Working Paper
388

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September 2007

Working Papers published since August 1997 (WP 279 onwards)
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The author is specifically thankful to Dr. U. S. Mishra, Associate Professor at CDS for his valuable suggestions and acknowledges for the inputs received from an open seminar at CDS and the financial support received from CDS for presenting the work, and for comments from the anonymous referee.

ABSTRACT

The paper examines whether energy use drives economic growth or vice versa in the Indian context during the period 1970-71 to 2004-05. Utilizing the Granger causality test, the study suggests that it is the economic growth that fuels more demand for both crude oil and electricity consumption and it is the only growth of coal consumption that drives economic growth. When influence of different components of energy on major two components of economic growth is investigated with the same causality test, none of the energy components found to be significantly influencing the two components of economic growth viz. private consumption and private investment. In contrast, the out of sample forecasts in the variance decomposition analysis of Vector Autoregression (VAR) suggests that there could be a bi-directional influence between electricity consumption and economic growth, other results remaining unchanged. Therefore, the study yields mixed and contradictory result as compared to the previous studies in the Indian context. However, on the basis of application of two econometric tools, the study with little more conviction could suggest for reducing crude oil and natural gas consumption at least in the consumption sectors which don't directly contribute to production or add to the capital formation of the economy, for achieving higher rate of growth in the economy.

Keywords: Energy Consumption, Economic Growth, Granger Causality, VAR & India

JEL Classifications: C32, E21, O11, Q43

The relationship between use of energy and economic growth has been a subject of greater inquiry as energy is considered to be one of the important driving forces of economic growth in all economies (Pokharel, 2006). In recent years, most of the non-oil producing economies are facing energy deficiency, as the oil producing economies are unable to meet up the world demand for oil. The supply constraint of energy could be attributed to the frequent geo-political tensions between the nations or natural physical supply constraints in the oil extracting regions[1]. The increasing world demand for oil,[2] leads to frequent escalation in the world oil prices.[3] Like shortage of oil, there exists shortage of electricity and other forms of energies viz. natural gas.[4] The shortage can

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1 Resource depletion often increases the quantity of human-made capital required to extract a unit of natural resource. These costs have been generally ignored in growth models (see Dorfman's (1982) critique of Dasgupta (1982).

2 The *IEO 2006* reference case projects increased world consumption of marketed energy from all sources over the next two and one-half decades. Worldwide oil consumption rises from 80 million barrels per day in 2003 to 98 million barrels per day in 2015 and then to 118 million barrels per day in 2030. Worldwide, transportation and industry are the major growth sectors for oil demand (IEO, 2006).

3 The SPECA countries, Azerbaijan, Kazakhstan and Turkmenistan and to some extent Uzbekistan, are reaping rich dividends from recent global trends in energy prices, marked by unprecedented price escalation. Given the growing demand for it, this trend in dividends is expected to continue in the future, thus assuring the oil-exporting countries continued prosperity.

4 The shortage of electricity arises due to greater share of hydro-electricity and insufficiency of water resource. As a result alternative generation of electricity in terms of thermal and nuclear is getting introduced to keep up with the ever-growing demand for energies.

significantly affect the consumption and production in the economy. One or the other forms of energy becomes vital to all the sectors of the economy viz. agriculture, industry and services. This energy dependence being common to every sector of the economy justifies the association between energy utilization and the overall economic growth rate in an economy. Hence, any deficiency in supply of oil, natural gas and electricity generations can directly constrain the economic activities, thereby inhibiting the growth rate. The declining supply of these sources of energy not only raises the input prices[5] but also influences the prices of other commodities leading to a rise in overall inflation rate and thereby dampening the aggregate demand and growth rate.

It needs to be noted that India domestically meets up 30 percent of its crude oil requirement and the rest is being imported from the oil producing nations[6]. In India, the transport sector is the principal consumer of petrol and diesel, followed by big and small industrial units. Similarly, electricity consumption share too is the largest by this sector (as shown in Appendix Table 1). India in the past had experienced a huge import bill on account of an increase in the price of crude oils. The inelastic oil demand and rising oil import bill had put pressure on the scarce foreign exchange resources and had also been largely responsible for shortages in energy supply. In the first oil embargo, India's import bill rose beyond 50 per cent, while the adverse impact of 1990-91 Gulf War caused a huge balance of payment deficit and pushed up the inflation rate to an all-time high of 13 per cent. These economic uncertainties had deterred the pace of growth of India (Ghosh, 2006).[7]

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5 Two years ago the international price of oil was just over USD 30 per barrel but today it is close to USD 75 per barrel (The Hindu, 15th August 2006).

6 India's dependence on imported energy has increased from a level of 18% of the total primary commercial energy supply (TPCES) in 1991 to 30% in 2003 (The Business Line, Nov 22, 2006).

7 It is only for the first time that India's net export in petroleum products had reached to a positive figure of Rs.10.36 billion in 2001-02 (Basic Statistics, Ministry of Petroleum & Natural Gas, GOI).

As regard to the relative consumption of various sources of energy as percent of the world total, India among the emerging Asian economies, occupies third place following China and Japan (as shown in Appendix Table 3). This raises the question whether India's energy consumption levels commensurate with levels of economic growth similar to other high as well as low energy consuming nations of the Asian region. In this context, this paper attempts to explore the possible impact of various forms of energy consumption on economic growth rate, which has not been examined in India. The prime motivation of the study relates to addressing the puzzle of the increasing levels of energy consumption to induce economic growth in the event of the increasing cost associated with it as well as the apprehensions regarding its sustained supply in future. Therefore, the study undertakes an empirical analysis, towards verifying this nexus of energy consumption and economic growth and suggesting policies that strikes a balance between consumption and conservation of energy in sustaining and speeding up the growth momentum of the economy.

THEORETICAL CONSIDERATION

The standard economic theory while recognizes labour and capital as two important inputs into the production process, does not treat energy *per se* as a factor of production. Energy is treated, instead, as an intermediate[8] product of labor and capital. The argument for or against this complex notion is not central to our present discussion. What is central is that, if energy is not a primary input to the economy, it follows that the availability of energy[9], and the price of energy, are not critical to economic activity or growth. From the neoclassical perspective, it could be argued that raising the price of energy by even a factor of two would only reduce the GDP by a negligible amount. The established theory assumes that growth is mostly attributable to the technological progress, which is assumed to be exogenous and automatic. The increase in the state of technical knowledge raises the return to capital, thereby offsetting the diminishing return to capital. However, Okun (1974, 1975), on the neoclassical line of thinking, argued that energy as compared to other production inputs, constitutes only relatively 'a small cost share' in total output. This being the case, energy price changes would have relatively a small impact on the economy. Others have also supported this view. Perry (1975, 1977) further suggested that it is hard to believe that high-energy prices can affect productivity and output growth, since it is only one of the many production components. This also supports to the belief that the increase in price of energy would substitute labour for capital without affecting production and growth (Ebohon, 1996). Bemdt and Wood (1975) argued that while energy and labour may be substitutable,[10]

8 Intermediate inputs are those created during the production period under consideration and are used up entirely in production, while primary factors of production are inputs that exist at the beginning of the period under consideration and are not directly used up in production (though they can be degraded and added to). Mainstream economists usually think, of capital, labor, and land as the primary factors of production, while goods such fuels and materials are intermediate inputs (Stern & Cleveland, 2004).

9 The primary energy inputs are stock resources such as oil deposits. Therefore, the quantity of energy available to the economy in any period is endogenous, though restricted by biophysical constraints such as the pressure in oil reservoirs and economic constraints such as the amount of installed extraction, refining, and generating capacity, and the possible speeds and efficiencies with which these processes can proceed. In some biophysical economic models geological constraints fix the rate of energy extraction. On the other hand, capital and labor are treated as flows of capital consumption and labour services rather than as stocks. These flows are computed in terms of the embodied energy use associated with them and the entire value added in the economy is regarded as the rent accruing to the energy used in the economy. Prices of commodities should then be determined by embodied energy cost - a normative energy theory of value or are actually correlated with energy cost - a positive energy theory of value (Stern & Cleveland, 2004). However, the ecological economists also argue that the energy required to produce fuels and other intermediate resources increases as the quality of resources such as oil reservoirs declines over time.

