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Economic growth, income inequality and environment: assessing the applicability of the Kuznets hypotheses to Asia

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ABSTRACT In light of growing threats to sustainable development, two serious challenges (that is, rising income inequality and environmental degradation) have been addressed by numerous empirical studies. However, the results of those surveys undertaken for varied samples over different time periods have in many cases turned out inconclusive regarding the validity of the two Kuznets related hypotheses that dealt with the challenges. Hence, the two hypotheses are tested in our study for the case of Asia with a view to exploring the interlink between the hypotheses, as there seems to be a limited literature on this issue, especially on Asia. The Kuznets inverted *U*-curve hypothesis that posits the relationship between income and income inequality has met varying degrees of acceptance. The recent work by Piketty, for example, refuted the hypotheses as irrelevant as the universally applicable theory, though Piketty himself has not dealt with in-depth analysis of Asia, the region that has had the largest increase in income inequality in the developing world since the 1990s. As for the second hypothesis (EKC curve) that postulates the relationship between income and environmental deterioration, diverse results produced by multitudinous surveys need to be re-examined by further studies, especially on Asia, the region that includes three of the world's top five largest GHG emissions resultant from the highest economic growth rate achieved since 1990. Our cross-country and non-econometric analysis of 20 Asian countries shows that the Kuznets inverted *U*-curve hypothesis is valid with some limitations. Both Asian trends in income inequality and in environmental degradation (CO2 emissions) appear, by and large, to follow Kuznets' hypothesized curve up to the lower level of high income as income rises, whereas a divergent trend could be observed among high income economies, generating a second inverted *U*-curve with frequent irregularities in the trend curve as income increases. Irregularities in the curves that are frequently observed among high income economies seem to be apparently generated by country-specific conditions, policy, technology and so on. Thus growth impacts on income inequality and environmental deterioration differ substantially among the high income economies, whereas among the countries with lower income, growth impacts generated on inequality are generally small, though their impacts on environment tend to be large. While environmental and income policy is often non-existent for low income countries, high income countries have generally introduced varied policies to cope with growing income inequality and environmental degradation. Since irregular patterns in the two Kuznets inverted U-curves seem to be generated by

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country-specific conditions and policies, that appear to be wide-ranging among economies within higher income range, econometric analyses that have produced divergent results on the validity of Kuznetsian hypothesis may need to be supplemented by different approaches that take in to account country-specific conditions. This study raises the question whether it is possible to promote equitable income growth that could reconcile with environmental protection. The governments of high income countries, the largest emitters of all income groups, may need to cope with the issue by devising policies that seek a proper link between development and environment.

Introduction

Widening income disparity and environmental deterioration in relation to economic growth have increasingly become pressing issues of our concern. A host of studies have examined since early 1990s two Kuznets-related hypotheses, that is, inverted *U*-curve hypothesis and Environmental Kuznets Curve (EKC) to investigate the possible relationships (between growth and income redistribution, and between growth and environment). The former hypothesis first promulgated by Kuznets in his path-breaking paper (1955) on the relationship between per capita income and income inequality predicts that income inequality widens at first as income increases, and reach the peak of the inequality before it gradually declines, forming the inverted *U*-curve shape. Since Kuznets' theory that is based on the observation of a limited number of developed and backward countries and yet for a specific time period, still needs to be examined by further empirical surveys covering different regions/countries for different time periods with newly compiled data for verification of the hypothesis, considering also that Piketty (2013) himself has refuted the universal applicability of Kuznets' hypothesis in his latest publication.[1] To quote some controversial discussions on the validity of the Kuznets inverted *U*-curve hypotheses, Ahluwalia (1976) and Barro (2008) both found support for it using cross-sectional data, while those who did not support the hypothesis were Saith (1983), and Anand and Kanbur (1993); one example that has a limited applicability is a study by Cornia *et al.* (2003). Hence, the need for re-examination of the Kuznets hypothesis as applied to the Asia region that has seldom been taken up for survey of this kind despite the fact that the Asia region has emerged rapidly from among the poorest to among the richest among the world's developing regions with its highest rate of economic growth, worsening income inequality at the fastest rate since 1990 and accompanying environmental deterioration at the same time.

The latter EKC hypothesis, apparently derived from the inverted *U*-curve, initiated by Grossman and Krueger (1991, 1995) and popularized by the World Bank Report (1992),[2] defines the changing relationship between income per capita and environmental degradation, that is, environmental quality declines in the early stage of economic growth, but beyond certain level of income per capita, the trend reverses as income rises, generating the EKC inverted *U*-curve. Since the introduction of the EKC hypotheses, numerous studies have been empirically undertaken by applying the samples of countries/ regions of different sizes and with varied types of pollutants surveyed over different time periods, which have led to diverse results concerning the validity of the EKC. Often the results differed even among the studies that used the same subset of environmental measures such as pollutants as CO2, SO2 or particulates.[3] For example, out of eight studies that incorporated the CO2 emissions in the model (that is, Holtz-Eakin and Selden (1995), Tucker (1995), Cole *et al.* (1997), Hill and Magnani (2002), Lantz and Feng (2006), Shafik (1994), De Bruyn *et al.* (1998), Friedl and Getzner (2003)), the last three studies failed to identify the EKC pattern, although each of the eight studies had different data samples and time effects observed for various time periods during 1960–2000. The results of studies in which sulphur dioxide (SO2) is used as a surrogate for pollutant emissions appeared to be more supportive of the existence of the EKC (for example, Selden and Song, 1994; Grossman and Krueger, 1995; De Bruyn *et al.*, 1998; Torras and Boyce, 1998, to name a few.), whereas Perman and Stern (2003) found no statistical support for the EKC in their studies using the SO2 as pollutants.

Thus, the results of those surveys predominantly undertaken by the early 2000s still remain rather inconclusive, leaving room for verification by ensuing studies with a different approach and samples for the updated time period. In view of the scanty empirical literature on recent development of income distribution and environmental quality in relation to economic growth in Asia, the issue of growing income inequality and environmental degradation is addressed in this essay to reassess the validity of the two Kuznets related hypotheses as applied to Asia. The Asian development path may need to be paid further attention in view of the growing environmental degradation and income inequality produced during the 1990–2010 period when Asian economy had undergone dramatic transformation, taking into account that the three of top five world biggest emitters are from Asia (China, India and Japan), and that an increase in the income inequality was the biggest of all world developing regions, though the overall poverty level decreased during the period.

Hence, the aim of this essay is twofold; first, to assess the relationship between economic growth and income inequality, as well as the relation between economic growth and environmental deterioration with a view to looking into possible growth impacts on income and environment, and second, to re-evaluate the aforementioned two Kuznets hypotheses by reviewing economic growth and its resultant change in income distribution and environmental change that had taken place in the selected Asian regions during 1990–2010 period. Here, in this survey, an empirical analysis is conducted by introducing Gini coefficient as a measure of income inequality, and CO2 emissions used as a surrogate for environmental decay, both of which correlate with income per capita as income increases. A sample of 20 ADB (Asian Development Bank) regional member countries with a fair size, equipped with available data is picked from four Asian regions/group (that is, South Asia, Southeast Asia, East Asia, ADB developed members)[4] for evaluation of two Kuznets hypotheses. A tentative observation based on the cross-country, non-econometric analysis employed due largely to the limited size of the sample with the aid of income elasticity seems to indicate that two Kuznets related hypotheses are valid with some limitations. It was found that the normal shape of the inverted *U*-curve could not be discerned for the economies with upper high income range. While our trend curves are provided with relatively smooth and regular shapes up to the lower income level of high income, seemingly second inverse-*U* curves often with irregularities can be

observed among countries within the higher income range. Irregularities in the trend curve appear to be frequently observed among high income economies as income level rises further. Our survey indicates that, by and large, irregularities appear to take place more frequently in the EKC curve than in the Kuznets inverse-*U* curve.

Those irregularities could most likely be accounted for by the country-specific policy and economic conditions that seem to have wide-ranging differences among high income countries as their overall income level increases.

The governments of the high income countries, the largest emitters of all income groups, may need to cope with the issue by devising policies that seek a proper link between development and environment as the government's dual role of redressing income inequality while reducing CO2 emissions involves complex procedures for policy formulations especially for high income countries. Singapore' s dramatic success in reducing CO2 emissions may present the case of the government initiative to combat the challenge, though the issue of the improvement in income inequality was left unsolved.

Economic growth and income inequality in Asia

Asia, often called the "growth center of the world", has achieved the highest average GDP growth rate of all the world's developing regions over two decades since 1990.[5] As a result of rapid economic growth in developing Asia averaging 7.0% annual growth rate of GDP during 1990–2010, the region's average per capita GDP increased from US$1,633 to $5,133, that has worsened income inequality in the region, though the region's proportion of the population living below the poverty line ($1.25-a-day) fell from 54%(1990) to 22% (2008).[6]

Income inequality in Asia widened at the fastest rate among six world developing regions as shown by an increase in the Gini index from 36.4 (1990) to 40.4 (2008), which was the largest increase of all six regions, though the size of the Gini index is third largest to Latin America and the Caribbean, and the Sub-Saharan Africa region,[7] though Asia's level of income inequality is still much higher when compared with that of 34 OECD countries, most of which had a Gini in the range of 25–35.[8]

The trend in income inequality by income group: A case of 20 Asian countries. Economic growth and resultant income inequality in our sample of ADB 20 Asian countries selected from four Asian regions (South Asia, Southeast Asia, East Asia and three developed ADB member countries (that is, Australia, New Zealand and Japan)) are summarized in the Table 1. The table shows that the overall average of per capita GDP for the sample countries increased from $7,900 (1995) to $12,978 (2010) enabled by the increase in the average GDP growth rate from 5.1% (1990–2000) to 5.6% (2000–2010) (Table 2), which had contributed substantially to reducing poverty levels in many countries in the region.[9] As a result of the highest average annual GDP growth rate achieved (that is, 5.9% (1990–2000) and 7.6% (2000–2010)) among the four income groups in our sample, the low income group of eight countries reduced its number of the member countries to two, bringing forth an increase in the number of lower middle income countries from three to eight.[10] However, the trend in overall economic growth rate by income group seems to be on the gradual decrease as shown by the declining average growth rate; 7.6% (low income group) → 5.3% (lower middle-income) → 4.8%(upper middle-income) → 3.6% (high income) during 2000–2010 (Table 2, Fig. 1).

In sharp contrast to the declining trend in economic growth rate, income inequality in terms of the Gini index shows a widening trend as income level increases from low income level (for the low income group) up to middle income level (for the upper middle-income group) at which point the largest income inequality is generated. Beyond that income level income, income inequality begins to improve, reaching the lowest level of income inequality of the four at the high income level (for the high income group) almost same as that of the low income group for both 1990s and 2000s (Table 1). Thus, the overall trend in the above picture would follow the Kuznets type Inverted *U*-curve. The general tendency seems to indicate, as suggested by the Kuznets hypothesis that income inequality has tended to flow in cycles in the following manner, that is, "inequality is low at low levels of development, inequality rises toward the upper middle income level, and then begins to fall as countries reach economic maturity".

In search for the inverted u-curve for 20 Asian Countries. Trends in income inequality at the varying income levels of the 20 sample countries are demonstrated in the Figs. 2 (a) and (b). The two trend curves with irregularities/fluctuations do not appear to

Table 1 | Gini coefficients and gdp growth by income group for ADB 20 Member countries: 1990–2000

(1990 classification of economies)

A sample of 20 countries	*GDP per capita ($)*	*Gini coefficients*		*Aver. ann. of GDP growth (%)*	
	1995	*1990s*	*2000s*	*1990–2000*	*2000–2010*
Low income Countries (LIC) (8)					
Vietnam	260	0.36	0.36	7.9	7.5
Cambodia	280	0.38	0.38	7.0	8.7
Bangladesh	330	0.34	0.32	4.8	5.9
Lao PDR	360	0.30	0.37	6.4	7.2
India	370	0.32	0.37	5.9	8.0
Mongolia	460	0.33	0.37	1.0	7.2
Pakistan	470	0.33	0.30	3.8	5.1
China	530	0.31	0.43	10.6	10.8
Average	383	0.33	0.36	5.9	7.6
Lower middle income countries (LMC) (3)					
Sri Lanka	700	0.33	0.40	5.3	5.6
Indonesia	980	0.35	0.43	4.2	5.3
Philippines	1,030	0.43	0.43	3.3	4.9
Average	903	0.37	0.42	4.3	5.3
Upper middle income countries (UMC) (2)					
Thailand	2,720	0.43	0.40	4.2	4.5
Malaysia	4,010	0.49	0.46	7.0	5.0
Average	3,365	0.46	0.43	5.6	4.8
High income countries (HIC) (7)					
Korea	10,770	0.25	0.31	5.8	4.1
Taipei (Taiwan)	13,086	0.31	0.34	6.4	3.9
New Zealand	14,950	0.31	0.32	3.3	2.6
Australia	19,440	0.30	0.33	3.7	3.2
Singapore	22,420	0.43	0.48	7.2	6.0
Hong Kong	23,490	0.43	0.43	3.6	4.6
Japan	41,350	0.32	0.33	1.0	0.9
Average	20,787	0.34	0.36	4.4	3.6
Overall average	7,900	0.35	0.38	5.1	5.6

Note: (1).: The above classification of countries into four income groups (that is, low income, lower middle income, upper middle income and high income) for the 1990–2000 is based on the definition of the World Bank (1992).
(2): Figures in the parenthesis are the number of countries in the group.
Source: Data from the World Bank (1992), (2012a),. ADB (2012a)

Table 2 | Gini coefficients and GDP growth by four income groups: 2000–2010

(2010 classification of economies)

