Asian Giants' Fossil Fuel Dependence and the Challenge of Low Carbon Growth: Contrasting Performance of Clean Energy Development, Trade and Investment

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ASIAN GIANTS' FOSSIL FUEL DEPENDENCE AND THE CHALLENGE OF LOW CARBON GROWTH: CONTRASTING PERFORMANCE OF CLEAN ENERGY DEVELOPMENT, TRADE AND INVESTMENT

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With sluggish growth in alternate technologies, economic growth across the world has remained largely fuelled by hydro-carbons whose burning has contributed to the menace of global warming. In such a situation, this study focusing on the economies of China, India and Japan – the three Asian Giants, aims at not only ascertaining their fossil fuel dependence but it also addresses its environmental implications. Moreover, it contrasts their attainments in clean energy development. An analysis of trade in climate smart technologies reflects the nature of mutual cooperation among these giants. Similarly, an analysis of recent trends in investment financing corroborates their pursuit of low carbon growth agenda which is a major cause of concern in most of the international climate change negotiations.

1. INTRODUCTION

Today's economic growth is largely energy-driven. No country can imagine economic growth without assured, whether indigenous or imported, energy supplies. With sluggish development in alternate technologies, there has remained a continuing dependence on hydro-carbons in the energy mix of a large number of nations and this dependence has grown to such a large extent that all the major economies are hunting for secured energy supplies across the world. However, the rapid depletion of fossil fuel reserves at global level[2] has made the whole situation so alarming that there have emerged concerns over sustaining economic growth in near future.

An upshot of such undue reliance on fossil fuels has been the large emission of Green House Gases (GHGs) which besides having a deleterious impact on environmental quality are a significant cause of rising global warming levels. Though the international community through its negotiations, dialogues and treaties is making attempts to

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[2] *BP Statistical Review of World Energy, 2016* through its Reserve to Production (R/P) ratio indicate that at the current rate of production, the reserves of oil, natural gas and coal are expected to last for another 50.7, 52.8 and 114 years respectively.

mitigate global warming[3], the outcomes are slow and unyielding. In such a situation, the world is looking for and working towards the development of better and promising energy supply options.

In fact, the experts consider a shift from carbon-rich fuels a *sine qua non* for sustaining growth trajectories in coming times. Available energy options are related to the tapping of solar energy, wind energy, geothermal energy, tidal energy, biomass and various other options such as the use of hydrogen as an energy source. So far, a large number of efforts are made to explore various energy alternatives. Despite the fact that these clean energy systems have high initial costs, the interventions made are striking and the clean energy capacity additions are significant. Yet, the attainments are much below potential and definitely, large efforts are required. It is noteworthy that a large number of countries are taking significant initiatives to attain low carbon growth through the development of sound institutional, legislative and market framework. Similarly, their progress in terms of trade, investment and RD&D is significant and gaining momentum.

This study, focusing on three Asian Giants, viz. China, India and Japan, has a three-fold objective. First, it aims at ascertaining the magnitude of fossil fuel dependence among the Asian Giants. Second, it tries to trace out the consequent environmental implications and thirdly, it aims at contrasting the performance of Asian Giants in the development of installed capacities of various clean energy constituents, such as hydro, solar, wind and biomass-based electricity systems. In addition, it also examines the nature of mutual trade in climate smart technologies and the financing of investment for promoting the growth of clean energy. For a detailed inquiry under each objective, the study makes a detailed analysis of available secondary data sources[4] along with drawing key insights from various research reports and studies.

Including this introductory section, there are eight sections. The next section elaborates on the nexus between economic growth, energy and the environment. The third section

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[3] One such significant effort has been the *Paris Agreement* which came into force on November 04, 2016 with the ratification of 103 countries. This agreement aims at combating globally the threat of climate change by keeping the global temperature levels well below 2 $^{\circ}$C.

[4] Some of the key secondary data sources are: CAIT Climate Data Explorer, BP Statistical Review of World Energy, US Energy Information Administration (IEA) Database, International Renewable Energy Agency (IRENA) RE Electricity Statistics and UN Comtrade Data.

locates Asian Giants in larger global setting. The fourth section examines the magnitude of fossil fuel dependence among them and the fifth section addresses environmental implications of such fossil fuel dependence. The sixth section contrasts Asian Giants' performance in clean energy development. The seventh section reveals emerging trends in trade and investment financing during recent years and the final section sums up.

2. ECONOMIC GROWTH, ENERGY & ENVIRONMENT: EMERGING TRENDS & ISSUES

Various growth models consider economic growth significantly dependent, either in fixed or variable proportions, on various factors of production such as land, labour, capital, enterprise, technology etc. It is generally believed that the levels of economic growth can be increased manifold with an optimal usage of these factors of production. In such models, the inputs like energy remain largely intermediate and do not figure significantly in growth modelling. However, there have been instances when energy *per se* has become a limiting factor to growth.[5] Similarly on environmental fronts, the reckless exploitation of natural resources and the rising levels of GHGs have started affecting adversely the growth process. Such outcomes urged for the need to rethink the whole approach towards the attainment of economic growth.[6]

In fact, the relation between economic growth, energy and the environment has been so intriguing that it provided space to a plethora of research[7] in which efforts are made to establish the causal relationships, through rigorous econometric analytical exercises, among these variables. Such detailed analyses of time-series data have been of great use for specific countries when they are at crossroads to choose among energy conservation or growth expansion policies.

It is noteworthy that the world economy during the 1970-2013 period has grown at an average annual growth rate of 3.13 percent.[8] During this period, there has been an

[5] A glaring example is of the oil crisis of 1973 when an oil embargo was proclaimed by the Organization of Arab Petroleum Exporting Countries. This led to the rising of global oil prices per barrel in 1974 from US $3 to about US $12.

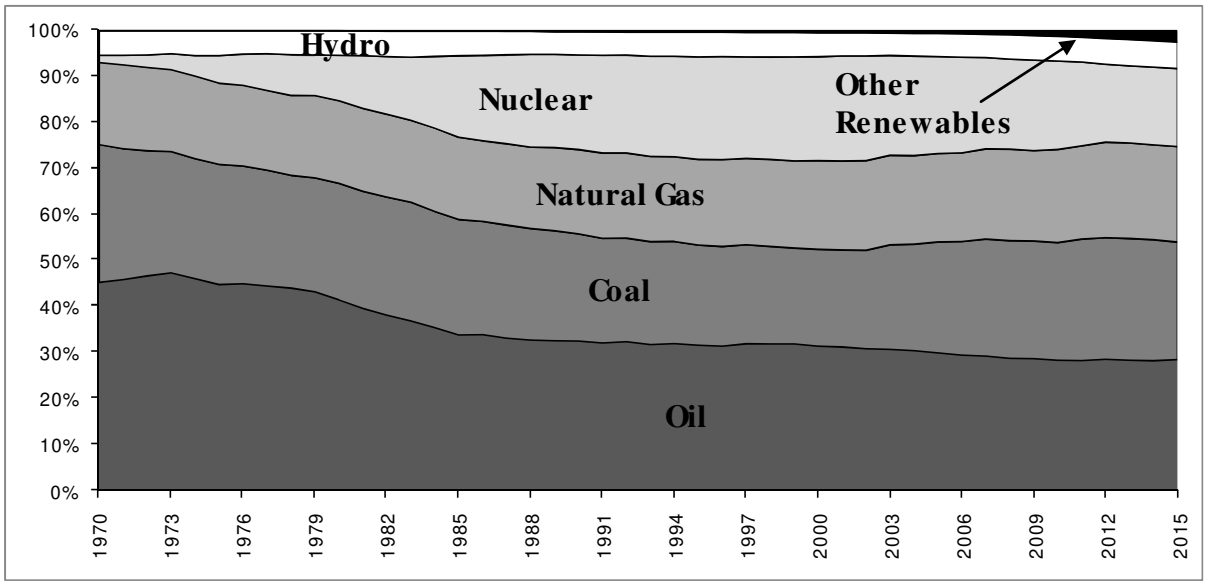
[6] Now-a-days, the researchers, in a growth accounting framework, are talking about 'Sustainable Growth', 'Green Growth', 'Environmental Governance' etc.

[7] See, for example, Lee (2006); Ozturk et al. (2010); Osigwe and Arawomo (2015) among others.