10 The most renowned debate relating to the substitutability and complementarity between natural capital and human capital are those between Herman Daly, Robert Solow, and Joseph Stiglitz. Daly (1979; 1997a) criticizes the growth models of Solow (1974) and Stiglitz (1979) because the production functions they use assume perfect substitutability of manufactured capital for natural capital. Daly argues that the two forms of capital largely are complements because human capital ultimately is derived from and sustained by energy, materials, and ecological services. Similar arguments have been made by other ecological economists (Ayres and Nair, 1984; Costanza and Daly, 1992; Cleveland and Ruth, 1997; Gutas, 1996; Stern, 1997, Victor et al., 1995).

the complementary relationship between energy and capital raises its importance far more than its cost share. Implicitly, the dynamic impact of this relationship for output and productivity underlines the important influence that energy has on economic growth.[11] Okun (1974, 1975) evidenced that energy and labour, on the one hand and capital and labour on the other, are substitutable. Thus, it is possible to compensate for an energy-induced decline in national income by substituting labour or capital. However, there is no unanimous agreement on the relationship between energy and capital.[12]

Contrary to the notion of Neo-classical perspective, which demonstrates that energy plays an insignificant role in the development process of an economy, however, the magnitude of energy's influence

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11 The economic significance of a fuel is its marginal product. This is to say the amount of economic value generated by a heat unit. The results of Kaufmann's (1994) econometric model indicates that the marginal product of fuels in the U.S. economy varies over time, but that there is a consistent ranking of fuel quality: primary electricity is the highest quality, followed by oil, gas, and coal. Energy quality plays a dominant role in determining the quantity of energy a society requires to produce wealth. Although the decline in energy/real GDP ratio in most industrial nations often is attributed to energy-saving technical change and substitutions caused by the energy price shocks, but a detailed empirical analyses indicate that much of the variation of the energy real/GDP ratio is due to shifts in the composition of fuel use, and this is due to the changes in the quality of fuel use (Cleveland, 2003). Substitution or technical change cannot reduce the amount of energy used to produce a unit of output. But characterizing that technical change has reduced the amount of energy used to produce one unit of output or characterizing the technical change as "energy saving" is misleading. Over the last forty years, technical change has reduced the amount of heat energy used to produce a unit of output by developing new techniques for using oil, natural gas, and primary electricity in place of coal. These technical innovations take advantage of the physical characteristics of these energies that allow oil, natural gas, and primary electricity to do more useful work per heat unit than coal. This interpretation implies that technical change is not something shaped solely by the mind of man but rather it is shaped in part by the physical attributes of energies available from the environment (Kaufmann, 1992).

12 Berndt and Wood (1975), Hudson and Jorgenson (1975) and Matsui *et al*, (1978) found that energy and capital to be complementary while Griffin (1979) found energy and capital substitutable (Ebohon, 1996).

on the economy has been hotly debated by macroeconomists. Consequently, efforts have been made on to discover the exact relationship between energy and other factors of production as to whether energy complements or substitutes other factors in production. Such knowledge would have significant bearing on energy policy formulation as already have been emphasized in most of the literature. The qualitative argument for introducing usefulness of these inputs as factors is that economic growth has always been a positive feedback cycle, in which lower cost leads to lower prices of goods and services which generates increased demand and through economies of scale, R & D and learning from experience, lowers the cost again. Efficiency gain in the economy as a result of energy consumption also leads to additional costs [13]. These costs would slow down the growth rate and make production less competitive. This is why the developed economies such as Canada and United States have greater reluctance to move forward on energy efficiency.[14]

Neoclassicals assume that the technological change[15] is endogenous and follows a stochastic path. The endogeneity is not needed

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13 Additional cost can arise due to negative externalities involved in using energy.

14 Energy efficiency usually refers to less use of energy per unit of output. Energy efficiency gain directly increases energy use by making energy appear effectively cheaper than other inputs and by stimulating economic growth, which further propels energy use. This has also other rebound effect. Gain in energy efficiency means reduction in price of certain consumer products. This spurs an increase in the demand for energy indirectly through released purchasing power redirected to energy-using goods and services. In contrast, production efficiency refers to using required energy with a view to improving production and cutting cost from other input sources.

15 According to this basic neoclassical growth theory, the only cause of continuing economic growth is technological progress. Intuitively, increases in the state of technological knowledge raise the rate of return to capital, thereby offsetting the diminishing returns to capital that would otherwise apply a brake to growth. The original models did not explain how improvements in technology come about. They are just assumed to happen exogenously, so that these models are said to have exogenous technological change. More recent models attempt to endogenize technological change - explaining technological progress within the growth model as the outcome of decisions taken by firms and individuals.

to explain past growth but one would be interested to allow the technology to follow a stochastic path. To model future technological change one needs to model the endogenous process. Such modeling also needs to take into account the technological change which cannot overcome the limits to substitution imposed by physical laws[16] and that there are decreasing returns to research effort. In this biophysical model of growth, increased energy use does not generate much economic growth unless accompanied by increased use of capital and labor. However, increasing capital and labor use without increasing energy use also results in little gain in output. Therefore, in our view, while energy is essential in production, increased energy use cannot have been the driver of economic growth. Instead, the inability to expand energy use would hold back or constrain the level of economic output. The innovations that increased energy supply at the beginning of the industrial revolution removed a constraint that prevented modern economic growth. Continuous smooth expansion of the energy supply and its rising quality has been essential to maintaining the growth path since then. The oil crises in the 1970s and early 1980s depict the story about what happens when there is a hiccup in this smooth expansion path. It could result in slowdown in economic growth.

The shifts in the mix of the other inputs, for instance from a more labour-intensive economy to a more capital-intensive economy can affect the relationship between energy and output and thereby, the energy consumption and economic growth (Stern and Cleveland, 2004). Studies have reached varying conclusions on whether capital and energy are complements or substitutes (Berndt and Wood, 1979; Apostolakis, 1990). Based on the differences in time series and cross-sectional results, Apostolakis (1990) concluded that capital and energy act more as substitutes in the long-run and more as complements in the short-run.

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16. There is a thermodynamic limit to substitution. Even there will be technological progress but there may be a diminishing return to scale without proportionate energy use.

There are evidences of complementarity where the cost share of energy is found to be small (Frondel and Schmidt , 2002).

The above theoretical discussion is based upon the relevant mainstream[17] and neoclassical theory of growth, biophysical theory, and resource economics models of growth[18], and the various mechanisms that can weaken and strengthen the links between energy and economic growth. Physical theory shows that energy is necessary for economic production and therefore, growth but the mainstream theory of economic growth, except for specialized resource economics models, downgrades the role of energy. In line with physical theory, the resources models of economic growth points out that along with the use of other resources, when the composition of energy use is more in favour of high quality energy, it leads to higher economic growth as the lower quality of energy may impede economic growth due to emission of CO2 and consequent large scale environmental degradation. The paper subsequently reviews some of the empirical literature that finds energy use per unit of economic output has been declined, but this is to a large extent due to a shift from poorer quality fuels such as coal to the use of higher quality fuels and especially to the electricity.[19] In contrasts, developing countries like

17 The mainstream growth theory focuses on institutional limits to growth. When mainstream economists address the technical limits to growth they tend not to take these possible constraints very seriously. The criticism of mainstream growth theory focuses on limits to substitution and limits to technological progress as ways of mitigating the scarcity of resources. If these two processes are limited then limited resources or excessive environmental impacts may restrict growth.

18 The resources models of economic growth points out that along with other resources in production when composition of energy use is more towards high quality energy, it leads to higher economic growth. But in long run the resource depletion and environmental degradation would adversely affect the economic growth rate. Besides, emission of co_2 may degrade human capital and thereby the productivity.

19 It is generally believed that electricity is the highest quality type of energy followed by natural gas, oil, coal, wood and biofuels in descending order of quality. This is supported by the typical prices of these fuels per unit of energy, which should be proportional to their marginal product. The general shift to higher quality fuels reduces the amount of energy required to produce a dollar’s worth of GDP.

India presents a different picture where either there is a decline or constancy in the various forms of energy consumption as a percentage of GDP and sometimes it is observed that they consume greater quantity of energy which is abundant in its supply in the domestic economy. The Appendix Table 4 shows that there is also a decline in electricity consumption as a percentage of GDP along with decline in other form of energy consumption. The decline in various forms of energy consumption is not associated with any compositional changes in the high quality of energy consumption. The decline in the ratio could be due to faster growth rate of GDP than the energy consumption, simultaneously with an absolute increase in various forms of energy consumption.