A sample of 20 countries	*GDP per capita ($)*	*Gini coeff.*	*GDP growth (%)*
	2010	*2000s*	*2000–2010*
Low income countries (LIC) (2)			
Bangladesh	700	0.32	5.9
Cambodia	750	0.38	8.7
average	725	0.35	7.3
Lower middle income countries (LMC) (8)			
Lao PDR	1,010	0.37	7.2
Pakistan	1,050	0.30	5.1
Viet Nam	1,160	0.36	7.5
India	1,260	0.37	8.0
Mongolia	1,870	0.37	7.2
Philippines	2,060	0.43	4.9
Sri Lanka	2,260	0.40	5.6
Indonesia	2,500	0.43	5.3
Average	1,646	0.38	6.4
Upper middle income countries (UMC) (3)			
Thailand	4,150	0.40	4.5
China	4,270	0.43	10.8
Malaysia	7,760	0.46	5.0
Average	5,393	0.43	6.8
High income countries (HIC) (7)			
Taipei (Taiwan)	19,251	0.34	3.9
Korea	19,720	0.31	4.1
New Zealand	29,350	0.32	2.6
Hong Kong	32,780	0.43	4.6
Singapore	39,410	0.48	6.0
Japan	42,050	0.33	0.9
Australia	46,200	0.33	3.2
Average	32,680	0.36	3.6

Note: (1) The year of country's Gini coefficients for the 1990s varies among countries between 1990 and 1999, and for the 2000s between 2000 and 2009.
(2) Income classifications in the Table 2 are based on World Bank definition in World Development Report 2012.
Refer to the World Bank definition (see endnote 28).
(3). Out of 38 ADB regional members, Central Asian countries and island countries in the Pacific are excluded from the above Table. Four countries in South Asia, that is, Afghanistan, Bhutan, Maldives and Nepal are not included in the sample because of unavailability of data or too small size of the country or GDP.
(4). Taiwan's average annual growth rate is based on data in ADB (2012a): 147: 163.
(5). Figures in the parenthesis are the number of countries in the group.
source: Hong Kong's Gini coefficient for the 1990s is from Hong Kong Census and Statistics Dept. http://www.hkeconomy.gov.hk/en/pdf/gini_comparison.pdf.
Singapore's Gini coeff. data is from: https://app.mof.gov.sg/Portals/0/Feature%20Articles/Income%20Growth%20Distribution%20and%20Mobility%20Trends %20-in%20-Singapore.pdf.
ADB (2012b), ADB (2014).

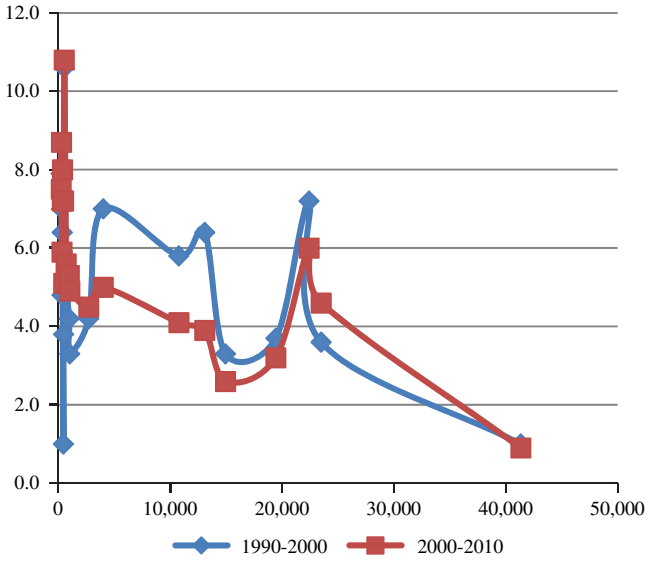

Figure 1 | The GDP Growth Rate—Income per Capita Relationship in 20 Asia: 1990–2010. This figure shows that as a general trend, that economic growth rate tends to decrease as income increases over the period as is indicated by the downward curves with irregularly upward slopes between lower middle and high income level. After reaching the peak within the range of lower level of high income, the curves demonstrate downward slope as income rises further to higher income (Source: Table 1). Note: (1). Vertical plot = average annual GDP growth rates (%), horizontal plot = GDP per capita($) of 20 countries that are arranged in order of the 1995 income. (2). Red line with square dot = average annual GDP growth rate for the (2000–2010), Blue line with the rhombic = average annual GDP growth rate for the (1990–2000) period.

present standardized Kuznets type inverted *U*-curve shapes, as both Figures (a) and (b) appear to have two inverse-*U* curves. However, looking into an overall trend in the two curves ((a) and (b)), there seems to exist an inverted *U*-curve type segment up to the income level of Korea and Taiwan with the peak topped by Malaysia, and the second inverse-*U* appears to be presented starting from the income levels of Korea and Taiwan, two countries with the lowest income among seven high income countries in the sample. Beyond that income level, five high income countries (that is, New Zealand, Hong Kong, Singapore, Japan and Australia) appear, by and large, to form another Kuznets type inverse-*U* curve with the peaks at the income level of Singapore followed by Hong Kong with the second largest Gini index among high income countries in both Figs. (a) and (b). The general trend in the Gini coefficients (income inequality) presented in the Fig. 2 seems to demonstrate a rising curve as per capita GDP increases from the low income to the middle income level (Malaysia) before it turns downward as income increases from middle income to the high income level (Korea). Then the second inverted *U*-curve seems to follow as income increases further, reaching the peak at the income level of Singapore before the trend curves reverse. A larger part of the irregularities/fluctuations in the curves appear to be caused by varied levels of income inequality observed among high income countries (Table 1, Fig. 2).

Figure 3 shows the change in Gini coefficient of the sample countries between the 1990s and the 2000s. The gap between the Gini coefficient of the 1990s and that of the 2000s could be construed as the extent of income inequality improvement or worsening. An irregularly large gap between the two periods would provide indication concerning policy change, institutional framework or rapid industrialization that have reduced or aggravated income inequality in the country.

As can be easily noticed from Fig. 3, China's gap between the 1990s and 2000s is found to be the largest of all, indicating that China's income inequality had worsened at the highest rate as indicated by the largest increase of Gini coefficient (0.12) from 0.31 to 0.43 (Table 1), while some countries had improved income inequality such as Pakistan, Thailand and Malaysia, all of which had the largest decrease in the Gini (−0.03).

Here we tentatively classify 20 sample countries into four types by the size of the change in Gini coefficient to investigate possible patterns of the relationship between change in income inequality and economic growth with a view to finding out what sort of

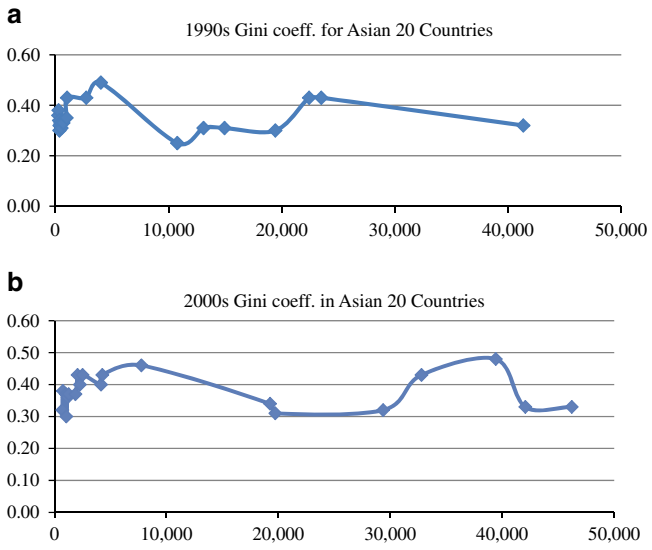

Figure 2 | The Income-Gini Coefficient Relationship for 20 Asian Countries: 1990s and 2000s. The above two Figures (a) and (b) are derived from Table 1 to examine the applicability of Kuznets Inverted U-Curve to the Asian 20 economies, which indicates how income inequality (Gini coefficient) changes as income increases. Income level on the horizontal axis represents per capita GDP income of the Asian 20 economies. The two figures drawn with seemingly more than one inverted *U*-shape do not seem to present regular inverted *U*-curves as a whole, however, up to the lower level of high income they seem to trace a regular upward curve for both (a) and (b). Then another inverted *U*-shape seems to be presented beyond that income level. It appears that irregularities of the depicted curves are generated by the limited number of high income countries in the sample. Thus so called hypothesized Kuznets inverted *U*-curve seems to have little validity especially for countries with high income in the Asian 20 sample countries (Source: Table 2). (a). 1990s Note: Vertical plot = Gini coefficients in different year in the 1990s, horizontal plot = GDP per capita ($) (1995). (b) 2000s. Note: Vertical plot = Gini coefficients of different years in the 2000s, horizontal plot = GDP per capita (2010).

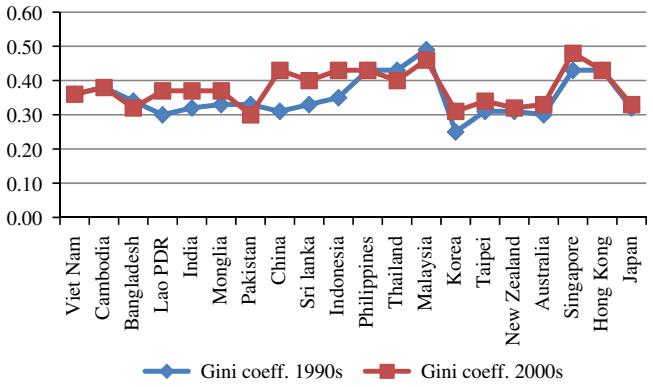

Figure 3 | Changes in the Gini coefficients in Asian 20 countries between 1990s and 2000s. The above Figure, another version of the Fig. 2 drawn with the name of the country in place of its income level on the horizontal axis is a graphical presentation of income inequality for the 20 Asian economies in the 1990s and the 2000s. It shows, by and large, rising trend with fluctuations until income increases to middle income (income level of Thailand and Malaysia) where the curve turns downward until income reaches the lower level of high income(Korea and Taiwan). Beyond that income level the second inverted *U*-curve seems to follow for the 1990s and 2010s. Thus, Kuznets inverted *U*-curve hypothesis can be recognizable for countries with middle income or lower than that level (Source: Table 1). Note: Vertical plot = Gini coefficient, Horizontal plot = Asian 20 countries listed in the order of increasing income per capita (1995). Gini data for both 1990s and 2000s are taken respectively at different years in the 1990s and 2000s.

countries in Asia have worsened or improved income inequality in relation to economic growth during the 1990s–2000s.

Four types of groups of countries could be categorized by the size of Gini coefficient change as follows.

(Note: figures in the parentheses indicate the increase of Gini coefficients). (Data based on Table 1).

Type (a) Countries with large increases in income inequality (the Gini increase of 0.05 or larger);
7 countries; China(0.12), Indonesia (0.08), Sri Lanka (0.07), Lao PDR (0.07), Korea (0.06), India (0.05), Singapore (0.05).

Type (b) Countries with small increases in income inequality (the Gini increase of 0.04 or less but above zero);
5 countries; Mongolia (0.04), Taipei (0.03), Australia (0.03), New Zealand(0.01), Japan(0.01)).

Type (c) Countries with no change in income inequality;
4 countries; Vietnam, Cambodia, Philippines, Hong Kong.

Type (d) Countries with improved income inequality (decrease in Gini coefficient);
4 countries; Bangladesh (−0.02), Pakistan(−0.03), Thailand (−0.03), Malaysia (−0.03).

The characteristic relationship between income growth and income inequality (Gini index) for each type is presented in Table 3. The largest increase in the Gini index took place for the Type (a) countries that have achieved, on average, the highest GDP growth rate of all types for both decades ((1990–2000) and (2000–2010)). In other words, those countries that have rapidly worsened income inequality have achieved the highest growth rate of all types. Above all, China's rapid economic growth and growing environmental deterioration is noteworthy. By and large, countries of this type are those that have recently emerged at a high rate of economic growth without due measures to cope with the increasing income inequality. Whereas the countries of Type (b) with their lowest rate of economic growth (3.1% and 3.6%) during 1990–2010 have increased income inequality at a moderate rate (increase in Gini coefficient: 0.02). This trend is common for high income countries which account for 80% of the Type (b) countries.

The highest level of income inequality (0.40) of all for both 1990s and 2000s is observed for Type (c) countries even though there is no increase in the Gini coefficient, which could be accounted for by the largest accelerated GDP growth rate from 5.5% to 6.4% during two decades. Included in this Type (c) are two low income countries (Viet Nam and Cambodia with their higher growth rates and Gini indices than the average of the low income group), one lower middle-income country (Philippines with her medium level growth rate and the largest Gini 0.43 in the Type (c), and one high income country (Hong Kong, the only country in the high income group that could accelerate its growth rate. All high income countries except Hong Kong had worsened the income inequality.

Type (d) countries could improve income inequality during the period as shown by a decrease in the Gini coefficient from 0.40 to 0.37. It is thus probable that the decrease in income inequality of

Table 3 | The type of country group by size of Gini index change for 20 Asian countries

Type (a)—(d)	*Change in Gini*	*Gini coefficient*		*GDP growth rate (%)*	
		1990s	*2000s*	*1990–2000*	*2000–2010*
Type (a) (7)	0.07	0.33	0.40	6.5	6.7
Type (b) (5)	0.02	0.31	0.34	3.1	3.6
Type (c) (4)	0.00	0.40	0.40	5.5	6.4
Type (d) (4)	-0.03	0.40	0.37	5.0	5.1

Note: (1) The figures in the parenthesis indicate the number of countries.
(2): The above figures are all average of the countries' data in each Type.
Source: Data from Table 1.

a moderate size was realized by the least increase in GDP growth rate (5.0% to 5.1%) between two decades (1990–2010).