[8] As per World Development Indicators, World Bank.

impressive increase in energy consumption across the world.[9] The primary energy consumption has increased at an annual growth rate of 2.21 percent over this period. A large part of this energy consumption was served by oil and coal (Figure 1). Natural Gas has also emerged as an important fuel source. Similarly, the share of Nuclear energy has increased over time. Hydro energy sources did not see much expansion in terms of their share in overall energy mix whereas there has been a mild increase in the share of other renewable energy sources.

Figure 1: Energy Mix Trend at World Level



Source: Based on BP Statistical Review of World Energy, 2016

As evident, there has been not only the dominance of fossil fuels, viz. oil, coal and natural gas in world energy basket over time but they have also remained largely irreplaceable. Owing to their carbon-rich nature, their burning contributed to global warming through GHG emissions. As per CAIT data,[10] the total volume of GHG emissions (including land use change and forestry) in 1990 was 30423.75 $MtCO_2e$ which got increased to 47598.55 $MtCO_2e$ in 2012. It indicates a compound annual growth of 2.06 percent. Within the GHGs, a major share is of the CO_2 emissions.

[9] While looking at the per capita energy consumption figures, one may say that it has risen from 1336.27 Kilograms of Oil Equivalent (KgOE) in 1970 to 1894.27 KgOE in 2013 which does not seem to be much impressive. But, at the same time, the perceptions are over-turned when we consider the absolute magnitudes of primary energy consumption. It has increased from 4909.89 Million Tonnes of Oil Equivalent (MTOE) in 1970 to 12873.14 MTOE in 2013.

[10] World Resources Institute, Washington D.C. provides Climate Analysis Indicators Tool (CAIT) to monitor climate change aspects. It is available at http://cait2.wri.org/

It is noteworthy that the magnitude of CO_2 emissions was 5891.71 $MtCO_2e$ in 1951. Since then, it got increased by 5.74 times. In such situation, there is a growing concern within the international community over the fact that the rising levels of GHGs, especially CO_2, are causing global warming. Owing to a large number of efforts,[11] the developed nations, at large, are making efforts to contain their CO_2 emissions. A move towards low-carbon economies is considered as a key strategy to attain this objective. In this line, a number of innovations are taking place and the development of clean energy sources, like solar, wind, geothermal, tidal, bio-fuels etc. is gaining momentum. Still there persist various technology-related issues but at the same time, efforts are being made to bridge the gap through trade and investment financing. But, on the whole, a good progress seems to be made. This study explores all these aspects through a comparative study of China, India and Japan, the three Asian Giants.

3. ASIAN GIANTS IN A GLOBAL SETTING: STATUS AND SIGNIFICANCE

In Asia, there are three major economies, viz. China, India and Japan. Spread over 9.85 percent of world's surface area, they reside about 40 percent of world population. In terms of population density, they are highly dense nations. Among these, the population density is the highest in India (419.6). Japan comes at the next level and it is relatively low in China which has the highest surface area among these three nations. China's surface area is 2.91 times higher than that of India and it is 25.43 times higher than Japan. Globally, China alone occupies 7.12 percent of world's surface area (Table 1).

A relatively large proportion of India's population resides in rural areas (67.3 percent), which is not the case with the economies of China and Japan where the share of rural population is 44.4 percent and 6.5 percent respectively. It indicates that Japan and China have made considerable progress in urbanization. In 1960, 63.27 percent of Japanese population was living in urban areas, which got increased to 76.2 percent in 1980 and 93.50 percent in 2015. Similarly, more population lived in urban China only after 2011. In India, the urbanization took place at an average annual growth rate of 1.10 percent over the 1960-2015 period.

[11] Earlier the efforts were limited but a major intervention was made through an international environment treaty, known as 'United Nations Framework Convention on Climate Change', at the Earth Summit (held at Rio de Janeiro) in 1992, which led to Kyoto Protocol in 1997 which lasted upto 2012. Recently, the Paris Agreement came into force on November 04, 2016 with its ratification by 105 parties.

Table 1: Selected Indicators of Asian Giants

Indicator	Year	Unit	China	India	Japan	World
Surface Area	2015	Million Sq.km.	9.56	3.29	0.38	134.33
		SiWT(%)	7.12	2.45	0.28	100
Population	2011	Million	1344.13	1247.45	127.82	7006.91
		SiWT(%)	19.18	17.80	1.82	100
		Density*	143.2	419.6	350.6	54
Urban Population	1980	% in Total	19.4	23.1	76.2	39.3
	2015		55.6	32.7	93.5	53.9
GDP	2015	US $ Billion	10866.44	2073.54	4123.26	73502.34
		SiWT(%)	14.78	2.82	5.61	100
GDP Growth	1981-90	%	9.38	5.57	4.64	3.16
	1991-00		10.46	5.60	1.14	2.80
	2001-10		10.52	7.42	0.80	2.85
	2011-15		7.82	6.74	0.62	2.61
Per Capita Income	1980	US $	193.3	271.9	9307.8	2514
	2015		7924.7	1581.6	32477.2	10004.9
Income Inequality		Gini Index	42.2 (2012)	35.2 (2011)	32.1 (2008)	NA
Poverty Head-Count Ratio (HCR)		@US $3.10/ day (2011 PPP)	99.1 (1981)	83.7 (1983)	NA	NA
			11.1 (2013)	57.96 (2011)	NA	NA

Note: *implies people per sq.km. of land area; SiWT – Share in World Total.
Source: Based on World Development Indicators, World Bank.

In fact, these Asian Giants account for a major share in world GDP. In 1980, they together contributed 13.15 percent to world GDP. In 1990, this share was 16.79 percent which increased further to 18.07 percent. In 2015, they contributed 23.21 percent share in world GDP.[12] In terms of growth rate of GDP, the pace has remained the highest for China over time. The second lead was taken by India and Japan recorded the lowest growth over time. However, in terms of per capita income, Japan occupied the highest rank. In 1980, India was ahead of China in terms of per capita income levels but in 2015, China remained ahead of India in this respect. However, there has prevailed a relatively high level of income inequality, as measured through the Gini Index, in China. Income inequality levels have been relatively low in India and Japan. But, in terms of Poverty HCR, 57.96 percent population in India is living below the daily earning of US $3.10 per day which is very high in comparison to 11.1 percent for China (Table 1).

[12]Within the Asian Giants, there are disparities in GDP growth. During recent years, the Chinese economy accounted for a major share. The share of Japanese economy was also considerable till 2000 but since then, it is recording a continuous decline in its GDP growth. In the case of India, there has taken place an increase in its contribution to global GDP over the period of time (see Table A1, in appendix).

Table 2: Selected Energy-related Indicators of Asian Giants

Indicator	Year	Unit	China	India	Japan	World
Primary Energy Consumption	1980	SiWT, %	6.29	1.54	5.37	100
	2015		22.92	5.33	3.41	100
Fossil Fuel Reserves*	Coal	Million Tonnes (% of world)	114500 (12.8)	60600 (6.8)	347 (0.03)	891531 (100)
	Oil		2.5 (1.1)	0.8 (0.3)	-	239.4 (100)
	Natural Gas	Trillion Cubic Feet	135.7 (2.1)	52.6 (0.8)	-	6599.4 (100)
Net Energy Import	1980	% of Energy Use	-2.91	9.42	87.43	-0.86
	2013		13.50	32.51	93.85	-3.31
Per Capita Energy Use	1991	Kg of oil equivalent	736.9	358.5	3580	1647.3
	2011		1994.4	574.3	3614.4	1859.2
Access to Electricity	1990	% of Population	94.23	50.9	100	75.65
	2012		100	78.7	100	84.58

Note: SiWT – Share in World Total; **implies that it refers to the year 2015.
Source: Based on World Bank (2016); BP Statistical Review of World Energy, 2016

In terms of energy-related indicators, the Asian Giants are quite distinct. The reserves of fossil fuels especially oil are very limited in China and India – Japan does not have any reserve of oil and natural gas. China has a relatively large reserve of natural gas than India. Similarly, its reserve of coal is significantly large. In terms of the magnitude of primary energy consumption, the disparities are much larger. China alone accounts for 22.92 percent of world's total primary energy consumption. Similarly, India and Japan also account for a significant share in world total.

