THE WILLIAM DAVIDSON INSTITUTE
AT THE UNIVERSITY OF MICHIGAN

RAPID ECONOMIC GROWTH AND INDUSTRALIZATION IN INDIA, CHINA & BRAZIL: AT WHAT COST?

By: Krishna Chaitanya.V

William Davidson Institute Working Paper Number 897
October 2007

RAPID ECONOMIC GROWTH AND INDUSTRALIZATION IN INDIA, CHINA & BRAZIL: AT WHAT COST?

Krishna Chaitanya.V
PhD candidate
Department of Applied Economics
University of Santiago de Compostela
Galicia, Spain
E-mail : kc_dcm@yahoo.co.in

Working Paper 2007 - No. 01

ABSTRACT

PURPOSE

The purpose of this paper is to examine whether the decline in environmental quality in India, China and Brazil is due to release of toxic gases which is an effect of high energy consumption? If so, the increase in energy consumption is due to rapid economic growth led by industrialization? Also examined is what effect does excessive economic growth rates have on energy consumption levels in these countries.

DESIGN / METHODOLOGY / APPROACH

The methodology adopted is a Log-linear model to estimate the environmental degradation caused by the increase in energy consumption. Followed by, regression analysis to estimate the relationship between energy consumption and growth variables. In order to probe the impact of excessive economic growth rates on energy consumption levels, threshold regression analysis is used.

ORIGINALITY

There is an expanding literature on emission, energy consumption and growth relationship, mostly in theoretical and research form. This paper provides the essentials in a unique format by first studying the interrelationship between emission and energy use.

Based on those results, the paper then examines the relationship between energy use and economic & industry growth variables. Using threshold regression analysis, the study then goes on to find whether higher economic growth rates (above normal average) lead to more energy consumption affecting environmental degradation. To the best of the author's knowledge, this is first such attempt.

FINDINGS

The claims brought forward by this study are that higher energy consumption indeed leads to CO2 emission in these countries. The higher energy consumption is a resultant of rapid economic growth, to which Brazil is an exception, creating scope for large demand which is caused by industrialization and growth in international trade related to industrial goods. The other significant finding is that as India and China pose higher economic growth rates, the higher would be the energy consumption levels leading to environmental imbalances.

KEYWORDS: *CO2 Emission, Energy Consumption, Economic Growth* & Industrialization.

JEL CLASSIFICATION: Q40, Q41, Q43, O13 & O14

PAPER TYPE

Research Paper

Acknowledgements: I would like to thank Mr. V. Venkat Sreedhar, Chief Finance Manager, West African Cements (WACEM), Togo, Africa, Dr. Jie He, Assistant Professor, Department Economics and GREDI, Faculty of Business Administration, University of Sherbrooke, Canada, for their discussion on the topic and valuable comments & suggestions while I was working on this paper. I also extend my heartfelt thanks to Mr. Srivyal Vyyuri, formerly with Ohio State University, USA & Founding member Sphoorti Foundation (www.sphoorti.org), India, for providing some valuable information about key databases. However, remaining errors if any are mine.

RAPID ECONOMIC GROWTH AND INDUSTRIALIZATION IN INDIA, CHINA & BRAZIL: AT WHAT COST?

01. Introduction

It is the mad rush for rapid economic growth led by industrialization in emerging economies like India, China and Brazil are having a negative impact on the ecological management. It is evident that rapidly growing economies are causing severe pollution problems in the form of emissions of various forms of gases like the CO2. The higher emissions in these countries are a resultant of higher energy consumption. Higher rate of growth of population, rapid industrialization, industrial trade, increase in number of vehicles as a result of a very high economic growth are acting as major driving forces towards higher energy consumption.

The economic growth exhibited in the countries like China and India are exuberant. The higher growth levels have placed these two economies in the different League of Nations altogether. China and India together contributes world's 30% of GDP in US $ constant PPP in 2002-03 (World Bank, 2004). At 2006, China is growing at over a growth rate of 10%, while India is growing at 9% growth rate, while Brazil is growing at a rate of 4%.

There are many voices which speak for higher growth rates especially for economies like India and China. This is because a country like India has made inadequate progress since 57 years of its independence. Poverty levels though decreased, still hovers over 25% of the population. The problem with previous years was a low growth of GDP, what many call as '*the Hindu Rate of Growth*' which resulted in a much low percapita income growth. The GDP of India between 1950 and 1980 was around 3% and annual growth of percapita income was just 1.5%. For a country like India which is world's second largest populous nation, this growth rate was found to be inadequate to make any significant impact on overall progress of the nation. Some initiation was taken up during the 1980s by the government of India to set things right. Though they were half hearted, it improved the per capita income growth to 3.0% as poverty levels fell from over 45% to 35% by the end of 1980. Thus, India realized that only strong economic growth rate could increase the percapita income levels of the people which inturn help in bringing down the poverty levels and improve the socioeconomic conditions of the poor. This further encouraged the government to make some serious corrections in its economic policies. Thus, the foundation for a strong economic growth was laid in the form of economic reforms in 1991 which is popularly known as Structural Adjustment Program (SAP). This program was a result of a "closed economic policy" which India followed over the decades which resulted in a severe macroeconomic crisis by early 1990s. The reforms focused on strengthening the economic growth which should translate into reduction of poverty levels, improving poor socio-economic conditions and better standard of living for the people of India. The reforms started yielding results by mid-1990s as India posted a growth rate of over 7% for three consecutive years followed by a low growth rate which was a result of world wide recession. On the other hand, the governments kept changing, but the reforms program continued. More reforms brought a much higher growth rate and this was evident during the early 2000 as the growth rate for the first seven years of 2000 was over 7.5% per annum. Thus, many argue that the higher growth rate is the only panacea for the ills poor socio economic conditions prevailing in the developing countries.

Similarly, in the case of China, Maddison, (1998), found in his research that in the last three decades China was able to significantly increase their investment growth rates which resulted in increase in their GDP growth of over 8% and this helped the country to achieve per capita income growth of over 6%. Chinese higher economic growth rates was appreciated by the World Bank in 2006 which stated in its report that it is because of the high economic growth rate, China was able to bring 75% of its poor population from below the poverty line. It is argued by many experts that if India has to have a percapita income growth of 6% at the present rate of growth of population consistently for the next ten years then it has grow rapidly. In the last one decade, most of the emerging economies like China, Taiwan, and Mexico have increased their investment levels significantly which resulted in a very higher GDP growth rates.

In the case of Brazil, the economic growth rate is under 5% level, though it experienced a growth rate of over 8% in the 1970s. Due to severe macro economic crisis led by external debt problems saw the economic growth crumble down to around 3% in 1980s, 1.50% in 1990s and 2.50% in early 2000. But the rapid growth in industry, industrial trade and transportation sector is driving the economy.

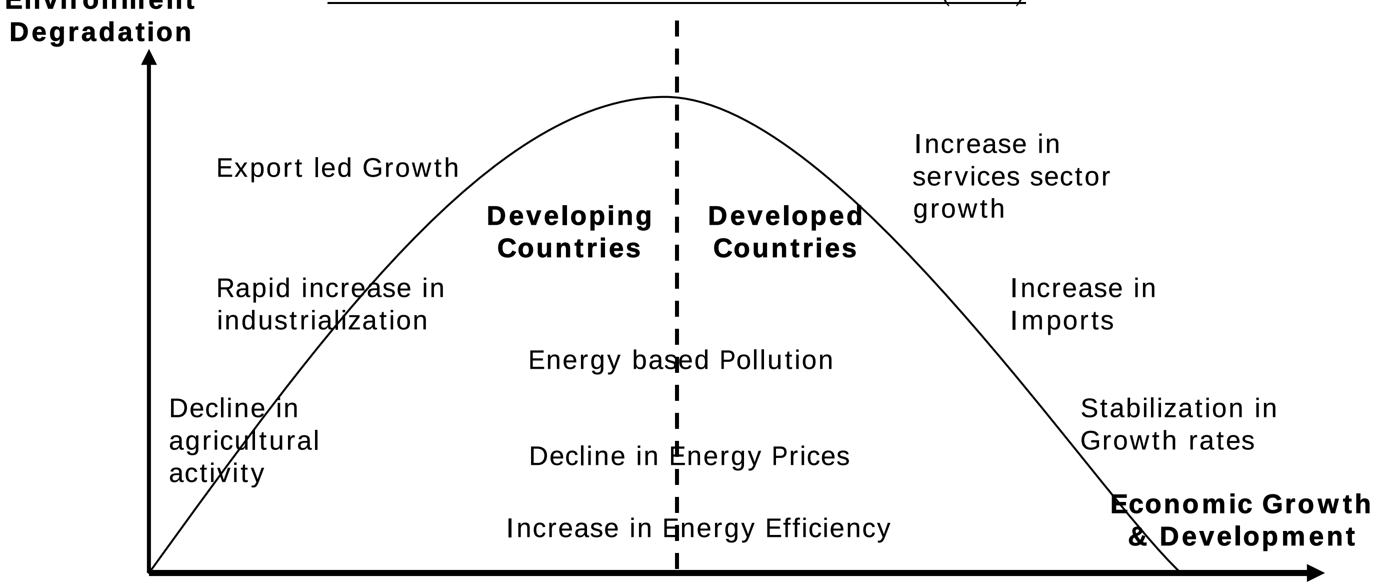
This being so, on the other hand another set of experts speak against this rapid rate of growth which emergining economies are exhibiting. They opine that there are environmental costs and damages associated with rapid economic growth which results in expanding of economic activities. This ever increasing consumption demand would have global side effects such as high emissions leading to global warming, greenhouse effects and destruction of forests.

Added to the above, the environmental degradation can also add to the problems of imposing higher costs on the poor by increasing the expenditure of health related issues. According to UN report, world's poorest 20% of population take this burden which is a resultant of environment degradation. It is also said to have responsible for world's 80% of the diseases due to pollution in the form of water, air and land due to rapid industrialization (United Nations Report, 1998).

Consider this example in the case of India and China, the cement companies' acquisitions in India. As on 2006, the cement industry is in a boom with over 50 new cement companies with a capacity of around 1000 tonnes per day are coming up. This means for each ton of cement produced in India, one ton of CO2 is released into the atmosphere! Going by the 2006 production levels in India and China, the later being number one in cement production in the world with production capacity of over 1000 million tons per year and not too far behind is India, which is in second slot with a production capacity of over 160 million tonnes per year. So, one can imagine the state of affairs of this rapid economic growth on sustainable development in both these countries. Going by this example, if only cement industry is like this, others manufacturing industries produce what type of gases one can well understand ! Considering that cement industry in India consumes over 20% of coal reserves and over 3 - 4% of total power generated (if the breakup is both domestic and industrial consumption) this may well increase to over 20% of total power consumption, so now the total energy consumption, (coal + power) is a huge consumption by all factors. Similarly the other manufacturing industries show how alarming the situation is in both these countries.

The problem associated in the case of India, China and Brazil is that these nations are in the stage of rapid industrialization. This stage is a resultant of high economic growth led by change in the structure of economic activities, higher industrial exports, lower industrial imports, higher production and industrial activity and high rate of growth in population. This is better explained by the Environmental Kuznet Curve (EKC).

Exhibit – 1: Environmental Kuznets Curve (EKC)



The Environmental Kuznets Curve (EKC) hypothesis states that pollution levels increase as the country develops, but begin to decrease as rising incomes pass beyond a turning point. This is reflected as inverted-U curve, expressing the relationship between pollution levels and income. Exhibit – 1 better explains this scenario.

This hypothesis was first proposed by Grossman and Krueger in 1992, and restated by them again in 1995.

As seen from exhibit – 1, there are many forces which are driving the relationship between environment degradation and economic growth. The upward movement of the curve captures the developing countries that move from agriculturally based economy to industrialization phase. In the next phase, the economy transforms into developed economy and then starts the downward movement of the curve with a shift towards services growth, increase in imports of industrial goods and stabilization of growth rates.

All three India, China and Brazil are said to be in the first phase where they are experiencing the structural shifts from agriculture to industrial growth. The share of agriculture for India has considerably declined from over 80% in 1950s to around 25% by 2007 and for China the decline in agriculture sector was from round 60% to 25% and industrial share in GDP went up from around 20% to over 50% during the same period of time. In the case of Brazil, its traditional strong hold is industry where its share was around 38% of GDP in 1970 itself. This slightly increased to over 40% in 2007. During the same period of time the levels of energy consumption and CO2 emissions have also drastically increased in these economies, exhibiting a relationship between economic growth led by industrialization and environment degradation. Thus, we hypothesis that:

Hypothesis 1: ***Rapid economic growth rate with structural shift towards industrialization in India, China and Brazil are leading to environment degradation.***

Both India and China have also witnessed a massive increase in its manufacturing exports and decline in its manufacturing imports. Whereas Brazil saw an increase in both manufacturing exports and imports. This trend is evident in the Environment Kuznets Curve (EKC) in the first phase of the curve. There was a constant increase in manufacturing exports for India from 1980s onwards. This increase was on surge during the 1990s. Similarly, there was a contrasting trend observed in the manufacturing imports. The imports of this segment declined at a slow pace during the 1980s. But in the 1990s the decline was at faster pace. The increase in manufacturing exports lead to extra energy consumption which goes into the production functioning of these goods, while the effects of imports of manufacturing goods is not clearly evident. This is because, if the imports are pure manufacturing goods then it is bound to act as substitute for the local made manufacturing goods, leading to decline in energy consumption. But if the imports are manufacturing capital goods, then it complements the existing manufacturing and industrial production, leading to increase in energy consumption levels. Thus, it is hypothesize that:

Hypothesis 2: ***Increase in manufacturing exports and decline in manufacturing imports leads to higher consumption of energy levels causing environment dilapidation.***

This hypothesis is tested only in the case of India and Brazil because the time series data for manufacturing exports and imports for China was not available and hence the study is forced to ignore these two key variables into the model for China.

02. Previous Research Findings

The above made arguments about the relationship between the environment degradation and rapid economic growth captured in the form on Environment Kuznets Curve (EKC) highlight the number of research studies done on these domain areas in the past.