Examining the Inverted *U*-curve: a case of four Asian income groups. When the sample of 20 countries are grouped into four income groups (that is, low income country (LIC), lower middle income country(LMC), upper middle income country (UMC) and high income country (HIC)) as defined by the World Bank (1992, 2012a, b), the trend traced by the average values of Gini coefficients of the four income groups seems to support the standard Kuznets inverted *U*-curve for both periods of the 1990s and 2000s as shown by the Fig. 4 that is portrayed from the data in Tables 4 and 5. As for the 1990s relationship between income inequality and income group, as average income level of each income group (GDP per capita) increases from the low income to the lower middle-income, then to the upper middle income level, their corresponding Gini coefficients also increase from 0.33 to 0.37, then to 0.46. However, this trend is reversed after reaching the highest Gini coefficient (0.46) at the level of the upper middle income when the Gini coefficient begins to fall reaching 0.34 for the high income group.

And for the period of the 2000s, likewise the average Gini coefficients are on the rising trend (that is,. 0.35 → 0.38 → 0.43) until income increases to the upper middle income with the highest income inequality, but then this trend reverses toward the Gini of 0.36 at the high income level. Thus, the Fig. 4 depiction based on the Gini coefficients of four income groups seems to follow Kuznets inverted *U*-curve with the peak at the middle income level.

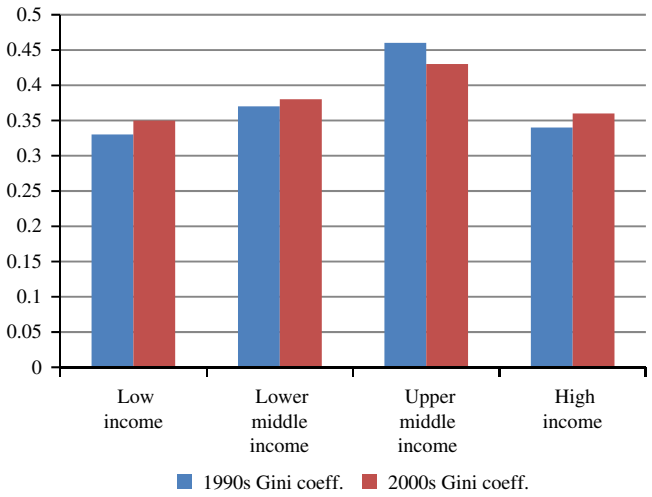

Figure 4 | The Gini–Income Relationship by Income group in Asia: 1990s and 2000s. The above is a graphical presentation of the Tables 4 and 5, indicating how income inequality changes as average income of each income group rises. The highest income inequality in terms of Gini coefficient is generated for the upper middle income group. But beyond this income level, income inequality starts to decrease as income increases. Thus, the overall trend does seem to fit Kuznets inverted *U*-curve when the Asian 20 economies are grouped into four income groups (Source: Tables 1 and 2). Note. Vertical plot = Gini coefficient, horizontal plot = income group classified by the World Bank (1992).

Income growth and income inequality in Asia

Income increase-income inequality relationship: Regional trend in Asia. Here our 20 sample countries are grouped into four regions, that is, South Asia, Southeast Asia, East Asia and Asia developed ADB members with a view to looking into regional pattern, if any, of the relationship between income and income inequality. The relationship between income and income inequality for four Asian regions can be presented in the Fig. 5 based on the data from Table 4 when the average income per capita of four regions are arranged on the horizontal axis. The similar trend curve is portrayed from the Table 5. Among four Asian regions, the South Asia region with its lowest average per capita income had the least level of income inequality for both 1995 and 2010. As income rises from low income (income level of the South Asia) to upper middle income (income level of the Southeast Asia), lower high income (income level of East Asia) and to high income (income level of the Asian developed ADB member countries), the Gini coefficient rises gradually to reach the peak at the income level of the Southeast Asia before it begins to decline falling to the bottom at the high income level for both periods. Whereas the GDP growth rate during 1990–2010 is on the rising trend as income increases from low income (South Asia) to upper middle income (Southeast Asia), but beyond that income level the decreasing growth rate continues at the income levels of the East Asia and of the Asian developed ADB member countries.

Among four Asian regions, the Southeast Asia region, classified as a lower middle income group, had achieved the highest average annual GDP growth rate of 6.3% for two consecutive decades (that is, (1990–2000) and (2000–2010)), which had brought forth the largest income inequality as indicated by their highest average Gini coefficients, that is, 0.40 (the 1990s) and 0.41 (the 2000s) among four Asian regions. In contrast, the high income group of three Asian developed countries had the lowest average annual GDP growth rate (2.7% and 2.2%) for two decades with the lowest Gini coefficients (0.31, 0.33), as suggested by Kuznets hypothesis. While the South Asia with its lowest GDP per capita had stepped up its GDP growth rate at the fastest rate from 5.0% (1990–2000)

Table 4 | Gini coefficients and income growth for Asian four income groups: 1990–2000

Income classification	*Average GDP per capita ($)*	*Average Gini coeff.*	*Average annu. GDP growth (%)*
	1995	*1990s*	*1990–2000*
Low income (8)	383	0.33	5.9
Lower middle income (3)	903	0.37	4.3
Upper middle income (2)	3,365	0.46	5.6
High income (7)	20,787	0.34	4.4

Note: Figures in the parenthesis are number of the countries in each of the income classification.
Source: Data from Table 1.

Table 5 | Gini coefficient and income growth for Asian four income groups: 2000–2010

Income classification	*Average GDP per capita ($)*	*Average Gini coefficient*	*Average annu. GDP growth (%)*
	2010	*2000s*	*2000–2010*
Low income countries (2)	725	0.35	7.3
Lower middle income (8)	1,646	0.38	6.4
Upper middle income (3)	5,393	0.43	6.8
High income e (7)	32,680	0.36	3.6

Note: Figures in the parenthesis are number of the countries in each of the income classification.
Source: Table 2.

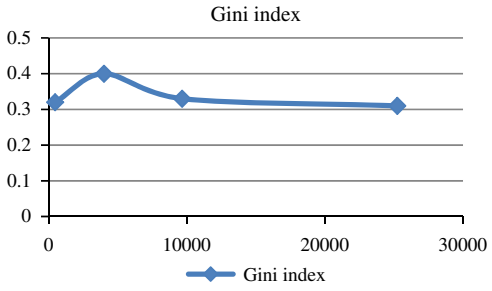

Figure 5 | Income inequality at the income levels of four Asian regions. Four dots in the above figure indicate the Gini coefficients at the average per capita income of four Asian regions, that is, from left South Asia, Southeast Asia, East Asia and Asia developed ADB members. The trend curve portrayed in the above figure seems to present Kuznets' Inverted *U*-shape (Source: Table 4). Note: Each dot indicates one of four Asian regions; from left South Asia, Southeast Asia, East Asia and Asia developed ADB members. Vertical axis = Gini coefficient, horizontal axis = income per capita of four Asian regions listed in order of income: South Asia, Southeast Asia, East Asia and Asia developed ADB members.

to 6.2% (2000–2010) with increasing Gini coefficient from 0.32 to 0.35 (Table 6).

GDP growth rate—income relationship by region: another inverted U-curve? The graphical presentation of the relationship between average GDP growth rate and average income of each region is given in Fig. 6 which shows the trend in average GDP growth rates at the average income level of four Asian regions (that is, South Asia, Southeast Asia, East Asia and ADB developed members). The curves depicted here indicate that as income level rises from low income (income level of the South Asia) to upper middle income(income level of Southeast Asia), GDP growth rate increases to the peak at the income level within the range of middle income. The upward trend reverses at the peak and GDP growth rate starts to decline as income rises to high income level (East Asia and ADB developed members). This trend curve appears to follow the Kuznets inverted *U*-curve.

Impact estimation: income-Gini elasticity approach. The Income-Gini elasticity is introduced here to look into the changing ratio between income growth and the increase in income inequality as income increases, i.e., the ratio (= percentage (%) change in Gini coefficient divided by the percentage (%) change in per capita income). The elasticity derived in this manner is capable of providing some indications for growth impact on income inequality, as it shows how much percentage change in income inequality in terms of Gini efficient could be generated by the percentage change in per capita income. Generally speaking, the low elasticity is more frequently observed among low income countries as they tend to have a minor change in the Gini coefficient compared with their relatively higher growth rate of income. While high-income economies tend to have a high elasticity due largely to their low rate economic growth relative to their larger rate of increase in income inequality (Table 7 and Fig. 6). Among top four income-Gini elasticity country ranking (Japan, Korea, Taipei and Singapore), Japan's exceedingly high income elasticity (1.846)[11] is largely because of her minimal growth rate during 1990–2010. Thus, the value of the income-Gini elasticity has a tendency to become large as income level rises from low income up to high-income as shown by the increasing elasticity, though the rising trend is interrupted at the upper middle-income level, that is, 0.020 (for the low income) → 0.081 (for the lower middle-income) → (−0.099) (for the upper middle-income) → 0.371 (for the high income). Among the four income groups, only the Asian upper middle income group (Thailand and Malaysia) with its highest average Gini coefficients for the 1990s could decrease income inequality with the second highest average GDP growth rate in the sample. The negative value of the elasticities for the Asian upper middle-income group are apparently caused by decreases in Gini coefficients during 1990s -2000s as their income inequalities were already large in the 1990s. In fact, Malaysia and Thailand are 2nd and 4th in the top 20 quintile ratios country ranking in the sample (Table 8).[12] Two other countries with negative elasticities were low income Bangladesh and Pakistan, only two countries among the low-income group that had decreased income inequality from their low level of the Gini in the 1990s, even though they accelerated average GDP growth rate during two decades (1990–2010) (Table 1). Among high income countries with large increases in

Table 6 | Economic growth and gini coefficient in four asian regions: 1990–2010

A sample of 20 countries	*GDP per capita ($)*	*Gini Coeff.*	*GDP per capita ($)*	*Gini coeff.*	*Aver. ann. of GDP growth (%)*	
	1995	*1990s*	*2010*	*2000s*	*1990–2000*	*2000–2010*
East Asia						
China	530	0.32	4,270	0.43	10.6	10.8
Hong Kong	23,490	0.43	32,780	0.43	3.6	4.6
Korea	10,770	0.25	19,720	0.29	5.8	4.1
Taipei (Taiwan)	13,086	0.31	19,251	0.34	6.4	3.9
Mongolia	460	0.33	1,870	0.37	1.0	7.2
Average	9,667	0.33	15,578	0.37	5.5	6.1
South Asia						
India	370	0.33	1,260	0.37	5.9	8.0
Pakistan	470	0.33	1,050	0.30	3.8	5.1
Bangladesh	330	0.28	700	0.32	4.8	5.9
Sri Lanka	700	0.33	2,260	0.40	5.3	5.6
Average	468	0.32	1,318	0.35	5.0	6.2
Southeast Asia						
Lao PDR	360	0.30	1,010	0.37	6.4	7.2
Cambodia	280	0.38	750	0.38	7.0	8.7
Indonesia	980	0.35	2,500	0.43	4.2	5.3
Malaysia	4,010	0.49	7,760	0.46	7.0	5.0
Philippines	1,030	0.43	2,060	0.43	3.3	4.9
Singapore	22,420	0.43	39,410	0.48	7.2	6.0
Thailand	2,720	0.43	4,150	0.40	7.2	6.0
Vietnam	260	0.36	1,160	0.36	7.9	7.5
Average	4,008	0.40	7,350	0.41	6.3	6.3
Asian Developed Members						
Australia	19,440	0.30	46,200	0.33	3.7	3.2
Japan	41,350	0.32	42,050	0.33	1.0	0.9
New Zealand	14,950	0.31	29,350	0.32	3.3	2.6
Average	25,247	0.31	39,200	0.33	2.7	2.2

Note: (1) Among the ADB member countries, Bhutan, Maldives, Nepal are excluded from the South Asia region, and Burunei Darussalam and Myanmar are excluded from the Southeast Asia due to unavailability of data or their too small country size for comparison in this survey. (2). ADB members of Central Asia and Pacific island countries are excluded from the above.
Source: ADB (2012a), ADB (2012b), ADB (2014).

Table 7 | Income-Gini elasticity for 20 Asian countries

Low income group (LIC)	
Viet Nam	0.000
Cambodia	0.000
Bangladesh	−0.052
Lao PDR	0.129
India	0.065
Mongolia	0.040
Pakistan	−0.074
China	0.055
Average	0.020
Lower middle income (LMC)	
Sri Lanka	0.095
Indonesia	0.147
Philippines	0.000
Average	0.081
Upper middle income (UMC)	
Thailand	−0.133
Malaysia	−0.065
Average	−0.099
High income group (HIC)	
Korea	0.289
Taipei (Taiwan)	0.205
New Zealand	0.033
Australia	0.073
Singapore	0.153
Hong Kong	0.000
Japan	1.846
Average	0.371

Note: A sample of 20 countries are listed in the increasing order of per capita GDP (1995) from above.
Source: Table 1

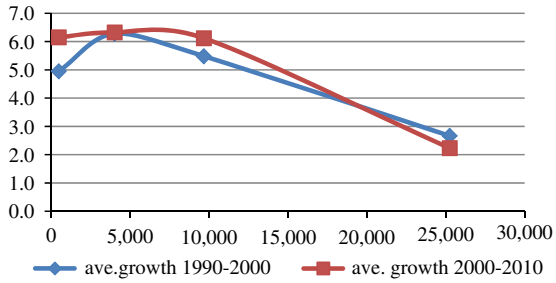

Figure 6 | The Income—GDP Growth Rate Relationship by Income Group: 1990–2010. The above Figure shows the average annual GDP growth rates during two decades ((1990–2000) and (2000–2010)) for four income groups. Four dots in each of the above two curves indicate the average GDP growth rate achieved at the average per capita income of each of four income groups (that is, Low income, Lower middle income, Upper middle income and High income). The trend curve shows the decreasing growth rate for high income countries, although growth rate seems to be on the rising trend for countries with income lower than middle income (Source: Table 6). note 1). Vertical plot = average annual GDP growth rate (%), horizontal plot = average GDP per capita ($). 2). Ave. growth = average annual GDP growth rate for both periods (1990–2000) and (2000–2010). 3). Each knot indicates one of four Asian regions/group in order of average GDP per capita to the right.