In the situation of limited reserves and indigenous production, these Asian Giants are largely relying on imported energy. Japan's dependence on imported energy is more than 90 percent. It is about a third for India. In 1980, it was merely one-tenth of its energy needs. In 1980, China was an energy-surplus nation but in 2015, its dependence on imported energy has been 13.50 percent. Similarly, the disparities exist among Asian Giants in terms of their per capita energy consumption levels with the Japan being at the top. In 2011, the per capita energy consumption levels in India has remained 6.29 times lower than that in Japan and 3.47 times lower than that in China. 100 percent of population in Japan and China has access to electricity but there are still 21.3 percent population who does not have access to electricity in India.

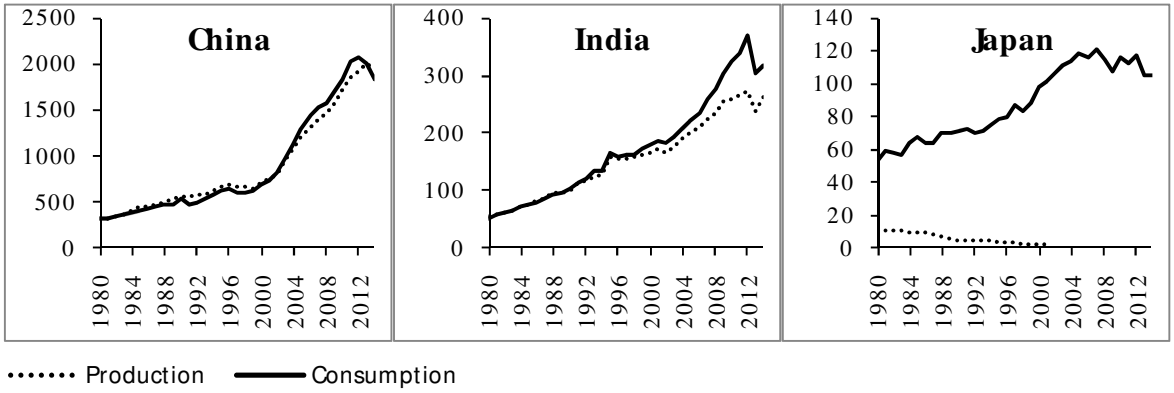
Given such contrasting profile of Asian Giants, it is of interest to explore further their fossil fuel dependence, environmental implications, clean energy development, trade and the financing of renewable energy. All these aspects are discussed below:

4. FOSSIL FUEL DEPENDENCE OF THE ASIAN GIANTS

4.1. COAL

Coal has remained a major source of energy for China over time. In 1970, it was meeting 82 percent of its total energy needs. But, there has taken place a decline in coal dependence at the rate of -0.55 percent over 1970-2015 period. In 2015, coal share in China's energy mix has been 64 percent. For India, though the coal has remained a major energy source, its share has remained relatively lower in the energy mix. In 1970, it was meeting about 58 percent of India's energy needs and this dependence has remained somewhat similar over the 1970-2015 period. In contrast, Japan relied on coal for meeting less than one-third of its total energy needs over time.

Figure 2: Coal Production-Consumption Trend of Asian Giants



Source: US Energy Information Administration Database

As mentioned above, both China and India hold large reserves of coal. Globally, both these economies account for one-fifth of total coal reserves. China is world's largest coal producer as well. In 2015, its contribution to global coal production was 47.7 percent. The coal production in China is, however, of such high magnitude that by R/P ratios,[13] it is observed that the coal reserves in China would last for another 31 years. For India, the coal reserves are expected to last for another 89 years. Japan, on the contrary,

[13] R/P (Reserve/ Production) ratio indicates the time duration over which the reserves would be over at the continued rate of production. It is estimated by dividing the reserve volumes with current production magnitudes.

produced coal in small volumes. In 1981, it produced only 11.1 MTOE which recorded an annual decline of -8.22 percent over time and in 2015, its coal production was only 0.6 MTOE.

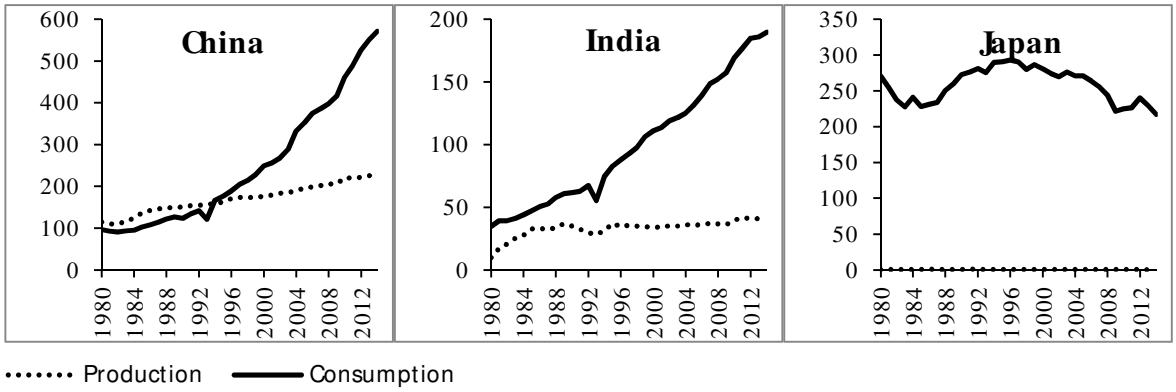
For China, equally high has been the volume of coal consumption. During the decade of 1980s, China produced more than its consumption for all the years except 1988. The production deficits appeared somewhat during the 1990s and the deficits were more frequent during the post-2000 period. For India, the indigenous coal production remained sufficient only for a few years and the production-consumption gap widened over time. India's coal net import became positive from 1990 onwards and it started coal import, though in small quantities, from countries like Australia, Indonesia and South Africa (Jain, 2014). For Japan, there always prevailed wide gap. Its coal consumption remained considerably high.

4.2. OIL

Oil has been a significant constituent of Japan's energy basket. In 1970, its share in energy mix was as high as 71.13 percent. Till late years of 1970s, the dominance of oil in Japan's energy basket remained within the range of 71-78 percent and a major reduction in its share at 66.77 percent came in 1980. Since then, there has taken place a significant reduction in its share over time – this reduction, on annual average basis, was -1.62 percent, -1.23 percent, -1.13 percent during 1980s, 1990s and post-2000 period. By 2015, it met about two-fifth of Japan's energy needs. For India, oil's significance in overall energy mix remained within the range of 27-34 percent over the 1970-2015 period. In 2015, it met 27.91 percent of India's energy needs. For China, oil's contribution remained within the range of 16-23 percent during post-1971 period.

Japan has no significant oil reserves. Its indigenous production has remained limited. China and India possess about 2.5 MTOE and 0.8 MTOE oil reserves respectively. Though they account for just 1.1 percent and 0.3 percent of world's total oil reserves, their share in global oil production is 4.9 percent and 0.9 percent respectively. By R/P ratio, it is expected that oil reserves in China and India would last for another 11.7 and 18 years respectively.

Figure 3: Oil Production-Consumption Trend of Asian Giants



Source: US Energy Information Administration Database

The oil production began at a modest scale in China. In 1965, its production was only 11.3 million tonnes which was just 0.72 percent of world's total oil production (Jain, 2014). In 1980, it was producing 114 million tonnes which got increased to 150 million tonnes in 1990 and 227 million tonnes in 2014. India produced 9.63 million tonnes of oil in 1980 which got increased to 40.47 million tonnes in 2014. Japan's indigenous production has remained very limited.[14] Nonetheless, these economies ventured into oil refining. China alone possesses 14.7 percent of world's oil refining capacities with refinery throughput of 10661 thousand barrels per day (in 2015). Similarly, India possesses 4.4 percent of world's total oil refining capacities with refinery throughput of 4561 thousand barrels per day. Japan has 3.8 percent of world's oil refining capacities.