There are a considerable number of studies that examine the link between energy consumption and economic growth. Following Kraft and Kraft (1978), earlier studies examined the Granger causality link between energy and income with diverse results are Akarca and Long, 1980; Yu and Hwang, 1984; Yu and Choi, 1985; Erol and Yu, 1987; Dilip M. Nachane, Ramesh M. Nadkarni and Ajit V. Karnik, 1988; Abosedra and Baghestani, 1989; Hwang and Gum, 1992 and Bentzen & Engsted, 1993. But they all suffer from omitted variables bias.

It was Stern, (1993) who was the first to advocate and use a multivariate setting, a powerful time series techniques to understand the relationship. Followed by Stern, many authors have done similar studies on a large scale sample (pooled regression analysis) for a 10 years time period. They have employed following model:

$$\mathbf{ES} = a_i + t_y + b_1\, GDP_{it} + b_2\, CV_{it} + e_{it} \quad \text{………………………………} (1)$$

Where, ES stands for Environmental Stress, GDP stood for Gross Domestic Product and CV for Control Variables. While, *a* stands for country specific effect, t = 1…..t years, i = i…..N countries and e = error term.

While, some other studies have taken into consideration the following form:

$$\mathbf{ES} = a_i + t_y + b_1\, GDP_{it} + b_2\, (GDP)^2_{it} + b_3\, CV_{it} + e_{it} \qquad \text{.................................... (2)}$$

Everything being similar, a new variable GDP square is taken into account. This variable specifies the acceleration of GDP of the country and includes all the structural changes taking place in the country. Some of the researchers have also taken into the following model:

$$\mathbf{ES} = a_i + t_y + b_1\, GDP_{it} + b_2\, (GDP)^2_{it} + b_3\, (GDP)^3_{it} + b_4\, CV_{it} + e_{it} \qquad \text{.................................... (3)}$$

Other things being similar, GDP cube is also considered. There is no specific meaning for this variable and that is the reason why this cubed term is not always included in most of the models.

To begin with, the studies conducted by Grossman and Krueger (1991), Lucas et al. (1992), Shafik and Bandyopadhyay (1992), where the first to work on the relationship between the environment degradation and economic growth. All these studies have taken into account the models specified above.

The credit goes to Grossman and Krueger (1991) who were the first to articulate the concept of Environment degradation and Economic Growth which became popular by the name Environment Kuznets Curve (EKC). They applied a critical test to the hypothesis that greater openness to trade will lead to lower environmental standards in order to retain international competitiveness. This was followed by the other two similar studies specified above.

In 1994, Selden and Song in their study have taken into consideration the role of trade in goods between the countries. In 1995, Grossman and Krueger comes out with the findings that the pollution generated in the production of industrial goods is related to consumption in another country when it is exported. They adopt the following model:

$$\mathbf{ES} = a_i + t_y + b_1\, GDP_{it} + b_2\, AGDP_{i\,(t-3)} + b_3\, (GDP)^2_{it} + b_4\, (GDP)^3_{it} + b_5\, TV_{it} + b_6\, CV_{it} + e_{it} \qquad \text{.................................... (4)}$$

Other things being similar as discussed above, the study also includes AGDP, average per capita income growth lagged to the last three years and TV, Trade Variables are also taken into consideration.

The role of industries is specified in the study by Low and Yeats, (1992) who show that pollution intensive industries accounts for a large share of exports from some developing countries. They also found a reversal trend for developed economies.

Kolstad and Krautkraemer (1993) point out the fact that there is a dynamic link between the environment, resource use and economic activity. They argue that while resource use (especially energy sources) yield immediate economic benefits, its negative impact on the environment may be observed in the long run.

Selecting the period of 1971-1991, Tucker, (1995) looked at changes in CO2 versus income in yearly cross-sectional analyses. The study found that the changes in CO2 emissions are clearly related to changes in oil prices, but does not incorporate them into the analysis.

The study by Jean Agras & Duane Chapman, (1998), takes into account the price of energy. This study highlights the importance of prices and then includes it in an econometric EKC framework testing energy-income and CO2-income relationships. These long-run price-income models find that income is no longer the most relevant indicator of environmental quality or energy demand.

In an another exemplary study by Suri & Chapman, (1998), examined the sources of commercial energy consumption, which is the root cause of serious environmental problems. It was found in the study that while both industrializing and industrialized countries have added to their energy requirements by exporting manufactured goods, the growth has been substantially higher in the former. At the same time, industrialized countries have been able to reduce their energy requirements by importing manufactured goods. The Exports of manufactured goods by industrialized countries has thus been an important factor in generating the upward sloping portion of the EKC and imports by industrialized countries have contributed to downward slope.

In a study conducted by Bernardini and Riccardo Galli, (1998) examined three fundamental factors that led to the decline in intensity of use of energy and materials for emerging Asian economies. They found that these three factors were changes in the structure of final demand, increases in the efficiency of materials and energy use and the substitution of more efficient materials and fuels.

Joy O Kadnar, (2004) in his research based on the energy consumption patterns, a model to predict the future short-term fossil fuel energy needs, using the relationship between consumption, population growth and real gross domestic product (GDP) for two situations (zero or no growth and a 5% sustained economic growth), was developed for Central Asian economies and obtained mixed results.

In a study conducted by Wietze Lise & Kees Van Montfort, (2006), tries to unfold the linkage between energy consumption and GDP by undertaking a cointegration analysis for Turkey with annual data over the period 1970–2003. The analysis shows that energy consumption and GDP are cointegrated. This means that there is a (possibly bi-directional) causality relationship between the two.

The study organized Ugur Soytas and Ramazan Sari, (2007) investigates the long run Granger causality relationship between economic growth, CO2 emissions and energy consumption in Turkey, controlling for gross fixed capital formation and labor. The most interesting result obtained in the study is that carbon emissions seem to Granger cause energy consumption, but the reverse is not true. The lack of a long run causal link between income and emissions may be implying that to reduce carbon emissions, Turkey does not have to forgo economic growth.

When it comes to similar studies on India, China and Brazil, there is one study worth noting by Antonio Focacci (2005), which proposes an empirical analysis concerning the environmental and energy policies in Brazil, China and India. The study includes ratio analysis using two key ratios namely, emission intensity ratio and energy-intensity ratio to relate to EKC model. The study results show mixed results with respect to application of Environmental Kuznets Curve model for these three economies. It shows that resulting trends in these three countries are different from the other developing countries.

All the research studies suggest that the ever increasing world wide CO2 emissions seems to be intensifying the problem of environment degradation resulting in global warming. This was also highlighted by the Intergovernmental Panel on Climate Change (IPCC) (2007). Since the emissions mainly result from consumption of energy, reduction in energy consumption seems to be the only way of handling this problem. But for an economy to grow, cutting the energy consumption levels seems less likely to be a possibility.

This turns the focus on some of the emerging economies like China, India and Brazil which are exhibiting a rapid economic growth rate led by industrialization to sacrifice their rapid rate of growth for betterment of environment quality. This inturn puts the spotlight to examine whether the rapid economic growth itself is the real cause of these problems in both these economies?

This paper tries to search answers to these question by investigating the relationship between the CO_2 emission and energy consumption relation on the first place and then studying the relationship between energy consumption and growth variables, especially economic growth, Industrialization and manufacturing trade. The study carries further by specifically testing the relationship between energy consumption and economic rate of growth at higher levels to find whenever these economies grow at a much higher levels of growth, does it really affect energy consumption or not.

The paper is organized as follows: Section – 3 captures the energy and CO_2 emissions scenario in India, China and Brazil. Section – 4 outlines the research variables and econometric models. Section – 5 discusses the empirical estimates and results. Finally, section – 6 concludes the paper, while section – 1 deal with introduction and section – 2 highlights the literature review of the past studies.

03. Energy & CO_2 scenario in China, India and Brazil

The Global energy consumption levels have predominantly seen the developed nations using more energy resources. The table – 1 captures the energy usage by major energy consumers in the world. The share of high income countries is 37% followed by United States of America with 29%.

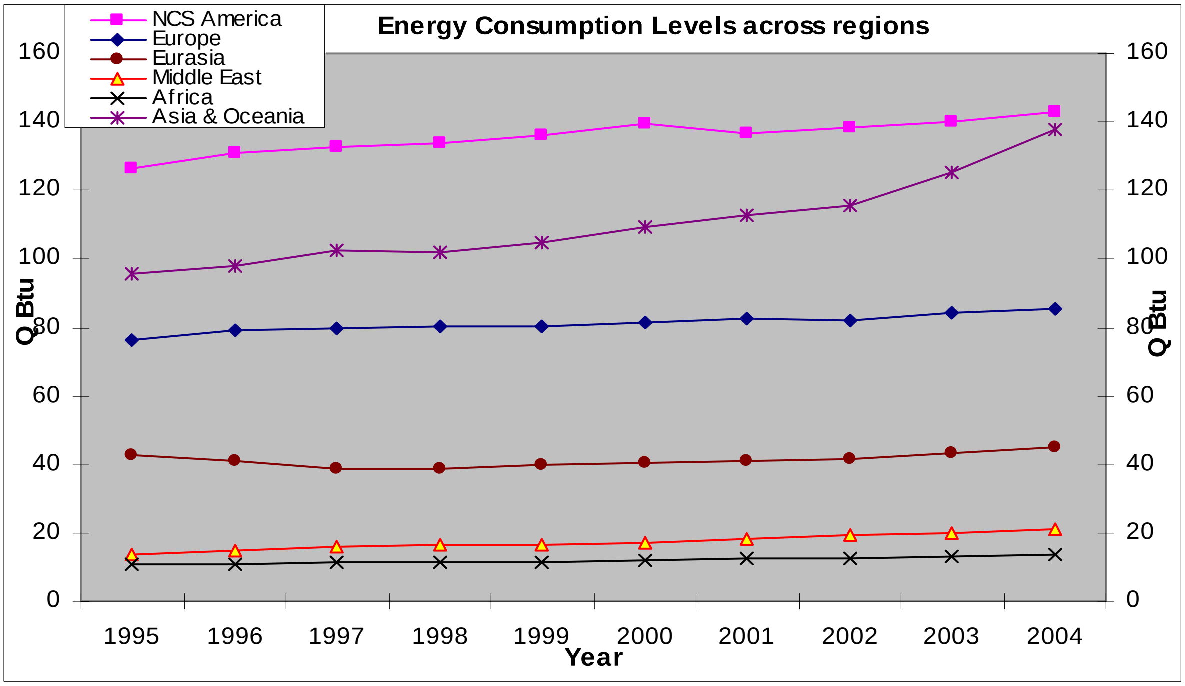
Table – 1: Global Energy Usage in 2003

Sl. No.	Countries	Share in total energy use
01	High Income Countries	37%
02	United States of America	29%
03	China	14%
04	Russian Federation	8%
05	Japan	6%
06	India	6%

Source: calculated from the data World Development Indicators 2002 and 2005, Washington D.C.

The share of other major consumers include 14% by China and 8% by the Russian Federation which is world's fourth largest energy supplier followed by Japan and India with 6% share respectively. The regional wise breakup of energy consumption levels is captured in the Graph – 1. During 1995 to 2004 the energy consumption levels for most of regions remained stable with marginal increase. However, in the case of Asia which is dominated by China and India there was constant increase in energy use. By the end of 2004, the energy consumption levels in Asia and Oceania region almost reach to the levels of North, Central and South American economies. This apart, Middle East and African regions also saw a small increase in their energy consumption levels for the same period.

Graph - 1



In terms of energy consumption levels, after United States, China, Japan, India and Brazil are the next consumers. The growth rate of energy consumption for India, China and Brazil are on raise from 1970 onwards. Table – 2 captures the energy consumption levels for these economies. The growth rate of energy consumption drastically increased from 1980 to 1990 for these three economies.

Table - 2: Energy Consumption in India, China & Brazil

(Total Thousands of Metric Tonnes of Oil Equivalent)

Countries	1980	1990	2001	2003	1980 - 2003	CGR	World Ranking
China	598,498	870,441	1,139,369	1,409,377	1,004,421	3.27	02
India	241,016	363,156	531,453	553,401	422,256	4.03	04
Brazil	111,471	132,985	185,083	193,245	155,696	2.57	07

Source: World Development Indicators 2002 and 2005, Washington D.C.

The raise was even higher during the decade of 1990s and early 2000. The compounded growth rate during this period of time for these three economies was exuberant. For China it was 3.27% followed by Brazil with 2.57%. But the highest compounded growth rate was registered by India with 4.03%.

The energy resources in India are mainly used for the purpose of generation of electricity, transportation, industrial and domestic uses. The complete energy situation in India can be gauged from the information presented in table – 3. From 1960 to 1980 the energy consumption in India grew at 7.96%. This stood at 4.53% for 1980 to 2000 period. Similar such trend can be observed in the energy production. The energy production grew at 8.02% during 1960 to 1980, while it grew at 4.11% from 1980 to 2000. But the interesting point is the net energy imports which grew at 6.8% for 1960 to 1980 and the growth rate almost remained constant for 1980 to 2000 period. This shows that one of the important objectives of energy policy of India of self sustainability is not achieved.

Table – 3: Energy Scenario in India: Average annual growth rate (%)

Items	1960	1970	1980	1990	2000[4]	2001[4]	2002[5]	1960 to 1980	1980 to 2000
Energy consumption									
- Total[(1)]	1.43	4.15	6.62	11.25	16.05	16.58	16.59	7.96	4.53
- Solids[(2)]	1.07	3.1	4.78	7.74	9.45	9.70	9.53	7.77	3.46
- Liquids	0.29	0.77	1.31	2.37	4.43	4.59	4.83	7.83	6.28
- Gases	N.A	0.02	0.05	0.39	1.07	1.14	1.18	-	16.55
- Primary electricity[(3)]	0.026	0.092	0.17	0.23	0.33	0.34	0.31	9.84	3.37
Energy production									
- Total	1.2	3.74	5.61	10.09	12.57	12.74	12.66	8.02	4.11
- Solids	1.1	3.17	4.69	7.53	8.96	9.09	9.03	7.52	3.29
- Liquids	0.02	0.29	0.39	1.43	1.38	1.37	1.41	16.01	6.52
- Gases	N.A	0.02	0.05	0.39	1.13	1.14	1.18	-	16.87
- Primary electricity[(3)]	0.026	0.092	0.17	0.23	0.33	0.34	0.31	9.84	3.37
Net import (Import - Export)									
- Total	0.26	0.5	0.97	1.22	3.57	3.78	3.93	6.8	6.73
- Solids	-0.03	-0.01	0.01	0.15	0.41	0.55	0.51	6.57	20.4
- Liquids	0.29	0.51	0.96	1.07	3.16	3.23	3.42	6.17	6.13
- Gases	N.A	N.A	N.A	N.A	N.A	N.A	N.A	-	-

Years represent financial years from 1st April of the year to 31st March of the next year.

