Cross-country Comparisons of Energy and Emissions Intensities: Implications for China and India*

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Abstract China and India (Chindia) have attracted a lot of attention nowadays due to their impressive economic performance, and the sheer size of their economies and potentially their markets. The rise of these two Asian giants has important implications for the rest of the world. One of the areas which have been intensely debated is energy consumption and the resultant consequences in China and India. These two countries are emerging not only as key players in the global energy market but also the main emitters in the world due to their large volume of energy consumption. Where do China and India stand internationally in terms of energy and emissions intensities? What can they learn from the experience of other developed economies? These are some of the questions to be investigated in this paper. Specifically, this paper aims to compare energy intensity and CO_2 emissions and their changing patterns over time among the world economies. It will link energy intensity and CO_2 emissions with the stages of economic development (the concept of the environmental Kuznets curve) and thus employ the cross-country comparison results to shed light on energy consumption and carbon emissions in China and India. Special attention will be paid to the comparison of consumption and emission patterns between the two giants and other Asian economies.

Key words Energy consumption, energy intensity, carbon emissions, emissions intensity
JEL codes O13, O57

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1. Introduction

As the economies of China and India take off, global concerns about their impact on energy consumption and climate change have increased and hence led to an expansion of the literature[1]. This study presents a comparative perspective of energy and emissions intensities across the world economies. The findings are then employed to draw implications for energy consumption and CO_2 emissions in China and India. The rest of the paper starts with a cross-country comparison of CO_2 emissions and energy consumption. This is followed by discussions of energy and CO_2 emissions intensities across the countries. Subsequently, the sources of cross-country variations are investigated. The findings are then employed to gain insights into energy consumption and CO_2 emissions in the two Asian giants, China and India. The final section concludes the paper.

2. Cross-country Comparison of CO_2 Emissions and Energy Consumption

Figure 1 shows that in 2003, among 125 countries, the world's largest economy, ie. USA, was also the largest energy consumer followed in turn by China, Russia, India, Japan and Germany.[2] In comparison with the United States, among the major economies, the Japanese economy tends to be the most energy efficient one while the Chinese economy is the least energy efficient economy followed by India and Russia. However, to some extent, Figure 1 may also reflect the possibility of underestimation of the size of the Chinese and Indian economies in terms of US dollars. As it is shown in Figure A1 in the

[1] For example, Shalizi (2007) presented some preliminary information about energy and emissions intensities in China and India, and adopted a multiregional global model to forecast energy consumption in the two countries up to the year 2050, and IEA (2007) delivered a special report on China and India. Other studies include Srivastava (1997), Nag and Parikh (2000), Paul and Bhattacharya (2004a, 2004b), Crompton and Wu (2005), Wu et al.(2006), and Zou and Chau (2006).

[2] Unless stated otherwise, data used in this paper were drawn from the online World Development Indicator database (www.worldbank.org).

appendix, China and India appear to be "the average" countries if GDP is measured in international currency. However, Japan and Russia are definitely the outliers (most efficient vs least efficient).

In general, energy consumption per capita is positively related to income level (Figure 2). There are exceptions. Energy-abundant countries tend to be outliers (e.g. Bahrain, Brunei, Iceland, Kuwait, Trinidad and Tobago, and United Arab Emirates) with exceptionally high per capita energy consumption relative to their income level. In the meantime, Hong Kong, Denmark, Switzerland and Japan are the other extremes with relatively low per capita consumption of energy. Among the middle income economies (with per capita income less than US$10,000 in 2003), Trinidad and Tobago shows exceptionally high consumption per capita. Among the economies with an income level of US$5000 per capita, the two largest consumers, China and India are very much "average" countries in terms of per capita energy consumption as shown in Figure 3. However, most transitional economies in Eastern Europe tend to be outliers (eg. Russia, Ukraine, Kazakhstan, Slovak and Estonia), implying the ample scope for improvement in energy efficiency in these economies.