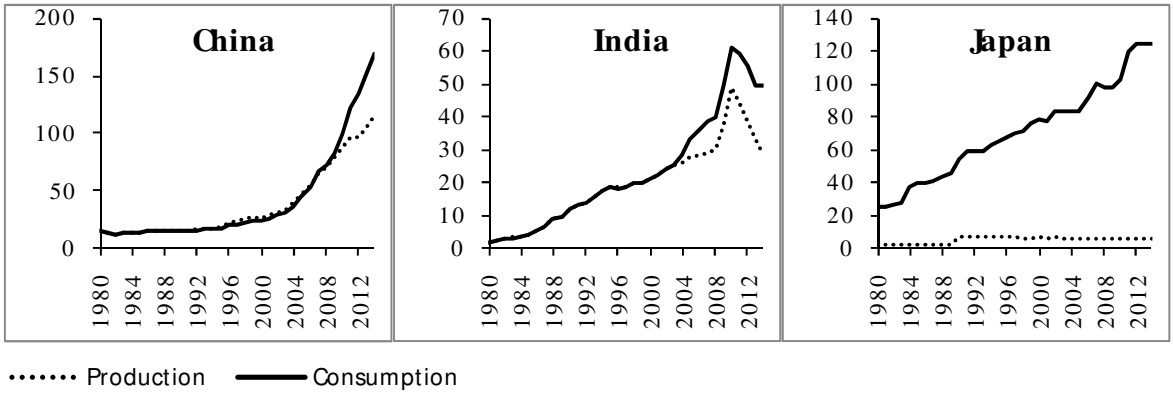
Oil consumption levels have remained considerably higher than indigenous production for all the three giants. India and Japan were always the net oil importing countries. Such was not the case with China where no significant production gap prevailed till 1973 (Jain, 2014). Similarly, the indigenous production remained higher than consumption during the 1974-92 period which indicates that till 1992, China has been a net oil surplus country. From 1993 onwards, there was widening of production-consumption gap due to relatively rapid growth in oil consumption. At present, all the three Asian Giants are net oil importers. A study by Gupta (2008) finds India, among the sample of 26 oil-importing countries, the third highly vulnerable country with oil vulnerability index (OVI) of 0.93. It finds China at 11th rank with OVI of 0.66. Similarly, the rank of Japan is found to be relatively low (18 with OVI=0.51).

[14] It was 0.55 million tonnes in 1980 which fell to 0.25 million tonnes in 2014.

4.3. NATURAL GAS

Among fossil fuels, the natural gas has been another emerging energy source which has gained a significant share in Japan's energy mix. In 2015, it met more than one-fifth of its overall energy needs. For China and India, its share in overall energy basket has remained limited to 5.89 percent and 6.50 percent. Japan does not have significant natural gas reserves whereas the size of such reserves is 3.8 and 1.5 trillion cubic metres in China and India. China's annual production of natural gas remained below 17 mtoe till 1995, beyond which it recorded a significant increase and the production went upto 124.2 mtoe in 2015. It is noteworthy that till 2006, China's indigenous production of natural gas remained sufficient for meeting its demand. But during the post-2006 period, the consumption of natural gas increased rapidly than its production which made China natural gas deficit country.

Figure 4: Natural Gas Production-Consumption Trend of Asian Giants



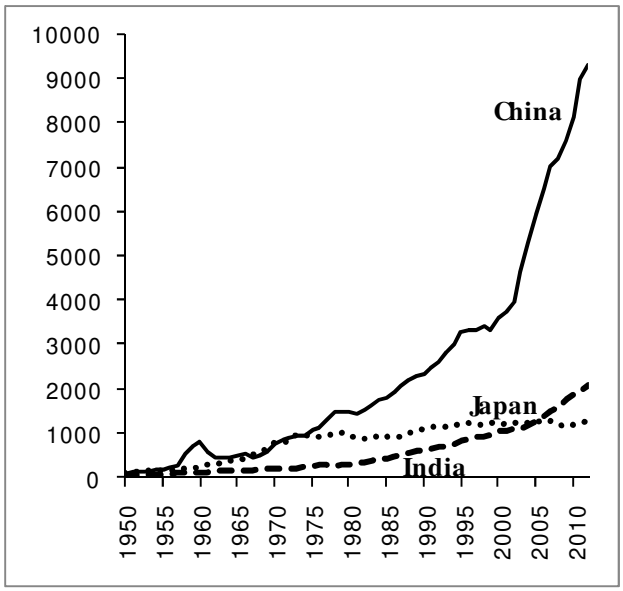
Source: US Energy Information Administration Database

India, on the contrary, did not register any significant production of natural gas till 1979. Since then, it made a rapid growth in production of natural gas. During 1980-90 period, the natural gas production grew at an annual rate of 22.77 percent. This production rate got reduced to 6 percent during 1990-2000 period. This rate further got reduced to 2.26 percent during 2000-14 period. It is noteworthy that India was not deficit in natural gas till 2002 when indigenous production was sufficient for domestic demand. But, there started appearing a production-consumption mis-match in the post-2002 period. As a consequence, India became a net importer of natural gas. Similarly, Japan's indigenous production of natural gas has been very limited whereas its demand has remained very high. As evident, Japan remained always a net importer of natural gas over time.

5. ENVIRONMENTAL CHALLENGES OF FOSSIL FUEL DEPENDENCE

With such heavy reliance on fossil fuels, the Asian Giants have emitted large volumes of CO_2 in atmosphere. Figure 5 depicts a comparative trend of CO_2 emissions during the post-1950 period. It is evident that till the early years of 1950s, the CO_2 emission levels were almost similar for China, India and Japan. But, the gap started widening since then and China made relatively more CO_2 emissions over the period of time. Japan's emission of CO_2 remained relatively high than India till 2005, beyond which India's CO_2 emissions grew at CAGR of 7.32 percent (Table 3). IEA (2015) reports that these Asian Giants are among the top ten CO_2 emitting nations in 2013 – China stays at the top with 28 percent share; India comes at the third level following United States and Japan comes at the fifth level following Russian Federation. In fact, the industrial nations remain the top emitters with relatively high levels of per capita CO_2 emissions.

Figure 5: CO_2 Emissions Growth



Source: CAIT-Historical Emissions Data

Table 3: CAGR of CO_2 Emissions

	China	India	Japan	World
1950-55	19.40	5.11	6.71	4.60
1955-60	32.52	7.12	10.39	4.67
1960-65	-9.42	6.50	10.70	3.99
1965-70	10.14	3.23	14.72	5.22
1970-75	7.04	5.23	2.96	1.99
1975-80	6.22	3.47	0.79	3.17
1980-85	4.15	8.00	-0.22	0.57
1985-90	5.53	7.15	3.74	2.40
1990-95	6.76	5.63	1.47	0.96
1995-00	2.05	4.95	0.49	1.68
2000-05	10.47	4.20	0.52	3.14
2005-12	6.65	7.32	0.07	2.28

Globally, the share of CO_2 in total GHG emissions has remained more than 90 percent during the post-1990 period. Other key gases are Methane and Nitrous Oxide whose shares in overall GHG emissions has remained within the range of 15-18 percent and 6-8 percent during this period.[15]

[15] As per CIAT-Historical Emissions Data

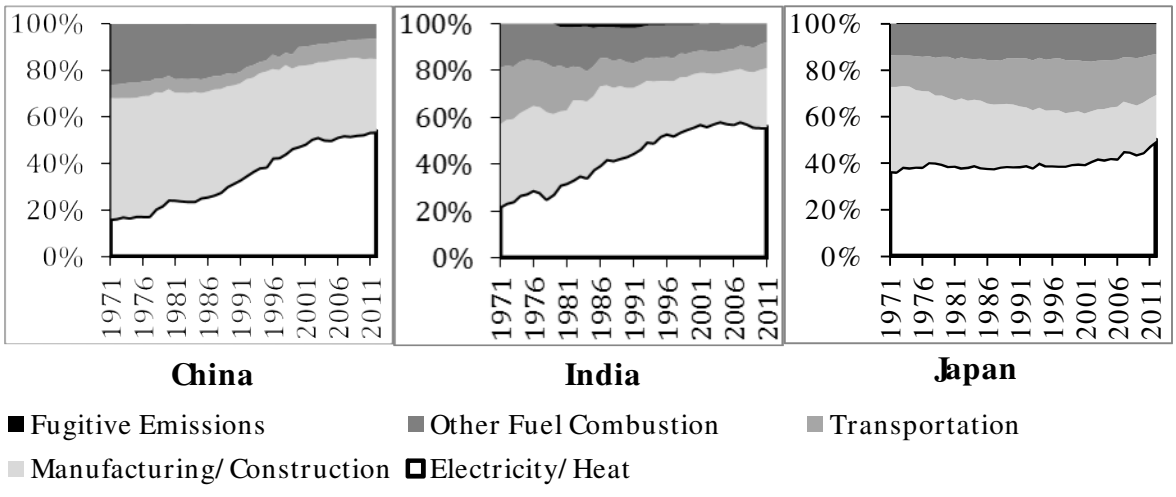
Table 4: Growth Trend in Total GHG Emissions