Gini coefficient together with their high values of income-Gini elasticity, Singapore's income inequality ranks top of all in the sample with her largest quintile ratio and the Gini coefficient (0.48) in the 2000s, while Korea and Taipei (Taiwan) have still relatively low Gini index and quintile ratios despite some increases achieved in both scores during the 1990s–2000s period when the GDP growth rates in these three countries declined (Tables 1, 3, 7, 8, Fig. 7).

Table 7 shows the income-Gini elasticity for the 20 Asian countries derived from the above mentioned formula, from which Fig. 7 is traced as income-Gini elasticity curve, and the inverted U-curve can be indicated up to the UMC range as suggested in the Fig. 8.

Income inequality by the Quintile ratio. Here the concept of the quintile ratio is introduced to show patterns of differences of per capita expenditure between the rich and the poor. Since Gini coefficient presents only an aggregate measure of inequality in a distribution, detailed patterns of differences across different levels of income cannot be specified by the size of Gini coefficient. As the quintile ratio is the ratio of the per capita expenditure of the top 20% to that of the bottom 20%, it is capable of giving some indications as to the differences of per capita expenditure between the rich and the poor. The following Table 8 shows country ranking of the quintile ratios for a sample of 20 ADB member countries.

According to Table 8, general trend of the income distribution for the sample of 20 Asian countries shows that income inequality

Table 8 | Quintile ratios ranking in ADB 20 member countries: 1990s–2000s

A sample of 20 countries	*Quintile ratio*	*Year of data*	*Quintile ratio*	*Year of data*
	1990s		*2000s*	
1. Singapore	12.3	1998	14.5	2008
2. Malaysia	12.0	1995	11.3	2009
3. Hong Kong	9.6	1996	n.a	n.a
4. Thailand	8.8	1990	6.9	2010
5. Philippines	8.3	1994	8.3	2009
6. China	6.0	1996	10.1	2009
7. Cambodia	5.8	1994	5.6	2009
8.Vietnam	5.6	1992	6.9	2010
9. Mongolia	5.5	1995	6.2	2008
10. Lao PDR	5.4	1997	5.9	2008
11. Sri Lanka	5.4	1995	5.8	2010
12.Taipei	5.3	1995	6.1	2012
13. Pakistan	5.2	1990	4.2	2007
14. Bangladesh	4.8	1996	4.7	2010
15. Korea	4.7	1998	5.5	2012
16. Indonesia	4.5	1996	6.3	2011
17. India	4.4	1994	5.0	2010
Developed Asian ADB regional members				
18. Japan	5.7	1995	6.2	2009
19. Australia	5.0	1995	5.3	2012
20. New Zealand	5.0	1991	5.2	2011
Average	6.5	---	6.8	---

Note: Quintile ratios are the ratios of the per capita expenditure of the richest 20% to that of the bottom 20%.
Source: ADB (2012b), ADB (2014)

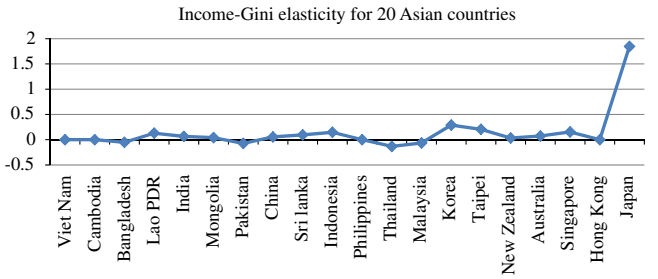

Figure 7 | Income-Gini elasticity for 20 Asian countries: 1995- 2010. The above Figure shows the trend of the income elasticity for the 20 sample economies listed on the horizontal axis in order of per capita income. The overall trend seems to indicate that the income elasticity is gradually increasing as income increase from low income (Vietnam) to lower middle income (Philippines) with some minor fluctuations within the range of 0.0 and 0.15 except for two countries(Bangladesh and Pakistan) with the negative elasticity. A lower value of income elasticity normally suggests that the growth impact on income inequality is small. High elasticities are prevalent among Asian high income economies, above all, Japan. Japan's exceedingly high income elasticity is caused largely by its minimal rate of income growth as against its increase in Gini coefficient. Relatively low income elasticity of China can largely be attributable to her highest economic growth in the sample, and to its large increase in Gini coefficient (Source: Table 4). note (1). Vertical plot = income-Gini elasticity, Horizontal plot = a sample of 20 countries arranged in order of increasing GDP per capita of 1995.

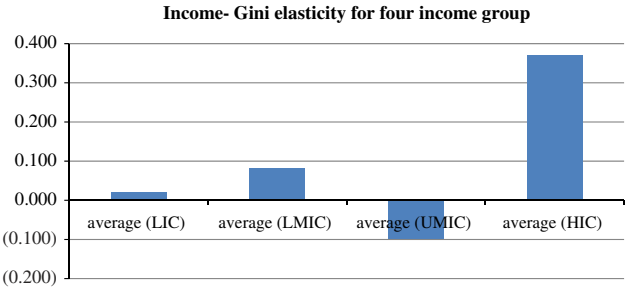

Figure 8 | The Income-Gini elasticity for Four Asian Income Groups in: 1990–2010. The Income-Gini elasticity (that is, the ratio of percentage change in the Gini coefficients divided by the ratio of percentage change in per capita income) can be an indication of the growth impact on income inequality. The above figure shows the average income elasticity by income group, indicating that income inequality grows as income level rises from low income to lower middle income, and the largest income inequality brought about for the group of high income countries due mainly to their lower income growth rate as against their increase in the Gini coefficients during 1990s-2000s. Only the upper middle income group (Thailand and Malaysia) reduced income inequality as their GDP growth rate declined during the period (Source:Tables 4, 7). note (1). Vertical plot = the value of income-Gini elasticity, Horizontal plot = average per capita income of the income group. 2) LIC = Low income group (8 countries), LMIC = Lower middle income group (3), UMIC = Upper middle income group (2), HICs = High income group (7). Classification of income group is based on World Bank (1992).

worsened as indicated by an increase in the average quintile ratio from 6.5 (1990s) and 6.8 (2000s).[13] Judging income inequality from the quintile ratio, more than half of the sample (13) countries demonstrated a higher ratio in the 2000s than in the 1990s, while the Gini coefficients of 12 countries became enlarged during the period.

Above all, Singapore is a country with the most unequally distributed income inequality as shown by the largest quintile ratios, that is, 12.3 (1998) and 14.5 (2008) (Table 8), indicating that the per capita expenditure of the top 20% is over tenfold as that of the bottom 20%. This ratio can corroborate the deficiency of the Gini coefficient to some extent by elucidating the differences of purchasing power between the rich and the poor. Singapore's income inequality as suggested by its highest Gini coefficient (0.48) of all sample countries for the 2000s can thus be made more clearly presented with the aid of the highest quintile ratio (2008) (Table 1). Indeed, the top five quintile ratios countries ranking in the 1990s (Singapore, Malaysia, Hong Kong, Thailand and Philippines) (Table 7) are equally within top five Gini coefficient countries ranking for the 1990s with their Gini coefficients of 0.43 or larger, while top eight quintile ratio ranking countries (the above mentioned five countries plus Sri Lanka, Indonesia and China) are also within the top eight Gini coefficient ranking countries as well. Income distribution in these countries is found to be more unequal than the rest of the sample countries.[14]

Among them, China's income inequality had enlarged at the fastest rate of all as shown by its biggest increase in the quintile ratio from 6.0 (1996) to 10.1 (2009), which is largely the result of the biggest increase in the Gini coefficient from 0.31 to 0.43 as well as of its highest economic growth rate during the period. However, five countries (that is, Thailand, Pakistan, Malaysia, Cambodia and Bangladesh) had seen a decrease in the quintile ratio during 1990s– 2000s out of which Thailand's decrease of quintile ratio was the largest (decrease from 8.8 to 6.9). Four of these except Cambodia are the same countries that had decreased their Gini coefficients, indicating betterment of income inequality by varying degrees. The Philippines is the only country that had not changed its Gini coefficient and quintile ratio for two decades, though the Gini coefficients of three other countries (that is, Viet

Nam, Cambodia, Hong Kong) had not indicated any improvement or worsening of income inequality, but as far as the quintile ratio shows, however, Cambodia became a little better off decreasing income inequality, whereas Viet Nam turned worse off increasing its income inequality.

Economic growth and greenhouse gas emissions: global and regional trends

Here we explore the relationship between economic growth and CO2 emissions with a view to investigating into the validity of Environmental Kuznets Curve for the Asian region.

First, the global picture will be surveyed by breaking world income groups (or economies) into four categories: LIC, LMC, UMC and HIC to find out a possible link between the CO2 emission and economic growth at different income levels. In this survey, the level of CO2 emission is used as a proxy for the overall level of greenhouse gas pollution since CO2 emission is the major component of ecological footprint.

The World Bank estimates seem to suggest that as income increases from low income level to higher income, the GDP growth rate tends to accelerate for the low and middle income (=LMC+UMC) groups during 1990–2010, though their annual growth rates of CO2 emissions remained almost unchanged (3.0 – 3.1%) during 1990–2008. However, the high income group's growth rate of GDP slowed down during the same period, resulting in the lowest annual growth of CO2 emission (0.8%) of four income groups during 1990–2010 with a smallest increase in per capita CO2 emissions from 1990 (Table 9).

CO2 emissions per capita (metric tons) generally tends to increase as income rises by shifting from low- income to middle-income, and to high-income economies, and the level of CO2 emissions in 2010 is higher than the level of 1990 for all income groups. However, the global level of CO2 emission per capita increased at the average annual rate of 2.1% over 28 years (1990–2008) as a result of comparable GDP average annual growth rates of 2.7% (1990–2000) and 2.8% (2000–2010), though the growth rate of CO2 emissions begins decreasing at the stage of lower middle income accompanied by the decreasing growth rate of GDP. Nonetheless, CO2 emissions per capita increased at a lower rate than GDP growth rate at varying rates throughout during the1990–2008 period for all global four income groups (Table 9).

Thus, the LIC had produced the smallest volume of CO2 emissions per capita (0.3 tons) of all four groups in 2009 even after two decades of its accelerated GDP average annual growth rate from 3.4% (1990 -2001) to 5.5% (2000–2010), and the HIC produced by far the largest volume of CO2 emissions per capita (11.2 metric tons in 2009), more than twice as much CO2 emissions of the UMC, though the high income group's annual growth rate of CO2 (0.8%) is less than one third of the former (Table 9).

Among the developing countries (low and middle income groups), the upper middle income group was the largest emitter of CO2 in 2008 having achieved the highest annual GDP growth rate during 2000–2010. Middle income group's (=LMC+UMC) larger volume of CO2 emission was apparently generated by its enhanced growth rate of GDP (6.4%) during the 2000–2010 period. However, the least change of CO2 emission (0.8%) of all four income groups between the 1990 and 2008 period was achieved by the HIC countries, though they were the largest emitter among four income groups, which was, no doubt, realized by technological progress in advanced countries.

Checking the global environmental Kuznets curve for four world income groups. Here, we first examine the EKC hypothesis by looking into the relationship between CO2 emission and income level for the four global income groups (that is, LIC, LMC, UMC, and HIC) as presented in the Table 9. When global economies are grouped in four income groups, the CO2 emissions per capita of four income groups are on the increasing trend as income level shifts from LIC until HIC for both 1990 and 2008 as shown in the table below.

The Table 10 does not seem to substantiate the EKC hypothesis as the CO2 emissions per capita continue to rise as income increases to high income level for both 1990 and 2008 that would not have downward slope without peak or turning point. However, looking over the rates of increase in CO2 emissions per capita in the Table for four income groups which show decreasing trend as income level increases from lower middle income (LMC) as from 3.1% (LMC), to 3.0% (UMC) and to 0.8% (HIC)) during 1990–2008 (Table 9), we find that the CO2 emissions would gradually be reduced, eventually following the

Table 9 | Growth trends of GDP and CO2 emissions by global and regional income group: 1990–2010

Global income group	*GNI per capita ($)*		*GDP average annual growth rate (%)*		*CO2 emissions*		
					per capita (metric tons)		*ann. growth (%)*
	1990	*2010*	*1990–2000*	*2000–2010*	*1990*	*2008*	*1990–2008*
World	4,200	9,097	2.7	2.8	4.2	4.8	2.1
Low income (LIC)	350	510	3.4	5.5	n.a.	0.3	3.0
Middle income	2,220	3,764	3.4	6.4	2.4	3.4	3.0
Lower middle income (LMC)	1,530	1,658	3.7	6.3	1.1	1.5	3.1
Upper middle income (UMC)	3,410	5,884	3.1	6.5	3.6	5.3	3.0
Low and middle income	840	3,304	3.4	6.4	2.2	3.0	3.0
South Asia	330	1,213	5.6	7.4	0.7	1.5	4.9
Sub-Sahara Africa	340	1,165	2.4	5.0	0.9	0.9	2.2
East Asia and Pacific	600	3,691	7.2	9.4	1.8	4.2	5.6
Middle East and N. Africa	1,790	3,839	3.0	4.7	2.6	4.6	4.2
Latin America and Carib.	2,180	7,802	3.3	3.8	2.3	2.9	2.5
Europe and Central Asia	2,400	7,214	-1.6	5.4	9.8	7.8	−0.8
High Income (HIC)	19,590	38,658	2.4	1.8	11.8	11.9	0.8

Note: (1). CO2 emission per capita growth is measured by metric tons.
(2). Growth rates of CO2 and GDP are average annual base.
(3). Carbon dioxide emissions are those stemming from the burning of fossil fuels and manufacture of cement. They include emissions produced during consumption of solid, liquid, and gas fuels and gas flaring.
(4). Classification of economies into four income groups (LIC, LMC, UMC and HIC) is based on World Bank definition. World Development Report 1992, 2012(a).[28]
Source: World Bank (2012(b)), (2014).