(1) Energy consumption = Primary energy consumption + Net import (Import - Export) of secondary energy.

(2) Solid fuels include coal, lignite and estimated commercial wood. The consumption of the wood is assumed to remain constant at 3.134 EJ (Ref.: S.K. Varma, "Coal- A Predominant Option" Proc. Power in the New Millennium Plans & Strategies, Indian Nuclear society, Aug 31- Sept 2, 1999)

(3) Primary electricity = Hydro + Nuclear + Wind

(4) Annual Reports 2001-2002 and 2002-03 of Ministries of Power, Coal, Petroleum & natural Gas, Non-conventional Energy Sources, Central Electricity Authority and Department of Atomic Energy of Government of India.

(5) Estimated from the latest results given in the Annual Reports of the year 2002-03 of various Ministries of Government of India. Electricity Figures are actual.

Source: IAEA Energy and Economic Database

It can also be noticed from the information provided that India consumes most of its energy in the form of solids, which include coal, lignite and commercial wood. The rate of growth of energy consumption for solids kept increasing from 1960 to 2002. However, the growth rate of liquids, which includes petroleum products like oil surged from 1990s onwards. Because of its scares oil resources the production of liquids couldn't grow at that faster rate. The net imports show that India is a heavy dependent on liquids from rest of the world. The rate of growth of liquid imports for India peaked in 1990s.

In the case of Brazil, rapid economic growth and industrialization in the 1970s and 1980s fueled the growth rate of energy consumption. From 1970 to 1990, the energy consumption and production grew at 4.45% and 4.72% respectively. During 1990 to 2002 both energy consumption and energy production witnessed a decline in their growth rates. While the decline was steep in energy consumption, in the case of production it was marginal.

Table – 4: Energy Scenario in Brazil: Average annual growth rate (%)

	1970	1980	1990	2000	2001	2002	1970 to 1990	1990 to 2002
Energy consumption								
- Total(1)	2.88	5.51	6.89	9.43	9.60	9.69	4.45	2.87
- Solids(2)	1.40	1.89	1.69	1.68	1.66	1.66	0.94	-0.15
- Liquids	1.09	2.34	2.80	3.98	4.04	4.08	4.81	3.19
- Gases		0.04	0.15	0.35	0.35	0.36	21.32	7.63
- Primary electricity(3)	0.38	1.24	2.25	3.42	3.54	3.58	9.25	3.93
Energy production								
- Total	2.09	3.56	5.27	7.57	8.00	8.27	4.72	3.82
- Solids	1.35	1.78	1.38	1.24	1.28	1.28	0.13	-0.64
- Liquids	0.36	0.51	1.72	3.07	3.36	3.58	8.16	6.26
- Gases	N.A	0.04	0.15	0.26	0.28	0.29	21.31	5.55
- Primary electricity(3)	0.38	1.24	2.01	3.00	3.09	3.12	8.63	3.73
Net import (Import - Export)								
- Total	0.84	1.95	1.50	1.62	1.77	3.41	2.98	7.05
- Solids	0.05	0.13	0.31	0.43	0.43	0.43	9.10	2.73
- Liquids	0.78	1.82	1.19	1.11	0.88	0.51	2.14	-6.77
- Gases	N.A	N.A	N.A	0.08	0.45	2.46	-	-

(1) Energy consumption = Primary energy consumption + Net import (Import - Export) of secondary energy.
(2) Solid fuels include coal, lignite and commercial wood.
(*) Energy values are in Exajoule except where indicated.
Source: IAEA Energy and Economic Database.

The net imports grew at around 3% during 1970 to 1990, while the growth rate surged during the 1990 to 2002 witnessing 7.05% growth rate. The primary electricity production had a different pattern, the average annual growth rate decreased from 8.63% from 1970 to 1990 to about 3.73% during 1990 to 2002. The overall energy consumption in Brazil in the recent times is led by liquid fuels whose share in total energy consumption as on 2002-03 is around 42.2%. The share of natural gases is about 3%, while the hydro and nuclear power is 37%, which is an interesting shift towards low emission led energy production. This can be well understood by the fact that the share of solids (largely coal and lignite) has come down from 49% in 1970 to 17.1% in 2002-03, there by achieving primary goal of its energy policy, efficient use of energy by preservation and expansion of oil production and electric power supply.

China being world populous nation with rapid industrialization has huge energy requirements. The energy production for China grew at 3.93% from 1980 to 2000. During the same period the energy production also grew at 3.58%. The total net imports registered an annual average growth rate of 24.41% in this period.

Predominantly, China due to its huge base of natural resources depends largely on solids, specially the coal. The energy consumption of solids growth rate was 8.62% in 19970 which increased to 28.65% in 2002. Similar pattern can be observed in production of solids. The energy consumption of liquids grew largely during the 1990s, more specifically in the mid-1990s. As of 2005, China is the world second largest consumer of oil after United States of America. Its consumption is further expected to grow in the years to come.

Table – 5: Energy Scenario in China: Average annual growth rate (%)

	1970	1980	1990	1997	1998	1999	2000	2001	2002	1980 to 2000
Energy consumption										
- Total[1]	10.22	19.02	28.90	40.48	38.74	40.89	41.09	38.83	43.60	3.93
- Solids[2]	8.62	14.18	22.26	28.95	26.96	29.06	28.49	25.90	28.65	3.55
- Liquids	1.29	3.73	4.80	8.26	8.33	8.70	9.33	9.12	10.14	4.70
- Gases	0.11	0.56	0.60	0.69	0.85	0.91	0.95	0.97	1.17	2.71
- Primary electricity[3]	0.20	0.56	1.24	2.57	2.60	2.22	2.32	2.83	3.64	7.34
Energy production										
- Total	10.26	19.81	32.05	38.80	36.41	40.21	40.00	34.43	40.97	3.58
- Solids	8.67	14.26	24.44	28.75	26.18	29.97	29.40	23.20	28.78	3.68
- Liquids	1.28	4.44	5.79	6.71	6.73	6.91	7.07	7.06	7.00	2.36
- Gases	0.11	0.56	0.60	0.81	0.91	1.08	1.18	1.17	1.30	3.83
- Primary electricity[3]	0.20	0.56	1.22	2.58	2.60	2.25	2.35	3.01	3.88	7.42
Net import (Import - Export)										
- Total	-0.05	-0.79	-1.29	0.67	0.39	-2.19	-62.51	N.A	1.51	24.41
- Solids	-0.06	-0.08	-0.34	N.A	N.A	-1.08	-1.16	N.A	-1.53	14.21
- Liquids	0.01	-0.71	-0.95	N.A	N.A	1.78	2.31	N.A	2.73	15.32[4]
- Gases	N.A	N.A	N.A	N.A	N.A	-2.89	-63.65	N.A	0.31	N.A

(1) Energy consumption = Primary energy consumption + Net import (Import - Export) of secondary energy.
(2) Solid fuels include coal, lignite and commercial wood.
(3) Primary electricity = Hydro + Geothermal + Nuclear + Wind.
(4) From 1999 to 2003.
Source: IAEA Energy and Economic Database and National Bureau of Statistics of China.

The energy consumption for liquids registered a growth rate of 1.29% in 1970. This figure increased to over 10% in 2002. Similarly the primary electricity also increased in 1990s. The primary electricity production also increased in 1990s, which is in line with its energy policy which stress on extensive development of both nuclear and hydro power over a period of time. As of 2003, China's hydroelectricity is about 380,000 MW, while its major energy producer, coal deposits are estimated to be 5,059 billion metric tons (IAEA, country report, 2003).

Interestingly, China is both world's largest coal and fuel consumer. Its total share of energy consumption in 2005 comes from solids led by Coal, whose share is 66%, followed by liquids led by oil with a share of 23%. The other two includes natural gas and primary electricity with a share of 3% and 8% respectively. This is precisely one of the reason why its net imports for liquids growth rate is over 15% from 1999 to 2003. This apart, the growth rate for other items in net imports is negative, while for liquids the growth rate actually increased from 0.01% in 1970 to 2.31% in 2002.

The tables 6A, 6B and 6C shows the detailed break up of total primary energy consumption and their projections computed by International Energy Agency (IEA) in 2005 for these three economies.

Table – 6A: Total Primary Energy Consumption in China (1971 – 2030)

(in Mtoe)

	1971	2002	2010	2030	Annual Growth Rates 2002 - 2030
Coal	192	713	904	1354	2.3%
Oil	43	247	375	636	3.4%
Gas	3	36	59	158	5.4%
Nuclear	0	7	21	73	9.0%
Hydro	3	25	33	63	3.4%
Biomass & Waste	164	216	227	236	0.3%
Other Renewables	0	0	5	20	-
Total	405	1242	1622	2539	2.6%

Source: World Energy Outlook Report - 2004, IEA

China is largely depended on coal and it is the primary consumer of energy in the country. It is due to high usage of coal and its burning, there is severe air pollution when toxic gases like sulfur are released into the atmosphere. However, the government of China has taken note of this situation and has been trying to move away from increase usage of coal towards other forms like gas, nuclear and hydro power and oil. According to the IEA in the next 30 years the growth rate of coal supply is set to come down and is expected to grow at 2.3% while other forms like nuclear and hydro power are expected to growth at 9% and 3.4% respectively. Similarly the dependence on natural gas is also set to increase and is expected to grow at 5.4%.

In the case of Brazil, it is interesting to note that its energy is supplied largely not by coal but with Biomass, hydropower and oil. This is precisely one of the most important reasons why the CO2 emission in Brazil is very less compared to that of India and China.

Table – 6B: Total Primary Energy Consumption in Brazil (1971 – 2030)

(in Mtoe)

	1971	2002	2010	2030	Annual Growth Rates 2002 - 2030
Coal	2	13	14	22	1.9%
Oil	28	88	109	172	2.4%
Gas	0	12	18	59	5.8%
Nuclear	0	4	4	6	2.0%
Hydro	4	25	31	45	2.2%
Biomass & Waste	35	46	51	65	1.2%
Other Renewables	0	0	0	2	42.9%
Total	70	188	228	372	2.5%

Source: World Energy Outlook Report - 2004, IEA

The share of oil usage is the highest in Brazil. It accounted for about 40% of total energy consumption in 1971 but increased to 48% in 2002. This is largely because of growing transportation sector in the country. In the years to come, Brazil's dependence on oil, Biomass, Hydro is expected to continue (IEA report, 2004).

Like China, India is also largely dependent on coal. This is followed by oil and Biomass. Because of its high dependence on coal the country faces huge pollution problems. The large share of biomass in energy consumption is due to the dependence of entire rural sector and also urban population to an extent.

Table – 6C: Total Primary Energy Consumption in India (1971 – 2030)

(in Mtoe)

	1971	2002	2010	2030
Coal	44	200	218	356
Oil	36	160	181	249
Gas	0	31	39	64
Nuclear	2	8	17	26
Hydro	22	24	32	48
Biomass & Waste	110	182	126	121
Total	214	605	623	846

Source: World Energy Outlook Report - 2004, IAE (Note: Appox. Values)

In the years to come the growth rates of coal and biomass are expected to come down while there would be an increase in dependence on usage of oil, natural gas and hydro power as a move towards lower emission targets set by the government. However, the industries in India are still largely energy intensity based and the problems of higher emission are bound to continue in the future.

All these three economies face the problem of higher emission due to their higher energy use. In the process of meeting the higher energy demand, the energy production leads to release of toxic gases like CO2 which leads increase in pollution levels. The table – 7 gives the picture of levels of CO2 emission in these three economies.

Table – 7: CO2 Emissions in India, China & Brazil

(Million Metric Tonnes)

Countries	1970	1980	1990	2000	2004
China	767.54	1,476.80	2,401.7	2,790.5	4,769.0
India	193.7	347.3	675.3	1070.9	1102.81
Brazil	86.26	183.41	202.61	307.52	323.32

Source: World Development Indicators 2002 and 2005, Washington D.C.

Economies like China, India and Brazil produce large quantities of emissions in absolute quantity of CO2. The CO2 emission for China rose from 767 million metric tonnes in 1970 to 4,769 million metric tonnes by 2004. Not too far behind is India which saw an increase of over 900 million metric million tonnes during the same period. Though the levels of emission for Brazil is less compared to that of India and China, it has also witnessed a rapid increase in its CO2 from 86 million metric tonnes in 1970 to over 323 million metric tonnes by 2004. According to World Bank's data, the growth rate of CO2 emission in China stood at 3.25% for 1980 to 2001. During the same period, India registered a growth rate of 5.80%. The emission in Brazil is slightly at a lower side. This is because of their high dependence on hydro power unlike in India and China which depend largely on coal and other forms which are harmful for the environment.

Table – 8: Energy Related CO2 Emissions: Major Contributors in 2003

Sl. No.	Sectors	China	India	Brazil
01	Industry	75%	67%	49%
02	Transportation	9%	16%	42%
03	Residential	5%	14%	7%
04	Commercial	11%	3%	2%
05	Total	100%	100%	100%

Source: Energy Information Administration, U.S. Department of Energy, 2002.

It is estimated that the industry sector is leading to larger emissions levels in all these three countries. This is followed by transportation sector and this is quite large in the case of Brazil. This clearly shows that the increase in the industrialization is brining in more harm to the environmental degradation at least in these three countries.

04. Research Variables & Econometric Models

In this section, first an attempt is made to identify the dependent variables to be adopted in the models. Then explore the possible exploratory variables that affect the dependent variables for India, China and Brazil. Going by the objectives of the study, the paper tries to develop two different models to explain the relationship between pollution which is driven by energy consumption and energy consumption being driven by different growth variables. Based on these variables, the paper then provides empirical evidence through an econometric estimate of a model applied to India, China and Brazil. The economic reasoning that justifies the presence of each of the explanatory variables which would be included in the equation is explained:

04. i. Environment Disturbances and Energy Consumption

a. Dependent Variables:

Environment Disturbances - Emissions:

It is presumed that that the ecological problems is largely driven the by emission of some of the toxic gasses like the CO_2. Higher levels of CO_2 emissions drastically effect the environment. Thus, paper takes into account the CO_2 emission in kilo tons as the dependent variable which is contributing to the pollution and disturbing the environmental balance.