	Period	Carbon dioxide (CO_2)	Methane (CH_4)	Nitrous Oxide (N_2O)	F-Gas	GHG Emissions
		1	2	3	4	1+2+3+4
China	1990-95	5.53	1.47	3.12	17.49	4.54
	1995-00	2.18	-0.75	0.33	32.62	1.69
	2000-05	11.18	4.11	3.72	22.95	9.79
	2005-12	7.15	1.13	4.14	4.09	6.28
India	1990-95	5.35	1.05	2.78	27.67	3.51
	1995-00	5.22	1.26	1.86	17.28	3.61
	2000-05	2.26	1.34	2.28	14.94	2.16
	2005-12	8.54	1.57	3.20	1.79	6.04
Japan	1990-95	1.56	-1.05	1.08	6.41	1.62
	1995-00	0.53	-2.88	-2.61	3.41	0.48
	2000-05	0.11	-2.37	-3.44	-0.49	-0.03
	2005-12	-0.40	-1.44	-1.34	1.55	-0.35

Source: Based on CIAT-Historical Emissions Data

Table 4 provides comparative estimates of growth in different GHG constituents during the post-1990 period. Average annual growth in CO_2 in both China and India appeared at a relatively high rate than Japan during this period. In Japan, the rate of CO_2 growth in fact has started containing. Similar is the case with the growth trend of other gases like methane and nitrous oxide where average annual growth rates are found to be largely negative. Such is not the case with China and India where the growth in these gases has taken place at relatively high rates of growth. However, in case of F-gas emissions, even Japan recorded positive growth. The emission rates of China and India for this gas has remained very high.

Figure 6: Trend in Sources of CO_2



Source: Based on CIAT-Historical Emissions Data

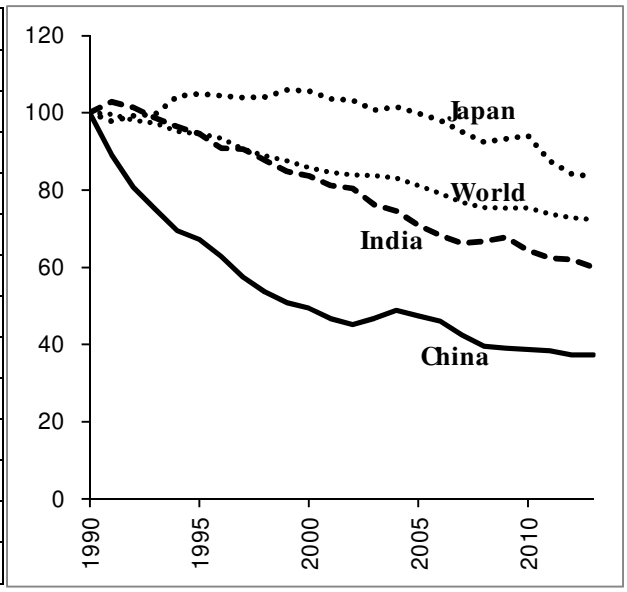
Given such trend in GHG composition, a consideration of CO_2 sources reveals that in the initial years, the contribution of electricity / heat to CO_2 emissions has been relatively lower, in contrast to Japan, in China and India but it is now emerging as a significant contributor. Other key contributor has been the manufacturing / construction sector. Its contribution has been relatively high in China than India and Japan. The contribution of transportation sector in China's overall CO_2 emissions has remained relatively low. Such is not the case with India and Japan where this sector accounted for a relatively large share in overall CO_2 emissions (Figure 6).

Amidst such situation, one may remain guided by the energy intensity trends which indicate the quantum of energy utilised to produce GDP worth US thousand dollars. Considering the post-1990 period, Table 5 reveals that among the three Asian Giants, the energy intensity levels have remained relatively high in China. India followed China and Japan recorded the lowest energy intensity over time. It implies that China and India used a relatively high quantum of energy for the production of almost similar magnitudes of GDP.

Table 5: Growth Trend of Energy Intensity

Year/Period	China	India	Japan	World
Magnitude of Energy Intensity				
1990	505.86	198.63	120.33	181.32
1995	339.83	187.74	126.23	171.46
2000	249.94	166.15	127.13	155.52
2005	239.93	140.79	120.12	147.13
2010	195.74	127.75	113.17	136.69
2013	188.59	119.08	100.46	131.09
CAGR(%) of Energy Intensity				
1990-95	-7.65	-1.12	0.96	-1.11
1995-00	-5.96	-2.41	0.14	-1.93
2000-05	-0.81	-3.26	-1.13	-1.10
2005-10	-3.99	-1.92	-1.18	-1.46
2010-13	-1.23	-2.32	-3.89	-1.38

Figure 7: Energy Intensity Decline Index



Note: Energy Intensity is measured as the use of energy (kg of oil equivalent) per US $1,000 GDP (constant 2011 PPP).
Source: Based on World Development Indicators, 2016.

It is also evident that there is a declining trend in energy intensity across the three countries and rapid declines are observed in China and India. In figure 7, considering

the 1990 energy intensity levels as base, a trend of decline is observed which indicates that the declines are relatively fast in China and India whereas such is not the case with Japan which is already having very lower levels of energy intensity and any effort to reduce further would require further technical innovations, for which Japan is making efforts given its commitment to contain global warming.

Given such declines in energy intensity levels, the Asian Giants are pursuing their agenda, though at different scales, of low carbon growth. For this, they are venturing into a variety of innovations to enhance energy efficiency levels – the introduction of improved equipment, appliance labelling, energy-efficient building standards, introduction of fuel diversification and adoption of electric vehicles, CNG are a few examples of such pursuit. Similarly, they are also making significant progress in the adoption of clean coal technologies – both Japan and China are pioneers in these technologies and India is also trying to introduce this technology in its coal-fired thermal power plants. Modified industrial cogeneration processes are another domain in which these nations are making advances.

6. STATE OF CLEAN ENERGY DEVELOPMENT

Clean energy development has been on the priority list for the Asian Giants in their pursuit of low carbon growth. India has established in 1992 the Ministry of New and Renewable Energy (MNRE)[16] to support clean energy development. Following Fukushima Nuclear Disaster in 2011 and amidst other environmental commitments, Japan is committed to increase reliance on clean energy sources. In its 'Fourth Strategic Energy Plan', adopted in 2014, it aims at enhancing the share of renewable energy to 24 percent by 2030. Similarly, China's Renewable Energy Law, 2005 aims at enhancing the share of renewable energy.

Table 6 presents comparative trend in different constituents of hydropower installed capacity development during the post-2000 period. It is evident that in Chinese hydropower development, there has taken place a decline in the share of share of hydro-plants of relatively smaller installed capacities. In 2000, the hydro-plants with <1

[16] Earlier it was known as Ministry of Non-Conventional Energy Sources. The current name was adopted in October 2006.

MW capacity were constituting 32.26 percent share in total hydro capacities and it got reduced to 8.10 percent in 2015. There has taken a considerable growth of large hydro-plants. In India, the share of small hydro-plants has remained very limited over time and there has been the dominance of large hydro plants even in 2000. Though the situation has been similar for Japan, here the share of mixed and pumped storage has remained relatively more dominant.