EMPIRICAL LITERATURE

Stern & Cleveland (2004) observed that in most of the studies energy and GNP growth cointegrate and that energy use does Granger cause GNP growth rather than GNP growth causing more energy consumption demand when additional variables such as energy prices or other production inputs were included. This limits the prospects for further large reductions in energy intensity. They observed that energy has a higher cost share in industrial sectors encouraging energy saving innovation in those sectors. Akarca and Long (1980), Yu and Hwang (1984), Yu and Choi (1985), Yu and Jin (1992) and Cheng (1995) found no causal relationship between total energy consumption and income for US. On the other hand, Kraft and Kraft (1978) and Abosedra and Baghestani (1989) detected a unidirectional causality from GNP growth to energy consumption. Similarly, Soytas and Sari (2003) investigated causality relationship between energy consumption and GDP in G7 along with nine other emerging markets and found that causality runs from GDP to energy consumption in Italy and Korea.

Hwang and Gum (1991) had evidenced a bi-directional causality for Taiwan, while Masih and Masih (1997) had found the same for both

Taiwan and Korea. Subsequently, Yang (2000) had also confirmed a bi-directional causality for Taiwan. Yu and Choi (1985) and Masih and Masih (1996) yielded contradictory results for Philippines. Yu and Choi (1985) using data from five countries, confirmed the absence of causality between GNP and total energy consumption for the US, UK and Poland but the causality from GNP to energy consumption was found for South Korea and the reverse for Philippines. While, Erol and Yu (1987) and Soytas and Sari's (2003) results were similar for Turkey, but a similar result for France, Germany and Japan were also found holding true in Soytas and Sari (2003) indicating a uni-directional causality from energy consumption to GDP growth. However, Erol and Yu (1987) found a bi-directional relation for Italy out of six industrialized countries studied. Mozumder and Marathe (2005) examined for Bangladesh and found that there is a unidirectional causality from per capita GDP to per capita electricity consumption. It indicates that the studies conducted in different countries context yielded different results. The differences in results may be due to the differences in the period of study considered, the structure and pattern of energy consumption and the statistical techniques applied.

Ebohon (1996) examined the casual linkage between energy consumption and economic growth for Nigeria and Tanzania. The results showed a simultaneous causal relationship between energy and economic growth for both the countries. The implications being unless energy supply constraints are eased, economic growth and development would remain elusive. Energy plays a key role in economic development. Horn (1999) observed that energy consumption per GDP unit and energy consumption per capita in relation to GDP per capita were extremely high for Ukraine, even in comparison to Russia and other transition countries. He attributed to the reasons of technical inefficiencies, structural factors (high share of basic industry) as well as the persistent economic crisis. Electricity consumption per capita in contrast nearly corresponded to the low average income in Ukraine. Their future projection for energy demand on the basis of certain assumption regarding the price elasticities, income elasticities and technological progress for each sector indicated that in contrast to the official projections the energy consumption in 2010 may be lower than in the base year 1995, even with a higher economic growth. They also projected that the use of renewable energy (wood, solar, wind, hydropower, etc.) would nearly double along with an increase in demand for oil and electricity consumption while there would be drop in coal and natural gas consumption during the projection period. In view of the slow growth prospect of overall energy demand the study suggested that it would not be necessary to expand coal production and electricity generation with nuclear energy in order to reduce energy imports. This conclusion would be strengthened if the government takes measures for improving the efficiency in energy use. The study also observed that energy efficiency in Ukraine today is far below than the western standards in all sectors, and a greater reduction of energy demand would be possible only by accelerating the replacement of old, inefficient appliances and facilities by new ones.

Aqeel and Butt (2001) investigated the causal relationship between energy consumption and economic growth in Pakistan. They pointed out that like other developing countries Pakistan is also an energy intensive growing economy, and as in most other non-oil producing countries its energy needs are also met by large quantities of imports. The annual consumption growth rate of net consumption of total energy is 6.4 per cent. The share of oil, gas and electricity is 48 per cent, 30 per cent and 15 per cent respectively. The share of imported oil was 92 per cent of net consumption of oil in 1995-1996, which is about 44 per cent of total net consumption of energy. Thus, to meet its growing needs of energy, Pakistan faces both energy constraints from the supply side and demand management policies. By applying cointegration and Hsiao's version of Granger causality, their study found that economic growth causes total energy consumption. When they disaggregated the energy consumption, it was found that economic growth leads to growth in petroleum consumption, and electricity consumption leads to economic growth without the presence of their feedback effect. There was no causality between economic growth and gas consumption. Therefore, the study suggested for adapting an energy growth policy in order to stimulate growth rate and employment in the country.

Employing vector error correction estimation method, Hondroyiannis, Lolos and Papapetrou (2002) examined the relationship between energy consumption and economic growth for Greece. The result showed that energy consumption is an endogenous variable affecting economic growth. In addition, economic efficiency reflected from price developments is a determining factor of both energy consumption and income behaviour. Finally, the study suggests for adoption of suitable structural policies aiming at improving the economic efficiency and boosting up economic growth and inducing energy conservation. Examining the causal relationship between GDP, energy consumption, and employment, Soytas and Sari (2003) and Sari and Soytas (2004) suggested that the causality runs from energy consumption to GDP in Turkey. This indicates that in the long run decreasing energy consumption may retard the economic growth of Turkey. However, others argued that there is no evidence of causality between energy consumption and GDP in Turkey (Altinay and Karago, 2004) and that consumption of different energy sources may have different effects on income of Turkey. Studying the relationship between energy and economy, Ediger (2004) have shown that the industrialization in Turkey has not been completed yet and energy demand should be increasing faster than national income until the energy intensity of the country reaches to a peak. Therefore, the decrease in rate of energy demand may be interpreted to indicate that the energy intensity peak would be achieved in the coming decades.

Further, in a recent study, by Ediger and Huvaz (2006) observed that although an almost linear relationship exists between primary energy consumption and total GDP of Turkey during 1980-00, the historical development of energy consumption and economic production demonstrates frequent fluctuations, evolving in a cyclic pattern. There exists a close relationship between energy and economy of Turkey and the average rate of change in GDP and primary energy consumption are 4.5 and 4.9, respectively. Therefore, whether or not the decrease in energy consumption rate is related to energy intensity peak would depend on the future rates of GDP (Ediger and Huvaz, 2006). If causality runs from energy consumption to GDP in the future and if the rates of energy consumption and GDP persist their past trends, any decrease in energy consumption is expected to slow down the economic growth during the forecasted period. In similar line, Sari & Soytas (2004) utilizing the recently developed generalized forecast error variance decomposition technique developed by Koop et al and Pesaran and Shin tried to determine the information content of the growth rate of energy consumption (i.e. how much of variance in the national income can be explained by the growth of different sources of energy consumption) in Turkey. They found that waste seemed to have the largest initial impact followed by oil. The total energy consumption explained around 21 percentage of forecast error variance of GDP.

Wolde-Rufael (2005) investigated the long run relationship between energy use per capita and per capita GDP for 19 African countries using the cointegration technique proposed by Pesaran, et al. (2001) and also the causality test proposed by Toda & Yamamoto (1995). The study found that there is a long run relationship between two series for only eight countries and causality for only 10 countries. In another attempt, Lee (2006) using Toda et al (1995) non-causality test examined the relationship between energy consumption and income in 11 major industrialized countries. He found that although energy consumption and income are neutral to each other in countries like UK, Germany, and Sweden, but there is bi-directional causality in USA and unidirectional causality from energy consumption to GDP in Canada, Belgium, The Netherlands and Switzerland suggesting that energy conservation may hinder economic growth. Further, causality relationship appeared to be unidirectional but reversed for France, Italy and Japan implying that in these three countries, energy conservation may be viable without being detrimental to economic growth.

In a most recent study, Pokharel (2007) showed how energy is important for Nepal given its economic structure where there exists heavy demand for both the traditional as well as commercial sources of energy in rural and urban areas respectively. Classifying the models into fuel and consumption sector models, he tried to determine various significant factors influencing energy consumption in different sectors. For fuel sector models, major fuels such as fuelwood, petroleum products, coal and electricity were considered whereas in consumption sector models, the energy-consuming sectors such as residential, industrial, transport and agricultural were considered. From the final regression model, the study found that fuelwood demand is largely due to rural population. The consumption of kerosene depends upon the price of kerosene, urban population, rural population and GDP of trade, hotels and restaurants. The increase in LPG consumption despite the increase in price indicates attractiveness of LPG as a major fuel source in urban households and in service sector. The petroleum consumption is not significantly related to the petroleum prices or the urban population. A bulk of vehicles using MS petrol is owned by the private sector (and the government) and the growth in the urban population does not correlate with the number of vehicles. However, the relation between the use of MS petrol and the number of vehicles is found to be significant. The model for high-speed diesel (HSD) consumption shows that increase in fuel price results in a decrease in HSD consumption. However, with increasing trend of vehicle registration, HSD consumption is expected to rise. Based on various econometric tools, the study also projected various forms of energy consumption demand from 1997 till 2012. The projection shows that the share of LPG and kerosene would increase mainly because of increased urbanization. This would in turn reduce the growth in fuelwood consumption. The coal consumption is expected to double between 2007-2012. Electricity consumption would increase. The consumption of electricity is supply constrained due to lack of investment in hydropower and slow pace of transmission and distribution system extension to consumption centers. The projected data also reveals that although the residential sector would still be the major consumer of energy but the share of energy consumed by this sector would be reduced in future. The share of energy consumption in other sectors would rise, with largest increase in share in agriculture followed by industrial and transport sectors. The energy requirement in transportation and agricultural sector would be higher due to the growth in agricultural inputs and significant increase in number of vehicles. The growth of energy consumption by the industrial sector would be higher than that of transportation sector. The increase in petroleum products for Nepal is inevitable mainly due to increasing demand for such products in transport, residential and service sectors.