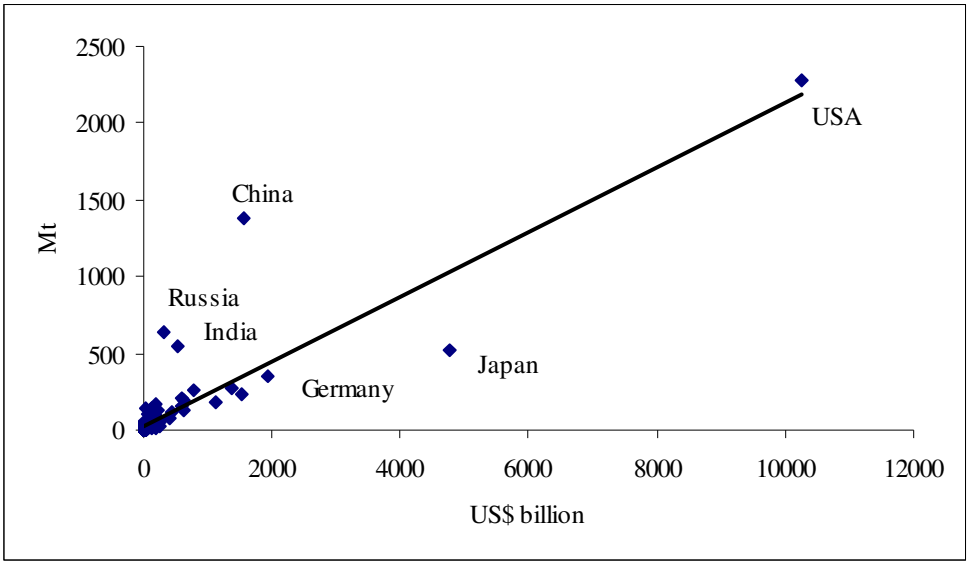

Figure 1 GDP and Energy Consumption in Selected Economies, 2003

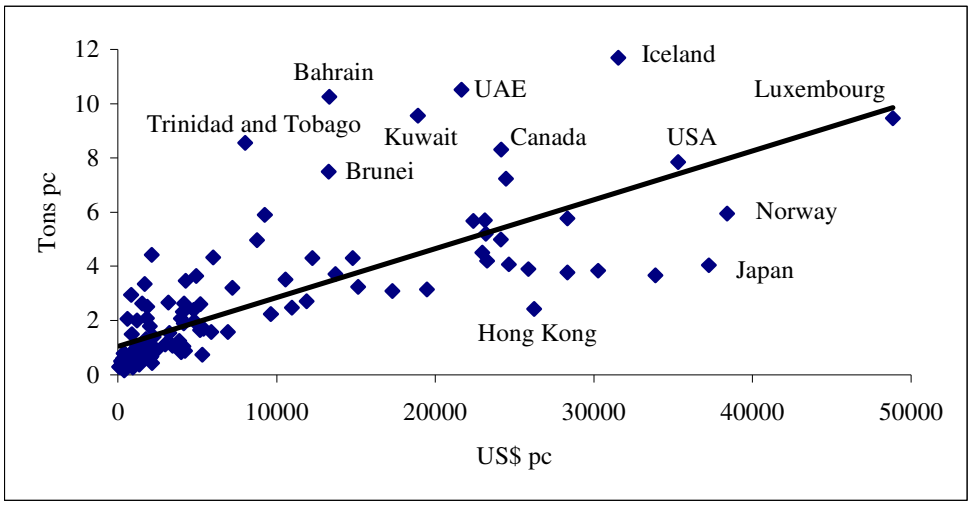

Figure 2 Energy Consumption and GDP per capita, 2003

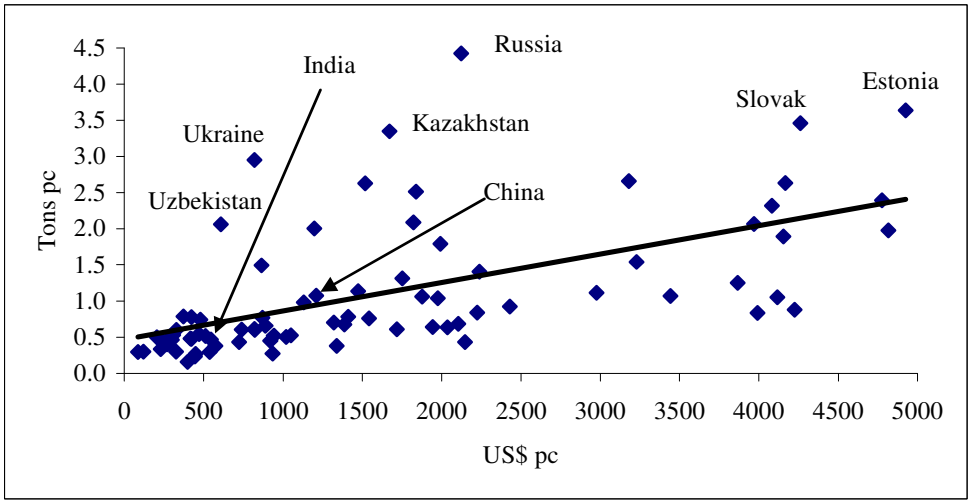

Figure 3 Energy Consumption and Income in Lower Income Economies, 2003

As expected, in terms of total CO_2 emissions in 2003, US led the world economies followed in turn by China, Russia, India, Japan and Germany (Figure 4). This situation is consistent with the consumption pattern of energy (Figure 1). Once again, among the largest economies, China, India and Russia appear to be more emissions intensive while

Japan and Germany are less emission intensive. This is still true for China and Russia even if GDP is measured in international currency (refer to Figure A2 in the appendix).

On a per capita basis, however, the situation is quite different. Figure 5 shows the distribution of CO_2 emissions per capita against income level. Apparently oil-rich economies are outliers (eg. Bahrain, Kuwait, Trinidad and Tobago, and United Arab Emirates). So are the four developed economies (i.e. Australia, Canada, the United States and Luxembourg). Figure 5 also clearly demonstrates an inverted-U curve with the turning point at approximately US$30,519 per capita and thus confirms the existence of the environmental Kuznets curve (EKC) as argued by others (Grossman and Krueger 1995, Selden and Song 1994). If the eight outliers with the largest CO_2 emissions per capita are removed, the inverted-U relationship is still held and the turning point is reduced to US$22,472 per capita. This relationship is still correct and the turning point occurs at a similar income level (approximately ppp$24,658 per capita in 2003) if income per capita is expressed in international dollars.

As expected, most less developed economies (LDCs) fall into the left half of the inverted-U curve in Figure 5. This is confirmed in Figure 6 which considers LDCs under per capita income of US$5000. However, in consistency with their energy inefficiency, several former centrally planned economies tend to be outliers (eg. Russia, Estonia and Kazakhstan). The two Asian giants are very much the "average" countries with India being on the curve and China being slightly above the curve. In addition, there is a close relationship between CO_2 emissions and energy consumption among countries in the world in terms of either aggregate (Figure 7) or per capita amount (Figure 8). For the latter, however, four countries tend to be outliers that consume either extremely clean energy (Iceland) or relatively emission-intensive energy (UAE, Kuwait and Bahrain).[3]

[3] In 2005, according to the online database (www.iea.org) of International Energy Agency, Iceland's energy supply included 56.0 per cent from geothermal/solar/wind sources, 16.6 per cent from hydro energy, 24.6 per cent from oil and 2.7 per cent from coal.