Table 6: Comparative Trend in Hydropower Installed Capacity Development

	Hydro Type	2000		2005		2010		2015	
		MW	%	MW	%	MW	%	MW	%
China	<1 MW	25600	32.26	25600	21.81	25600	11.92	26000	8.10
	1-10 MW	27000	34.03	42000	35.78	57620	26.84	83000	25.86
	10+ MW	21752	27.41	44190	37.64	116230	54.14	189200	58.96
	M&PS	5000	6.30	5600	4.77	15250	7.10	22710	7.08
	Total	**79352**	**100**	**117390**	**100**	**214700**	**100**	**320910**	**100**
India	<1 MW	43	0.17	57	0.17	60	0.15	62	0.13
	1-10 MW	438	1.72	674	2.07	992	2.47	1173	2.54
	10+ MW	23460	92.08	28608	87.82	34255	85.44	40236	86.98
	M&PS	1536	6.03	3236	9.93	4786	11.94	4786	10.35
	Total	**25477**	**100**	**32574**	**100**	**40093**	**100**	**46256**	**100**
Japan	<1 MW	149	0.32	152	0.32	155	0.33	161	0.33
	1-10 MW	3437	7.42	3502	7.41	3514	7.36	3534	7.19
	10+ MW	18433	39.79	18479	39.07	18693	39.16	18537	37.72
	M&PS	24305	52.47	25159	53.20	25374	53.15	26914	54.76
	Total	**46324**	**100**	**47292**	**100**	**47736**	**100**	**49146**	**100**

Note: M&PS=Mixed and Pumped Storage
Source: IRENA, RE Electricity Statistics

Table 7: Comparative Trend in Solarpower Installed Capacity Development

	Technology Type	2000		2005		2010		2015	
		MW	%	MW	%	MW	%	MW	%
China	Solar PV	19	100	70	100	800	99.66	43180	99.97
	CSP					3	0.34	14	0.03
	All	19	100	70	100	803	100	43194	100
India	Solar PV			4	100	37	100	4964	96.06
	CSP							204	3.94
	All			4	100	37	100	5167	100
Japan	Solar PV	330	100	1422	100	3618	100	33300	100
	CSP								
	All	330	100	1422	100	3618	100	33300	100

Note: Solar PV=Solar Photovoltaic; CSP=Concentrated Solar Power
Source: IRENA, RE Electricity Statistics

Table 7 presents the post-2000 comparative trend in solarpower installed capacity development across the Asian Giants. The magnitude of solarpower installed capacity development is provided across the technologies of solar Photovoltaic (PV) and Concentrated Solar Power (CSP). It is found that in Japan, the whole solarpower installed capacity development is of Solar PV technology. Somewhat similar is the case in China and India where there has been the dominance of solar PV. During recent years, there has also taken some development of CSP installed capacities.

Table 8: Comparative Trend in Windpower Installed Capacity Development, MW

	Wind Energy				On-Shore Wind Energy				Off-shore Wind Energy			
	C	I	J	W	C	I	J	W	C	I	J	W
2000	341	1267	136	17330	341	1267	136	17263				67
2001	383	1456	303	23969	383	1456	303	23892				77
2002	449	1702	339	30858	449	1702	339	30621				237
2003	547	2125	582	38703	547	2125	581	38196			1	507
2004	763	3000	812	47116	763	3000	811	46519			1	597
2005	1269	4430	1050	58509	1269	4430	1049	57825			1	684
2006	2668	6270	1309	73281	2668	6270	1308	72397			1	883
2007	6031	7845	1538	93552	6029	7845	1527	92458	2		11	1094
2008	12174	9655	1880	119664	12173	9655	1869	118222	2		11	1442
2009	17672	10926	2085	150180	17670	10926	2074	148021	2		11	2159
2010	31410	13065	2334	182743	31310	13065	2309	179600	100		25	3144
2011	48046	16084	2536	222050	47836	16084	2511	218260	210		25	3791
2012	62956	18421	2614	271713	62665	18421	2589	266339	291		25	5374
2013	76560	20150	2661	303462	76143	20150	2611	295912	417		50	7550
2014	96370	22465	2794	350293	95930	22465	2744	341799	440		50	8494
2015	129340	25088	3035	416639	128781	25088	2985	404927	559		50	11712

Note: C,I,J and W refer to China, India, Japan and the World respectively.
Source: IRENA, RE Electricity Statistics

Similarly, Table 8 provides comparative trend in windpower installed capacity development. Here, China's performance is remarkable. Its windpower installed capacity increased from 341 MW to 1,29,340 MW over the 15 year period – most of this increase took place in the post-2005 period. It is also noteworthy that more than 99 percent of China's windpower installed capacity development took place in the form of on-shore wind energy. Same is the case with India and China. In China and Japan, there has taken place some addition in off-shore wind energy but such development has remained largely missing in India.

Table 9: Magnitude of Biomass-based Electricity Generation Capacities, in MW

		Bagasse	Renewable municipal waste	Other solid biofuels	Solid biofuels	Liquid biofuels	Biogas	Bioenergy
		(i)	(ii)	(iii)	A(i+ii+iii)	B	C	A+B+C
China	2000			1100	1100			1100
	2005			2000	2000			2000
	2010			5500	5500			5500
	2015			10320	10320			10320
India	2000			347	347		36	383
	2005	491	46	377	914		71	984
	2010	1603	141	1279	3023		128	3151
	2015	3050	274	2103	5427		179	5605
Japan	2000		1501	1160	2661			2661
	2005		1501	1510	3011			3011
	2010		1501	2140	3641			3641
	2015		1501	2575	4076			4076

Source: IRENA, RE Electricity Statistics

Table 9 provides a comparative profile of biomass-based electricity generation capacities. It is noteworthy that the Bagasse-based electricity generation capacities are there only in India and they are largely missing in China and Japan. Similar is the case with Biogas-based electricity generation capacities. China does not have any capacities using renewable municipal waste. Japan has a relatively high magnitude of such installed capacities. All the three giants are relying on other solid biofuels and no one has electricity generation capacities utilising liquid biofuels.

7. EMERGING TRENDS IN TRADE AND INVESTMENT FLOWS

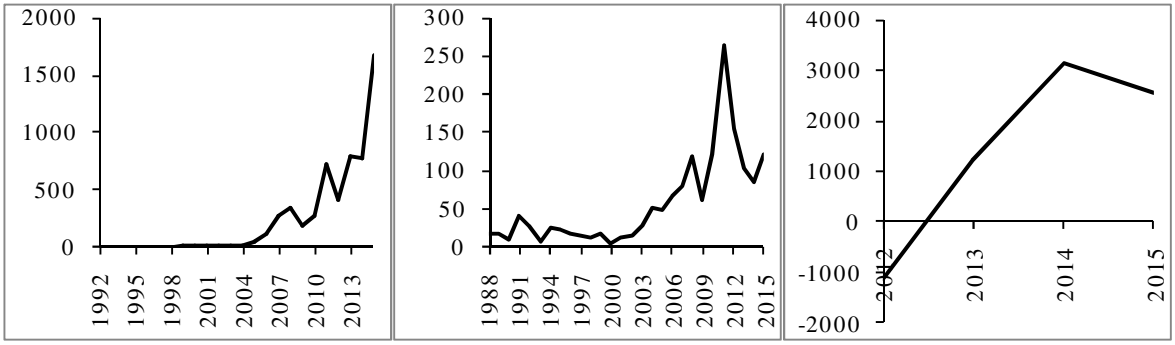
7.1. TRADE FLOWS

In above-discussed expansion of renewable energy capacities, there has been, in fact, an increased contribution of trade. Considering this aspect, we discuss here the magnitude of mutual trade that takes place among China, India and Japan. We further focus on trade in climate smart energy technologies. Three kinds of technologies, viz. wind power equipments, solar power equipments and the flurescent light bulbs are focused here.[17]

[17] For this analysis, we examine UN Comtrade data. For wind power technologies, the used HS Codes are 848340, 848360 and 850230. For Solar power technologies, the used HS Codes are 850720, 853710 and 854140. Similarly, the flurescent light bulbs have HS Codes of 853931. This selection of codes for climate smart energy technologies is in line with Crawford (2011) and Mathur and Chakrabarty (2016).

It is evident that the Asian Giants are engaged in high volumes of mutual trade in climate smart technologies and there are imports, exports and re-imports and re-exports. This data is examined and the estimates of net exports in each technology are generated.