Masih and Masih (1996, 1997) in a multivariate framework examined the relationship between total energy consumption and real income of Asian economies such as India; Pakistan; Malaysia; Singapore; Indonesia; Philippines; Korea; and Taiwan. Energy consumption was found to be neutral with respect to income for Malaysia, Singapore and Philippines, unidirectional causality existed from energy consumption to GNP for India, exactly the reverse for Indonesia and mutual causality was present for Pakistan.

In a recent attempt, Paul and Bhattacharya (2004) applying alternative econometric time series models viz Engle-Granger co-integration, Granger causality test and Johnsen's multivariate cointegration technique on the Indian data for the period 1950-96, found that Engle-Granger and Johnsen cointegration results, while they show that in the long run economic growth leads to energy consumption, in contrast, the standard Granger causality shows that energy consumption leads to economic growth. The finding from Granger causality is also consistent with Johnsen's error correction result. From their survey, they found that while Cheng (1999) had established a unidirectional influence from economic growth to energy consumption but Adjaya (2000) found causality in the reverse direction. Ghosh (2005) using cointegratioin and error correction modeling approach found the existence of a long-run equilibrium relationship between total petroleum products consumption and economic growth in India for the period of 1970-71 to 2001-02.

However, it is to be noted that the previous studies tried to relate the aggregate energy consumption with economic growth in India but there may be a practical difficulties in aggregating the various forms of real energy consumption as their units of measurement differ. The conversion depends upon the quality or productivity of energy. Therefore, the present study makes a departure from the earlier studies by trying to relate various forms of energy consumption with economic growth. This will help us to formulate different policy strategies for different forms of energy demand. The previous studies have either taken aggregate energy consumption or if there is a disaggregation, they have considered some forms of energy at their levels and further leaving the most important component of energy i.e. electricity. Probably this is the reason why the studies have employed the traditional cointegration technique. But the present study considers the various forms of growth of real energy consumption and then tries to relate with real growth rate of the economy. Besides directly examining the impact of different forms of energy consumption on economic growth rate, the study also examines the influence of energy on different components of economic growth rate such as private consumption and private investment. This would help in understanding the mechanism of influence of energy on economic growth.

The present study does not explicitly take into consideration of price effect as it has implication towards complemetarity and substitutability among the various forms of energy consumption.

Nevertheless, price is not the sole factor responsible for substitutability and complementarity of various forms of energy. It is their accessibility or availability, which can matter most for their use. There may be a demand for certain forms of energy, but due to their unavailability, the user may desire or rely on different forms of energy. Therefore, once accessibility is normalized, it will be easier for making a comparison between different forms of energy whether there is substitutability or complementarity relationship. But this is an arduous task. This can be undertaken as a challenging area of research in the future studies. Although some studies have considered the substitutability and complementarity relationship between different components of energy but they have only considered the price effect ignoring their accessibility in the market.

DATA BASE

The study considers the annual data from 1970-71 to 2003-04. The data relating to different forms of energy consumption and GDP at constant prices have been collected from www.indiastat.com and verified with Indian Petroleum and Natural Gas Statistics, Ministry of Petroleum Natural Gas Economics and Statistics Division, Government of India, and Energy Statistics, Ministry of Statistics and programme Implementation, Central Statistical Organisation (CSO). The forms of energy are expressed as a ratio to GDP at constant prices (1993-94=100) in order to measure them as per unit of output (see Appendix Table 4). The growth of energy variables in the empirical analysis has been related to the simple growth rates of GDP as well as major ingredients of growth of GDP such as private consumption and private investment.[20] Growth rate of GDP is defined as the change in the GDP in two consecutive periods divided by its initial period value. The same formula has also been followed for computing growth rates of rest of the variables. Private

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20 The data relating to private consumption and investment have been collected from CSO.

investment refers to the gross private capital formation and private consumption refers to gross domestic private final consumption as reported by CSO.

METHODOLOGY

The study employs time series econometric procedures in order to understand the dynamic relationship of growth of various forms of energies consumed with the growth rate of the economy i.e. whether energy consumption fuels economic growth or it is the growth rate of income measured by GDP at factor cost which drives the demand for more energy consumption in the economy. Before utilizing the time series model for estimating the relationships, the study carries out unit root testing procedures in order to apply suitable time series estimating procedures appropriate to the context as disregarding the unit root tests may result in biased estimates. Since the growth rates are usually expected to be stationary at their levels, therefore, the study proposes to employ Granger causality test and variance decomposition analysis of vector auto-regression (VAR) method for empirical analysis. One of the important points needs to be borne in mind is that Granger causality test and variance decomposition analysis of VAR are most suitable techniques when all the variables are stationary at their levels[21]. The Granger causality test demonstrates the direction of causality flowing from one to the other variables and *vice versa* or the information content in one variable in correctly predicting another variable, while variance

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21 Toda and Phillips (1993) have shown that when the variables are integrated, the F-test procedure for causality test is not valid as the test statistic does not have a standard distribution. The existence of non-stationarity in the time series can lead to spurious regression results and invalidate the conclusions reached using Granger causality. This would cast doubt on the results. The causality test can be carried out when the stationarity properties of the data is identified. Furthermore, it is only possible to infer a causal long-run relationship between non-stationary time series, when the variables concerned are cointegrated. If cointegration analysis is omitted, causality tests present would give the evidence of simultaneous correlations rather than actual causal relations between the variables.

decomposition analysis explains the variation in one variable due to the shocks in itself and shocks in another in a out of sample forecasts. In other words, variance decomposition can be viewed as an out of sample causality test. In carrying out these econometric tests, one of the important factors is to properly determine the lag length of the variables in the models. The lags of the models have been selected on the basis of Akaike Information Criteria (AIC) and Final Prediction Error (FPE) Criteria. Otherwise, it is realized that the incorporation of insignificant variables may overparameterise the model estimation, producing biased estimates and hence arriving at wrong inferences.

Granger (1969) causality test regresses a variable y on a lagged value of itself and another variable x. lf x is significant; it means that it explains some of the variance of y that is not explained by lagged values of y itself. This indicates that x is causally prior to y and said to dynamically cause or Granger cause y. The model can be specified as follows:

$$y_t = \sum_{j=1}^{m} \alpha_j y_{t-j} + \sum_{j=1}^{m} \beta_j x_{t-j} + u_t$$

The estimated model in the bi-variate VAR can be specified as:

$$z_t = \begin{bmatrix} x_t \\ y_t \end{bmatrix} = \beta + \beta_1 t + \sum_{i=1}^{k+1} A_t \, z_{t-1} + u_t \quad A_t = \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix}$$

x represents the left hand side variables or dependent variables and y represents the right hand variables or independent variables. However, in a VAR system all variables are endogeneous.

RESULT DISCUSSION

Prior to applying causality test, the study investigates the order of integration of the variables used in the analysis. It could be noticed from Table 1, that using DF and ADF tests, all the variables are found to be integrated of order zero or stationary in levels. This result has also subsequently been confirmed from Phillips Perron (PP) unit root test as reported in the following table.