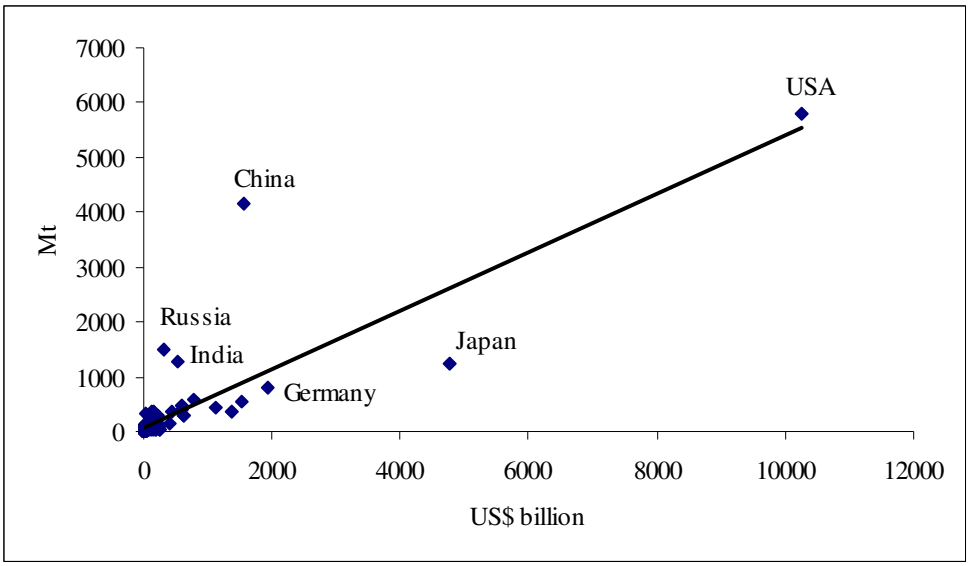

Figure 4 CO_2 Emissions and GDP, 2003

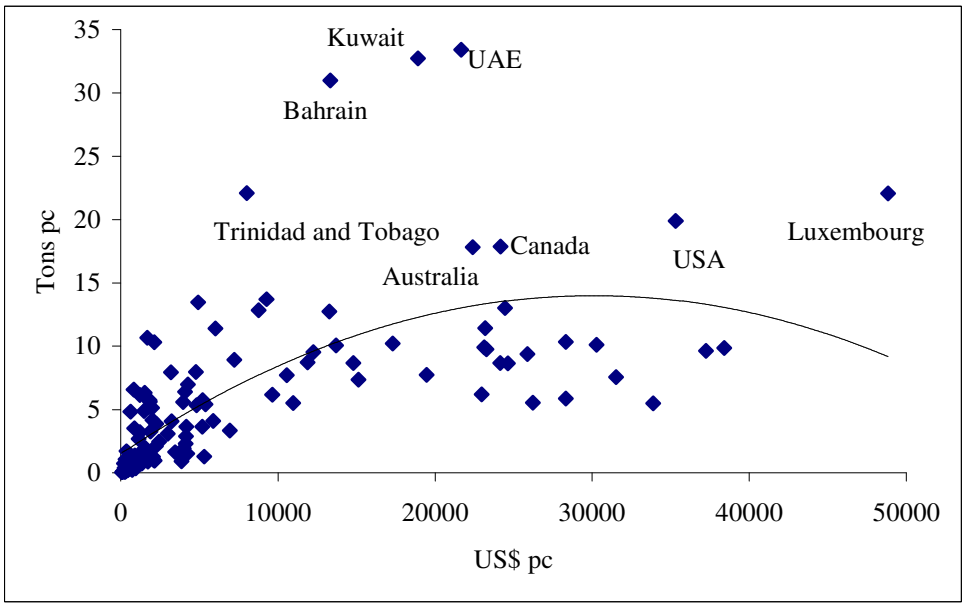

Figure 5 CO_2 Emissions and GDP per capita, 2003

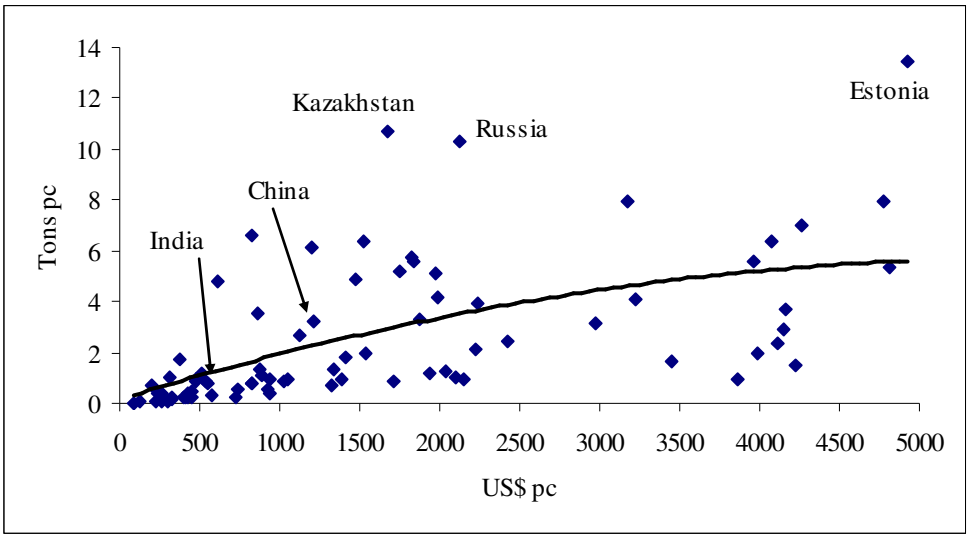

Figure 6 CO_2 Emissions and GDP in Lower Income Economies, 2003

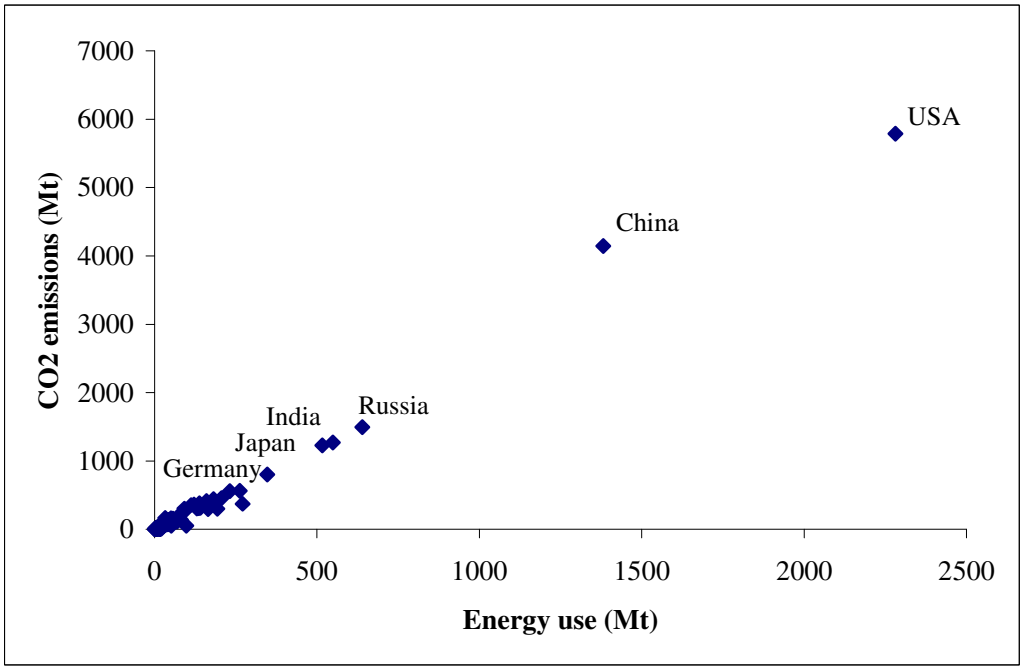

Figure 7 Aggregate Energy Consumption and CO_2 Emissions in 2003

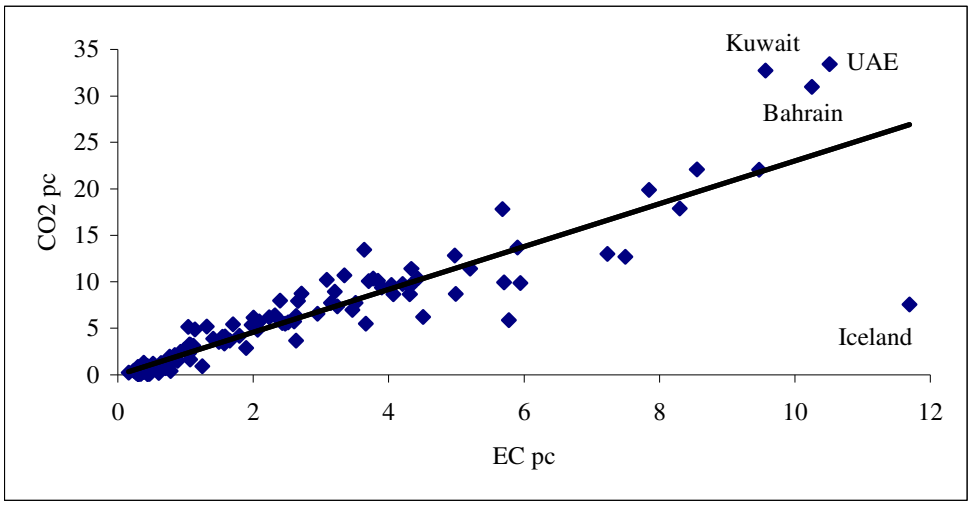

Figure 8 Per Capita Energy Consumption and CO_2 Emissions in 2003

3. Energy and Emissions Intensities

Energy intensity (EI) or emissions intensity (EM) is formally defined as the amount of energy consumed or CO_2 emitted per unit of GDP. In general, energy and emission intensities decline as income increases (Figures 9 and 10). There is however no clear evidence of the existence of an environmental Kuznets curve. In terms of international dollars, emission intensity and income level tend to follow an inverted-U curve and hence confirm the existence of the environmental Kuznets curve with a turning point of ppp$15,731 per head (See Figure A3 in the appendix). Furthermore, as expected, emissions intensity tends to be positively related to energy intensity (Figure 11).

Energy and emissions intensities may also be affected by other factors such as the level of urbanization and industrialization, and development of the service sector. To examine the impact of these factors on cross-country variations in energy and emissions intensities a regression analysis approach is employed. Given the availability of data, several factors are considered in the analysis. They include the stage of economic development, economic structure (service and manufacturing sector income shares), and level of urbanization. It must be pointed out that energy and emissions intensities are also likely

to be affected energy prices and environmental regulations. The latter are however excluded from the regression analysis due to the paucity of information.