Environment Disturbances = *CO_2 Emission in Kilo Tons tonnes oil equivalent*

b. Independent Variables:

Energy Consumption:

The CO_2 emission in rapidly developing economies like India and China are largely because of the growing needs in the form of high energy consumption. Whenever there is an abnormal increase in energy consumption levels, it leads to a greater CO_2 emission. Thus, the paper takes into account energy consumption in kilo tons oil equivalent per country.

Energy Consumption = *Energy Use in Kilo tonnes oil equivalent per country*

The direct relationship is presumed between the energy use and CO2 emission in developing economies. Environmental damage almost always hits the hardest to those living in poverty. (United Nations, Human Development Report 1998 & Human Development Report, 1998).

04. ii. Energy Consumption and Growth Variables

a. Dependent Variables:

Energy Consumption:

There are severe environmental threats in most of the developing economies like India and China because of the growing needs in the form of high energy consumption. It is hypothesized in the earlier argument that as energy consumption increases it leads to more emission of some dangerous toxic gases. Thus, the paper takes into account energy consumption in kilo tons oil equivalent per country.

Energy Consumption = Energy Use in Kilo tonnes oil equivalent per country

b. Independent Variables:

b. i. Growth of Market Size:

The energy uses in the fast emergining economies are largely due to the rapid growth rate of their economies. These higher growth rates are putting increasing pressure on energy consumption in the form of increasing needs. As emerging markets develop and expand, they release increasing quantities of toxic gasses into the atmosphere because of higher energy consumption. Increase in those emissions may eventually be raged by rising GDP, increasing the attractiveness of environmental protection as a consumable. Thus, the GDP growth rates are positively associated with the energy use in the emerging countries like India, China and Brazil. Thus, growth of GDP, i.e. annual percentage change in GDP in the current year to previous year is taken into consideration.

Growth of market size = ΔGDP/GDP per country

b. ii. Industrialization:

It is a known fact that the production and industrial activities involve energy as an essential input. It is one of the key sources of industrialization. As emerging economies keep growing at higher rates leading to rise in income and progression of economy into the industrial stage, the energy need increases significantly due to the emergence of transportation networks, introduction of various factories and other infrastructure requirements that needs sustained sources of energy. This economic transition stage results in much higher energy consumption and subsequently the energy needs increase drastically for these economies.

There were a lot of data problems as the data on commercial energy use, manufacturing as a function of total industrial production was not available for India, China and Brazil. Hence, the paper considered the share of industrial output in the total GDP.

Industrialization = Share of Industrial Output in GDP per country

b. iii. Population

Population growth is another key indicator that is taken into consideration because of the size of population specially in China and India. As the population grows the needs also increase. The size of population coupled with rise in GDP growth and higher per capita income creates demand for various products and this leads to increase in energy consumption. Both India and China have large number of population residing in rural areas depending more on agriculture. This set of population though are not concerned with the industry, consumes energy in the form of fuel. Thus, in these rural communities though the energy consumption is low but is usually met in the form of fuel and biomass. In order to find the impact of population on energy consumption in India, China and also Brazil, the paper considers the rate of growth of population in these countries.

Population = Rate of Growth of Population per country

b. iv. Registered Vehicles

Transportation is a major contributor to energy use. This becomes even more important variable when it is about these three economies which are geographically the largest countries in the world. Locations with high levels of travel, long-distance travel, level of public transportation and the number of total vehicles in the country typically tend to have a very high-energy consumption.

Both India and China are highly populated nations with raising incomes creating the demand for motor vehicles. Added to this, the vast public transport systems of both nations also play a key role. In the case of India, the data for number of registered vehicles was not available. But the Ministry of Roads and Highways and Government of India provides the time series data on registered vehicles per 1000 people and this variable was taken as proxy for total number of registered vehicle in each year. There was no such problem in the case of China as the data on total number of vehicles in each year was available and rate of growth of vehicles was calculated from it.

Registered Vehicles = Registered vehicles per 1000 inhabitants for India

Growth rate of total number of registered vehicles for China

There was the problem of data availability in the case of Brazil. The time series data for number of vehicles was absent. In order to consider this variable into the model, it was decided to take the IPEA's Transportation Index constructed from 1975 to 2007.

Proxy for Registered Vehicles for Brazil = Transportation Index

b. v. Manufacturing Exports

The paper also takes into account the country's advancement in international trade as an advent of its rapid economic growth and its impact on energy consumption levels. The participation in international trade was further broken into various categories only to find that the exports of manufacturing products were on rise for India, China and Brazil. This means that the manufacturing products produced are also exported to different parts of the world, leading to much higher energy consumption in both the economies. It was found in Suri and Chapman, (1998) that the manufacturing exports are on raise for all the developing economies in the world. It was also evident in their research that the rate of growth in this segment was even higher for the developing economies.

The other interesting aspect to this argument is that the demand for these products from these economies is increasing at a faster rate and the clients being the developed economies. This is because of the availability of these products at a much cheaper rate because of the low cost resources in developing economies, especially in China, India and Brazil.

The paper takes into account the effect of manufacturing exports as the share in total exports for India and Brazil because of the lack of data availability on pure manufacturing exports as function of GDP. However, the other disappointing aspect is that the data for this variable was not available for China and was forced to be ignored.

Manufacturing Exports = Share of manufacturing exports in total exports for India

b. vi. Manufacturing Imports

The role of imports of manufactured goods has a double edge impact on energy consumption. Thus, it is important to know whether the imports of manufacturing goods are on increase or otherwise.

The increase in imports of manufacturing goods lead to decline in energy consumption if those goods are used to replace the manufactured goods which are produced domestically which consume high energy levels. Thus, imports of these manufacturing goods, by replacing domestic production, would reduce the energy requirements of the country.

However, there is also a contrasting argument which states that if the increase in manufacturing imports like the capital intensive goods or machinery can lead to increase in energy consumption levels. This is because imported capital intensive goods would be used for the production, adding to the existing production levels in the country. This is exactly true in the case of Brazil as there was an increase in manufacturing imports to total imports during the study period.

Thus, the net effect of increase in manufacturing imports can be either positive or negative for the developing economies. In a research study by Chapman, (1998) it was found that for almost all the developing economies, the manufacturing imports are in declining trend and even for economies where there is a rise in this segment of imports, the rate of growth is very negligible. In the case of India also, the share of manufacturing imports in its total exports have been declining since from 1970s (World Development Indicators, 2006).

There was data availability problem for China and this variable was not considered in the model for China. In the case of India and Brazil, the pure data on manufacturing imports were not available and hence the share of manufacturing imports in total imports was taken into consideration.

Manufacturing Imports = Share of manufacturing Imports in total Imports for India

b. vii. Gross Fixed Capital Formation (GFCF)

The paper includes the variables Gross Fixed Capital Formation for China to see its impact on energy consumption. There is a strong belief that the level of capital intensive projects going on in the country in various infrastructure related projects and in other industrial sectors is leading to increase in energy consumption levels. The GFCF in China as of 2006 stood at over 40% of GDP. Massive amount is spent on infrastructure, creating transportation and electricity delivery networks which are having a considerable influence on energy consumption in the country. But, this is not similar with India and Brazil as the GFCF to GDP is the lowest and hence we do not include this variable for thse two countries as it makes no significance.

Gross Fixed Capital Formation = GFCF as percentage of GDP for China

04. iii. Data Sources

The time period selected for the study for India and China is from 1970 to 2005. However, for Brazil, due to lack of availability of some of variables from 1970, the study period from 1975 to 2005 was considered. The time frame selection was done precisely because of two reasons. One, large sample data availability and two, during this 25 to 30 year period, all the three economies witnessed structural shift from agriculture sector to industrialization and increase in industrial trade. The data used in the study are mostly of secondary in nature, collected from authentic sources. The sources comprise of website, which include Government of India, Government of China, IPEA's website in Brazil and website of World Bank's Development Indicators: 1970-2005.

The data for CO2 emission for both the countries is taken from World Bank's World Development Indicators (1970-2005) series. Similarly, the variables like energy consumption, GDP growth rates, share of industry in GDP, rate of growth of population, manufacturing exports and imports as a share in total exports and imports respectively for India and Gross Fixed Capital Formation for China are also adapted from the World Bank data series.

However, the data related to total number of registered vehicles for China was adopted from the Government of China's official statistical website. Similarly, the data for India's number of registered vehicles per 1000 inhabitants was taken from the Government of India's official statistical website (CSO) on social-economic data series released in 2002 and for the last three years, the data was computed from the values taken from Government of India's Ministry of Roads and Transportation website.

The exact place from where the data was taken from the above mentioned sources are placed in the following table:

Table – 9: Data Sources of the variables used in the study

Sl. No.	Variables	Exact Data Base Sources
01	CO2 Emission	http://ddp-ext.worldbank.org/WDI
02	GDP Growth Rates	http://ddp-ext.worldbank.org/WDI
03	Share of Industry in GDP	http://ddp-ext.worldbank.org/WDI
04	Manufacturing Exports	http://ddp-ext.worldbank.org/WDI
05	Manufacturing Imports	http://ddp-ext.worldbank.org/WDI
06	Registered Vehicles	http://mospi.nic.in/mospi_cso_rept_pubn.htm (India) http://morth.nic.in/writereaddata/sublinkimages/Table%20No.htm http://chinadataonline.org (China)
07	Transportation Index	http:// www.ipeadata.gov.br
08	Population	http://ddp-ext.worldbank.org/WDI
09	Gross Fixed Capital Formation	http://ddp-ext.worldbank.org/WDI

With this elaborated description on research variables, their selection and data sources, the paper now turns to apply some econometric models which are aimed at explaining the effect of energy consumption levels in both countries on CO2 emission and influence of growth variables on energy consumption levels.

04. iv. Empirical Models

In order to assess the variables affecting CO2 and energy consumption, two different relationships were examined using time series variables from 1970 to 2005.

CO2 Equation:

$$Q_t = \alpha + \beta_1 Z_t + \varepsilon$$

$$\text{.................................. (5)}$$

Q_t is the dependent variable, which is CO2 in the country or otherwise and t is the current year. But, if the equation is taken in its present form may incur the problem of serial correlation. To counter this problem, as exactly pointed out by Chapman, (1998), the dependent variable and independent variable are lagged for one year. Thus, the paper set-up an autoregressive-distributed lag formulation (AD (1, 1)) and despite the simplicity of this model, most every type of single-equation model in empirical time series econometrics is a special case of it (Hendry, 1995).

Thus, the equation in the corrected form would be:

$$Q_t = \alpha + \beta_1 Q_{(t-1)} + \beta_2 Z_t + \beta_3 Z_{(t-1)} + \varepsilon_t \qquad \text{.................................. (6)}$$

Where,

Q_t = CO2 Emission
$Q_{(t+1)}$ = CO2 Emission to one lagged value to control autocorrelation
Z_t = Control variable
$Z_{(t-1)}$ = Control Variable to one lagged value autocorrelation
ε_t = Error term

The paper takes the LOG values for all the variables in order to see the elasticity.

Energy Consumption Equation:

$$Y_t = \alpha + \beta_1 g_t + \beta_2 X_t + \varepsilon_t \qquad \text{.................................. (7)}$$

Where,

Y_t = Energy Consumption
g_t = GDP Growth variable
X_t = Control variables
ε_t = Error term

04. v. Threshold Regression Analysis

In the next stage, the paper introduces threshold regression analysis by including three different levels of GDP growth rates to see their impact on the energy consumption levels. This would show whether the higher GDP growth rates of India, China and Brazil share a positive relationship or otherwise with the energy consumption levels in their respective countries.

The three different levels of GDP growth rates are identified as below:

For India: above 6.5%; above 7% and above 7.5%
For China: above 8%; above 9.5% and above 11%

For Brazil: above 5% and above 6%

This is presented in the interactive form, where the dummy takes the value 1 with the GDP growth rate of the respective country crosses the three specified levels and takes 0 otherwise.

Scenario – 1:

Interactive form = GDP Growth rate X 1 **If GDP growth rate exceed:**

i. 6.5%, 7% & 7.5% for India

ii. 8%, 9.5% & 11% for China

iii. 5% & 6% for Brazil

Scenario – 2:

Interactive form = GDP Growth rate X 0 **If GDP growth rate DO NOT exceed:**

i. 6.5%, 7% & 7.5% for India

ii. 8%, 9.5% & 11% for China

iii. 5% & 6% for Brazil

In order to ensure that the model specified is correct and is free from any other defects, the paper employs Durbin Watson test. The paper uses alternative method called Breusch-Godfrey LM test. The paper also reports correlation matrix in annexures for all models. Thus, the above models are estimated by using the Ordinary Least Squares (OLS) method. The regression is run using the statistical package – E-views, version 5.1.

05. Empirical Results and Estimates

The paper now turns towards the empirical results and estimates for both the equations on CO2 emission and energy consumption for India and China. In the first phase, the paper discusses the results from CO2 emission and energy consumption relationship for India and China. In the next phase, the paper examines the results of energy consumption and growth relationship for both the countries. Also discussed are the results from threshold regression analysis.

i. CO2 and Energy Consumption Relationship: Panel Data Results

The results of CO2 emission by energy consumption with a common coefficient and separate coefficient results for India, China and Brazil for the period 1970 to 2005 are presented in table – 10 and table – 11 respectively.

Table – 10: Panel Data Results of CO2 emission by Energy Consumption

Dependent Variable: LOG (CO2)				
Method: Pooled Least Squares				
Sample(adjusted): 1971 2005				
Included observations: 35 after adjusting endpoints				
Number of cross-sections used: 3				
Total panel (balanced) observations: 105				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
C	0.028997	0.009875	2.936475	0.0041*
LOG(Energy Consumption)	1.262905	0.129346	9.763775	0.0000*
LOG(Energy Consumption(-1))	-1.166560	0.131158	-8.894308	0.0000*
LOG(CO2(-1))	0.924468	0.024221	38.16776	0.0000*
R-squared	**0.999081**	Mean dependent var		1.827981
Adjusted R-squared	**0.999053**	S.D. dependent var		1.067789
S.E. of regression	0.032854	Sum squared resid		0.109017
Log likelihood	211.6974	F-statistic		36585.56
Durbin-Watson stat	**1.975172**	Prob(F-statistic)		0.000000

Note:
* Significant at 1% confidence level

It is evident from the result that on an average one unit of energy consumption is leading to an increase in CO2 emission by 126% for the said time period. The coefficient of energy consumption gives the CO2 emission elasticity. The energy consumption is statistically significant at 1% confidence level. The R square value of 0.99 means 99% of variation in the logs of CO2 emission which is explained by the logs of energy consumption during 1970 to 2005 period and the adjusted R square value also stand at 99%. The presence of serial correlation problem is nullified by the Durbin Watson test value which is 1.97. Overall goodness of the fit is highly significant.