Table 1: Unit Root Test

Growth Rate of Variables	DF	ADF	PP
Coal	-5.45^{C}	$-3.63(1)^{C}$	$-5.45(1)^{C}$
Petroleum	-5.28^{C}	$-3.87(1)^{C}$	$-5.27(1)^{C}$
Electricity	-4.25^{C}	$-3.05(1)^{C}$	$-4.24(1)^{C}$
Natural Gas	-4.46^{C}	$-3.71(1)^{T}$	$-4.49(1)^{C}$
Aggregate energy	-4.45^{C}	$-3.71(1)^{C}$	$-4.43(1)^{C}$
GDP	-7.09^{T}	$-3.81(1)^{T}$	$-7.51(1)^{T}$

Note: The critical values at 1%, 5% and 10% are -3.64, -2.95 and -2.61 respectively (without trend but intercept, denoted by superscript C) and -4.26, -3.55 and -3.20 respectively (with trend and intercept, denoted by superscript T).

The lag order in Granger causality and VAR have mainly been selected on the basis of AIC, SBC and FPE criterions. Wherever these tests have shown bias towards selecting a lower order lag or no lag we either consider LR criteria or arbitrarily fix the lag length at one. As there might be a structural shocks affecting the behavior of energy demand and thereby the growth rate, therefore, the stability of the parameters in VAR has been checked with the help of AR characteristics polynomial and CUSUM test[22]. The CUSUM test results plotted in Appendix-B indicate that all the model estimated through VAR are stable and therefore VAR estimates could be reliable. It is also found that many

22 The Cusum test result is based on the model when energy variable is dependent. Similar is the result when growth is considered as dependent variable. The VAR estimates reported here satisfy normality, no autocorrelation and no heteroscedasticity properties. Plotting the correlagram of the residuals in VAR shows that the statistics lie within 5% band.

of the time paths resulting from the impulse response coefficients converge to zero that reflects the stability of the estimated model

Table 2: Lag Length Selection

Model	Lags	LR	FPE	AIC	SBC	HQ
Coal Growth	0	NA*	130.68	10.54	10.64*	10.57*
	1	7.72	128.52*	10.53*	10.80	10.62
Crude Petroleum Growth	0	NA*	397.96*	11.66*	11.75*	11.69*
	1	3.50	455.02	11.79	12.07	11.88
Electricity Growth	0	NA*	102.10	10.30	10.39*	10.33*
	1	6.397	105.29	10.33	10.60	10.42
	2	9.332	95.61*	10.23*	10.69	10.38
Natural Gas Growth	0	NA*	1378.35	12.90	12.99*	12.93
	1	7.83	1347.91	12.88	13.16	12.97
	2	9.33	1217.54*	12.77*	13.24	12.92*
Aggregate Energy Growth	0	NA	47.36*	9.53*	9.62*	9.56*
	1	3.58	54.44	9.67	9.95	9.76
	2	9.53*	48.47	9.54	10.02	9.69

Note: * indicates lag order selected by the criterion, LR: sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SBC: Schwarz information criterion, HQ: Hannan - Quinn information criterion. The lags selected in the model are mainly on the basis of FPE and AIC criterion as other criterions are biased towards a smaller lag. When both criterions select zero lag we have considered minimum lag length as one or we rely on different selection criteria as VAR cannot be estimated without any lags.

Since all of the above variables are found to be of integrated of order zero, therefore, it is an appropriate case for conducting bi-variate

Granger causality test by relating growth of different forms of energies with economic growth measured by growth rate of GDP. The Granger causality test results shown in Table 3 indicate that except coal which influences/causes economic growth rate, growth rates of other forms of energy do not cause growth rate of income. Rather, growth rate of income Granger causes growth rate of electricity and natural gas including aggregate energy consumption demand in the country. This provides evidence that except coal energy, other forms of energy considered in the analysis none of them, do play significant role in economic growth rate of the Indian economy. In turn, it is the growth rate of national income that leads to more demand for energy consumption. This implies that when national income rises, it directly leads to more consumption demand for electricity and natural gas energies. [23]

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23 It is important to note that since all the energy variables are in growth rates, hence they are free from the unit of measurement. In the sense, whether they are converted into uniform units or different units wouldn't affect the empirical results except aggregation problem when they are of different units. However, when prices of different energy variables are taken into consideration from the period 1981-2005 (as per the data availability) we find that coal growth consumption causes its own price and liquid petroleum price causes electricity price along with electricity demand leading to coal growth demand and there is absence of cross price elasticity of energy demand implying absence of complementarity and substitutability relationship among different energy consumption demand in a standard demand function setting. However, there may be a complementarity and competitive relationship, which is revealed from one quantity leading to another quantity and one price leading to another price. For instance, there may be a complementarity relationship between electricity use and coal use, as electricity generation itself requires coal energy. Liquid petroleum and electricity may be competitive in some instances as one price is leading to the other price in the causality test.

Table 3: Granger Causality Test

Growth Rate of Variables	GDP	Coal	Crude Petroleum	Electricity	Natural Gas	Aggregate Energy
GDP (Growth)	-	0.50 (1)	1.76(1)	2.84***(2)	4.62**(1)	4.30(2)**
Coal (Coalgr)	7.61*(1)	-	-	-	-	-
Crude Petroleum (Crude Petroleumgr)	0.35(1)	-	-	-	-	-
Electricity (Electricitygr)	1.64(2)	-	-	-	-	-
Natural Gas (Naturalgasgr)	0.56(1)	-	-	-	-	-
Aggregate Energy	0.23(2)	-	-	-	-	-

Note: The numbers in the above table indicates the F-statistics. The direction of Granger causality flows from the left hand row variables to right hand column variables. The figures in the parenthesis are the lags selected into the model on the basis of AIC criteria for carrying out the Granger causality test. It is important to note that when influence of different components of growth of energy on major two components of economic growth such as private consumption and private investment was investigated with Granger causality test, none of the components of energy found to significantly influencing either of the components of economic growth viz. private consumption and private investment.

After carrying out the Granger causality test, we have estimated the dynamic causality relationship between growth of energy consumption and growth rate of GDP through variance decomposition analysis of vector autoregression (VAR) technique. The variance decomposition is computed for 20 horizons for an out of sample forecast. We use level of growth rate of all variables in order to obtain robust estimates as all the variables are found to be stationary at their levels. The impulse responses as estimated from the VAR have quite similar short-run dynamics for all energy components, and they display mean reversion at short horizons as can be noticed from the graphs shown in Appendix B. They also display a good deal of persistence.

The variance decomposition analysis between growth of coal energy and growth rate of GDP reported in Table 4 shows that when one standard deviation shock is given to the growth of GDP, it does not explain the variation in the growth rate of coal energy over the entire horizon. Rather, the variation in growth rate of coal energy is being explained by its own shocks. The bottom part of the table shows the results of variance decomposition of growth rate of GDP. This shows that the growth rate of GDP is being constantly and significantly explained by the shocks in the growth rate of coal energy consumption. It almost explains 18 percentage of variation in the growth rate of GDP from 2nd horizon to 20th horizon under consideration. This implies that there is a one-way causality from coal energy consumption to growth rate of GDP (income) in the economy. This is also consistent with the previous Granger causality test result.

The impulse response of coal growth to one standard deviation shock in growth rate (shown in Figure 1) is insignificant and short lived, until 3rd horizon and after that the effect of shock on coal consumption growth has decayed. While the response is initially found to be negative and it improves after some horizon. However, the response of growth to one standard deviation shock (shown in Figure 2) improves significantly and the positive response is persistent till 4th horizon. The cusum test for the corresponding model shown in Figure 3 shows that parameters estimated in VAR are stable as the statistic resulting from the test fall within a minimum significance band and therefore the results could be robust.

Table 4: Variance Decomposition of Growth of Coal

Variance Decomposition of COALGR:			
Period	S.E.	COALGR	GROW
1	3.87	100.00	0.00
2	3.92	99.91	0.09
3	3.92	99.91	0.09
7	3.92	99.91	0.09
10	3.92	99.91	0.09
15	3.92	99.91	0.09
20	3.92	99.91	0.09
Variance Decomposition of GROW:			
Period	S.E.	COALGR	GROW
1	2.81	0.32	99.68
2	3.10	17.79	82.21
3	3.11	18.33	81.67
7	3.11	18.34	81.66
10	3.11	18.34	81.66
15	3.11	18.34	81.66
20	3.11	18.34	81.66

Note: Corresponding standard errors are reported to respective each coefficient of error variance. Grow indicates GDP growth.

Table 5 reports the variance decomposition results of growth of crude petroleum consumption in relation to the growth rate of GDP. It shows that the crude petroleum energy consumption is not being explained by the shocks in the growth rate of GDP and largely it is being explained by its own variations or shocks. This is almost similar to the Granger causality test results, where we found growth rate of GDP does not have any influence on the crude petroleum consumption. Similarly, the variance decomposition of growth rate of GDP produced in the bottom part of the table also shows that the growth rate of GDP is not significantly being explained by the shocks in crude petroleum consumption. That means consumption of crude petroleum products is not key to the growth rate of output/income in the country or insignificant in contributing to the economic growth of the economy. This result is also consistent with the Granger causality result obtained previously.