Figure 8: Trend in Net Export of Solar Energy Equipments (US $ Million)

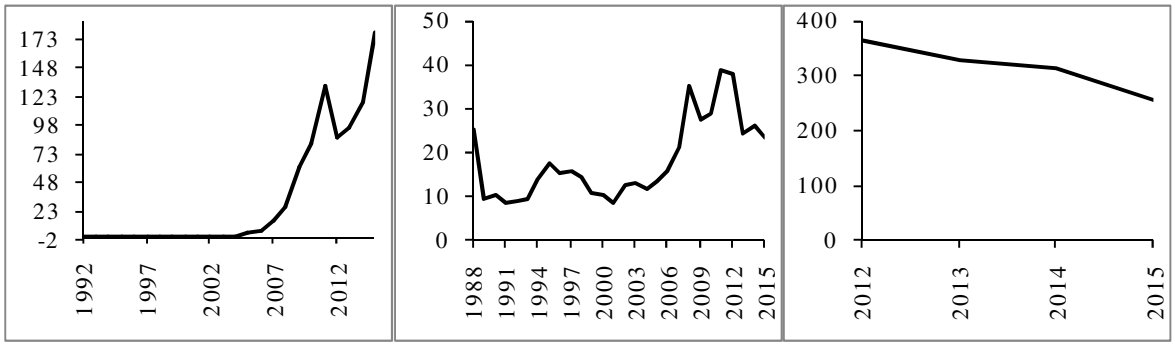


China to India **Japan to India** **China to Japan**

Source: Based on UN Comtrade Data

Figure 8 depicts net exports of solar energy equipments from 1) China to India, 2) Japan to India and 3) China to Japan. It may be observed that the net exports of solar energy equipment from China to India became significant from 2004 onwards and since then they have recorded a robust growth. There has been a continuing trend of net exports from Japan to India but the net exports became relatively more significant from 2004 onwards. Similarly, a trend of net exports of solar energy equipment is observed from China to Japan.

Figure 9: Trend in Net Export of Wind Energy Equipment (US $ Million)



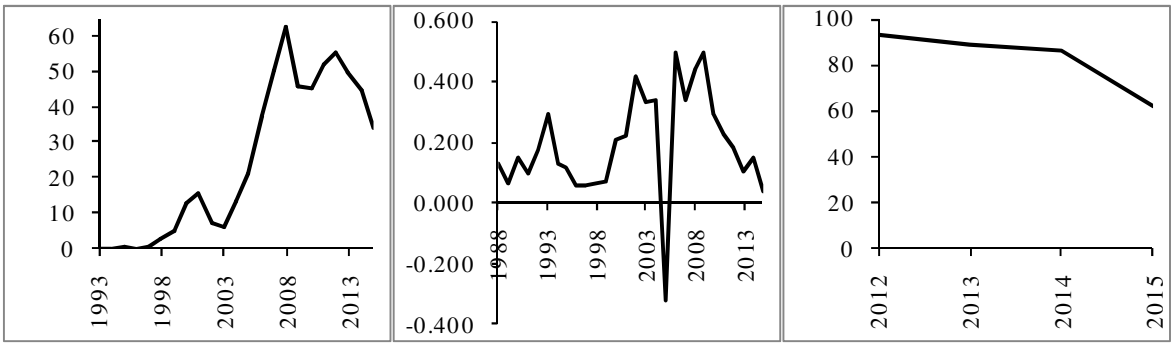
China to India **Japan to India** **Japan to China**

Source: Based on UN Comtrade Data

Figure 9 depicts the trend in net exports of wind energy equipment from a) China to India, b) Japan to India and c) Japan to China. It is evident that a considerable volume of

net exports of wind energy equipment is taking place between these nations. The net exports of wind energy equipment from China to India have recorded robust growth from 2005 onwards. The net exports from Japan to China are relatively high but they have recorded a decline over the 2012-15 period.

Figure 10: Trend in Net Export of Flurescent Light Bulbs (US $ Million)



China to India **Japan to India** **China to Japan**

Source: Based on UN Comtrade Data

Figure 10 depicts trend in net exports of flurescent light bulbs. It is evident that there have been positive net exports of these bulbs from China to India from 1996 onwards and they have recorded a significant increase over time. Similarly, China is also making significant volumes of net exports of bulbs to Japan. Japan's net export to India has remained somewhat moderate.

7.2. INVESTMENT FINANCING

There has taken place a huge investment in renewable energy over the 2004-15 period. In 2004, globally US $ 46.60 billion were invested which got an impressive beginning and till 2008, it recorded robust growth. In subsequent year, there was a minor decline which picked up in next two years. Following another decline for two years, the renewable energy investment again picked up at global level and in 2015, investment worth US $ 285.91 billion was made (Table 10). A major share of this investment went for the development of solar energy. The wind energy development cornered another major share. As far as other renewable energy sources such as biomass & waste-to-energy, liquid bio-fuels, geothermal/ marine energy are concerned, the magnitude of global investment has been somewhat moderate during the 2004-15 period.

Table 10: Global Trend of Renewable Energy Investment during 2004-15 Period

Year	Renewable Energy Investment (US $ Billion)							Average Annual Growth Rate, %						
	S	W	SHP	BWE	LB	GM	All	S	W	SHP	BWE	LB	GM	All
2004	11.95	19.04	2.62	7.73	4.02	1.24	46.60							
2005	16.15	29.02	7.27	9.73	9.62	1.05	72.84	35.1	52.4	177.5	25.9	139.3	-15.3	56.3
2006	22.20	39.83	7.55	11.92	28.17	2.35	112.02	37.5	37.3	3.9	22.5	192.8	123.8	53.8
2007	38.87	61.17	6.74	16.24	28.29	2.71	154.02	75.1	53.6	-10.7	36.2	0.4	15.3	37.5
2008	61.61	75.42	7.65	17.09	18.54	1.89	182.20	58.5	23.3	13.5	5.2	-34.5	-30.3	18.3
2009	64.40	79.77	6.19	14.73	10.37	3.21	178.67	4.5	5.8	-19.1	-13.8	-44.1	69.8	-1.9
2010	103.69	98.69	7.92	15.68	10.10	3.10	239.18	61.0	23.7	27.9	6.4	-2.6	-3.4	33.9
2011	154.82	84.22	7.21	17.96	10.33	3.96	278.50	49.3	-14.7	-9.0	14.5	2.3	27.7	16.4
2012	146.17	81.91	6.36	13.50	7.23	2.11	257.28	-5.6	-2.7	-11.8	-24.8	-30.0	-46.7	-7.6
2013	119.06	90.58	5.51	10.54	5.68	2.63	234.00	-18.5	10.6	-13.4	-21.9	-21.4	24.6	-9.0
2014	143.78	105.66	5.48	10.41	4.72	2.98	273.03	20.8	16.6	-0.5	-1.2	-16.9	13.3	16.7
2015	161.04	109.64	3.91	6.02	3.08	2.22	285.91	12.0	3.8	-28.6	-42.2	-34.7	-25.5	4.7

Note: S=Solar; W=Wind; SHP=Small Hydropower; BWE=Biomass & Waste-to-energy; LB=Liquid Bio-fuels; GM=Geothermal / Marine Energy
Source: UNEP (2016)

While focusing on China and India, we observe that these Asian Giants have made a significant investment in the development of various renewable energy sources. The Chinese renewable energy investment which was US $ 3 billion in 2004 got increased to US $ 102.9 billion in 2015. Similarly, the Indian renewable energy investment got increased from US $ 2.7 billion in 2004 to US $ 10.2 billion in 2015 (Figure 11).

Figure 11: New Investment in Renewable Energy, US $ Billion

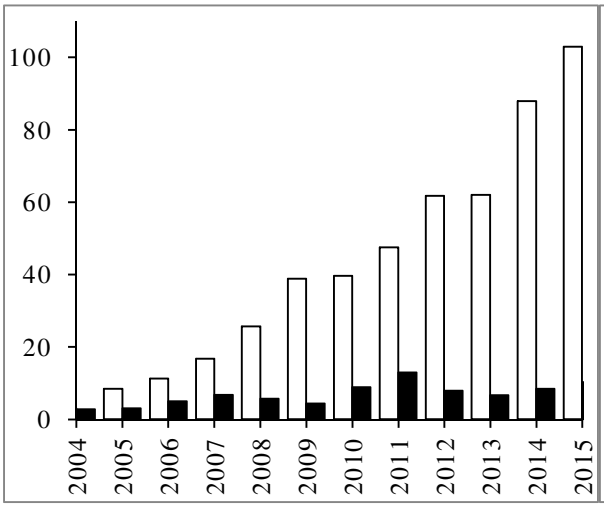
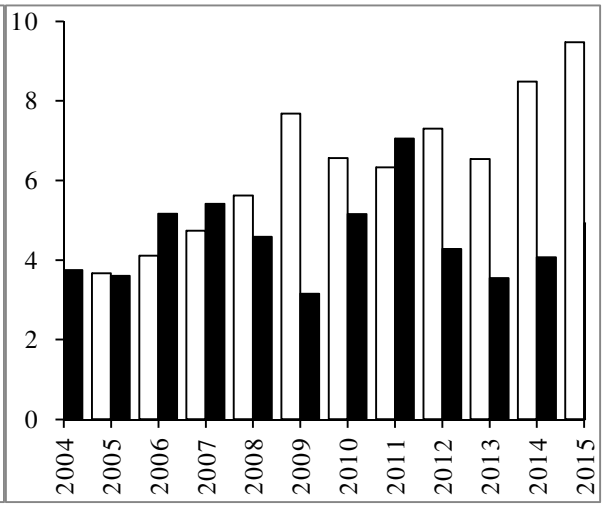