EKC pattern aided most likely by the introduction of improved technology for environmental protection in high income countries. Thus, our application of the EKC hypothesis to the above mentioned four global income groups can be partially substantiated.

The Asian pattern of GDP growth—CO2 emissions relationship. First, the relationship between GDP growth rate and the rate of increase in CO2 emissions will be investigated for the Asian developing regions before we examine the EKC hypothesis as applied to a sample of 20 countries.

Out of six global developing regions, two Asian regions (that is, the South Asia, and the East Asia & Pacific) classified initially as low income group (LIC) in 1990,[15] then as lower middle-income (LMC) in 2010, had been growing at a higher rate of GDP growth than the rest of regions since 1990(Table 9). With their income still at a lower level than the average income of the six, the Asian developing regions have achieved the highest rates of GDP growth and the largest rate of increase in the CO2 emissions. In fact, the highest growth rate of CO2 emissions (5.6% (1990–2008)) was observed in the East Asia and the Pacific region where the highest GDP growth rate (7.2% (1990–2000) and 9.4% (2000–2010)) were achieved. The second highest growth rate of CO2 emissions was registered by the South Asia region that had also the second highest GDP growth rate of the six. Nonetheless, per capita income (GNI) ranking for both East Asia and the Pacific, and the South Asia still remained as low as 4th and 5th, respectively of the global six developing regions in 2010, whereas the top ranking per capita income region was Europe & Central Asia with upper middle income status, that had rapidly accelerated its GDP average growth rate from negative rate (−1.6%) (1990–2000) to positive 5.4% rate (2000–2010), having apparently brought about the largest volume of CO2 emissions per capita during 1990–2008, though the CO2 had decreased at the annual rate of -0.8% during the time (Table 9, Fig. 10).

Thus, it follows that among six developing income groups, the low income group with its prevalently lower CO2 emissions per capita tends to have higher rates of GDP growth and of CO2 emissions increase, while those of high-income group's are generally low.

Looking into the shape of trend curve in the Fig. 9 in which six global developing regions are listed on the horizontal plot in order of average per capita income (1990), an inverted *U*-curve can be detected at least up to the certain income level, but beyond which the curve seems to show irregular patterns. For example, in the case of the 2008 CO2 emissions per capita, as per capita income rises from low income (LIC) (average income of the South Asia) to lower middle income (LMC) (average income of the Middle East and North Africa), the CO2 emissions per capita also increases, but later begins to decreases as income increases from the LMC to UMC (average income of the Latin America and Caribbean) at which level the CO2 emissions start to increase as income increases further from the UMC. The increasing trend of the CO2 per capita seems to be maintained in view of the the larger volume of CO2 emissions produced in the group of high income developed countries than those in the Europe and Central Asia region (income level of the UMC). The curve of the1990 CO2 emissions is basically similar to that of the 2008 CO2 emissions. Thus, for the most part, the curves of both 1990 and 2008 seem to portray the EKC pattern for the six global developing regions up to the income level within the range of middle income though the curves show increasing trend at higher income level with no seemingly downward trend for the time being (Table 9, Fig. 9).

Table 10 | CO2 emissions per capita by World income group

			(Metric ton)	
	LIC	*LMC*	*UMC*	*HIC*
1990	n.a	1.1	3.6	11.8
2008	0.3	1.5	5.3	11.9

Note: LIC = low income group, LMC = lower middle income group, UMC = upper middle income group, HIC = high income group.
Source: Table 9.

Environmental Kuznets curve for impact estimation. The impact of economic growth on environmental degradation can be analyzed by looking into the relationship between income per capita and environmental pollutants, or the relationship between economic growth and environmental pollutants. Grossman = Krueger's Environmental Kuznets Curve (EKC) is applied as an alternative approach to find out possible link between income and environmental degradation.

Here, we investigate into the pattern of EKC for a sample of 20 Asian ADB member countries to estimate the impact of economic growth on environmental degradation. CO2 emissions per capita is used as a surrogate for environmental degradation in this survey. The impact estimation will be conducted by exploring three relationships.

(1) the relationship between GDP growth rate and CO2 emissions per capita,
(2) the relationship between income level and CO2 emissions per capita,
(3) CO2- income elasticity (or income elasticity of CO2 emissions) approach.

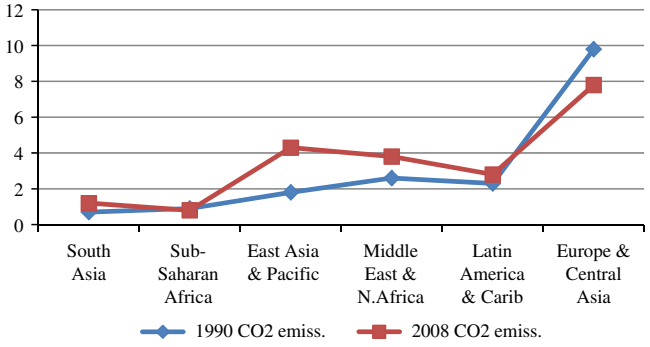

Figure 9 | Change in the level of CO2 emissions by Six Global Developing Region: 1990–2008. The above Figure is depicted based on the World Bank data to examine the applicability of the Environmental Kuznets Curve (EKC) to six global developing regions. When six global developing regions are listed on the horizontal axis in the order of per capita income, CO2 emissions per capita are generally on the rising trend as income level increases from low income (South Asia) to middle income (Europe and Central Asia) developing region accompanying some minor fluctuations for the case of the 2008. Thus, two curves drawn for world six developing regions do not present the EKC pattern although the curve for 2008 CO2 emissions seems to form inverted *U*-curve up to the income level (Latin America and Caribbean) of the upper middle income. 20 countries in our sample are selected from both the South Asia, and East Asia and Pacific regions (Source: Table 9). Note: Vertical plot = CO2 emissions per capita (metric tons). Horizontal plot = Six global developing regions listed in order of increasing GNI per capita (1990) to the right.

(1) The relationship between GDP growth rate and CO2 emissions per capita. First, the possible link between GDP growth rate and CO2 emissions will be examined to find out the impact of economic growth on environmental degradation.

Here, Asian 20 countries are grouped into four income groups (low income, lower middle income, upper middle income and high income) from Table 11 with a view to observing the relationship between GDP growth rate and CO2 emissions by income group (Table 12).

Table 12 indicates the relationship between GDP average annual growth rate and CO2 emissions per capita over the 2000–2010 period for the Asian 20 countries that are grouped into four income groups, that is, low-income, lower middle-income, upper middle-income, and high-income. The table shows that, as income increases from low-income to upper middle- income, the GDP annual average growth rate increases gradually from 6.1% (low income group) until it rises to 6.8% for the upper middle-income group accompanying corresponding increase in CO2 emissions per capita. However, a further shift of income group from the upper middle income to high income indicates slowing-down of GDP growth rate that falls to 3.8% for the high income group despite its increase in the CO2 emissions per capita. Thus, Fig. 10 can be drawn based on the Table 12.

Assuming that the level of CO2 emissions per capita in 2010 is largely caused by economic growth during 2000–2010, Fig. 11 could be drawn based on data from Table 10, which can be quite illustrative indicating that CO2 emissions per capita is, by and large, on the increasing trend as income rises. At an early stage of industrialization, the GDP growth rate tends to be higher while CO2 emissions per capita is generally small for countries with income level lower than upper middle-income. However, as income rises further from the upper middle income to high income, the GDP growth rate starts decreasing. This trend is clearly portrayed by Fig. 10 derived from Table 12.

(2) The relationship between income level and CO2 emissions per capita for 20 Asian countries. In regard to the relationship between income level and CO2 emissions for a sample of 20 Asian countries, the Fig. 12 portrayed in the following demonstrates the relationship between the levels of CO2 emissions per capita and income per capita of the countries that are listed on the horizontal plot in order of GNI per capita.

The overall rising trend of the CO2 emissions is displayed in the Figure as borne out by the increase in average CO2 emissions per capita in the sample from 3.9 (1990) to 4.8 tons (2010) as average per capita income increased from $5,351 (1990) to $13,443 (2010) (Table 11). Judging from the gaps that lie between the 1990 CO2 and 2010 CO2 emissions for each of sample countries in the Figure, very little change in the emissions had taken place during 1990–2010 in the countries with income level lower than upper middle income. The gaps are apparently expanding from the income level with upper middle-income (that is, Thailand's income). However, after high-income Singapore had substantially reduced the emissions during the period, the gaps in other higher income countries (Hong Kong, New Zealand, Australia and Japan) almost diminished though their CO2 emissions appear to be increasing.

From the above, it can be deduced that the increase in CO2 emissions between 1990 and 2010 is relatively limited except for China as income rises from low to lower middle-income, in other words, the impact of economic growth on the environment is rather minor for countries at the lower stage of industrialization in the region, whereas the impacts become greater for countries with the upper middle income or larger, but appear gradually smaller in high-income developed countries in Asia. The larger gaps observed among upper middle-income groups and new entrants to high income countries seem to be the results of inefficient or lack of measures to cope with growing demand for environmental protection.

The rising trend of the CO2 emissions for 20 Asian countries can be clearly demonstrated by grouping them into four income groups, that is, low income, lower middle income, upper middle income and high income.

A summary of the relationship between CO2 emissions and income level by income group is presented in the Table 13, which indicates that CO2 emissions per capita increases as income rises from low income to higher income both for 1990 and 2010. The rising trend of Asian CO2 emissions portrayed in Fig. 13 is

Table 11 | Economic growth, Income and CO2 emissions for 20 Asian Countries: 1990–2010

20 Countries	*GNI per capita ($)*		*GDP average annual growth (%)*		*CO2 emission per capita (metric tons)*	
	1990	*2010*	*1990–2000*	*2000–2010*	*1990*	*2010*
Viet Nam	130	1,270	7.9	7.5	0.3	1.7
Cambodia	140	740	4.6	3.2	0.06*	0.3
Lao PDR	190	980	6.5	7.0	0.1	0.3
Bangladesh	290	690	4.8	8.2	0.1	0.4
China	330	4,240	10.3	10.8	2.1	6.2
India	390	1,290	6.0	8.0	0.8	1.6
Pakistan	410	1,060	3.7	5.1	0.6	0.9
Sri Lanka	470	2,260	5.3	5.6	0.2	0.6
Indonesia	620	2,550	4.2	5.3	0.8	1.8
Philippines	720	2,740	3.2	4.9	0.7	0.9
Mongolia	1,430	1,900	1.0	7.9	4.6	4.2
Thailand	1,490	4,320	4.2	4.5	1.7	4.3
Malaysia	2,370	8,150	7.0	5.0	3.1	7.6
Korea	6,480	21,320	5.7	4.1	5.7	11.8
Taipei	8,321	19,252	6.7	4.2	8.2	11.4
Singapore	12,040	44,790	7.8	6.6	15.6	2.7
Hong Kong	12,660	33,620	4.0	4.6	4.8	5.1
New Zealand	13,520	28,990	3.0	2.6	7.1	7.2
Australia	17,460	46,510	4.1	3.3	16.8	16.9
Japan	27,560	42,190	1.3	0.9	8.9	9.1
Average	5,351	13,443	5.1	5.5	4.1	4.8

Note: (1). Countries are listed in order of increasing GNI per capita (1990).
(2). GNI ($) = GNI per capita (PPP), and CO2 = CO2 emissions per capita (metric tons) are from ADB (2012a).
(3). GDP average ann. growth (%) data are from World Bank (2002): 236–237 and (2012a): 398–399.
(4). *0.06 is an estimated value based on the ADB (2013) 's data instead of original ADB (2012a)'s value of 0.0, since zero is a rounded up figure. ADB (2013) data indicate that total CO2emissions in Cambodia increased from 451,000 (1990) to 4,180,000 metric tons (2010). ADB (2013): 154. Since Cambodia's percentage change of per capita emissions of CO2 during 1990–2010 is between 500% and 550% (ADB, 2013: 149), the largest change among ADB 43 regional member countries, plausible 525% change is projected to calculate Cambodia's average growth rate of CO2 emissions during the period. ADB (2012a), ADB (2013: 149).
(5). Taipei's GDP growth data is from Taiwan National Development Council. 2015 Taiwan Statistical Data Book (2015: 51). Taiwan's CO2 data for 1990 is substituted by 1996 data (ADB, 2013: 154).
(6). Income classification of a sample of 20 countries listed according to 1990 GNI per capita by World Bank is, low income countries (LIC) with $610 or less: 8 countries (from Viet Nam to Sri Lanka in the table), lower middle income (LMC) with $610-$2,465: 5 countries(from Indonesia to Malaysia), upper middle income (UMC) with $2,466–$7,619: only Korea, high income (HIC) with $7,620 or more: 6 countries (from Taipei to Japan).According to the World Bank, 2010 income classification, low income countries (LIC) with $1,005 or less: 3 countries (Bangladesh, Cambodia, Lao PDR), lower middle income (LMC) with $1,006–$3,975: 7 countries(Pakistan, India, Viet Nam, Mongolia, Sri Lanka, Indonesia, Philippines), upper middle income (UMC) with $3,976–$12,275: 3 countries (China, Thailand, Malaysia), high income (HIC) with $12,276 or more: 7 countries (Taipei, Korea, New Zealand, Hong Kong, Japan, Singapore, Australia).
(7). Income classifications for 1990 and 2010 are based on the definitions of World Bank (1992) and (World Bank, 2012a) (see endnote 28).
(8). Some minor differences in the income per capita data of 2010 between Table 1 and Table 9 are because of difference of sources, the former is from World Bank (2012a), while the latter from ADB (2014).
Sources: ADB (2014), ADB (2013), ADB (2012a), World Bank (1992, 2012a). Taiwan National Development Council (2015).