Table – 11: Results of CO2 emission by Energy Consumption for India,China& Brazil

Dependent Variable: LOG (CO2)				
Method: Pooled Least Squares				
Sample(adjusted): 1971 - 2005				
Included observations: 35 after adjusting endpoints				
Number of cross-sections used: 3				
Total panel (balanced) observations: 105				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
C	0.035903	0.012316	2.915108	0.0044*
LOG(EC (-1))	-1.114128	0.136202	-8.179946	0.0000*
LOG(CO2(-1))	0.925986	0.027190	34.05570	0.0000*
INDIA - LOG(Energy Consumption)	1.204977	0.133888	8.999854	0.0000*
CHINA - LOG(Energy Consumption	1.206512	0.133229	9.055911	0.0000*
BRAZIL - LOG(Energy Consumption	1.177304	0.138699	8.488187	0.0000*
R-squared	**0.999106**	Mean dependent var		1.827981
Adjusted R-squared	**0.999061**	S.D. dependent var		1.067789
S.E. of regression	0.032718	Sum squared resid		0.105976
Log likelihood	213.1829	F-statistic		22134.74
Durbin-Watson stat	**1.993877**	Prob(F-statistic)		0.000000

Note:
* Significant at 1% confidence level

It can be noted from the results that for India, China and Brazil the energy consumption if increased by one unit, it leads to an increase of 120% and 117% respectively in CO2 emission. The values are statistically significant for both at 1% confidence level. The R square value of 0.99 means 99% of variation in the logs of CO2 emission for both the countries which is explained by the logs of energy consumption during 1970 to 2005 period and the adjusted R square value also stand at 99%. In this case also, the presence of serial correlation problem is nullified by the Durbin Watson test value which is 1.99 and the overall goodness of the fit is highly significant. The above results indicate that rapidly developing countries like India, China and Brazil are more prone to CO2 emission and both energy consumption and emission are functionally related to each other.

ii. Energy Consumption and Growth Relationship

This section presents the results of regression estimates in measuring the influence of growth variables on energy consumption for India, China and Brazil. The table – 4 is the standard model which captures the regression estimates for energy consumption and growth equation for India, while table – 5 and 6 are also the standard models estimates the regression results for energy consumption and growth equation for China and Brazil respectively. The descriptive statistics for India, China and Brazil are mentioned in Annexure – 1, 2 & 3 in the annexure section at the end.

iii. Threshold Regression Analysis:

In the second step, for the equation on energy consumption and growth, there are three different models capturing the impact of higher GDP growth on energy consumption at three different growth rate levels for India. Similar test is also conducted for China and Brazil. Each model is unique in nature and differs from the other two. These models are captured in tables – 4A, 4B, and 4C. The table – 4A presents the inclusion of GDP growth rate at above 6.5% level and also includes all other variables in the model. The table – 4B captures the second model with has GDP growth rate variable which is above 7% level to see the influence on energy consumption, while the table 4C includes the model in which GDP growth rate of above 7.5% is taken into consideration.
Similarly for China there are three different models which are unique in nature and differ from the other two. These models are captured in tables – 5A, 5B, and 5C. The table – 5A presents the inclusion of GDP growth rate at above 8% level and also includes all other variables in the model. The table – 5B captures the second model with has GDP growth rate variable which is above 9.5% level to see its influence on energy consumption, while the table 5C includes the model in which GDP growth rate of above 11% is taken into consideration.

However for Brazil, given its low growth rate profile, it was decided to form only two models. These models are covered in tables – 6A and6B. The table – 6A presents the inclusion of GDP growth rate at above 5% level and also includes all other variables in the model. The table – 6B captures the second model with has GDP growth rate variable which is above 6% level to see its influence on energy consumption.

This apart, the study also tests for presence of serial correlation problem by employing in the first phase the Durbin Watson test and then Breusch-Godfrey's LM test for India, China and Brazil in their respective standard models. Also the paper makes an attempt to detect the presence of multi collinearity problem for both the standard models of the equations by computing Variance Inflation Factor (VIF) values and Tolerance limit values.

Energy Consumption and Growth Equation for India: Standard Model

The results show standard model of the relationship between Energy consumption and growth. As expected all the growth variables exert a positive correlation with energy consumption.

Table – 12: Standard Model for Energy Consumption & Growth for India

Dependent Variable: Energy Consumption				
Method: Least Squares				
Sample: 1970 - 2005				
Included observations: 36				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
C	-1.060612	0.373091	-2.842767	0.0081*
GDP Growth	0.011958	0.008228	1.453250	0.1569+
Industrial Growth	0.083715	0.013985	5.986116	0.0000*
Registered Vehicles	0.054047	0.002815	19.19851	0.0000*
Population	0.200504	0.110945	1.807236	0.0811***
Manufacturing Exports	0.013611	0.005046	2.697244	0.0115**
Manufacturing Imports	-0.002964	0.003696	-0.801814	0.4292
R-squared	**0.991594**	Mean dependent var		3.488056
Adjusted R-squared	**0.989854**	S.D. dependent var		1.289936
S.E. of regression	0.129930	Akaike info criterion		-1.070982
Sum squared resid	0.489569	Schwarz criterion		-0.763076
Log likelihood	26.27768	F-statistic		570.1260
Durbin-Watson stat	1.645117	Prob(F-statistic)		0.000000
Testing for presence of Serial Correlation: Breusch-Godfrey Serial Correlation LM Test				
F-statistic	0.648520	Probability		0.427429
Obs*R-squared	0.814936	Probability		0.366665

Note:
* Significant at 1% confidence level
** Significant at 5% confidence level
*** Significant at 10% confidence level
+ Significant at 15% confidence level

The interesting point to be noted is the significance of Manufacturing exports, industrial growth and registered vehicles variables on energy consumption, which is stronger than that of the GDP growth.

The 1% increase in manufacturing exports lead to corresponding increase in energy consumption levels by 1.36% and is statistically significant at 5% confidence level. This proves the point that the manufacturing exports are indeed contributing to a great level of pollution by consuming more energy. This is well explained by the fact that manufacturing exports for India have been growing since the early 1980s. A similar contrasting trend can be observed in the case of manufacturing imports. The manufacturing imports exhibit a downward trend since 1980s as a result the manufacturing imports have negative correlation with the energy consumption and are not statistically significant either.

The share of industry sector in GDP exerts a positive relationship with energy consumption. Infact, the increase in 1% growth in share of industry of GDP is leading to a growth of 8.37% for energy consumption and is statistically significant at 1% confidence level. Ever since India attained independence in

1947, its dependence was more on agriculture sector. But over the years the dependence of agriculture sector has reduced and the share of industry has been on raise along with the service sector. The share of industry in GDP was under 10% during the 1950s has increased rapidly to around 30% by 2007.

The number of registered vehicles proxied by the number of vehicles available per 1000 inhabitants in the country is making a positive impact on energy consumption levels and is statistically significant at 1% confidence level. The impact of this variable per 1% increase on energy consumption is 5.40%, which is next to industry share variable. During the 1970, according to the government of India data, the number of vehicles available per 1000 inhabitants was only 3 and this gradually increased to 66 by 2006. The increase in the number was rapid from the 1980s onwards.

The highest impact on energy consumption variable is made by the rate of growth of population in India. The population in India is considered to be world's second largest and is expected to take over China by 2020. Though efforts are made by the government agencies, volunteer organization and other funding groups to ensure the reduction in growth rate of population; its growth rate is still amongst the highest in the world by any standards. The population in India is growing at a rate of over 1.25% per annum. A 1% increase in population in India is leading to a 20% growth in energy consumption levels. This is statistically significant at 10% confidence level.

When it comes to the general rate of growth of GDP, an increase of 1% in this variable is leading to an increase in 1.12% growth in energy consumption levels. This is statistically significant at 15% confidence level. One reason which can be attributed for this can be the fluctuating trend which the GDP growth rate has exhibited during the decade of 1970 to 1980. The period of 1980 to 1990 saw a very low rate of growth in GDP for India. The rate of growth though increased slightly during the 1990 to 2000 period, the increase was marginal compared to the previous decade. But the real change was about to come in the early 2000s where the GDP surged by over 7.5% mark consistently for the next seven years.

High GDP growth rate which is a resultant of raid industrialization, increasing demand for goods and vehicles, coupled with a very high rate of growth in manufacturing exports and population are having a drastic impact on the energy consumption levels in the country.

The R square value of 0.99 means 99% of variation in energy consumption for India which is explained by growth variables during 1970 to 2005 period and the adjusted R square value stand at 98%, which indicates that the overall goodness of the fit is highly significant. The Breusch-Godfrey Serial Correlation LM Test stated below the equation results show that the model does not suffer with serial correlation problem. The correlation matrix is presented in Annexure – 3.

i. Energy Consumption and Growth Equation for India: Threshold Regression Models

The table – 12A, 12B, and 12C presents the estimation of the three equations in which the dummy variable GDPD is introduced in the interactive form (Dummy multiplied by GDP) to check that at which higher GDP growth rate levels the effect on energy consumption is recognized even stronger.

Table – 12A: Threshold Regression Analysis for India at GDP growth > 6.5%

Dependent Variable: Energy Consumption				
Method: Least Squares				
Sample: 1970 - 2005				
Included observations: 36				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
C	-1.153812	0.373161	-3.091997	0.0044*
GDP Growth > 6.5% (GDPD)	0.011104	0.006482	1.712981	0.0974***
Industrial Growth	0.084196	0.013686	6.152087	0.0000*
Registered Vehicles	0.054201	0.002781	19.48839	0.0000*
Population	0.239157	0.115534	2.070012	0.0475**
Manufacturing Exports	0.014117	0.004979	2.835280	0.0083*
Manufacturing Imports	-0.002946	0.003648	-0.807704	0.4258
R-squared	**0.991810**	Mean dependent var		3.488056
Adjusted R-squared	**0.990116**	S.D. dependent var		1.289936
S.E. of regression	0.128246	Akaike info criterion		-1.097071
Sum squared resid	0.476962	Schwarz criterion		-0.789165
Log likelihood	26.74728	F-statistic		585.3237
Durbin-Watson stat	**1.660455**	Prob(F-statistic)		0.000000
Testing for the presence of Serial Correlation:	**Breusch-Godfrey Serial Correlation LM Test**			
F-statistic	0.644936	Probability		0.428694
Obs*R-squared	0.810534	Probability		0.367962

Note:
* Significant at 1% confidence level
** Significant at 5% confidence level
*** Significant at 10% confidence level

This model shown above has GDP dummy variable identified as 1 whenever the GDP growth rate for India from 1970 to 2005 exceeds 6.5% level and 0 otherwise.

It is to be noted that whenever the GDP growth rate of India has crossed 6.5% level, it has exerted a positive relationship with energy consumption. If the GDP growth rate above 6.5% is increased by 1% it leads to an increase in energy consumption level by 1.11%. This is statistically significant at 10% confidence level. This only suggests that the positive effects on energy consumption whenever the GDP growth rate for India crosses above 6.5%.

Among the other variables, viz., industry share in GDP and registered vehicles associate a positive relationship with energy consumption level and both are statistically significant at 1% confidence level. The population growth variable is also having a positive association with energy consumption and is statistically significant at 5% confidence level.

The manufacturing trade variables, manufacturing exports and imports have a contrasting relationship with energy consumption. The former has a positive statistically significant relationship at 1% confidence level while the later exert a negative relationship and has no statistical significance.

Table – 12B: Threshold Regression Analysis for India at GDP growth > 7%

Dependent Variable: Energy Consumption				
Method: Least Squares				
Sample: 1970 - 2005				
Included observations: 36				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
C	-1.201002	0.369856	-3.247217	0.0029*
GDP Growth > 7% (GDPD)	0.013129	0.006548	2.004945	0.0544**
Industrial Growth	0.083467	0.013473	6.194975	0.0000*
Registered Vehicles	0.054512	0.002745	19.85975	0.0000*
Population	0.266538	0.116904	2.279975	0.0301**
Manufacturing Exports	0.014082	0.004896	2.876399	0.0075*
Manufacturing Imports	-0.002843	0.003587	-0.792652	0.4344
R-squared	**0.992079**	Mean dependent var		3.488056
Adjusted R-squared	**0.990441**	S.D. dependent var		1.289936
S.E. of regression	0.126120	Akaike info criterion		-1.130498
Sum squared resid	0.461282	Schwarz criterion		-0.822592
Log likelihood	27.34896	F-statistic		605.3841
Durbin-Watson stat	**1.603362**	Prob(F-statistic)		0.000000
Testing for presence of Serial Correlation	**Breusch-Godfrey Serial Correlation LM Test**			
F-statistic	0.938341	Probability		0.340998
Obs*R-squared	1.167319	Probability		0.279953

Note:
* Significant at 1% confidence level
** Significant at 5% confidence level

This model shown above has GDP dummy variable identified as 1 whenever the GDP growth rate for India from 1970 to 2005 exceeds 7% level and 0 otherwise.

It is to be noted that whenever the GDP growth rate of India has crossed 7% level, it has exerted a positive relationship with energy consumption. If the GDP growth rate above 7% is increased by 1%, it leads to an increase in energy consumption level by 1.13%. This is statistically significant at 10% confidence level. This only suggests that the positive effects on energy consumption whenever the GDP growth rate for India crosses above 7%.
One interesting point which is worth noting here is that the when GDP growth rate is increased above 7% level compared to previous 6.5%, the increase in energy consumption levels has gone up by 0.02%. This suggests that whenever the growth rate of GDP is increasing, the energy consumption levels are also exerting a marginal increase.

Among the other variables, viz., industry share in GDP and registered vehicles associate a positive relationship with energy consumption level and both are statistically significant at 1% confidence level. The population growth variable is also having a positive association with energy consumption and is statistically significant at 5% confidence level.