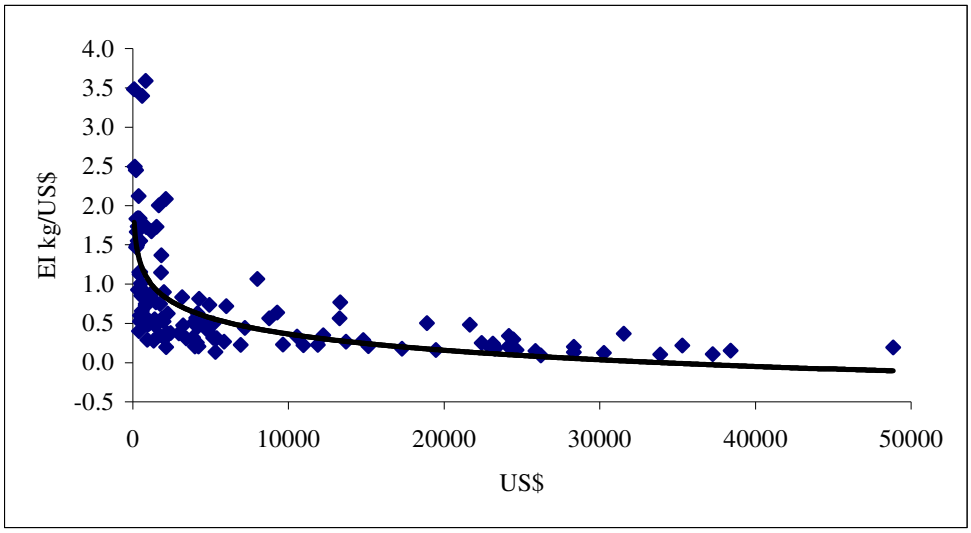

Figure 9 Energy Intensity and Level of Income, 2003

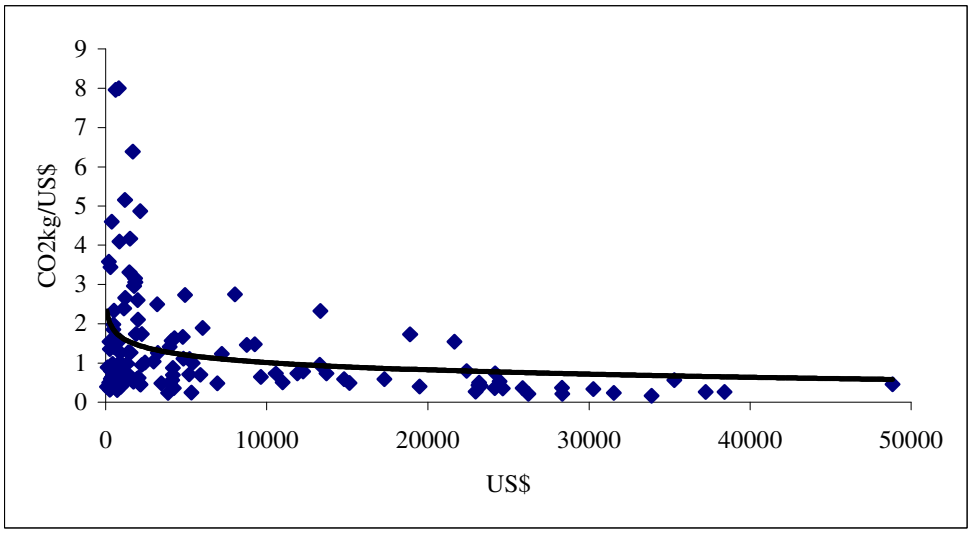

Figure 10 Emissions Intensity and Level of Income, 2003

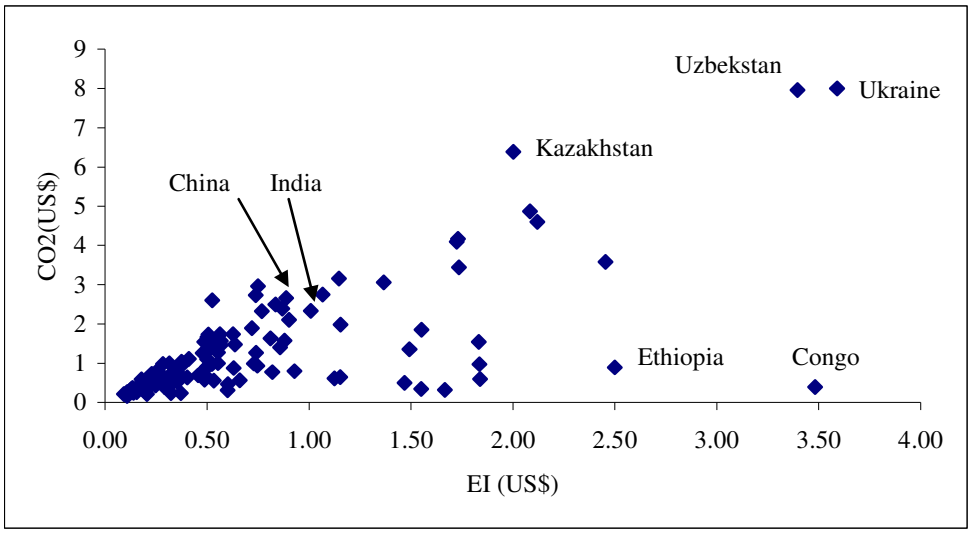

Figure 11 Emissions and Energy Intensity in 2003

The stage of economic development variable (*Y*) together with its quadratic form is included to check whether an environmental Kuznets curve is observed and where the turning point is. It is measured by GDP per capita and expressed in terms of US dollars. Both energy (*EI*) and emissions (*EM*) intensities are affected by manufacturing activities or the level of industrialization (*IND*) among the economies. The degree of urbanization (*URB*) and service sector development (*SER*) can be closely related but may have different impacts on energy and emissions intensities. Symbolically,

$$\log Intensity = \alpha_0 + \alpha_1 \log Y + \alpha_2 (\log Y)^2 + \alpha_3 IND + \alpha_4 SER + \alpha_5 URB + u \qquad (1)$$

where intensity represents both energy (EI) and emissions (EM) intensities.

In general, regression results in Table 1 show that both energy and emissions intensities are affected positively by the level of industrialization and negatively by the degree of urbanization and the development of services. It can be concluded that energy intensity has an U-shaped relationship with income while emissions intensity follows an inverted U-shaped curve. Thus the environmental Kuznets relationship is once again confirmed in

this cross-country analysis with a turning point at around US$1559. Thus, controlling for other factors, emissions intensity declines at an earlier stage of development than emissions per capita without taking into consideration of other factors. For developed economies, further reduction in emissions intensity will result from the combined forces of service expansion and manufacturing contraction. In the mean time for low income economies, the direction of change is not clear as many countries have yet to develop their manufacturing sectors – a force for further expansion of emissions intensity and to expand their services and urban sectors – a force for the fall in emissions intensity.

Table 1 Estimation Results

Variables	logEI	logEM
Constant	4.082 (3.374)*	-5.234 (-3.085)*
logY	-0.680 (-2.110)**	1.588 (3.508)*
$(logY)^2$	0.023 (1.171)	-0.108 (-3.958)*
IND	0.007 (1.003)	0.021 (2.203)**
SER	-0.015 (-3.287)*	-0.012 (-1.868)***
URB	-0.002 (-0.546)	-0.002 (-0.423)
Adjusted R^2	0.67	0.31
Sample size	112	111

Notes: *, ** and *** indicate significance at the level of 1%, 5% and 10%. The results are based on 2003 data with several outliers being removed.