Table 12 | Relationship between GDP growth and CO2 emissions for four Asian income groups: 2000–2010

Asian 4 income groups	*GDP growth (%)*	*CO2 emissions.*
	2000–2010	*2010*
Low Income (3)	6.1	0.3
Lower middle income (7)	6.3	1.7
Upper middle income (3)	6.8	6.0
High Income (7)	3.8	9.2

Note: (1). Figures in the parenthesis are the number of countries.
(2). Classification of economies is based on the definition of 2010 World Bank (2012a).
Source: Table 10

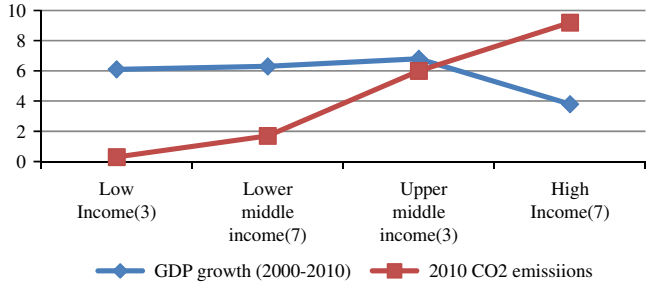

Figure 10 | The GDP growth—CO2 emissions relationship by Asian Income Group: 2000–2010. The above Figure is a graphical presentation of Table 12 indicating possible impacts of GDP growth rate (2000–2010) on the emissions of CO2 emissions in 2010. It shows that CO2 emissions per capita keep increasing as income rises from low income (Low income group) to high income though the average growth rate that was rising slowly until upper middle income level (Upper middle-income group) fell to 3.8% at the high income level (High income group) (Source: Data from Table 12). note (1). Vertical plot = GDP ann. average growth rate (%), and CO2 emissions per capita (tons). Horizontal plot = Four income groups listed in order of average GNI per capita (2010). Income group classification is based on the 2010 definition (World Bank, 2012a, b). 2). Figures in the parenthesis are numbers of countries in the group.

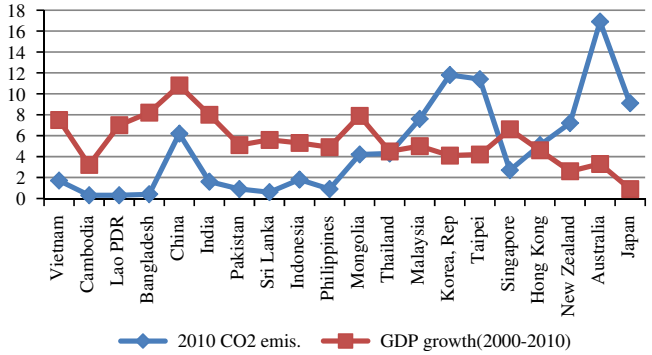

Figure 11 | The GDP growth—CO2 emissions Relationship by Asian Country:2000–2010. The above Figure is a country based representation of the relation between GDP growth and the level of CO2 emissions, indicating a possible growth impact on the CO2 emissions for the 20 sample countries. The general trend seems to suggest that the level of CO2 emissions gradually rises as income increases whereas the GDP growth rate has a tendency to decline accompanying increasing fluctuations observed among high income countries. Thus, the trend curves show that the growth impact on CO2 emissions seems to become larger from the level of upper middle income (Thailand and Malaysia) and on though the increasing trend is interrupted by Singapore that has drastically reduced the emissions by policy measures (Source: Table 11). Note): Vertical plot = GDP growth rate(%) for square dot line (red), and CO2 emissions per capita(metric tons) for rhombic dot line (blue). Horizontal plot = countries listed in order of increasing GNI per capita of 1990 to the right.

identical to the global trend we have seen in Fig. 9 that has no turning point. However, it should be noted that, though an overall average CO2 emissions per capita of 20 Asian countries increased from 4.1(1990) to 4.8 tons (2010), the CO2 emissions by income group decreased between 1990 and 2010 for all income groups except for the upper middle income group that has increased the emissions from 5.7 to 6.0 tons during the time. It thus follows that economic growth in terms of increase in income per capita seems to have brought about increasing pollutants (CO2 emissions), despite an overall minor decline in the level of the emissions for most income groups due largely to the economic growth that have changed the number of countries in respective income group between 1990 and 2010 (Table 13).

(3) The CO2-income elasticity approach. The CO2-income elasticity approach may be introduced to evaluate the impacts of income increase on CO2 emissions. The CO2-income elasticity (or income elasticity of CO2 emissions) derived by calculating the ratio of a percent change in CO2 emissions per capita over a percent change in income is capable of indicating the direct relationship between income growth and CO2 emission increase, that is, how much CO2 would be produced by incremental economic growth. At the same time, this elasticity, can be an indication of the efficiency level in saving CO2 emissions in the course of development .[16] In other words, the elasticity seems to suggest that, the smaller the amount of CO2 emission produced, the higher the efficiency of reducing CO2 emissions realized by technological advance, leading to a lower value of the elasticity, which takes place predominantly in industrialized countries.[17] However, it should be noted that a smaller value of the elasticity can be observed also when income per capita increases at a faster rate than the increase in CO2 emissions. The case of China's low elasticity is an example.

Since the impacts of economic growth on the increase in CO2 emissions are distinctively different among four income groups, different patterns of impacts among income groups could be discerned by the size of CO2-income elasticity as shown in the Table 14. As the change in the average elasticities of four income groups is demonstrated by the shift of the elasticity, that is, 0.675 (LIC) → 0.328(LMC) → 0.467 (UMC) → 0.041(HIC), the largest impact of economic growth on the emissions is estimated to have taken place for the low income group, while the weakest impact took place for the high income group (Table 14, Fig. 14).

Table 13 | Average per capita Income and CO2 emissions by Income group for Asian 20 countries: 1990 -2010

Income group (number of countries)	*1990*		*Income group (number of countries)*	*2010*	
	GNI ($)	*CO2 emis.*		*GNI ($)*	*CO2 emis.*
Low income (8)	294	0.5	Low income (3)	803	0.3
Lower middle income (5)	1,325	2.2	Lower middle income (7)	1,867	1.7
Upper middle income (1)	6,480	5.7	Upper middle income (3)	5,570	6.0
High income (6)	15,260	10.2	High income (7)	33,810	9.2

Note (1). GNI($) = GNI(income) per capita ($), CO2 emis. = CO2 emissions per capita (metric tons).
(2). Figures in the parenthesis are the number of countries in respective income group.
(3). Classification of the income group is based on World Bank. World Development Report 1992 and 2012.
Source: Data from Table 11.

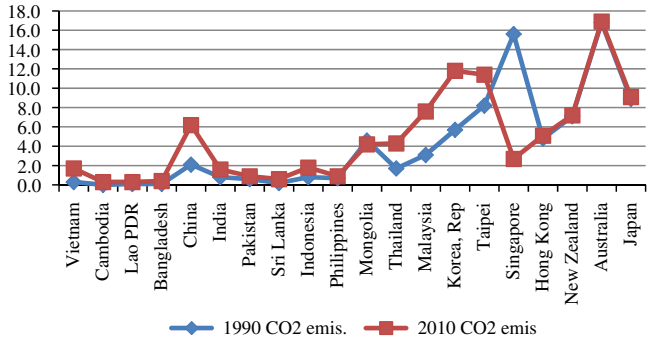

Figure 12 | Changes in CO2 emissions per capita in Asia during 1990–2010. The Fig. 12 shows the changes in CO2 emissions per capita during 1990–2010 for each country of the sample. As the gap between the two curves indicate an increase or decrease in the CO2 emissions, the success of emissions control is demonstrated by the size of the gap. For countries with income lower than upper middle income, the gaps are relatively small except for China, but the gaps become larger for countries with upper middle income and lower level of high income (Thailand and Malaysia, Korea and Taipei), though the increasing trend in the CO2 emissions among high income countries is disturbed by Singapore's sharp drop in the CO2 emissions (Source: Table 11). Note: Vertical plot = CO2 emissions per capita (metric tons). Horizontal plot = Countries listed in order of per capita income of 1990 to the right.

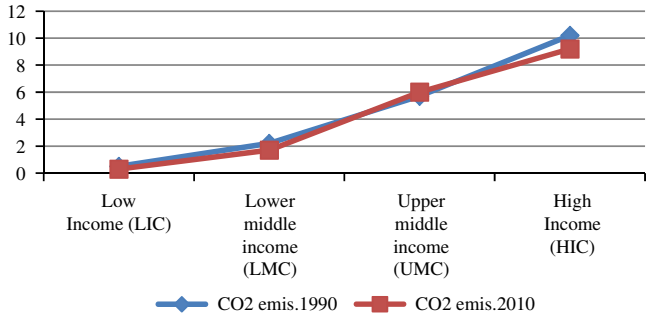

Figure 13 | Trend in CO2 emissions by Asian income group: 1990 and 2010. The above figure shows the increasing trend in CO2 emissions per capita as income level increases from low income (the average of low income group) to higher income (average of lower middle, upper middle income to high income). Thus, when Asian 20 sample countries are grouped into four income groups, the figure portrayed from the data does not present inverted U-curve for both 1990 and 2010 (Source: Table 13). Note: Vertical plot = CO2 emissions per capita (metric tons). Horizontal plot = four income groups, that is, Low income, Lower middle income, Upper middle income and High income group.

Assessment of Asian environmental Kuznets curve: 1990 and 2010. Here the two curves are delineated in the Figs. 15 (a) and (b) with a view to examining whether they follow the standard EKC or not. Apparently, the overall shapes of both (a) and (b) with two different inverted *U*-curves each do not seem to present a normal EKC pattern. However, looking closely into the shapes of the two curves, they appear to be following the EKC pattern until income increases to the certain income level that is lower than the average income of high income countries. In the case of (a) 1990, first Kuznets type inverted *U*-curve is depicted up to the lower high income level (between $10,000 and $15,000) of Hong Kong with the peak at Singapore's income level, and the second inverse-*U* appears to be formed by four high income countries (Hong Kong, New Zealand, Australia and Japan) with the second peak at Australia. As for the portrayed EKC in (b) 2010, the curve seems to follow roughly a normal standardized EKC pattern with its peak topped by Korea until income level reaches Hong Kong's income level that is a little over $30,000. Beyond this point, another inverted *U*-curve appears to be created by three high income countries (that is, Hong Kong, Japan and Singapore) with its peak achieved at Japan's income level, while Australia with its highest per capita income and the largest per capita CO2 emissions of the sample countries in 2010 indicate the rising trend in the EKC curve, generating so-called *N*-curve type pattern in the EKC trend.[18]

Thus, irregularities of the two curves in the Fig. 15 seem to be generated by varied CO2 emissions produced by countries of high-income group when the sample countries are arranged in order of income per capita on the horizontal axis in the above Figure. Noticeable irregularities of the curve in the (a)1990 are actually created by four high income countries (that is, Hong Kong, New Zealand, Australia and Japan), and those of (b) 2010 by three high income countries (Hong Kong, Japan and Singapore). The shift of income per capita ranking within the high income group that took place between 1990 and 2010 is another factor for creating irregular patterns, as indicated, for example, by substantial increase in income per capita that lifted Australia from the 2nd (1990) to the top (2010) in per capita income ranking of the 20 sample countries.

In regard to the curve pattern for the low income countries in the Fig. 15 closer investigation of the curves in the (a) 1990 and (b) 2010 reveals the irregular shape created by countries with income level lower than the lower middle-income. Since the graphical presentation of Asian EKCs (Fig. 15) provides a limited information concerning their shape and trend of the curve for the income level between low income and lower middle income, country-specific conditions may need to be taken into account.

Table 14 | The CO2—income elasticity for ADB Asian 20 countries: 1990–2010

Countries	*CO2-Income elasticity*
LIC (8)	
Vietnam	0.532
Cambodia	0.776
Lao PDR	0.481
Bangladesh	2.175
China	0.165
India	0.433
Pakistan	0.315
Sri Lanka	0.525
Average	0.675
LMC (5)	
Indonesia	0.402
Philippines	0.102
Mongolia	−0.265
Thailand	0.805
Malaysia	0.595
Average	0.328
Countries	*CO2-Income elasticity*
UMC (1)	
Korea, Rep	0.467
Average	0.467
HIC (6)	
Taipei	0.297
Singapore	−0.304
Hong Kong	0.038
New Zealand	0.086
Australia	0.004
Japan	0.127
Average	0.041

Note: (1). CO2-income elasticity = (% change in CO2 emissions per capita)/(% change in GNI per capita).
(2). The above classification of economies by income group is based on 1990 definition of World Bank (1992: 307).
(3). Figures in the parentheses are the number of countries for each income group.
Source: Table 11.

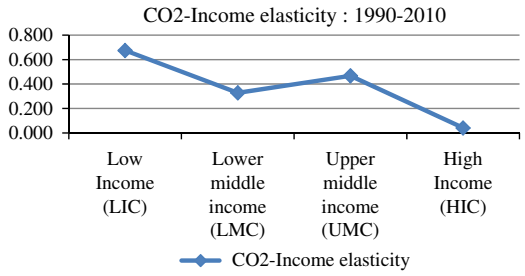

Figure 14 | The CO2- Income elasticity by Asian income group: 1990–2010. The CO2—Income (GNI) elasticity is the ratio (that is, percentage change in CO2 emissions per capita divided by percentage change in income per capita) capable of indicating the growth impact on CO2 emissions as well as efficiency achieved for reducing CO2 emissions as the rate of income increases during 1990–2010. As shown by decreasing trend in the elasticity, the largest growth impact on CO2 emissions is produced at the low income level, which gradually declines and becomes the smallest at the high income level. Thus, the countries of high income group can be taken as having successfully reduced CO2 emissions or as their economies grow (Source: Table 14). Note (1). Vertical plot = size of CO2—Income elasticity, Horizontal plot = Four income groups in Asia. (2). Income classification of the above is based on the definition of World Bank 1990 income level.