The manufacturing trade variables, manufacturing exports and imports have a contrasting relationship with energy consumption. The former has a positive statistically significant relationship at 1% confidence level while the later exert a negative relationship and has no statistical significance.

Table – 12C: Threshold Regression Analysis for India at GDP growth > 7.5%

Dependent Variable: Energy Consumption				
Method: Least Squares				
Sample: 1970 - 2005				
Included observations: 36				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
C	-1.112079	0.353169	-3.148860	0.0038*
GDP Growth > 7.5% (GDPD)	0.017395	0.007167	2.427264	0.0217**
Industrial Growth	0.080005	0.013329	6.002140	0.0000*
Registered Vehicles	0.054073	0.002658	20.34127	0.0000*
Population	0.283406	0.113389	2.499419	0.0183**
Manufacturing Exports	0.015104	0.004788	3.154470	0.0037*
Manufacturing Imports	-0.004662	0.003567	-1.306995	0.2015
R-squared	**0.992504**	Mean dependent var		3.488056
Adjusted R-squared	**0.990953**	S.D. dependent var		1.289936
S.E. of regression	0.122691	Akaike info criterion		-1.185637
Sum squared resid	0.436536	Schwarz criterion		-0.877730
Log likelihood	28.34146	F-statistic		639.9757
Durbin-Watson stat	**1.663070**	Prob(F-statistic)		0.000000
Testing for presence of Serial Correlation: Breusch-Godfrey Serial Correlation LM Test				
F-statistic	0.580004	Probability		0.452678
Obs*R-squared	0.730586	Probability		0.392693

Note:
* Significant at 1% confidence level
** Significant at 5% confidence level

In this model the GDP dummy variable is identified as 1 whenever the GDP growth rate for India from 1970 to 2005 exceeds 7.5% level and 0 otherwise.

When the GDP growth rate of India has crossed 7.5% level, it has also exerted a positive relationship with energy consumption. If the GDP growth rate above 7.5% is increased by 1%, it leads to an increase in energy consumption level by 1.17%. This time it is statistically significant at 5% confidence level. This once again proves that there is a strong positive effect on energy consumption whenever the GDP growth rate for India crosses above 7.5%.

The two interesting point are highlighted here are that the when GDP growth rate is increased above 7.5% level compared to previous 7% and 6.5%, the increase in energy consumption levels has gone up by 0.06%. This suggests that more the increase in GDP growth rate, higher the energy consumption levels. The other point which attracts the attention is that the statistical significance of this variable. As GDP growth rate kept increasing its statistical significant improved from 10% to 1% confidence level suggesting that the findings are robust. The other variables in the model exert a similar relationship with energy consumption as analyzed in the previous models. The R square and the adjusted R square values for all the models specified discussed above are high. The Breusch-Godfrey Serial Correlation LM Test results show that no models suffer with serial correlation problem.

ii. Energy Consumption and Growth Equation for China: Standard Model

The standard model of relationship between Energy consumption and growth for China is captured in table - 13. As expected all the growth exerts a positive correlation with energy consumption.

Table – 13: Standard Model for Energy Consumption & Growth for China

Dependent Variable: Energy Consumption				
Method: Least Squares				
Sample: 1970 - 2005				
Included observations: 36				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
C	10.14049	5.925498	1.711332	0.0973**
GDP Growth	0.091366	0.055698	1.640403	0.1114**
Industrial Growth	0.471469	0.131922	3.573843	0.0012*
Growth of Vehicles	0.287714	0.082534	3.485999	0.0015*
Population	-0.674354	0.493475	-1.366540	0.1819
GFCF	0.802876	0.069031	11.63070	0.0000*

R-squared	**0.880339**	Mean dependent var	8.267500
Adjusted R-squared	**0.860395**	S.D. dependent var	3.201151
S.E. of regression	1.196068	Akaike info criterion	3.346968
Sum squared resid	42.91738	Schwarz criterion	3.610888
Log likelihood	-54.24543	F-statistic	44.14163
Durbin-Watson stat	**1.571577**	Prob(F-statistic)	0.000000
Testing for detecting Serial Correlation: Breusch-Godfrey Serial Correlation LM Test			
F-statistic	2.458285	Probability	0.127755
Obs*R-squared	2.813194	Probability	0.093492

Note:
* Significant at 1% confidence level
** Significant at 10% confidence level

The share of industry sector in GDP exerts a very strong positive relationship with energy consumption in China. The increase in 1% growth in share of industry of GDP is leading to a growth of 47% for energy consumption and is statistically significant at 1% confidence level. Unlike India, Chinese growth is largely driven by the industrial sector growth. Ever since the 1970s the share of industry in GDP was above 40%. This slowly increased to over 45% after the market reforms which were introduced by Deng Xiaoping in 1978. This in a way led to industrialization in China. As of 2006, the share of industry in GDP is near to 50%.

This is followed by the number of registered vehicles in the country which is also making a strong positive impact on energy consumption levels and is statistically significant at 1% confidence level. The impact of this variable per 1% increase on energy consumption is 28.77%. During the 1970, according to the government of China data, the number of vehicles in the country was around 42 lakhs. This increased to 31 crores by 2006.

The other variable which is also exerting a very strong positive relationship with energy consumption levels is the Gross Fixed Capital Formation (GFCF). An increase in 1% in GFCF is leading to increase in energy consumption level by 80%. This is also statistically significant at 1% confidence level. The important point to be noted is that the investments in the capital intensive projects in China are quite higher than any other emerging markets. The GFCF as a percentage of GDP itself is above 40%. This is precisely why China is also attracting a large chunk of FDI. On the other hand the government is also facilitating this by covering other costs by subsidizing the entire requirements of the people, thereby allowing the cost to be controlled. Thus, artificial shock absorber is created by the government with respect to the cost, which makes cost inputs look cheaper in China.

The most interesting point to be noted is the negative association of rate of growth of population with energy consumption. This can be attributed to the slow rate of growth of population in China due to government 'one child policy'. This policy has drastically reduced the rate of growth of population in China from 4% in late 1960s and early 1970s to less than 1% by 2006. The current rate of growth of population in China is around 0.93%. This is also one the reason why that Chinese are expected to be overtaken by Indians by 2020.

Coming to the GDP growth, an increase of 1% in this variable is leading to an increase in 9.13% growth in energy consumption levels. This is statistically significant at 10% confidence level. Over the years China has exhibited a tremendous growth in GDP. In most of the years from 1970, China has registered a double digit growth. The growth rate of GDP picked up especially from 1978 onwards when it introduced market reforms in the country. It should be noted that from 1978 to 2007, China has only three years in which the growth rate was less than 8%. For China, a tremendous GDP growth rate as a resultant of a very high GFCF, coupled with rapid industrialization, increasing demand for goods and vehicles, are having a radical impact on the energy consumption levels in the country.

The R square value of for the model is 88% of variation in the energy consumption which is explained by the growth variables during 1970 to 2005 period and the adjusted R square value stand at 86%. The Breusch-Godfrey Serial Correlation LM Test stated below the equation results show that the model does not suffer with serial correlation problem, which indicates that the overall goodness of the fit is highly significant.

Energy Consumption and Growth Equation for China: Threshold Regression Models

The table – 13A, 13B, and 13C presents the estimation of the three equations in which the dummy variable GDPD is introduced in the interactive form (Dummy multiplied by GDP) to check that at which higher GDP growth rate levels the effect on energy consumption is recognized even stronger.

Table – 13A: Threshold Regression Analysis for China at GDP growth > 8%

Dependent Variable: Energy Consumption				
Method: Least Squares				
Sample: 1970 - 2005				
Included observations: 36				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
C	9.366371	5.682074	1.648407	0.1097***
GDP Growth > 8% (GDPD)	0.097334	0.045104	2.158012	0.0391**
Industrial Growth	0.465532	0.126779	3.671986	0.0009*

Growth of Vehicles	0.280520	0.080338	3.491756	0.0015*
Population	-0.731214	0.480975	-1.520274	0.1389+
GFCF	0.818905	0.068055	12.03304	0.0000*
R-squared	**0.887127**	Mean dependent var		8.267500
Adjusted R-squared	**0.868315**	S.D. dependent var		3.201151
S.E. of regression	1.161646	Akaike info criterion		3.288566
Sum squared resid	40.48267	Schwarz criterion		3.552485
Log likelihood	-53.19418	F-statistic		47.15724
Durbin-Watson stat	**1.591740**	Prob(F-statistic)		0.000000
Testing for detecting Serial Correlation:	**Breusch-Godfrey Serial Correlation LM Test**			
F-statistic	1.283328	Probability		0.266561
Obs*R-squared	1.525585	Probability		0.216776

Note:
* Significant at 1% confidence level
** Significant at 5% confidence level
*** Significant at 10% confidence level
+ Significant at 15% confidence level

This model shown above has GDP dummy variable identified as 1 whenever the GDP growth rate for China from 1970 to 2005 exceeds 8% level and 0 otherwise.

It is to be noted that whenever the GDP growth rate of China has crossed 8% level, it has exerted a positive relationship with energy consumption. If the GDP growth rate above 8% is increased by 1% it leads to an increase in energy consumption level by 9.73%. This is statistically significant at 5% confidence level. This only suggests that the positive effects on energy consumption whenever the GDP growth rate for India crosses above 8%.

The industry share in GDP, GFCF and registered vehicles associate a very strong positive relationship with energy consumption level and both are statistically significant at 1% confidence level. The population growth variable however is having a negative association with energy consumption and is statistically significant at 15% confidence level.

Table – 13B: Threshold Regression Analysis for China at GDP growth > 9.5%

Dependent Variable: Energy Consumption				
Method: Least Squares				
Sample: 1970 - 2005				
Included observations: 36				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
C	10.90047	5.596939	1.947577	0.0609***
GDP Growth > 9.5% (GDPD)	0.098378	0.038320	2.567250	0.0155**
Industrial Growth	0.518804	0.127175	4.079439	0.0003*
Growth of Vehicles	0.286700	0.077890	3.680838	0.0009*
Population	-0.700260	0.466415	-1.501367	0.1437+
GFCF	0.845285	0.068973	12.25522	0.0000*
R-squared	**0.893092**	Mean dependent var		8.267500

Adjusted R-squared	**0.875275**	S.D. dependent var	3.201151
S.E. of regression	1.130534	Akaike info criterion	3.234270
Sum squared resid	38.34324	Schwarz criterion	3.498190
Log likelihood	-52.21685	F-statistic	50.12325
Durbin-Watson stat	**1.523113**	Prob(F-statistic)	0.000000
Testing for detecting Serial Correlation: Breusch-Godfrey Serial Correlation LM Test			
F-statistic	1.656131	Probability	0.208304
Obs*R-squared	1.944822	Probability	0.163146

Note:
* Significant at 1% confidence level
** Significant at 5% confidence level
*** Significant at 10% confidence level
+ Significant at 15% confidence level

This model shown above has GDP dummy variable identified as 1 whenever the GDP growth rate for China from 1970 to 2005 exceeds 9.5% level and 0 otherwise.

Whenever the GDP growth rate of China has crossed 9.5% level, it has exerted a positive relationship with energy consumption. If the GDP growth rate above 9.5% is increased by 1%, it leads to an increase in energy consumption level by 9.84%. This is statistically significant at 5% confidence level. This only suggests that the positive effects on energy consumption whenever the GDP growth rate for China crosses above 9.5%.

It is to be noted that when the GDP growth rate is increased above 9.5% level compared to previous 8%, the increase in energy consumption levels has gone up by 0.11%. This suggests that whenever the growth rate of GDP is increasing, the energy consumption levels are also exerting a marginal increase.

The other variables in the model like, industry share in GDP, GFCF and registered vehicles associate a very strong positive relationship with energy consumption level and both are statistically significant at 1% confidence level. The population growth variable however is having a negative association with energy consumption and is statistically significant at 15% confidence level.

Table – 13C: Threshold Regression Analysis for China at GDP growth > 11%

Dependent Variable: Energy Consumption				
Method: Least Squares				
Sample: 1970 - 2005				
Included observations: 36				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
C	11.69499	5.299470	2.206822	0.0351**
GDP Growth > 11% (GDPD)	0.102995	0.031025	3.319746	0.0024*
Industrial Growth	0.519620	0.118668	4.378786	0.0001*
Growth of Vehicles	0.244685	0.075222	3.252824	0.0028*

Population	-0.679304	0.439865	-1.544347	0.1330***
GFCF	0.792087	0.059468	13.31957	0.0000*
R-squared	**0.904638**	Mean dependent var		8.267500
Adjusted R-squared	**0.888744**	S.D. dependent var		3.201151
S.E. of regression	1.067746	Akaike info criterion		3.119989
Sum squared resid	34.20245	Schwarz criterion		3.383909
Log likelihood	-50.15980	F-statistic		56.91793
Durbin-Watson stat	**1.715987**	Prob(F-statistic)		0.000000
Testing for detecting Serial correlation	**Breusch-Godfrey Serial Correlation LM Test**			
F-statistic	0.563077	Probability		0.459068
Obs*R-squared	0.685679	Probability		0.407638

Note:
* Significant at 1% confidence level
** Significant at 5% confidence level
*** Significant at 15% confidence level

In this model the GDP dummy variable is identified as 1 whenever the GDP growth rate for China from 1970 to 2005 exceeds 11% level and 0 otherwise.

When the GDP growth rate crossed 11% level, it has also exerted a positive relationship with energy consumption. If the GDP growth rate above 11% is increased by 1%, it leads to an increase in energy consumption level by 10.30%. This time it is statistically significant at 1% confidence level. This once again suggests that the strong positive effects on energy consumption whenever the GDP growth rate for India crosses above 11%.

Like the case in India, here also the two interesting point are that the when the GDP growth rate is increased above 11% level compared to previous 9.5% and 8%, the increase in energy consumption levels has gone up by 0.58%. This suggests that more the increase in GDP growth rate, higher the energy consumption levels. The other interesting point is that the statistical significance of this variable. As GDP growth rate kept increasing its statistical significant improved from 5% to 1% confidence level once again suggesting that the findings are robust. The R square values and the adjusted R square values for all the models are high. Also, there are no signs of serial correlation problem.

Energy Consumption and Growth Equation for Brazil: Standard Model

The results capture the standard model of the relationship between Energy consumption and growth. The results for Brazil are quite contradictory to that of earlier ones for India and China.