Figure 12: New Renewable Energy Investment per US $1000 worth GDP



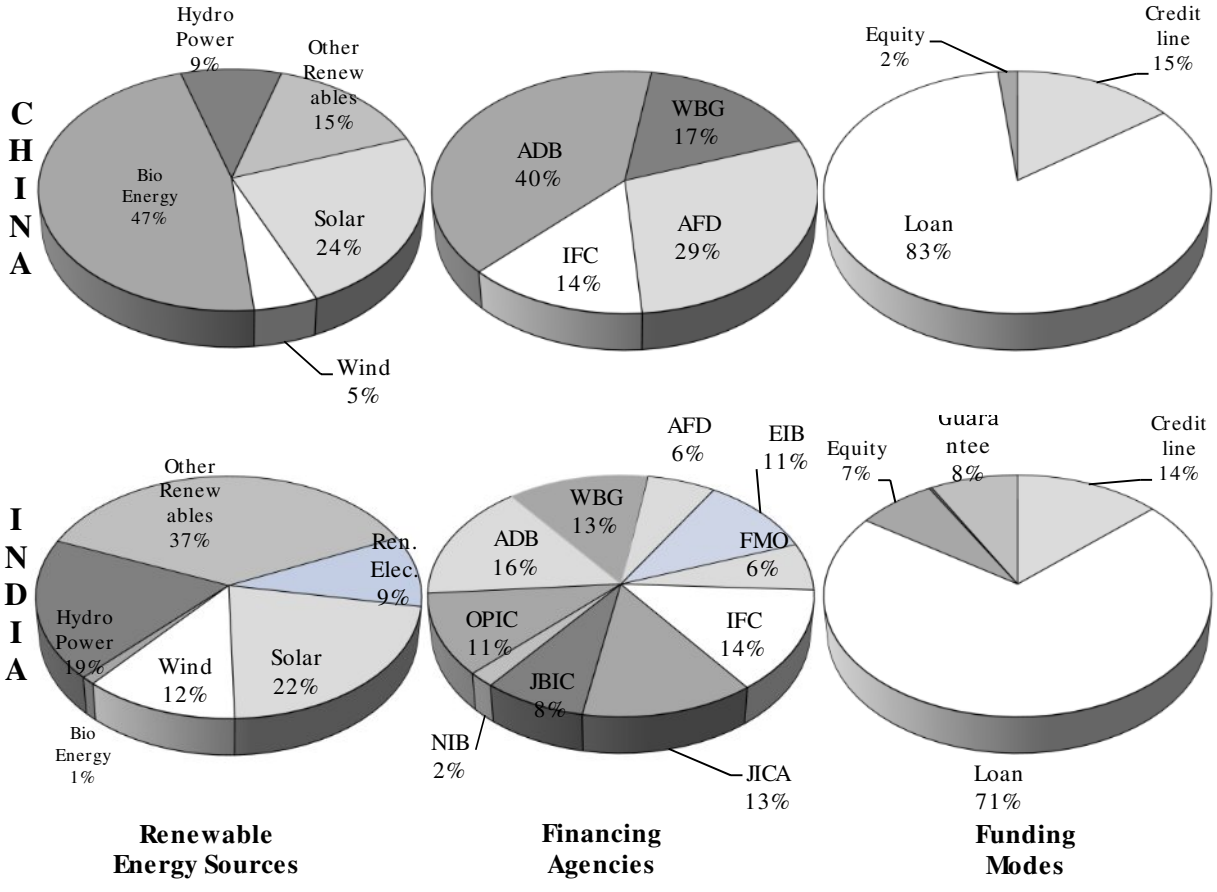
□ China ■ India

Source: Based on UNEP's Global Trends in Renewable Energy Investment, 2016 and World Development Indicators, 2016

Large renewable energy investments by the Chinese economy are always lauded which, in fact, remains conditioned by the relatively large size of the Chinese economy. While making the estimates scale neutral, we have derived estimates of renewable energy investment for every US $ 1000 worth gross domestic product. These estimates indicate that both India and China have made somewhat similar investment in the development of renewable energy – out of the 12 year period under consideration (2004-15), India's investment was relatively high for four years (Figure 12).

Figure 13 depicts comparative picture of new renewable energy investment managed by China and India through funding from various sources. The estimates provided represent cumulative figures for 2009-15 period. It is found that out of the total new renewable energy investment, China's major share went to the development of bio-energy. The new investment in solar energy is comparable for China and India.

Figure 13: Comparative Renewable Energy Investment Scenario, 2009-15 Aggregate



Source: Based on IRENA Renewable Energy Finance Database

Regarding funding agencies, China's renewable energy investment is financed by major agencies like ADB, ADF, WBG and IFC whereas India has mobilised renewable energy investment from a variety of sources and the financing by two prime agencies, viz. ADB and WBG has remained relatively lower in the case of India. It is also noteworthy that most of the renewable energy investment has been in the form of loans only.

8. SUMMING-UP

While focusing on the Asian Giants of China, India and Japan, this study has drawn comparative insights into the consumption of fossil fuels, viz. coal, oil and natural gas. It has also examined the magnitude of GHG emissions along with its composition and sources over time while discussing the pursuit of low carbon growth agenda. Subsequently, the study has examined the growth pattern of various constituents of clean energy. Similarly, it has examined the pattern of mutual trade in climate smart energy technologies. Insights into the nature and pattern of financing renewable energy investment adds to the key contribution of Asian Giants on the fronts of clean energy development. Overall, the efforts of Asian Giants have been significant. But, there are still various issues that need to be taken seriously.

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Appendix:

Table A1: Temporal Account of Asian Giants' GDP

Year	China		India		Japan		World	
	GDP*	GS(%)	GDP*	GS(%)	GDP*	GS(%)	GDP*	GS(%)
1980	189.65	1.70	189.59	1.70	1086.99	9.75	11154.09	100
1990	358.97	1.59	326.61	1.45	3103.70	13.76	22563.11	100
2000	1205.26	3.62	476.61	1.43	4731.20	14.20	33321.29	100
2001	1332.23	4.02	493.95	1.49	4159.86	12.55	33134.20	100
2002	1461.91	4.25	523.97	1.52	3980.82	11.57	34418.04	100
2003	1649.93	4.27	618.36	1.60	4302.94	11.13	38656.29	100
2004	1941.75	4.46	721.58	1.66	4655.80	10.69	43534.85	100
2005	2268.60	4.81	834.21	1.77	4571.87	9.70	47121.20	100
2006	2729.78	5.35	949.12	1.86	4356.75	8.54	51045.34	100
2007	3523.09	6.12	1238.70	2.15	4356.35	7.57	57542.83	100
2008	4558.43	7.23	1224.10	1.94	4849.18	7.69	63087.80	100
2009	5059.42	8.46	1365.37	2.28	5035.14	8.42	59793.28	100
2010	6039.66	9.21	1708.46	2.60	5498.72	8.38	65612.00	100
2011	7492.43	10.29	1815.87	2.49	5908.99	8.11	72818.11	100
2012	8461.62	11.38	1824.96	2.45	5957.25	8.01	74373.33	100
2013	9490.60	12.43	1863.21	2.44	4908.86	6.43	76362.59	100
2014	10351.11	13.26	2042.44	2.62	4596.16	5.89	78088.52	100
2015	10866.44	14.78	2073.54	2.82	4123.26	5.61	73502.34	100

Note: *implies that GDP refers to current US $(in Billions); GS stands for `Global Share'.
Source: World Development Indicators, World Bank.