Conspicuous fluctuations of the curves observed among high-income countries could generally be generated by the following; (1) Singapore's significant reduction of CO2 emissions despite her rapid economic growth, (2) Australia's unabated large scale emissions of CO2 emissions despite its substantial increase in per capita income, (3) Japan's persistent high level of CO2 emissions in spite of its lower income growth, which are largely the causes for the appearance of the curves provided with more than one turning point. Thus, the Asian pattern of the EKC portrayed in the above can be construed that the impacts of economic growth on CO2 emissions differ substantially among high income countries. Whereas the irregularities of the curve among countries with income lower than middle income can be observed for China (low income country group) and Mongolia (lower middle income group), as both countries have each produced the largest CO2 emissions per capita in their income group respectively. With the aid of the CO2-income elasticity curve portrayed in the Fig. 16, the anomalous relationship between income growth and the emissions increase can be detected for three countries, that is, Bangladesh and Mongolia from low income group, and Singapore from high income group. Bangladesh's high elasticity (2.175) stands out among sample countries, which is due to its large increase in CO2 emissions (from 0.1(1990) to 0.4 tons (2010)) as against its rate of economic growth during 1990–2010 (Table 11) while Mongolia and Singapore are only two countries with their negative CO2-income elasticity that could reduce their CO2 emissions during two decades since 1990. China's unexpectedly low elasticity (0.165) is derived from her high rate of increase in the emissions brought about by an enormous growth rate. In light of converging curve of the CO2-income elasticity in Fig. 16, the small values of the elasticities seems to be reasonably capable of accounting for the irregular part of the EKC curve generated by high income countries.

Hence, in our survey of a sample of Asian 20 countries, Kuznets hypothesis seems to be substantiated only for income groups with income level up to UMC. And beyond the UMC level, the EKC trend curve seems to be shaped by varying emissions of CO2 per capita produced by countries with higher income than the average of the high-income group, generating irregular EKC pattern.

Government policy for income and environment

Kuznets hypothesis and income inequality policy in Asia. Though the Asian region's past economic growth has contributed to boosting living standards and lifted millions out of poverty, widening income inequality still prevails. More than 80% of the region's population lived in countries with worsening Gini coefficients during the 1990s and 2000s.[19] These distributional consequences of Asia's rapid growth have often been ascribed to technological progress, globalization, and market-oriented reform as the major drivers of growth that have led to widening inequality in the last two decades (ADB, 2012a), although at the same time these variables have effected reduction in income inequality to some degree by raising an income of low wage labour as predicted by the standard trade theory. Various factors such as inequality of education, urbanization are also involved in affecting the effects on income inequality. China that has the largest annualized positive change in Gini coefficient in Asia during the 1990s-2000s is said to have followed a *U*-shaped trend pattern over the last 50 years driven by rising regional and urban-rural inequality with the turnaround point located around the

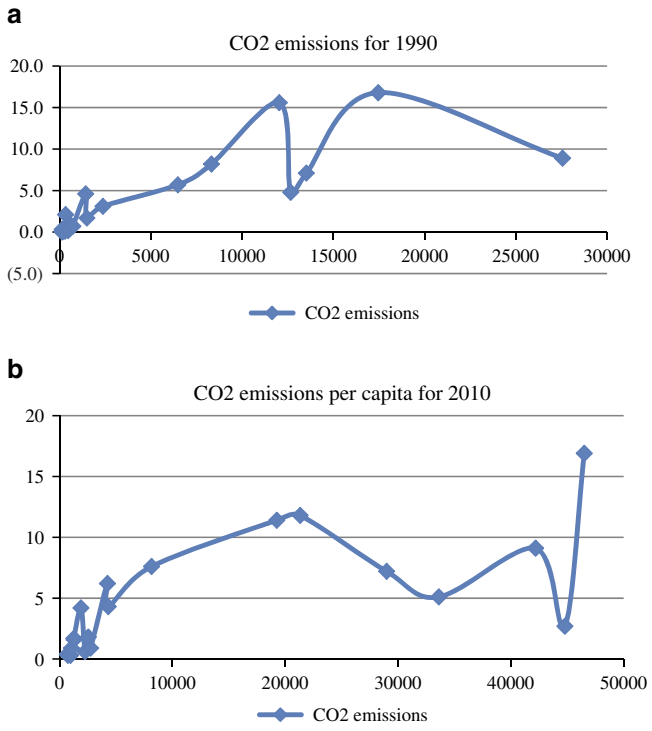

Figure 15 | Environmental Kuznets Curve for Asian 20 economies: 1990 and 2010. The two curves in the above ((a) and (b)) derived from the data in Table 11 show the changing CO2 emissions per capita for the income levels of 20 Asian economies listed on the horizontal axis in order of per capita income. Either curve (a) or (b) equipped with seemingly two peaks each does not seem to present standard shape of the Environmental Kuznets curve (EKC) which posits an inverted-*U* relationship between per capita income and CO2 emissions. However, up to the lower level of high income, both curve trend follow the EKC pattern, but the trend reverses beyond the high income level before the curve shows upward trend again for the second peak as income further increases. The major difference in the curve between (a) and (b) is observed for the income level higher than the average of high income, indicating that the curves are provided with more irregularities among countries with higher income level as income rises from 1990 to 2010 (Source: Table 11). (a) 1990. note (1). Vertical plot = CO2 emissions per capita (metric tons). Horizontal plot = GNI per capita ($) (1990). (2). Average GNI per capita of 20 countries = $5,351. Aver. CO2 emissions per capita = 4.1 tons. (b) 2010 Note (1). Vertical plot = CO2 emission per capita (metric tons). Horizontal plot = GNI per capita ($) (2010). (2). Average GNI per capita = $13,443. Average CO2 emissions per capita = 4.8 tons.

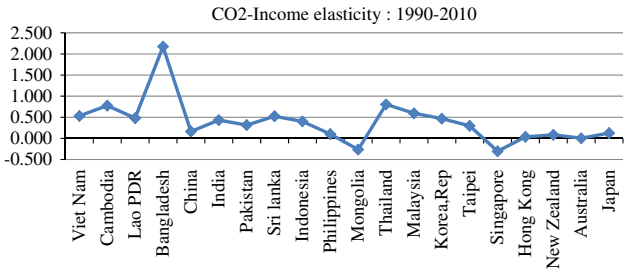

Figure 16 | CO2–income elasticity for ADB Asian 20 countries: 1990–2010. The above Figure shows the trend in the CO2-income elasticity for 20 Asian economies listed on the horizontal axis in order of income per capita of 1990. The overall declining trend in the curve seems to indicate decreasing impacts of growth on the increase in CO2 emission as income rises from low income (the income level of Vietnam) to higher income level, accompanying fluctuations/irregularities. However, the decreasing trend curve reverses for the upper middle income (Thailand, Malaysia), before the curve turns downward at the lower level of high income (Korea and Taipei) with the elasticity nearing to zero as income further rises to the higher level of income. This is indicative of an shrinking impact of growth on the emissions, or of a large carbon emission efficiency effects generated among high income countries (Yandle *et al.*, 2004). However, a smaller size of CO2 elasticity will not reveal by itself the real picture. China's low elasticity is due to its highest economic growth rate together with its second highest rate of CO2 emissions increase in the sample. The largest negative elasticity of Singapore was achieved by a sizable decrease in CO2 emissions by her government policy (Source: Tables 11 and 14). Note: Vertical plot = CO2-GNI elasticity. Horizontal plot = countries are listed in order of GNI per capita income of 1990.

mid 1980s when the government-led "open and reform policy" was promoted (Ota, 2007, Cornia *et al.*, 2003).

In regard to the test of the Kuznets Inverted-*U* hypothesis that was originally presented from the evidence of a limited number of developed and developing economies, divergent results have not yet been settled. While Ahluwalia (1976) and Barro (2008) seems to be supportive of the Kuznets Inverted-*U* curve in the cross-sectional data, Anand and Kanbur (1993) did not support the inverse-*U* in cross-country data. Above all, Piketty (2013) himself has criticized the Kuznets hypothesis for its limited applicability to the specific countries and time periods.

The redistributive policy of income inequality is at the hand of the government in both advanced and developing countries. Generally speaking the governments have historically mitigated inequality through public policy (Dabla-Norris *et al.*, 2015). In developing Asia, widening income gaps strengthen the case for greater use of fiscal policy to redress the income inequality and advance economic growth,[20] although policymakers in the region have generally used fiscal policy more to support growth than to affect income distribution.

Among fiscal policy tools, government expenditures and taxation are known to have tangible effects on inequality (ADB. ADO, 2014).

However, in light of varied levels of income inequality among Asian countries, the nature of appropriate fiscal policies largely depend on country-specific conditions and institutional settings of individual countries in the region, and that those policies need to be reformulated as the level of industrial development enter advanced stage.

Environmental policy framework. The improvement of the environment with income growth depends largely on policies and institutions (Panayatou, 1997). Hence, the shape of EKC depends critically on the government policies and institutional framework to control the emissions of pollutants. Below listed are determining factors of policy making for environment preservation, which are also determinants of the impact of economic growth on the emissions of pollutants.

(1) Stages of industrial development (level of industrialization), the state of technology
(2) Institutional settings
(3) Types of pollutants: SO_2, CO_2, contaminated water, particulates and so on.
(4) Land size, population density
(5) Economic factors:

(a) Income level: Lower income countries are less inclined to introduce pollution abatement technology,
(b) Scale of economic activity,
(c) Structure of economic activity,
(d) Resource endowment.

(6) Social structure
(7) Political system.[21]
(8) Size of income inequality: In a country where income is unevenly distributed, conservative ruling class will resist the demand for social reform such as environmental regulations that might harm their interests under the authoritative government. Thus, policies to introduce change to rectify prevailing income inequality will not easily be materialized.

The environmental and economic policy in Asian countries. In Asia, since the 1970s the East Asian NIEs, and East and Southeast Asian economies have increasingly strengthened their environmental regulatory systems, implementing environmental performance standards for pollution control (Angel and Rock, 2001). The Asian region faces environmental challenges in terms of total volume of CO_2 emissions, as three of the top five world largest CO_2 emitters are in Asia (that is, China, India and Japan), although Asian per capita level of the CO_2 emissions is still lower than that in developed countries.[22]

Looking carefully into the irregular shapes in our depicted curves in Fig. 2 and Fig. 15, two inverted *U*–curves can be observed in each of them. As for the inverse-*U* curve in the Fig. 2, the second inverse-*U* curve appear to start from the income level of Korea, reaching the peak (largest income inequality) achieved by Singapore for both 1990 and 2010 before the curve turns downward falling to the low level of income inequality of Japan as income increases. The curve portrayed shows that the second inverse-*U* curve is generated by seven countries (that is, four NIEs and three HIC countries).

As for the latter EKC curve also, the countries that formed first curves with their peaks differ from those that formed the second curves for both 1990 and 2010. Owing to the differences of country specific economic policies and performances among high income countries, substantial irregularities in the EKC patterns were generated in 2010 by NIEs and three HICs, specifically by Korea, Hong Kong, Singapore, New Zealand, Japan and Australia.

The irregular pattern of inverted *U*-curve generated by the group of countries with a higher level of income seems to suggest that irregularities in the curve seems to be the more likely to take place, the higher, the income level rises. Thus irregularities are frequently observed among high income countries, whereas the trend curves for countries with lower income seem to be rather regular-typed for both Inverted *U*-curve and EKC curve.[23] Those irregularities in the curves for high income range could largely be attributable to the variety of country-specific conditions in high income countries where policies and measures of different type are introduced to cope with the varying degrees of environmental deterioration that have significantly resulted from the different levels of government interventions and technological development.

From the above, those countries that have largely contributed to generating irregularities in the Asian EKC trend could be exemplified by the aforementioned countries from the high income group and China from the low and middle income groups. From Table 15 below, it can be deduced that those countries that have achieved higher GDP growth rate appear to have worsened income inequality as indicated by the large increases in Gini index above 0.04 in the seven countries during the 1990–2010, while four countries with improved income equality especially two upper middle-income countries (UMC) (that is, Malaysia, Thailand) tended to have larger increase in CO2 emissions generated at higher rates of GDP growth during the period. Seven high income countries (HIC group) composed of three high income Asian developed economies (that is, Japan, New Zealand and Australia), and four new entrants to high income status (former NIEs) (that is, Singapore, Korea, Hong Kong, Taipei) seem to be involved in generating varying relationships (that is, the relation between income and inequality, and the relation between income and CO_2 emissions). The policy dimensions and country-specific conditions underlying in the above mentioned countries are briefly illustrated in the following, focusing on selected countries involved in generating irregularities in the hypothesized Inverse-*U* curve.

The policy trend by income group: checking major actors of irregularities in the Kuznets inverse-U curves. Here some observations are tentatively made about change in income inequality and CO2 emissions by income group in relation to economic growth in Asia.

As we have seen, the CO_2 emissions per capita increase as income level rises from low income (LIC) to high income (HIC) level, and an increase in the CO_2 emissions by income group during 1990–2010 became larger as income rises up to the upper middle income (UMC) that had the largest increase (3.6 tons), while the emissions for the seven HIC group including the NIEs reduced during the same period. However, the CO_2 emissions per capita produced by the three high income developed countries in the sample was the largest for both 1990 and 2010 (Table 16).