4. Where Are China and India Heading?

While the regression results reported in the preceding section indicate the potential sources of variation in energy and emissions intensities, it is difficult to draw implications for individual economies given the diversity of economic structure, energy consumption pattern and resource endowment among the world economies. This section sheds some

light on the future trend of energy consumption and emissions in China and India by comparing the two giants with the world's major economies and in Asian perspectives.[4]

On a per capita basis, the trend of changes in energy consumption and emissions is not unambiguous. In general, the world's major economies are divided into different models or clubs ranging from less energy/emissions intensive economies (such as Portugal, Hong Kong, Denmark, France, Sweden and Japan) to more energy/emissions intensive ones (such as Russia, Luxembourg, Canada, Australia and US). These distinctions are clearly illustrated in Figures 12 and 13. Which club that China and India will join has important implications for the world's energy consumption and climate change. Should China and India opt for the energy/emissions intensive model, per capita energy consumption and emissions would be twice as high as the cleaner development model pursued by countries such as Japan, France, Sweden and Portugal (see Table 2). Given the large population base, such a scenario would put enormous pressure on the world's environment and resources.

Among the world's major economies, with the exception of Russia, energy and emissions intensities fall as per capita income increases (Figures 14 and 15). It can be anticipated that China and India will follow this trend. Both energy and emissions intensities in the two giants will decline over time. This is confirmed by historical statistics from China and India (Figures 16 and 17). In particular, the fall in energy and emissions intensities has been impressive in China. In comparison with China, the changes have however been less dramatic in India which had much lower energy and emissions intensities in 1971 than China, reflecting the relatively minor role of the manufacturing sector in the Indian economy. As a matter of fact, emissions intensity in India kept rising modestly until the 1990s when it peaked. Since the early 1990s, it has shown the trend of decline. During the years leading to 2003 both energy and emissions intensities had converged in the two economies.

[4] These economies include 21 OECD members (Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Hong Kong, Japan, Korea, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, United Kingdom, United States), four East Asian economies (Indonesia, Malaysia, the Philippines and Thailand) and Russia.

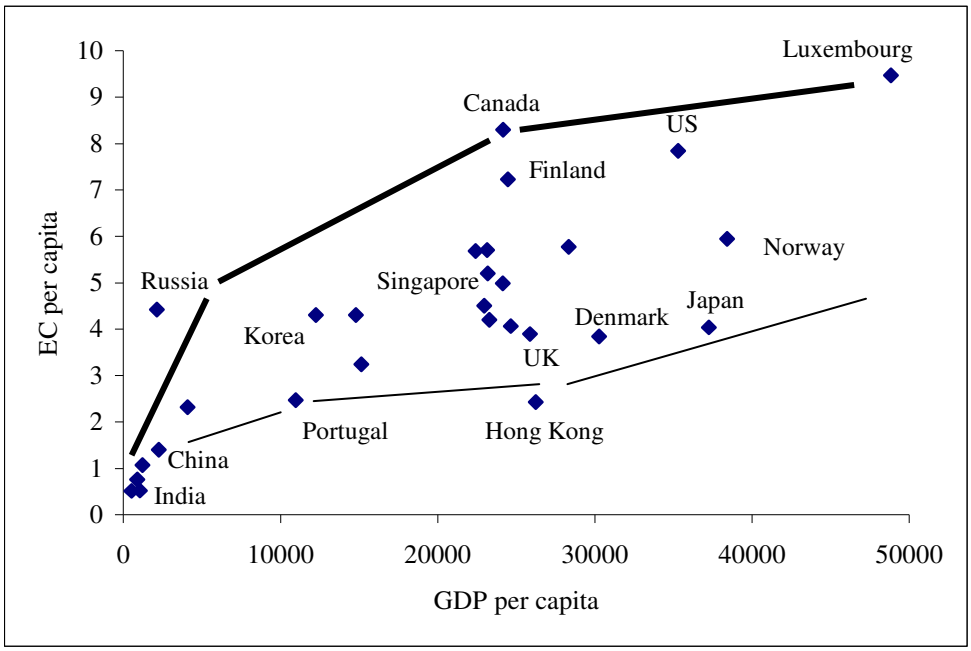

Figure 12 Energy Consumption and Income in Selected Economies 2003

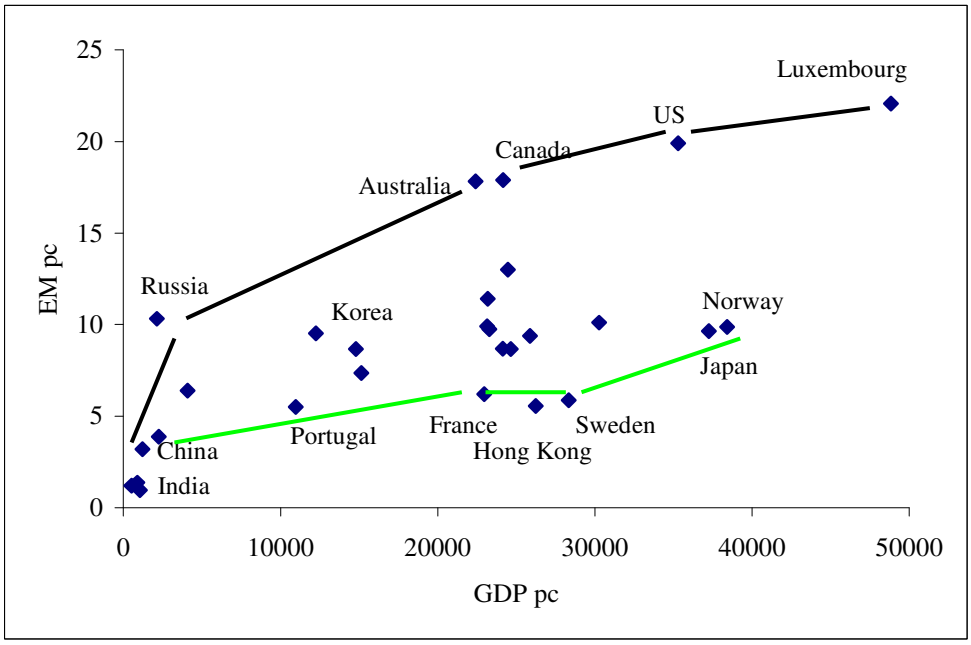

Figure 13 Emissions and Income in Selected Economies 2003

Table 2 Summary Statistics of Selected Countries

Countries	GDPpc	ECpc	EMpc	EI	EM
India	511	0.515	1.196	1.008	2.339
China	1209	1.072	3.216	0.887	2.660
Sweden	28327	5.774	5.881	0.204	0.208
Denmark	30273	3.840	10.113	0.127	0.334
Japan	37244	4.041	9.641	0.108	0.259
Sub-mean	31948	4.552	8.545	0.146	0.267
Australia	**22405**	**5.682**	**17.816**	**0.254**	**0.795**
United States	**35313**	**7.843**	**19.904**	**0.222**	**0.564**
Luxembourg	**48838**	**9.472**	**22.063**	**0.194**	**0.452**
Sub-mean	**35518**	**7.666**	**19.927**	**0.223**	**0.604**

Notes GDPpc, ECpc and EMpc refer to per capita GDP (US$), energy consumption (tons) and emissions (tons).EI and EM represent energy intensity (kg/$) and emissions intensity (kg/$).