The impulse response of crude petroleum growth to one standard deviation shock in growth is positive and persistent for a shorter horizon as shown in Figure 4. In contrast, although the response of growth to the shocks in growth of petroleum products is insignificant and lasts for short horizon, but it is negative for initial horizon and positive for the later horizon as shown in Figure 5. The corresponding cusum test results shown in Figure 6 shows that parameters estimated in VAR are stable and therefore the results could be relied upon with certain degree of accuracy.

The variance decomposition of growth rate of electricity consumption reported in Table 6 shows that the variation in electricity growth rate is initially being explained by its own shock but from 3rd horizon onwards, growth rate of GDP to a certain significant degree explains the variation in the growth rate of electricity consumption demand. This implies that with the growth of income, there may be an increasing demand for electricity consumption in the economy. The variance decomposition result for growth of GDP produced in the same table indicates that growth rate besides being explained by its own shocks, it is also significantly being explained by the shocks in electricity consumption and this holds almost throughout all the horizons. At the 1st horizon, 13 percentage of the variation in growth rate is being explained by the growth of electricity consumption and at the 2nd horizon it is 21 percentage and from 3rd horizon until the 20th horizon, around 23 percentage of variation in growth rate of GDP is being explained by the variation in growth of electricity consumption. This implies that there is a bi-directional causal relationship between growth of electricity

Table 5: Variance Decomposition of Growth of Crudpetroleum:

Variance Decomposition of CRUDPETROLGR:			
Period	S.E.	CRUDPETROLGR	GROW
1	6.61	100.00	0.00
2	6.80	94.71	5.29
3	6.81	94.71	5.29
7	6.81	94.70	5.30
10	6.81	94.70	5.30
15	6.81	94.70	5.30
20	6.81	94.70	5.30
Variance Decomposition of GROW:			
Period	S.E.	CRUDPETROLGR	GROW
1	3.08	1.81	98.19
2	3.11	3.16	96.84
3	3.11	3.16	96.84
7	3.11	3.16	96.84
10	3.11	3.16	96.84
15	3.11	3.16	96.84
20	3.11	3.16	96.84

consumption and economic growth in India. This is contrary to the results obtained from the Granger causality test reported above as Granger causality shows uni-directional causality running from growth of GDP to growth of electricity consumption.

The impulse response of growth of electricity consumption to one standard deviation shock in growth rate of gdp is persistent till 12th horizon and it is found to be positive as shown in Figure 7. Similarly, the response of growth rate to one standard deviation shock in electricity growth as shown in Figure 8 is found to be positive but the shock lasts for about 10th horizon and decays thereafter. This implies there could be a stable equilibrium relation between the two. The cusum test for the corresponding model shown in Figure 9 shows that parameters estimated in VAR are stable.

Table 6: Variance Decomposition of Growth of Electricity:

Variance Decomposition of ELECTRIGR:			
Period	S.E.	ELECTRIGR	GROW
1	3.22	100.00	0.00
2	3.38	99.44	0.56
3	3.58	89.22	10.78
7	3.68	88.32	11.68
10	3.68	88.27	11.73
15	3.68	88.27	11.73
20	3.68	88.27	11.73
Variance Decomposition of GROW:			
Period	S.E.	ELECTRIGR	GROW
1	2.88	13.65	86.35
2	3.02	21.43	78.57
3	3.06	23.22	76.78
7	3.09	23.16	76.84
10	3.09	23.16	76.84
15	3.09	23.16	76.84
20	3.09	23.16	76.84

The variance decomposition analysis of growth of natural gas consumption presented in Table 7 shows that around 10 percentage to 26 percentage of variation in the growth rate of natural gas is being explained by the growth rate of GDP from 2nd horizon to the 20th horizon. That means it is the growth of income, which causes more demand for natural gas consumption in the economy confirming the Granger causality test results. However, when one considers the variance decomposition of growth rate of GDP presented in the bottom part of Table 7, it indicates that the variation in growth rate of GDP is not being explained by the growth rate of natural gas consumption. Rather, it is almost absolutely being explained by its own shocks. This implies that the growth of consumption of natural gas is driven by growth of real GDP in the economy.

The impulse response of growth rate of natural gas consumption to one standard deviation shock in growth is persistent till 12th horizon and the relation is found to be positive as shown in Figure 10. Similarly, the response of growth to crude oil consumption growth is although initially found to be positive but insignificant as shown in Figure 11. The cusum test for the corresponding model shown in Figure 12 shows that parameters estimated in VAR are stable.

From the above variance decomposition analysis, it could be noticed that there is no causal relationship between growth rates of crude oil with growth rate of GDP. However, while there exists a unidirectional casual influence from growth rate of GDP to natural gas and from coal consumption growth to economic growth but there exists a bi-directional causal relationship between growth of electricity consumption and economic growth.[24] This is well in conformity with some of the Granger causality test results reported previously except the causal influence from electricity consumption to GDP growth.

In contrast, the Granger causality test result showed that there is a causal influence of growth of coal energy to GDP growth rate and GDP growth rate to growth of electricity, and natural gas and further to aggregate energy consumption (converted in uniform units). This result in the Indian context is quite contrary to the previous studies carried out by Masih and Masih (1996, 1997) and Paul and Bhattacharya (2004),

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24 When the growth rate of aggregate energy consumption and growth rate of GDP is considered, the variance decomposition analysis shows same result as the Granger causality. The results are not reported for sake of brevity.

Table 7: Variance Decomposition of Growth of Naturalgas:

Variance Decomposition of NATUGSGR:			
Period	S.E.	NATUGSGR	GROW
1	10.32	100.00	0.00
2	11.91	89.92	10.08
3	13.20	74.02	25.98
7	13.49	73.44	26.56
10	13.49	73.42	26.58
15	13.49	73.42	26.58
20	13.49	73.42	26.58
Variance Decomposition of GROW:			
Period	S.E.	NATUGSGR	GROW
1	2.96	0.11	99.89
2	3.05	3.24	96.76
3	3.07	3.95	96.05
7	3.10	3.95	96.05
10	3.10	3.95	96.05
15	3.10	3.95	96.05
20	3.10	3.95	96.05

where Masih et al (1996, 1997) found a bi-directional causality and Paul and Bhattacharya (2004) from the standard Granger causality test found that energy consumption leads to economic growth. Therefore, the present study yields mixed and contradictory result in the Indian context as to judge whether the country should conserve energy or consume more energy for achieving higher growth rate in the economy. However, the empirical analysis from application of both the econometrics techniques strongly suggests coal consumption has a strong bearing on the economic growth rate. Similarly, the variance decomposition analysis suggests that electricity consumption which is a highly qualitative energy source as compared to other forms of energy may significantly contribute towards economic growth of the country in the future. But when we consider the aggregate energy consumption growth, both the Granger causality as well as variance decomposition tests show that it is the growth of GDP which causes the overall growth of energy consumption demand but the opposite does not hold true in the Indian context, thereby implying for an energy conservation policy in India. This is also well in consistent with Ghosh (2005) finding that consumption demand for energy is driven by higher rate of economic growth in the economy.

CONCLUSION

The paper examined the linkage between various forms of energy consumption growth and economic growth in India. Besides the direct impact of energy consumption on economic growth, it also examined the influence of various forms of energy consumption growth on growth of private consumption and private investment as different components of GDP growth. The relationship has been examined using Granger causality test as well as variance decomposition and impulse response analysis of vector auto regression (VAR) technique. Granger causality method is applied to examine whether the information content in a variable (independent) is correctly able to predict the other variable (dependent) and vice versa, whereas variance decomposition of VAR analysis, as an out of sample causality test, explains the variation in one variable how much can be attributed to its own shock as against the shock to the other variables in a system. The result from the application of Granger causality test suggests that it is the growth rate of GDP which leads to more demand for the natural gas and electricity and the overall energy consumption, and it is only the coal energy consumption which has an influence on GDP growth and none of the energy growth components influence private consumption and private investment growth rates. In contrast, variance decomposition analysis suggests that there could be two-way causality between electricity energy consumption growth and economic growth in the future and there could be a similar unidirectional influence from economic growth to natural gas consumption growth and from coal consumption growth to economic growth as observed in Granger causality test. Hence, the study provides mixed and contradictory evidence on the relationship between energy consumption and GDP growth rate as compared to the previous studies carried out in the Indian context. However, with little more conviction from application of both the statistical tools, the study could suggest for reducing oil and natural gas consumption especially in the consumption sectors of the economy, for achieving higher economic growth as these sources are not contributory to economic growth rather the consumption of these could be growth driven, which may have adverse impact on the balance of payment position of the economy in the future.

