not required; LMDI is consistent in aggregation in the sense that estimates of an effect at the subgroup level can be aggregated to give the corresponding effect at the group level. However, Ang (2005) pointed out that the LMDI approach fails to deal with negative and zero values in the data set. In emission studies, negative values seldom occur; a more likely situation is the occurrence of zero values. Ang et al. (1998) have suggested for substitution of the zeroes by small positive constants; however, Wood and Lenzen (2006) argue that replacements of large number of zeroes may produce significant errors.

Pani and Mukhopadhyay (2011) introduced the management accounting variance analysis decomposition model as an alternative to the LMDI approach. The starting point of the model is the IPAT based (Kaya 1990) identity, where emission is expressed as the product of its identified driving forces. In management accounting, where total revenue/cost is expressed as a product of price/cost per unit and the total quantity of sale/production respectively, the variance analysis technique is used to measure the change in total revenue/cost attributable to change in factors (price/cost per unit or the quantities). This method has been applied by Pani and Mukhopadhyay (2011) in identifying the responsibilities of each of the driving factors in changing the level of emission. The method is very simple to comprehend and does not require much advanced mathematical or econometric knowledge; nonetheless, it possesses all the advantages of LMDI and can also deal with zero or negative values (Pani and Mukhopadhyay, 2011).

The previous studies on decomposition have emphasised on the relative roles of population, GDP, emission and energy intensities in aggregate, and in some cases, with sectoral breakups of production, consumption and import–export patterns (Wu et al., 2007; Kojima and Bacon, 2009; Löfgren and Muller, 2010; Yunfeng and Laike, 2010). The studies on sectoral breakups argue that downsizing the more polluting sectors and shifting towards less polluting ones could be a means to reduce emission in a particular country. The sectoral shift of a country not only provides opportunity to reduce its relative energy consumption, but also to extend its choice towards less polluting energy source. For example, a country downsizing its heavy industries that require coal and petroleum as the main sources of energy, may expand its service sector like information and communication sector requiring less energy only in the form of electricity, which may be generated even from clean sources like solar, wind, etc.

Therefore, as a strategy for emission cut, a particular country might opt for sectoral shifts towards services and downsize its polluting production sector by framing strict environmental laws including different kinds of penalties. However this is possible and viable only if the production sector flourishes in some other countries. This is because the service sector is just an ancillary sector that cannot be sustained without the production sector. In fact, production of goods and services complement each other. All goods and services have given demand, which are increasing in the face of rising population and consumption. As a result, each production sector (even the polluting ones) has an economic prospect. This implies that downsizing of a polluting industry in a country leads to its expansion in some other countries in order to meet the growing demand for its product. This phenomenon finds support in the ‘pollution haven hypothesis’ (PHH) and ‘dirty industry migration’ (DIM) theory that argue that when a pollution intensive or ‘dirty’ industry faces restrictions and is forced to downsize in a country (mainly developed) due to stringent environmental regulations, it opts to migrate to countries (mainly developing) that in the pursuit of economic development are even