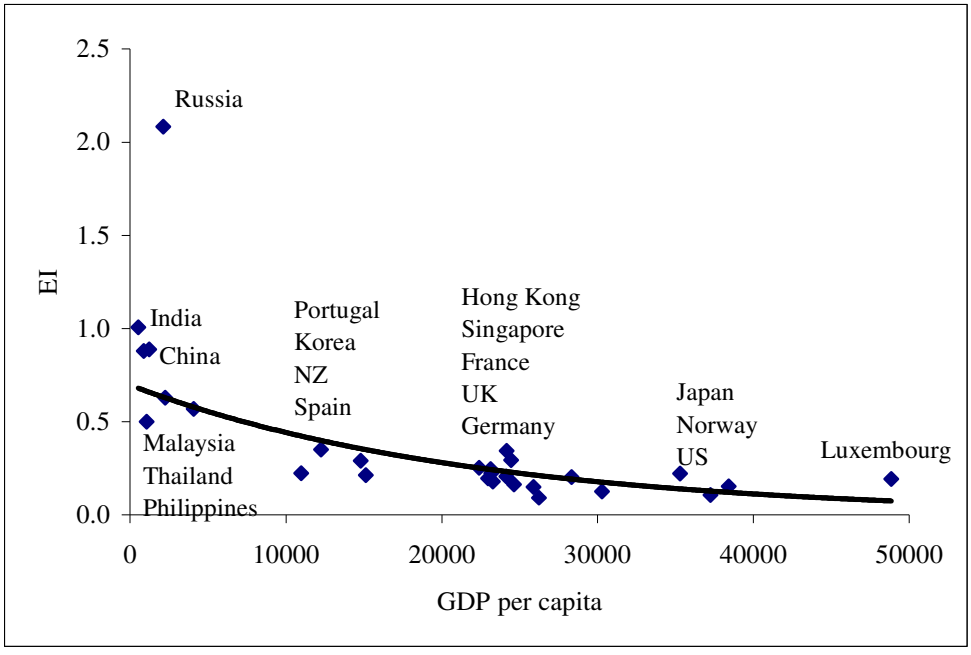

Figure 14 Energy Intensity and Income in 28 Economies, 2003

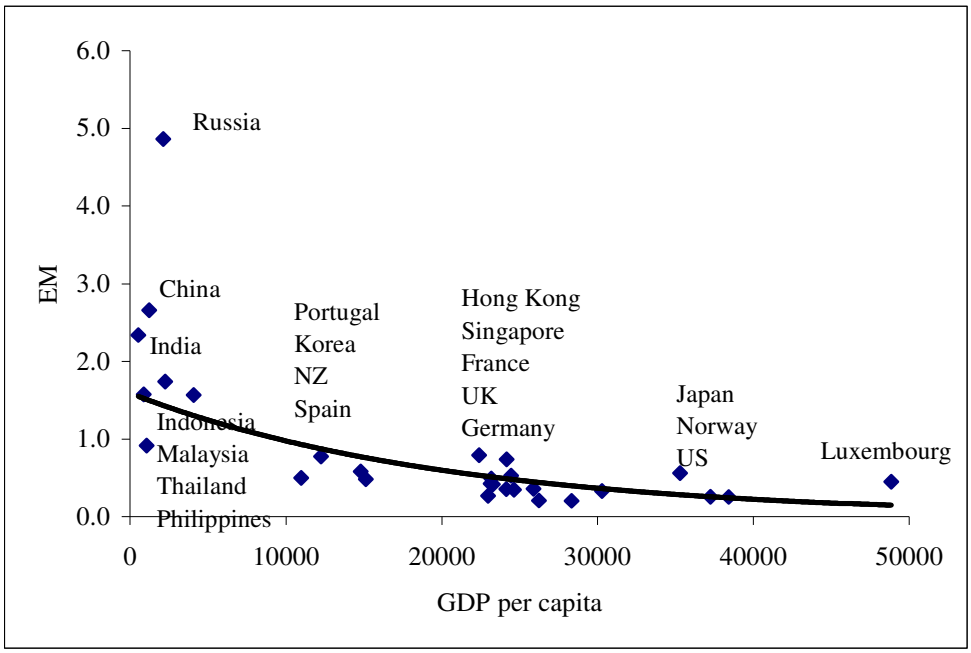

Figure 15 Emissions Intensity and Income in 28 Economies, 2003

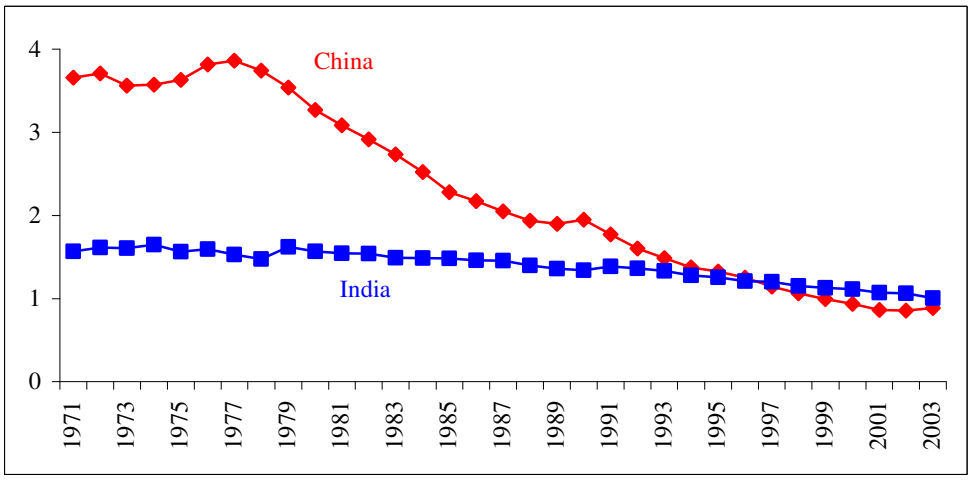

Figure 16 Energy Intensity in China and India, 1971-2003

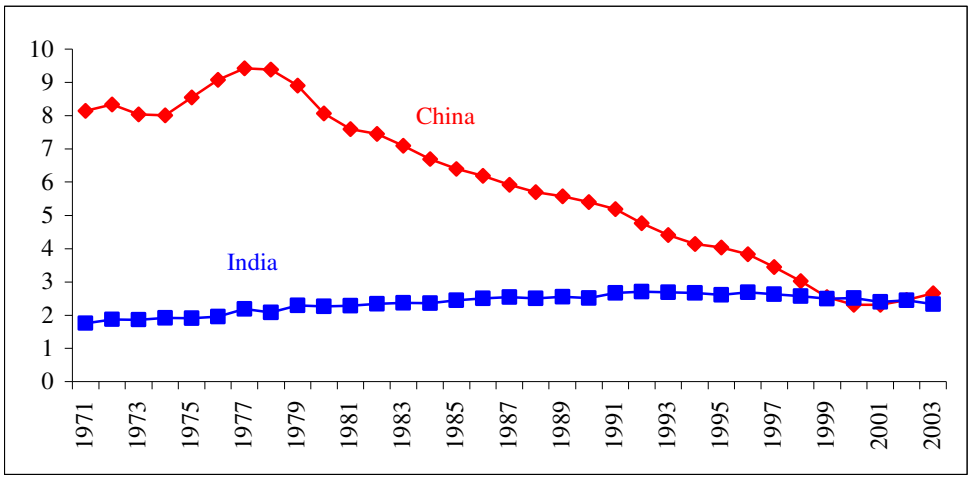

Figure 17 Emissions Intensity in China and India, 1971-2003

If the four largest Asian economies (China, Japan, India and South Korea) are considered together, an interesting finding is that they are converging in terms of both energy and emissions intensity (Figures 18 and 19). In particular, energy intensity has declined dramatically in both China and India. By 2003, in terms of energy and emissions intensity, China and India reached the similar level as Korea in the 1970s. The sharp contrast between the US and the four Asian giants raises the question whether there is an Asian model in energy use and emissions control. Given the fact that the four largest economies in Asia are at different stages of development, will China and India be able to tunnel through the Korea and Japan path? That is, will China and India be able to perform even better than Korea and Japan in the future (following the red lines in Figures 18 and 19)? If China and India can maintain their practices in the past decades, tunneling through is highly possible as there is still a long way for the two countries to catch up with their Asian rich neighbors.