Given the fact that GDP growth fuels rate of energy consumption but the reverse does not hold good in the Indian context, the energy policy in the country should be to curb these conventional non-renewable energy consumption such as crude oil and natural gas as import of these forms of energies are expensive. The government incurs large amount of expenditure in importing and distributing these energies at the subsidized rates (resulting in oil pool deficit of the country), which has got much implications for maintaining a sound macroeconomic environment as it can impact on the balance of payment. Rather limited use of these energies can keep the environment clean and financial position of the macro economy stable. Therefore, there should be an effort to exploit the renewable sources of energy for consumption and production purposes, which would economise the use of these natural resources in the economy. Otherwise, given the continued economic growth, there would be more demand for these sources of energy resulting in escalation of prices and macroeconomic imbalances. However, since coal and electricity contributes to economic growth, there should be sectoral efficient allocation policy on energy, as industrial sector, which is a major driver of economic growth, consumes lots of these forms of energies. Another interesting question from the above empirical analysis emerges is that, why is it that coal consumption contributes to the economic growth, while other sources do not significantly influence economic growth? Is it due to its abundant supply and reliance placed on it or conversion of coal into electricity and other forms of energy? In other words, this tends to ask; had there been an increase in supply of energy from other sources,[25] there would have been much better economic growth? Then given the supply constraint, what should be the energy policy for a country in general and for India in particular? Is there a possibility of converting the abundant availability of coal into other qualitative energies? These are the relevant researchable issues for the future research which needs to be addressed for a rational national energy policy in a country. Pokharel (2007), in Nepal economy context, suggests that in order to retard the fuel import growth it requires inter-fuel substitution towards indigenous resources, mainly hydropower. The expansion of hydropower would replace diesel-based electricity generation. Electricity can be treated as a potential fuel to replace petroleum products mainly in households and transportation sector. One can also undertake a study on the energy use in different sectors and their contribution to the growth of the sector as each sector has got different energy use intensity for different forms of energy use.

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25 In recent years, ethanol, wind, solar and biofuel energy from Jatropha have been emphasized as the alternative sources to these usual energy. However, generating energy from solar and wind sources are found to be more expensive although these are renewable sources.

APPENDIX - A

Appendix Table 1: Sector-wise Percentage Share of Electricity Consumption in India

Sector	1953-54	1960-61	1970-71	1980-81	1990-91
Industry	39.8	40.7	51.6	57	50.4
Transport	46.2	44.9	29.4	23.5	24.5
Household	9.9	10.6	14.3	12.3	13.8
Agriculture	1.7	1.8	3.8	6.1	9
Others	2.4	2	0.9	1.1	2.3

Note: The data on the basis of above sectoral classifications is not available after 1990-91. Therefore Appendix Table 2 serves as a supportive data to the above table.

Appendix Table 2: Sector-wise Percentage Share of Electricity Consumption In India

Category	1996-97 (Actual)	1997-98 (Actual)	1998-99 (Actual)	1999-00 (Prov.)	2000-01 (RE)	2001-02 (AP)*
Domestic	18.1	18.6	19.5	20.6	21.3	21.3
Agricultural	30.8	31.8	32.3	29.2	29.1	28.8
Industrial	32.9	31.8	30.2	30.3	30.5	

Source: Indiastat.com

Appendix Table 3: Relative Consumption of Various Energies in Certain Emerging Asian Economies as a Per Cent to the World Total Consumption

	1980	1985	1990	1995	2000	2001	2002	2003	2004
Coal Consumption					**(Million Short Tons)**				
India	3.14	3.96	4.85	6.49	7.96	8.05	8.25	7.87	7.84
China	16.67	18.64	21.33	29.22	25.14	26.20	26.85	30.19	33.82
Japan	2.37	2.44	2.40	2.77	3.32	3.26	3.30	3.25	3.34
Pakistan	0.05	0.06	0.08	0.09	0.09	0.09	0.10	0.12	0.09
Sri Lanka	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Australia	1.80	1.77	1.97	2.19	2.76	2.72	2.76	2.50	2.46
Philippines	0.02	0.06	0.05	0.07	0.19	0.19	0.18	0.16	0.17
Thailand	0.04	0.12	0.27	0.45	0.47	0.53	0.53	0.50	0.50
New Zealand	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.07	0.06
Net Hydroelectric Power					**(Billion Kilowatthours)**				
India	2.70	2.58	3.30	2.92	2.78	2.86	2.44	2.85	3.05
China	3.34	4.68	5.82	7.52	9.09	10.12	10.46	10.63	11.93
Japan	5.10	4.20	4.11	3.31	3.26	3.26	3.14	3.57	3.41
Pakistan	0.50	0.62	0.78	0.93	0.64	0.73	0.85	1.02	0.99
Sri Lanka	0.08	0.12	0.14	0.18	0.12	0.12	0.10	0.13	0.11
Australia	0.74	0.69	0.65	0.64	0.63	0.64	0.60	0.61	0.57
Philippines	0.20	0.28	0.28	0.25	0.29	0.28	0.27	0.30	0.31
Thailand	0.07	0.19	0.23	0.27	0.23	0.24	0.28	0.28	0.22
New Zealand	1.13	1.00	1.08	1.10	0.91	0.83	0.96	0.89	0.97
Petroleum					**(Thousand Barrels per Day)**				
India	1.02	1.49	1.76	2.25	2.77	2.82	2.90	2.94	2.97
China	2.80	3.14	3.45	4.81	6.25	6.35	6.60	6.99	7.75
Japan	7.86	7.38	7.79	7.98	7.26	7.08	6.92	6.89	6.48
Pakistan	0.16	0.27	0.33	0.43	0.48	0.47	0.46	0.42	0.39

Sri Lanka	0.05	0.05	0.05	0.07	0.10	0.09	0.10	0.10	0.10
Australia	0.94	1.06	1.11	1.14	1.12	1.11	1.11	1.09	1.06
Philippines	0.36	0.25	0.35	0.47	0.46	0.45	0.43	0.42	0.41
Thailand	0.35	0.37	0.61	0.97	0.95	0.91	0.98	1.04	1.09
New Zealand	0.14	0.14	0.16	0.18	0.17	0.17	0.18	0.18	0.18
Net Nuclear Electric Power (Billion Kilowatthours)									
India	0.44	0.33	0.29	0.29	0.57	0.72	0.70	0.65	0.57
China	0.00	0.00	0.00	0.56	0.65	0.66	0.99	1.65	1.83
Japan	11.49	10.50	10.07	12.52	12.49	12.07	11.01	9.06	10.37
Pakistan	0.00	0.02	0.02	0.02	0.02	0.08	0.07	0.07	0.07
Sri Lanka	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Australia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Philippines	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thailand	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
New Zealand	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: International Energy Annual 2004 (Energy Information Administration)

Appendix Table 5: Energy Use Per Unit Of Output (In Percentage)

	Coal/GDP	Crude Petroleum/ GDP	Natural Gas/GDP	Electricity/ GDP	Aggregate Energy/GDP
1970-75	0.532	0.275	0.010	0.574	1.390
1975-80	0.573	0.282	0.015	0.688	1.558
1980-85	0.581	0.300	0.024	0.781	1.686
1985-90	0.611	0.346	0.053	0.923	1.934
1990-95	0.576	0.299	0.079	1.069	2.023
1995-00	0.517	0.278	0.081	1.042	1.918
2000-05	0.457	0.356	0.085	0.922	1.819

Note: All energy in Peta Joules as a percent to GDP at factor Cost at constant prices