Table – 14: Standard Model for Energy Consumption & Growth for Brazil

Dependent Variable: Energy Consumption				
Method: Least Squares				
Sample: 1975 - 2005				
Included observations: 31				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
C	0.098465	0.411791	0.239114	0.8130
GDP Growth Rate	-0.002894	0.005359	-0.540137	0.5941
Industry Share	0.007773	0.005467	1.421881	0.1579***
Transportation Index	0.011144	0.002609	4.272070	0.0003*
Manufacturing Exports	0.018881	0.002455	7.690939	0.0000*
Manufacturing Imports	0.008010	0.002684	2.984027	0.0064*
Population	-0.133380	0.065307	-2.042359	0.0523**
R-squared	**0.937973**	Mean dependent var		1.420645
Adjusted R-squared	**0.922467**	S.D. dependent var		0.335777
S.E. of regression	0.093496	Akaike info criterion		-1.706107
Sum squared resid	0.209798	Schwarz criterion		-1.382303
Log likelihood	33.44466	F-statistic		60.48842
Durbin-Watson stat	**1.520087**	Prob(F-statistic)		0.000000
Testing for detecting Serial Correlation: Breusch-Godfrey Serial Correlation LM Test				
F-statistic	1.665452	Probability		0.209692
Obs*R-squared	2.093171	Probability		0.147959

Note:
* Significant at 1% confidence level
** Significant at 5% confidence level
*** Significant at 15% confidence level

As expected the 1% increase in manufacturing exports lead to corresponding increase in energy consumption levels by 1.87% and is statistically significant at 1% confidence level. This proves the point that the manufacturing exports are indeed contributing to a great level of pollution by consuming more energy. This is well explained by the fact that manufacturing exports for Brazil are on raise from the 1980s.

Interestingly, similar trend is observed in the case of manufacturing imports. The manufacturing imports for Brazil have been increasing and its share in total imports is over 70%. It is positively significant at 1% confidence level. This shows that manufacturing imports are indeed acting as substitute for energy consumption. This may be due to the increase in heavy machinery and other machinery items which are widely used in manufacturing

The share of industry sector in GDP exerts a positive relationship with energy consumption. The increase in 1% growth in share of industry of GDP is leading to a growth of 0.77% for energy consumption and is statistically significant at

15% confidence level. The share of industry in GDP was in between 38% to 40% between the study period in Brazil.

The number of registered vehicles proxied by the transportation index is making a positive impact on energy consumption levels and is statistically significant at 1% confidence level. The impact of this variable per 1% increase on energy consumption is 1.11%.

The impact of rate of growth of population on energy consumption is negative and is statistically significant at 5% confidence level. This can be attributed to the decline in the rate of growth of growth of population for Brazil from mid 1990s onwards.

The results are interesting for the rate of growth of GDP. It shows a contradictory trend to the theory and also to the earlier results in the case of China and India. This apart, the variable of GDP growth rate is not statistically significant. This contradictory trend in the results with respect to GDP growth rate can be due to the external debt and other financial crisis which affected the growth rate of Brazil in the 1980s and 1990s. The growth rate of GDP of Brazil from 1970 to 2005 was 4.12%. While the breakup of the growth rate shows that from 1970 to 1980 the GDP grew at 8.50%. But the growth rate during 1980 to 1990 was only 3%, while the GDP grew merely at 1.84% from 1990 to 2000. It recovered a little during the next five years, 2000 to 2005 and registered a growth rate of 2.50%. In the case of India and China it is quite opposite as China grew at a growth rate of 8% from 1970 to 2005, while India grew at around 6 to 6.5% from the same period. The growth rates for both these economies accelerated during 1980s, 1990s and in early 2000.

Clearly in the case of Brazil, it is the industrialization, increase of transportation, manufacturing exports and imports are having far-reaching impact on energy consumption levels than the growth rate of GDP.

The R square and the adjusted R square values stand at 93% and 92% repectively, which indicates that the overall goodness of the fit is highly significant. The Breusch-Godfrey Serial Correlation LM Test stated below the equation results show that the model does not suffer with serial correlation problem.

Energy Consumption and Growth Equation for Brazil: Threshold Regression Models

The table – 14A and 14B presents the estimation of the three equations in which the dummy variable GDPD is introduced in the interactive form (Dummy multiplied by GDP) to check that at which higher GDP growth rate levels the effect on energy consumption is recognized even stronger.

Table – 14A: Threshold Regression Analysis for Brazil at GDP growth > 5%

Dependent Variable: Energy Consumption				
Method: Least Squares				
Sample: 1975 - 2005				
Included observations: 31				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
C	0.130227	0.411438	0.316518	0.7543
GDP Growth rate > 5% (GDPD)	-0.000987	0.005887	-0.167716	0.8682
Industry Share	0.007213	0.005404	1.334635	0.1945+
Transportation Index	0.010973	0.002622	4.185531	0.0003*
Manufacturing Exports	0.019088	0.002541	7.513003	0.0000*
Manufacturing Imports	0.007657	0.002611	2.932748	0.0073*
Population	-0.137575	0.065490	-2.100707	0.0464**
R-squared	**0.937293**	Mean dependent var		1.420645
Adjusted R-squared	**0.921616**	S.D. dependent var		0.335777
S.E. of regression	0.094008	Akaike info criterion		-1.695195
Sum squared resid	0.212100	Schwarz criterion		-1.371392
Log likelihood	33.27553	F-statistic		59.78857
Durbin-Watson stat	**1.457949**	Prob(F-statistic)		0.000000
Testing for detecting Serial Correlation: Breusch-Godfrey Serial Correlation LM Test				
F-statistic	2.177738	Probability		0.153580
Obs*R-squared	2.681332	Probability		0.101531

Note:
* Significant at 1% confidence level
** Significant at 5% confidence level
+ Significant at 20% confidence level

This model shown above has GDP dummy variable identified as 1 whenever the GDP growth rate for Brazil from 1975 to 2005 exceeds 5% level and 0 otherwise.

Another interesting point to be noted from the results displayed above is that whenever the GDP growth rate of Brazil has crossed 5% level, it has exerted a negative relationship with energy consumption. However, the point to understand is that the rate of decline in energy consumption when GDP is growing at 5% is decline at a slower pace when compared to the average rate of growth of GDP at 4.12%. If the GDP growth rate above 5% is increased by 1% it leads to a decline in energy consumption level by 0.009%. However, this variable is not statistically significant.

Among the other variables, viz., industry share in GDP and registered vehicles associate a positive relationship with energy consumption level. The later exert a positive relationship and is statistically significant at 1% confidence level, while the former has no statistical significance.

The manufacturing trade variables, manufacturing exports and imports have a positive relationship with energy consumption and both are statistically significant at 1% confidence level. The population growth variable is having a negative association with energy consumption and is statistically significant at 5% confidence level.

Table – 14B: Threshold Regression Analysis for Brazil at GDP growth > 6%

Dependent Variable: Energy Consumption				
Method: Least Squares				
Sample: 1975 - 2005				
Included observations: 31				
Variables	**Coefficient**	**Std. Error**	**t-Statistic**	**Probability**
C	0.124997	0.411060	0.304084	0.7637
GDP Growth Rate > 6% (GDPD)	-0.000725	0.006169	-0.117514	0.9074
Industry Share	0.007237	0.005520	1.311022	0.2023
Transportation Index	0.010988	0.002620	4.194155	0.0003*
Manufacturing Exports	0.019122	0.002575	7.427206	0.0000*
Manufacturing Imports	0.007674	0.002628	2.920091	0.0075*
Population	-0.136963	0.065373	-2.095102	0.0469**
R-squared	**0.937255**	Mean dependent var		1.420645
Adjusted R-squared	**0.921569**	S.D. dependent var		0.335777
S.E. of regression	0.094036	Akaike info criterion		-1.694599
Sum squared resid	0.212226	Schwarz criterion		-1.370796
Log likelihood	33.26629	F-statistic		59.75056
Durbin-Watson stat	**1.451672**	Prob(F-statistic)		0.000000
Testing for detecting Serial Correlation: Breusch-Godfrey Serial Correlation LM Test				
F-statistic	2.232598	Probability		0.148720
Obs*R-squared	2.742902	Probability		0.099687

Note:
* Significant at 1% confidence level
** Significant at 5% confidence level
+ Significant at 20% confidence level

In this model the GDP dummy variable is identified as 1 whenever the GDP growth rate for Brazil from 1975 to 2005 exceeds 6% level and 0 otherwise.

Comparing the results of this with the earlier ones, one interesting point which emerges is that of rate of growth of GDP. When the GDP growth rate is increased above 6% level compared to previous 5% the decline in energy consumption levels has gone up by 0.002%. This suggests that more the increase in GDP growth rate, higher would be the decline in energy consumption levels. However, in neither of the equations GDP growth variable is not statistically significant.

Common Trends:

There are some common findings which emerge from this study on India, China and Brazil with respect to the relationship between growth variables and energy consumption, which has a direct association with CO2.

For both India and China, GDP growth rates and higher levels of GDP growth rates are having direct positive relationship with energy consumption level. But in the case of Brazil, GDP growth rate is having a negative influence on energy consumption.

Table – 15A: Effects of higher GDP Growth Rates on Energy Consumption for India

GDP Growth rates	Coefficient	Change	Cumulative Change	T-stat	Probability
GDP Growth rate (1970-2005)	1.11%	-	-	1.45	Sig. @ 15%
GDP Growth > 6.5%	1.11%	0.00%	0.00%	1.72	Sig. @ 10%
GDP Growth > 7%	1.13%	+0.02%	0.02%	2.00	Sig. @ 10%
GDP Growth > 7.5%	1.17%	+0.04%	0.06%	2.43	Sig. @ 5%

As the growth rates of GDP for India and China are graduating to higher levels, it is leading to a marginal increase in energy consumption levels. Both the countries are emergining and are competing with each other in many areas and are exerting a rapid economic growth in the recent times.

Table – 15B: Effects of higher GDP Growth Rates on Energy Consumption for China

GDP Growth rates	Coefficient	Change	Cumulative Change	T-stat	Probability
GDP Growth rate (1970-2005)	9.13%	-	-	1.65	Sig. @ 10%
GDP Growth > 8%	9.73%	+0.60%	0.60%	2.16	Sig. @ 10%
GDP Growth > 9.5%	9.84%	+0.11%	0.71%	2.56	Sig. @ 5%
GDP Growth > 11%	10.30%	+0.46%	1.17%	3.32	Sig. @ 1%

In the case of Brazil also a similar kind of trend in observed but with a negative relationship. As the GDP growth rate levels increase, it is leading to a slower decline in energy consumption levels.

Table – 15C: Effects of higher GDP Growth Rates on Energy Consumption for Brazil

GDP Growth rates	Coefficient	Change	Cumulative Change	T-stat	Probability
GDP Growth rate (1975-2005)	-0.28%	-	-	-0.54	NOT Sig.
GDP Growth > 5%	-0.009%	-0.27%	-0.271%	-0.17	NOT Sig.
GDP Growth > 6%	-0.007%	-0.02%	-0.273%	-0.11	NOT Sig.

One similarity in all the three nations' growth is that it is largely driven by industrialization process. However, the degree ranges among the three. In the case of China, the growth is largely driven by rapid industrialization and massive investments in capital intensive projects. In the case of India the pace of industrialization has caught up only in the post liberalization period (after 1991). India's growth is equally driven by both industrialization and services sector. The slow growth of industrialization in India is also leading to large scale industrial products exports which again exert a positive relation with levels of energy consumption. In the case of Brazil, it is largely driven by industrialization from the 1970s onwards. It is predominantly know as industrializing nation.

Both in India and China, due to their massive size and economic activities and population, the number of registered vehicles are at increase. This undoubtedly needs massive energy consumption. In the case of Brazil, the transportation sector is widely known to be the second best reason for contributing to the pollution. This can be gauged from the fact that the production levels of motor vehicles is on rise. Also, Brazil is world's eight largest motor vehicle producer. But on another aspect there is a contrasting relationship existing between the three nations on energy consumption levels. This is with respect to the rate of growth of population in both the nations. As detailed in the analysis, this might be because the population growth rate for China has actually declined from 4% in 1970s to under 1% by 2006. Infact the population growth rate at the moment for China is 0.93%. Same is the case with Brazil, which has seen a rapid decline in rate of growth of population from 1970s to 2007. Its growth rate in 1970s was above 2.75% which declined to around 1% by 2007. While India's population growth rate at 2006 is still above 1.65% and is expected to become world most populous nation by 2020.

06. Concluding Remarks

While the existing empirical works till date have focused on the effects of economic growth and trade on environmental degradation. This work contributed a new approach to the study of environment quality and growth by examining for India, China and Brazil to show that the higher levels of growth led by industrialization process is leading to imbalances in environment.

This paper examines the effects of energy consumption on CO_2 emission leading to environment degradation in India, China and Brazil. Also examined is the role played by the rapid economic growth led by industrialization on the levels of energy consumption. The study then extends in a different approach to see at what higher levels of economic growth do the energy consumption is getting effected.

The results suggest that indeed growth of energy consumption is having an impact on the CO2 emission in both these countries. The high levels of energy consumption are driven by rapid economic growth, industrialization, international trade in industrial goods, along with rate of growth of registered vehicles. This suggests that too much of economic growth is too bad for environmental quality. However, the cut in energy consumption levels is not possible because of its negative effect on growth. But surely, the fast emergining economies like India, China and Brazil which are very highly dependent in energy usage and are the largest energy consumers can look forward to cut down the rate at which they are growing, which can lead to restoration in environment imbalances in the years to come.

There is also a huge scope to carry forward this research study further by looking at the aspects of long run relationship and direction of causality between energy consumption, economic growth and industrialization in India, China and Brazil. This would ensure more robust results and much more meaningful analysis which could be helpful for the policy makers in both these countries to frame an inclusive environment quality led growth policies in the years to come.

07. References

1. Akarca, A.T. and Long, T.V., (1980). “On the Relationship between Energy and GNP: A Reexamination.” Journal of Energy and Development 5: 326-331.

2. Akbostanci, E., Turut-Asik, S. and Tunc, G.I. (2006) “The Relationship Between Income and Environment in Turkey: Is There an Environmental Kuznets Curve?.” International Conference in Economics-Turkish Economic Association Sept. 11-13, Ankara, Turkey.