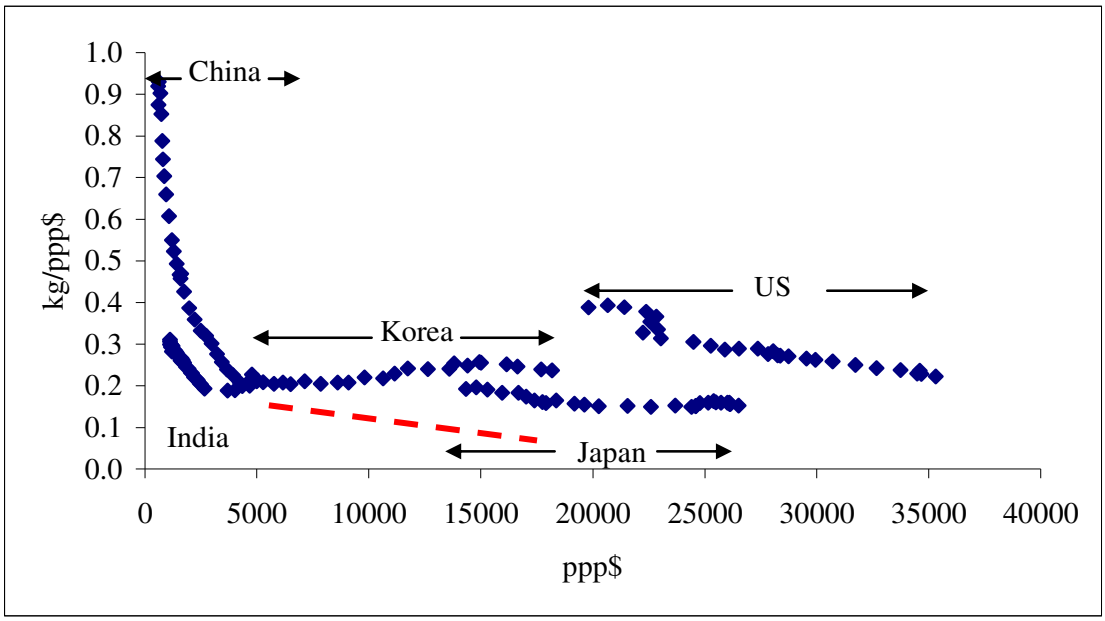

Figure 18 Energy Intensity, 1975-2003: Asia vs US

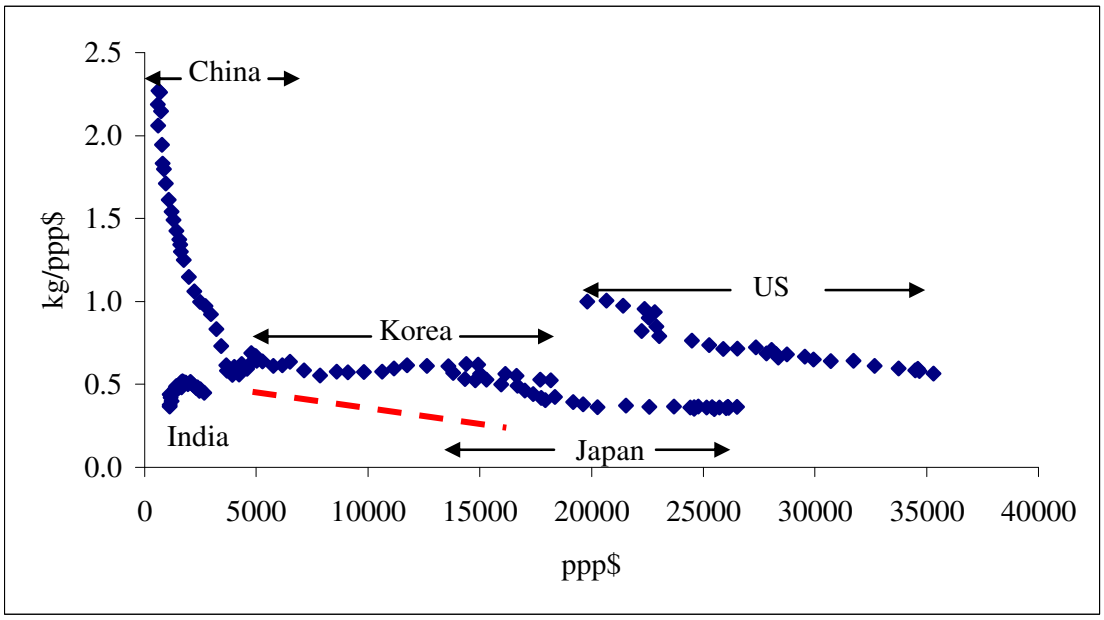

Figure 19 Emissions Intensity, 1975-2003: Asia vs US

5. Concluding Remarks

In summary, there is clear evidence of the close association between income and energy consumption and hence CO_2 emissions. As expected, the world's biggest economies are also the largest energy consumers as well as emitters. On a per capita basis, however, there is considerable variation among the nations in terms of energy consumption and emissions. The major economies in the world are divided into different clubs from less energy/emissions intensive to more energy/emissions intensive. Whether China and India join the energy/emissions intensive group or not has important implications for the world's energy supply and control of climate changes.

There is already evidence that energy and emissions intensities have fallen substantially in the two giants particularly in China. In comparative perspective, the four largest Asian economies China, Japan, India and Korea are also converging in terms of energy and emissions intensities. Asian countries have shown a unique Asian model in energy use and emissions controls. Given the current development stage and long catch-up process of China and India, the two countries have a good chance to "tunnel through", that is, pursuing an even less energy and emissions intensive strategy than Korea and Japan which are already champions in terms of energy efficiency and emissions control among the developed world.