APPENDIX-B

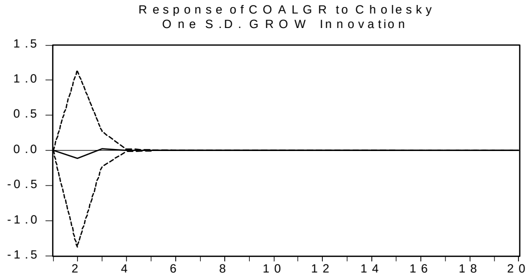

Figure 1: Impulse Response of Coal Growth to One S.D. Innovation in Growth

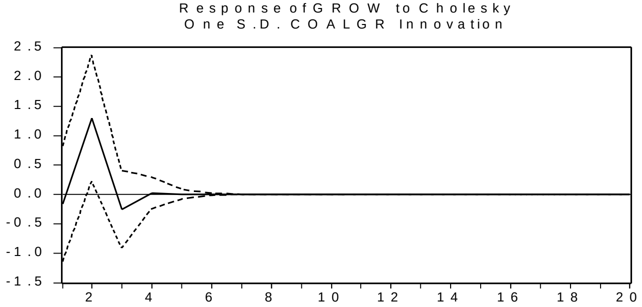

Figure 2: Impulse Response of Growth to One S.D. Innovation in Coal Growth

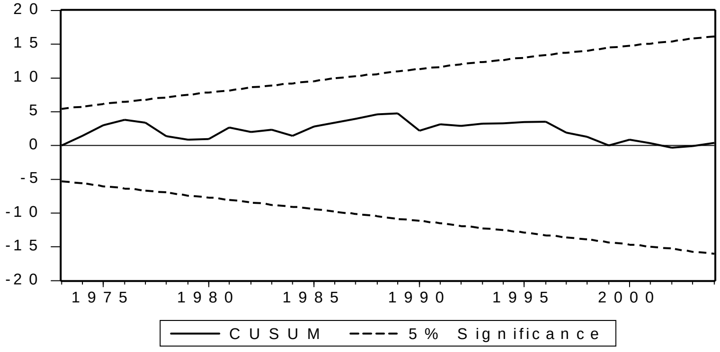

Figure 3: Cusum Test for Coal Consumption Growth and Growth Model

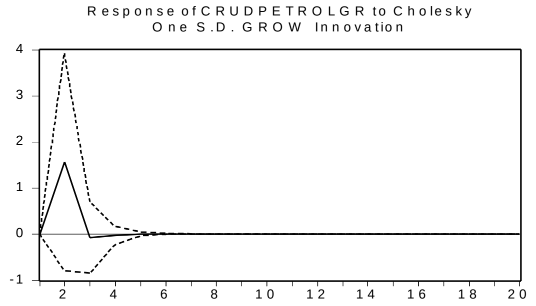

Figure 4: Impulse Response of Crude Petroleum Growth to One S.D. Innovation in Growth

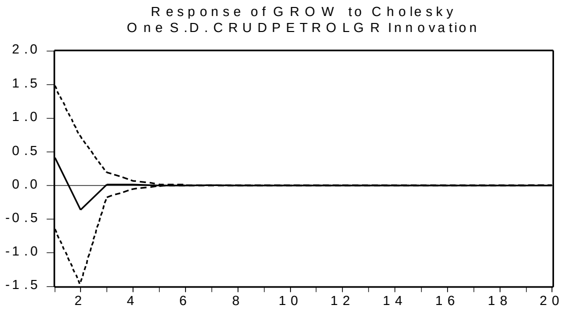

Figure 5: Impulse Response of Growth to One S.D. Innovation In Crude Petroleum Growth

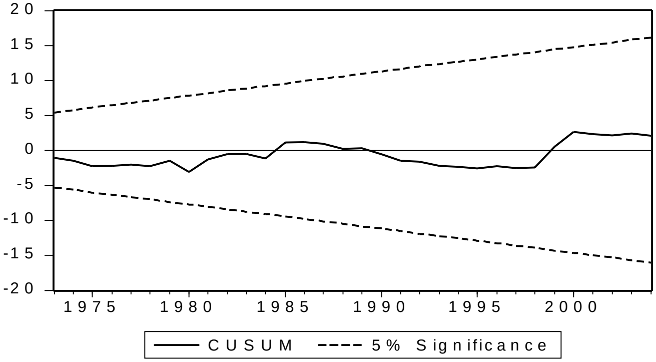

Figure 6: Cusum Test For Crude Petroleum Consumption Growth And Growth Model

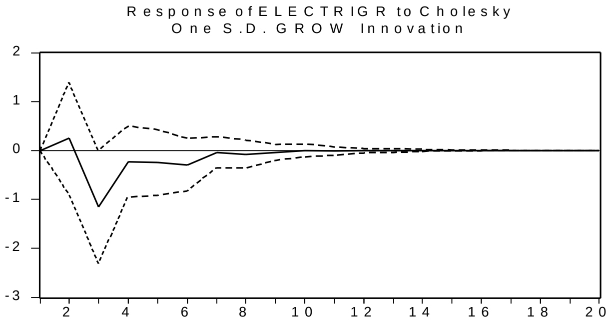

Figure 7: Impulse Response of Electricity Growth to One S.D. Innovation In Growth

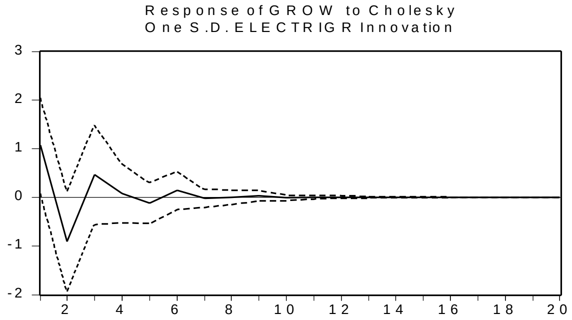

Figure 8: Impulse Response of Growth to One S.D. Innovation in Electricity Growth

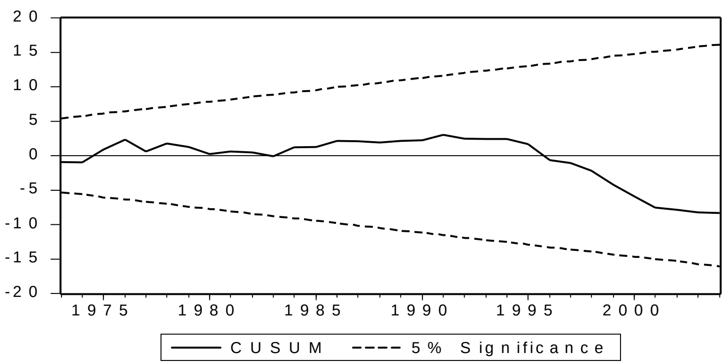

Figure 9: Cusum Test For Electricity Consumption Growth and Growth Model

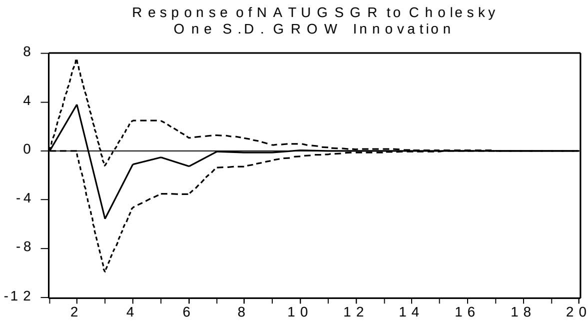

Figure 10: Impulse Response of Natural Gas Growth to One S.D. Innovation in Growth

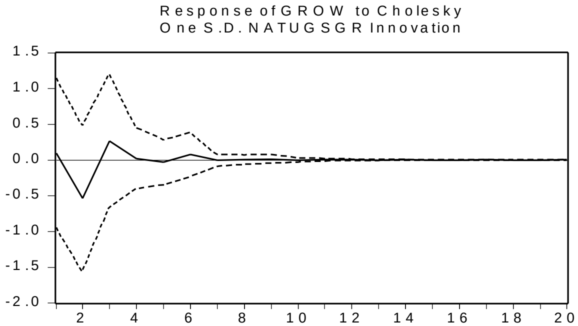

Figure 11: Impulse Response of Growth to One S.D. Innovation in Natural Growth

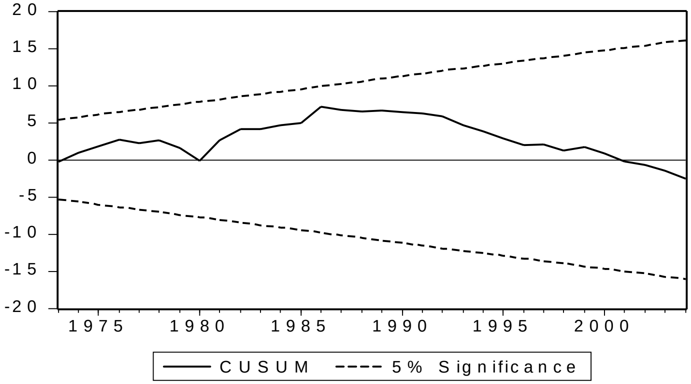

Figure 12: Cusum Test For Natural Gas Consumption Growth and Growth Model1

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