3. Bentzen, J. & Engsted, T., (1993). “Short-Long-run Elasticities in Energy Demand.” Energy Economics 15: 9-16.

4. Dilp M. Nachane, Ramesh M. Nadkarni and Ajith V. Karnik , 'Co-Integration and Causality Testing of the Energy-GDP Relationship: A Cross-Country Study', Applied Economics, 20:11, 1511 – 1531.

5. Erol, U. and Yu, E.S.H., (1987). “On the Causal Relationship between Energy and Income for Industrialized Countries.” Journal of Energy and Development 13: 113-122.

6. Focacci, Antonio. (2005), “Empirical analysis of the environmental and energy policies in some developing countries using widely employed macroeconomic indicators: the cases of Brazil, China and India”, Energy Policy 33, pp. 543–554

7. Galli R, “Relationship Between Energy Intensity & Income Levels: Forecasting Long Term Energy Demand in Asian Emerging Economies”, Energy Journal (1998), 19:4; 85–106.

8. Grossman, G., Krueger, A., 1992. Environmental Impacts of a North American Free Trade Agreement. WPS: c158, WW School of Public & International Affairs, Princeton.

9. Grossman, G., Krueger, A., 1995. Economic growth & environment. Q. J. Econ. 110 (2), 352–377.

10. Government of India (2004), Central Statistical Organization, Special reports, India.

11. Hwang, D.B.K., Gum, B. (1992), “The causal relationship between energy and GNP: the case of Taiwan”, The Journal of Energy and Development, 16: 219-226.

12. IPCC (2007). “Climate Change 2007: The Physical Science Basis.” Contribution of Working Group to 4th Report of Intergovernmental Panel on Climate Change, Paris.

13. IPEADATA, 2003. Analytical Indexes Database (Transportation Index). www.ipeadata.gov.br.

14. IAEA Energy and Economic Database, 2006.

15. Jean Agras & Duane Chapman, 1998, A dynamic approach to the Environmental Kuznets Curve Hypothesis, Ecological Economics 28 (1999) 267–277.

16. Joy O Kadnar, 1998, The Central Asian Republics – Economic Growth and Fossil Fuel Shor t-term Needs Forecast, Business Brefings: The Oil & Gas Review, 2004, 1-5.

17. Kouris G, “The Determinants of Energy Demand in the EEC Area” Energy Policy (1976), 6:4 pp. 343–355.

18. Kraft, J. and Kraft, A., (1978). “On the Relationship between Energy and GNP.” Journal of Energy and Development 3: 401-403.

19. Low, P., Yeats, A., 1992. Do dirty industries migrate? In: Low, P. (Ed.), International Trade and the Environment. World Bank Discussion Papers No. 159, Washington, DC.

20. Ministry of Power, Coal, Petroleum, Natural Gas, Central Electricity Authority & Department of Atomic Energy, Government of India, Annual Reports 2001 to 2003.

21. National Bureau of Statistics of China, PRC, 2007

22. Roberto Schaeffer, Alexandre Salem Szklo, Fernando Monteiro Cima and Giovani Machado, 2005. Indicators for sustainable energy development: Brazil’s case study. Natural Resources Forum 29 (2005) 284–297.

23. Selden, T.M., Song, D., 1994. Environmental quality and development: is there a Kuznets Curve for air pollution? J. Environ. Econ. Manage. 27 (2), 147–162.

24. Shafik, N., Bandyopadhyay, S., 1992. Economic Growth and Environmental Quality: Time-Series and Cross-Country Evidence. Background Paper for World Development Report 1992, The World Bank, Washington, D.C.

25. Suri, V., Chapman, D., 1998. Economic Growth, Trade and Energy: Implications for the Environmental Kuznets Curve. Ecological Economics, Special Issue on the Environmental Kuznets Curve, 25 (1998) 195–208.

26. Stern, D.I. (1993). “Energy use and economic growth in the USA: a multivariate approach.” Energy Economics 15: 137-150.

27. Tucker, M., 1995. Carbon dioxide emissions & global GDP. Ecol. Econ. 15 (3), 215–23.

28. Ugur Soytas & Ramazan Sari, 2007, Energy Consumption, Economic Growth, and Carbon Emissions: Challenges Faced by an EU Candidate Member, MARC Working Paper Series Working Paper No. 2007-02

29. Varma, S.K. (1999), "Coal- A Predominant Option" Proc. Power in the New Millennium Plans & Strategies, Indian Nuclear society, Aug 31- Sept 2.

30. Wietze Lise & Kees Van Montfort, 2006, Energy consumption and GDP in Turkey: Is there a Co-integration relationship?, Energy Economics August (2006), pp. 1 – 13.

31. World Development Indicators (2006), World Bank, Washington D.C.

32. World Resource Institute (1998), World Resources: A Guide to the Global Environment, Oxford University Press, New York.

33. Yu, E.S.H. and Hwang, B.K., (1984). “The relationship between energy and GNP: further results.” Energy Economics 6: 186-190.

34. Yu, E.S.H. & Choi, J.Y., (1985). “The Causal Relationship between Energy & GNP: An International Comparison.” Journal of Energy & Development 10: 249-272.

08. Annexures

ANNEXURE – 1: Descriptive Statistics for India

Items	EC	GDP	IG	MV	POP	ME	MI	GDPD1	GDPD2	GDPD3
Mean	3.488056	5.000000	25.36111	23.14139	1.916667	64.80556	51.05556	2.652778	2.472222	2.055556
Median	3.290000	5.500000	26.00000	17.23000	2.000000	68.00000	51.00000	0.000000	0.000000	0.000000
Maximum	5.800000	10.00000	28.00000	64.66000	2.000000	79.00000	67.00000	10.00000	10.00000	10.00000
Minimum	1.780000	-5.000000	20.00000	2.800000	1.000000	45.00000	38.00000	0.000000	0.000000	0.000000
Std. Dev.	1.289936	3.023716	2.257088	19.51051	0.280306	10.46305	6.360343	3.854162	3.820891	3.648440
Sum	125.5700	180.0000	913.0000	833.0900	69.00000	2333.000	1838.000	95.50000	89.00000	74.00000
Observations	36	36	36	36	36	36	36	36	36	36

Note: EC= Energy Consumption; GDP = Growth rate of GDP; IG = Share of Industry in GDP; MV = Registered Motor Vehicles; ME = Manufacturing Exports; MI = Manufacturing Imports; GDPD1 = Growth rate of GDP Dummy when GDP > 6.5%; GDPD2 = Growth rate of GDP Dummy when GDP > 7%; GDPD3 = Growth rate of GDP Dummy when GDP > 7.5%;

ANNEXURE – 2: Descriptive Statistics for China

Items	EC	GDP	IG	MVG	POP	GFCF	GDPD1	GDPD2	GDPD3
Mean	8.267500	9.083333	45.02778	11.67083	1.333333	30.44444	8.416667	3.722222	7.388889
Median	7.880000	9.000000	45.00000	11.60000	1.000000	30.00000	9.000000	0.000000	9.000000
Maximum	15.24000	19.00000	49.00000	18.90000	3.000000	39.00000	19.00000	19.00000	19.00000
Minimum	3.650000	-2.000000	40.00000	5.460000	1.000000	24.00000	0.000000	0.000000	0.000000
Std. Dev.	3.201151	3.872061	2.076895	2.731653	0.585540	4.038702	4.824787	6.204197	5.683449
Sum	297.6300	327.0000	1621.000	420.1500	48.00000	1096.000	303.0000	134.0000	266.0000
Observations	36	36	36	36	36	36	36	36	36

Note: GDPD1 = Growth rate of GDP Dummy when GDP > 8%; GDPD2 = Growth rate of GDP Dummy when GDP > 9.5%; GDPD3 = Growth rate of GDP Dummy when GDP > 11%;

ANNEXURE – 3: Descriptive Statistics for Brazil

Items	EC	GDP	IG	TI	ME	MI	POP	GDPD2	GDPD1
Mean	1.420645	3.064516	39.25806	9.540323	47.22581	57.96774	1.677419	2.483871	2.612903

Median	1.360000	3.000000	40.00000	7.230000	53.00000	58.00000	2.000000	0.000000	0.000000
Maximum	1.980000	10.00000	46.00000	31.50000	59.00000	76.00000	2.000000	10.00000	10.00000
Minimum	0.910000	-4.000000	27.00000	0.340000	23.00000	33.00000	1.000000	0.000000	0.000000
Std. Dev.	0.335777	3.492234	5.519467	9.583310	10.50305	14.13385	0.475191	3.384976	3.363306
Sum	44.04000	95.00000	1217.000	295.7500	1464.000	1797.000	52.00000	77.00000	81.00000
Observations	31	31	31	31	31	31	31	31	31

Note: TI = Transportation Index; GDPD1 = Growth rate of GDP Dummy when GDP > 5%; GDPD2 = Growth rate of GDP Dummy when GDP > 6%.

ANNEXURE – 4: Correlation Matrix for India

Items	EC	GDP	IS	MV	POP	ME	MI
EC	1.000000						
GDP	0.403914	1.000000					
IS	0.714657	0.360032	1.000000				
MV	0.691200	0.372094	0.602924	1.000000			
POP	-0.516455	-0.370810	-0.222035	-0.590746	1.000000		
ME	0.704512	0.336854	0.702341	0.657745	-0.336906	1.000000	
MI	0.264957	0.141135	0.181664	0.271997	-0.205664	0.322595	1.000000

ANNEXURE – 5: Correlation Matrix for China

Items	EC	GDP	IS	MV	POP	GFCF
EC	1.000000					
GDP	0.160358	1.000000				
IS	0.377628	-0.003849	1.000000			
MV	-0.232892	0.101749	-0.170677	1.000000		
POP	-0.570696	-0.113416	-0.595187	0.354934	1.000000	
GFCF	0.874679	0.277101	0.560516	0.015245	-0.547711	1.000000

ANNEXURE – 6: Correlation Matrix for Brazil

Items	EC	GDP	IS	TI	ME	MI	POP
EC	1.000000						
GDP	-0.206414	1.000000					
IS	-0.578697	0.161665	1.000000				
TI	-0.348777	-0.092469	0.395312	1.000000			
ME	0.692392	-0.313032	-0.391462	0.155983	1.000000		
MI	0.610472	-0.070866	-0.754909	-0.260423	0.590379	1.000000	
POP	-0.613402	0.093306	0.477615	0.467901	-0.492504	-0.721246	1.000000

Note: EC= Energy Consumption in kilo oil tonnes equivalent; GDP = Growth rate of GDP; IS = Share of Industry in GDP; MV = Registered Motor Vehicles growth rate; POP = rate of growth of Population ME = Manufacturing Exports as % of total exports; MI = Manufacturing Imports as % of total imports; GFCF = Gross Fixed Capital Formation as % of GDP and TI = Transportation Index.

DAVIDSON INSTITUTE WORKING PAPER SERIES - Most Recent Papers

The entire Working Paper Series may be downloaded free of charge at: www.wdi.umich.edu

CURRENT AS OF 11/9/07

Publication	Authors	Date
No. 897: Rapid Economic Growth And Industrialization In India, China & Brazil: At What Cost?	Krishna Chaitanya.V	Oct 2007
No. 896: Factors influencing corporate governance in post-socialist companies: an analytical framework	Andreas Heinrich, Aleksandra Lis and Heiko Pleines	Oct 2007
No. 895: Real Convergence, Price Level Convergence and Inflation Differentials in Europe	Balázs Égert	Oct 2007
No. 894: Determinants of House Prices in Central and Eastern Europe	Balázs Égert and Dubravko Mihaljek	Oct 2007
No. 893: What Do We Really Know About Fiscal Sustainability in the EU? A Panel Data Diagnostic	António Afonso and Christophe Rault	Oct 2007
No. 892: The Political Economy of Corruption and the Role of Financial Institutions	Kira Boerner and Christa Hainz	Oct 2007
No. 891: Growth, Volatility and Political Instability: Non-Linear time Series Evidence for Argentina 1896-2000	Nauro Campos and Menelaos Karanasos	Sept 2007
No. 890: Social Costs of Mass Privatization	David Stuckler and Lawrence King	Sept 2007
No. 889: A Rise By Any Other Name? Sensitivity of Growth Regressions to Data Source	Randall Filer, Dana Hajkova and Jan Hanousek	July 2007
No. 888: Mind the Gap! Social Capital, East and West	Jan Fidrmuc and Klarita Gerxhani	June 2007
No. 887: Ever Closer Union or Babylon Discord?	Jan Fidrmuc, Victor Ginsburgh and Schlomo Weber	July 2007
No. 886: FDI & the Consequences towards more complete capture of spillover effects	Bruno Merlevede and Koen Schoors	Aug 2007
No. 885: Consumption Smoothing and Vulnerability in Russia	Christopher J. Gerry and Carmen A. Li	July 2007
No. 884: National Cultural & Financial Systems	Solomon Tadesse and Chuck Kwok	March 2005
No. 883: Stock Markets Liquidity, Corporate Governance and Small Firms	Solomon Tadesse	June 2005
No. 882: The MNC as an Agent of Change for Host-Country Institutions: FDI & Corruption	Chuck Kwok and Solomon Tadesse	Sept 2006
No. 881: The Allocation and Monitoring Role of Capital Markets: Theory and International Evidence	Solomon Tadesse	March 2003
No. 880: Tunisia: Sources of Real Exchange Rate Fluctuations	Sfia Mohamed Daly	March 2006
No. 879: Financial Development & Technology	Solomon Tadesse	June 2007
No. 878: Consolidation, Scale Economics & Technological Change in Japanese Banking	Solomon Tadesse	Feb 2005
No. 877: Innovation, Information and Financial Architecture	Solomon Tadesse	June 2007
No. 876: Corporate Cash Holdings, National Culture, and Multinationality	Andres Ramirez and Solomon Tadesse	June 2007
No. 875: The Economic Value of Regulated Disclosure: Evidence from the Banking Sector	Solomon Tadesse	Jan 2006
No. 874:Banking Fragility & Disclosure: International Evidence	Solomon Tadesse	Sept 2006
No. 873: The Impact of Outward FDI on Home-Country Employment in a Low-Cost Transition Economy	Jaan Masso, Urmas Varblane and Priit Vahter	May 2007
No. 872: Local Distributional Effects of Government Cash Transfers in Chile	Claudio A. Agostini and Philip Brown	May 2007