Appendix

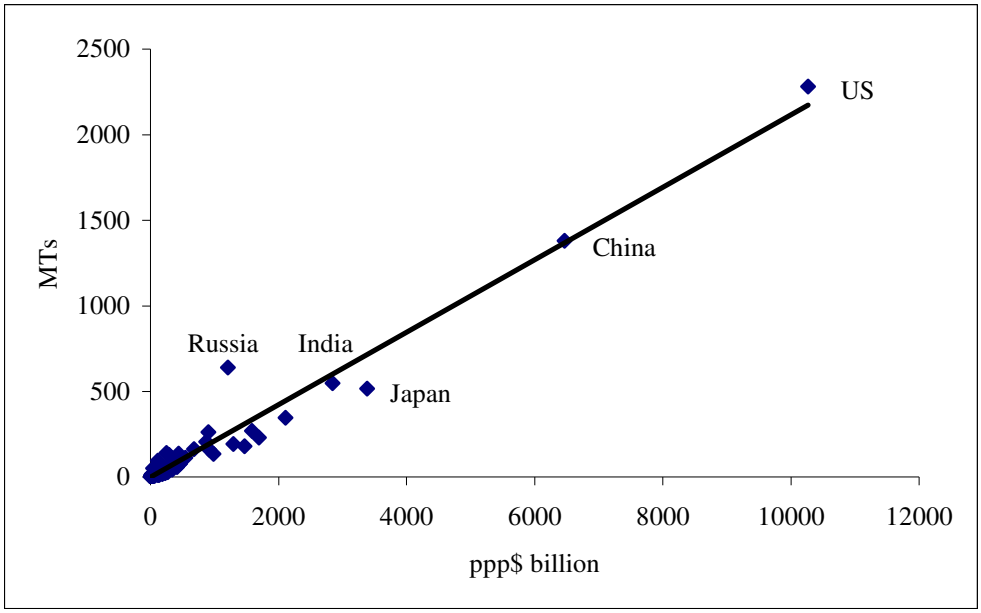

Figure A1 Energy Consumption and GDP in 2003

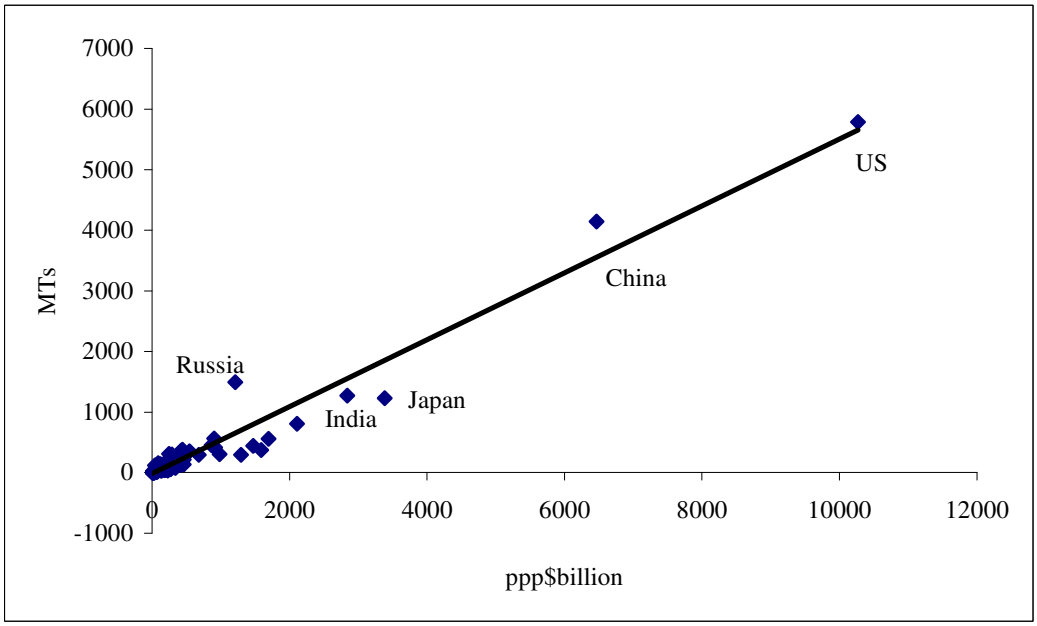

Figure A2 CO_2 Emissions and GDP in 2003

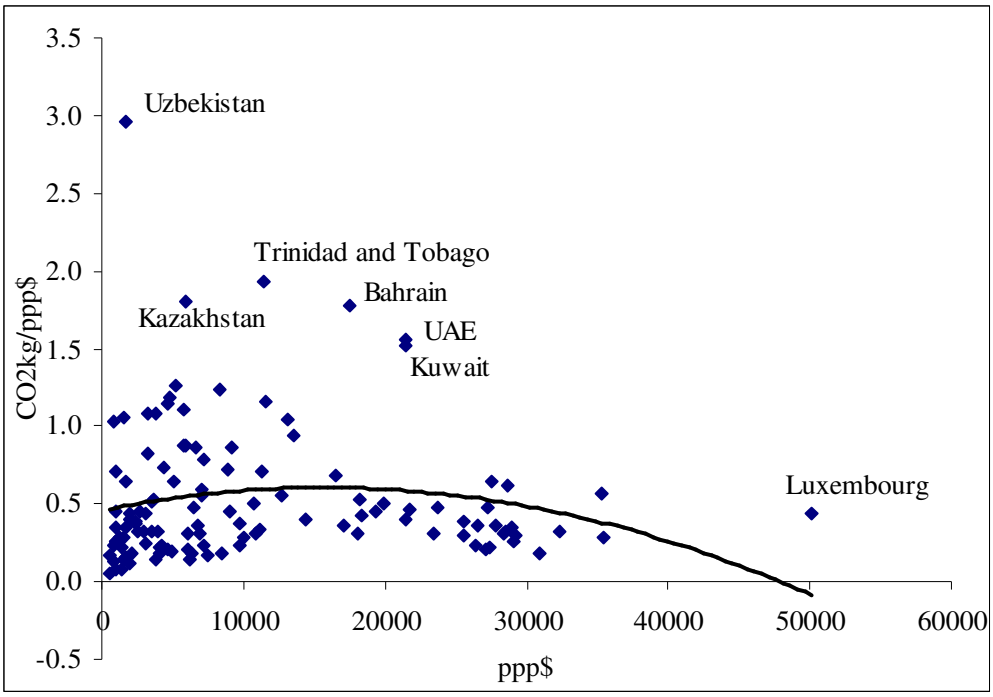

Figure A3 Emissions Intensity and Income Level in 2003

References:

Crompton, Paul and Yanrui Wu (2005), "Energy consumption in China: past trends and future directions", Energy Economics 27, 195-208.

Grossman, G. and A. Krueger (1995), "Economic growth and the environment", Quarterly Journal of Economics 110 (2), 352–77.

IEA (2007), World Energy Outlook 2007: China and India insight, International Energy Agency, Paris.

Nag, Barnali and Jyoti Parikh (2000), "Indicators of carbon emission intensity from commercial energy use in India", Energy Economics 22(4), 441-61.

Paul, Shyamal and Rabindra N. Bhattacharya (2004a), "Causality between energy consumption and economic growth in India: a note on conflicting results", Energy Economics 26, 977-83.

Paul, Shyamal and Rabindra N. Bhattacharya (2004b), "CO_2 emission from energy use in India: a decomposition analysis", Energy Policy 32, 585-93.

Selden, T.M. and D. Song (1994), "Environmental quality and development: Is there a Kuznets curve for air pollution emissions?", Journal of Environmental Economics and Management 27, 147-62.

Shalizi, Zmarak (2007), "Energy and Emissions", in Dancing with giants: China, India and the global economy edited by L. Alan Winters and Shahid Yusuf, Washington, D.C : The World Bank.

Srivastava, Leena (1997), "Energy and CO2 emissions in India: increasing trends and alarming portents" Energy Policy 25(11), 941-49.

Tilton, John E. (ed) (1990), World metal demand: trends and prospects, Washington, D.C : Resources for the Future, Distributed worldwide by Johns Hopkins University Press.

Wu, Libo, Shinji Kaneko and Shunji Matsuoka (2006), "Dynamics of energy-related CO_2 emissions in China during 1980 to 2002: The relative importance of energy supply-side and demand-side effects", Energy Policy 34, 3549-72.

Zou, Gaolu and K.W. Chau (2006), "Short- and long-run effects between oil consumption and economic growth in China", Energy Policy 34, 3644-55.