With the changes in environmental quality by income group as above mentioned, development in income inequality will be reviewed in relation to economic growth with a view to referencing for the policy formulation. (Tables 15 and 16)

Income inequality in the two groups of lower income (the LIC) and (the LMC) exacerbated substantially during the two decades (1990–2010) due largely to the accelerated growth rate achieved in the two income groups (Table 1). The LIC's income inequality has aggravated substantially from the lowest level of the Gini index 0.33 (1990s) to 0.36 (2000s) as its GDP growth rate increased at the highest rate of all from 5.6% (1900–2000) to 7.2% (2000–2010). China's rapid rise in both income inequality and GDP growth rate has apparently changed the average of the LIC considerably. The LMC's income inequality has worsened at the fastest rate from 0.37 (1990s) to 0.42 (2000s), as its GDP growth rate accelerated during the two decades (from 4.2% (1990–2000) to 5.3% (2000–2010)).

Of all income groups, only the upper middle income (UMC) group of two countries has improved income inequality while its CO2 emissions per capita have increased at the highest rapid rate. However, it should be kept in mind that the two UMC countries (Malaysia and Thailand) had still the largest Gini coefficients in the 2000s despite their reduction in income inequality (−0.3) during the 1990s –2000s.

The differences of income inequality and growth rate among high income countries, especially between the NIEs (four new entrants to the high income status) and the HIC (three high-income developed countries) can be overviewed in the Table 16. Though the meager GDP growth rate of the three HICs (high-income three developed countries) has decreased slightly during two decades (1990–2010), income inequalities have generally seen a mild deterioration accompanying minor increase in their CO2 emissions per capita, while the NIEs' income inequality has increased substantially despite their substantial drop in the GDP growth rate (from 6.1% (1990–2000) to 4.9% (2000–2010) that have brought about some decreases in CO_2 emissions per capita during the 1990–2010.

Table 15 | Change in Income inequality, Growth rate and CO2 emissions by size of the Gini increase in Asia

A sample of 20 countries	*Change in Gini Index*	*Quintile ratio*		*Change in quintile ratio*	*GDP aver. growth rate (%)*		*Change in growth rate (%)*	*CO2 emissions per capita (ton)*		*Change in CO2 emission*
	1990s-2000s	*1990s*	*2000s*	*1990s-2000s*	*1990–2000*	*2000–2010*	*1990–2010*	*1990*	*2010*	*1990–2010*
Countries with worsened income inequality (increase in Gini index) (9)										
China (LIC)	0.12	6.0	10.1	4.1	10.3	10.8	0.5	2.1	6.2	4.1
Indonesia (LMC)	0.08	4.5	6.3	1.8	4.2	5.3	1.2	0.8	1.8	1.0
Lao PDR (LIC)	0.07	5.4	5.9	0.5	6.5	7.0	0.5	0.1	0.3	0.2
Sri Lanka (LMC)	0.07	5.4	5.8	0.4	5.3	5.6	0.3	0.2	0.6	0.4
Korea (HIC)	0.06	4.7	5.5	0.8	5.7	4.1	-1.6	5.7	11.8	6.1
Singapore (HIC)	0.05	12.3	14.5	2.2	7.8	6.6	-1.2	15.6	2.7	-12.9
India (LIC)	0.05	4.4	5.0	0.6	6.0	8.0	2.0	0.8	1.6	0.8
Mongolia (LIC)	0.04	5.5	6.2	0.7	1.0	7.9	6.9	4.6	4.2	-0.4
Taipei (HIC)	0.03	5.3	6.1	0.8	6.7	4.2	-2.5	8.2	11.4	3.2
Average	0.06	5.9	7.3	1.3	5.9	6.6	0.7	4.2	4.5	0.3
Countries with no change in income inequality (4)										
Viet Nam (LIC)	0.00	5.6	6.9	1.3	7.9	7.5	-0.4	0.3	1.7	1.4
Cambodia (LIC)	0.00	5.8	5.6	-0.2	4.6	3.2	-1.4	0.1	0.3	0.2
Philippines (LMC)	0.00	8.3	8.3	0.0	3.2	4.9	1.7	0.7	0.9	0.2
Hong Kong (HIC)	0.00	9.6	n.a.	n.a.	4.0	4.6	0.6	4.8	5.1	0.3
Average	0.00	7.3	6.9	0.4	4.9	5.1	0.1	1.5	2.0	0.5
Countries with improved income inequality (negative increase in Gini index) (4)										
Bangladesh (LIC)	-0.02	4.8	4.7	-0.1	4.8	8.2	3.4	0.1	0.4	0.3
Pakistan (LIC)	-0.03	5.2	4.2	-1.0	3.7	5.1	1.4	0.6	0.9	0.3
Malaysia (UMC)	-0.03	12.0	11.3	-0.7	7.0	5.0	-2.0	3.1	7.6	4.5
Thailand (UMC)	-0.03	8.8	6.9	-1.9	4.2	4.5	0.3	1.7	4.3	2.6
Average	-0.03	7.7	6.8	-0.9	4.9	5.7	0.8	1.3	3.3	1.9
Developed high income countries with slightly worsened income inequality (minor increase in Gini index) (3)										
Australia (HIC)	0.03	5.0	5.3	0.3	4.1	3.3	-0.8	16.8	16.9	0.1
New Zealand (HIC)	0.01	5.0	5.2	0.2	3.0	2.6	-0.4	7.1	7.2	0.1
Japan (HIC)	0.01	5.7	6.2	0.5	1.3	0.9	-0.4	8.9	9.1	0.2
Average	0.02	5.2	5.6	0.3	2.8	2.3	-0.5	10.9	11.1	0.1

Note (1) Classification of the economies is based on the definition of World Bank (1992), that is, LIC = Low income economies, LMC = Lower middle income economies, UMC = Upper middle income economies, HIC = High income economies.
(2): Figures in the parenthesis are number of countries in the income group.
Source: Tables 6, 8, 11.

Table 16 | Change in income inequality, CO2 emissions with economic growth by Asian income group (average of the country data in each income group)

Asian Income group	*Change in Gini Index*	*GDP average growth rate (%)*		*Change in GDP growth rate (%)*	*CO2 emissions per capita (ton)*		*Change in CO2 emissions*
	1990s-2000s	*1990–2000*	*2000–2010*	*1990–2010*	*1990*	*2010*	*1990–2010*
LIC (8)	0.03	5.6	7.2	1.6	1.1	2.0	0.9
LMC (3)	0.05	4.2	5.3	1.1	0.6	1.1	0.5
UMC (2)	−0.03	5.6	4.8	−0.8	2.4	6.0	3.6
HIC group (7)*	0.03	4.7	3.8	−0.9	9.6	9.2	−0.4
NIEs (4)	0.04	6.1	4.9	−1.2	8.6	7.8	−0.8
HIC (3)	0.02	2.8	2.3	−0.5	10.9	11.1	0.2

Note: (1) Classification of the economies is based on the definition of World Bank (1992), i.e., LIC = Low income country, LMC = Lower middle income country, UMC = Upper middle income country,
(2)*: HIC group (7) is composed of former NIEs (that is, Korea, Taiwan, Hong Kong and Singapore) and HICs of three developed Asian high-income countries (i.e., Australia, New Zealand and Japan).
(3): Four NIEs are new entrants to high income status.
(4): Figures in the parenthesis are number of countries in the income group.
Source: Tables 1, 3, 6, 8, 11.

(1) China's policy. China's open and reform policy initiated by Deng Xiaoping actually triggered the road to development in 1979 (Ota, 2000, 2002, 2003a, b, 2007). As the decline in environmental quality is felt, China's people's congress confirmed in 1996 sustainable development as one of the nation's basic strategies. Prevention of industrial pollution became an important element in the area of sustainable development outlined in the five year plan in 2001 (Chen and Santos-Paulino, 2013). Then China ratified Kyoto Protocol in 2002. China's problem of pollution reduction is compounded by people's heavy dependence on coal consumption as primary energy consumption.

China is most outstanding for having worsened income inequality most rapidly, while having produced the third largest increase in CO2 emissions per capita at the highest GDP growth rate of all the 20 countries over the two decades (1990–2010) (Table 15; Ota, 2003c). China's large increase in CO2 emissions during 1990–2010 is brought about by her highest economic growth in the sample with an ineffective control of emissions.

Among the low income countries of the 1990 classification of the income group, China's case is rather unique as its growth impact on the emissions cannot properly be estimated from its smaller size of the CO2-GNI elasticity ((0.165). Unlike most of low income countries, China's largest rate of increases in the CO2 emissions (from 2.1 to 6.2 tons) took place accompanying the highest rate of economic growth in the sample countries during 1990–2010, that is, China's GNI per capita increased more than ten times accompanying a disproportionately smaller increase in CO2 emissions per capita during the 1990–2010 period (Table 11).[24] Under the pressures from developed countries, China announced its 2020 carbon intensity target by which carbon emission per Yuan of GDP will be reduced by 40–45% by 2020, compared to a 2005 benchmark (Cao, 2010).

(2) Singapore's environmental policy and income inequality. Of all countries in the sample, Singapore is the most successful country in having reduced CO2 emissions by over 80%, from 15.6 (1990) to 2.7 (2010) tons in the region as shown by its largest negative CO2-income elasticity (–0.304),[25] indicating that the CO_2 was efficiently controlled by government policies (Table 11, Fig. 12). The county's CO2 emissions per capita dropped sharply from the peak in the inverted *U*-curve in1990 EKC to the trough in the 2010 EKC, the lowest level of all. Singapore's sizable drop in the emissions is largely caused by the government's guidance to switch to cleaner natural gas for power and other energy efficiency measures (Low Carbon Singapore, 2009). With a long-term vision, the small sized city-state country was able to reduce emissions with the government-led initiative without sacrificing substantial economic growth and competitiveness. It relied on research and development; effective implementation; and a combination of engineering, political commitment, and community-based measures led by the government initiative. Despite Singapore's tremendous reduction of CO_2 emissions achieved by well-coordinated government interventions, the income inequality had worsened at a rapid rate, reaching the worst level of income inequality (Gini of 0.48) in 2000s in terms of the Gini index together with its highest quintile ratio that rose from 12.3 to 14.5 during 1998–2008, which had taken place at the relatively high GDP growth rates during the two decades (i.e., 7.8% (1990–2000), 6.6% (2000–2010) (Tables 3, 8, 15). Singapore' s dramatic success in reducing CO2 emissions may present the case of the government initiative to combat the challenge, though the issue of the improvement in income inequality was left unsolved.

(3) Environmental and income policies in emerging countries and the former NIEs countries:

(3)-1 Thailand and Malaysia. Thailand and Malaysia were classified as members of the upper middle-income group that is characterized as unique in the sense that income inequalities that had increased with liberalization in both countries since the 1980s have improved accompanying substantial increase in CO_2 emissions during 1990–2010, admitting though that their income inequalities in the 1990s were at the worst level of the sample countries, which have certainly contributed to forming important segments of Kuznets inverted *U*-curve.

Of all eight countries in the sample that have increased in CO2 emissions only Thailand and Malaysia have decreased their quintile ratios, indicating that the income inequality has improved by having increased their average per capita expenditure of the poorest 20% households between 0.7 and 1.9. (Table 15). Since income inequality has a negative effect on poverty reduction, preventing a further worsening of income inequality needs to be stressed in the poverty reduction policies in the country (Deolalikar, 2002).

(3)-2 Korea, Taiwan and Hong Kong: New entrants to the high income status. Together with Singapore, three East Asian countries (that is, Korea, Taiwan, Hong Kong) are newly promoted Asian high income countries once called NIEs (Newly Industrializing Economies) that have achieved sustained and equitable export-led high growth and rapid industrialization. These new entrants to high income status appear to have contributed significantly in generating irregular patterns of both Kuznets inverted U-curves. Among nine countries that have worsened income inequality during 1990–2010, only three countries (Korea, Singapore and Taipei) have decreased their GDP growth rates in the 2000–2010, though their size of increase in CO_2 emissions are varied substantially. Excluding Singapore that has most substantially reduced per capita CO_2 emission, Korea and Taipei are among the top five CO_2 emissions country ranking while both have worsened income inequality considerably during 1990–2010. Hong Kong is rather unique with its zero increase in the Gini during the period when moderate increases in CO_2 emissions and GDP growth rate have taken place (Table 15).

(4) Australia's Policy. Among three Asian high income developed countries, Australia has experienced a larger increase in income inequality (Gini index) generated at the higher GDP growth rate than other two countries (Japan, New Zealand) (Table 15).

Australia, an anomaly among high income economies, and worst carbon emitter per capita among major western nations, has produced by far the largest volume of CO_2 emissions per capita of the 20 sample countries for both 1990 and 2010, distorting the trend in the EKC curve.[26] Contrary to Kuznets' standard inverted *U*-pattern, Australia's per capita CO_2 emissions generated at the highest income level is the largest in 2010, depicting the upward trend in the curve (Fig. 15). Australia's government science agency failed to consistently decrease the emissions. Australia has been criticized for watering down its climate policies, for its decisions to scrap the carbon price, limit the emissions reduction target and so on. Current policy trends include the development of emissions offsets, energy efficiency measures, the imposition of fuel emissions standards, the provision of financial incentives, funding of research and development activities, etc. These approaches to emissions control have been widely criticized as being inadequate to meet the current targets (Nielson). Australia's per capita CO2 emissions increase was disproportionally minimal compared with its relatively high economic growth rate.

(5) Japan's policy for environmental and income redistribution. Though Japan, once reputed to be one of most successful countries that could control emissions of pollutants produced during the period of *10-year long high economic growth* (mid 1960s-mid 1970s), and has achieved the largest improvement in air quality (World Bank, 1992), currently Japan is the 5th largest emitter of CO_2 emissions in the world with its increased CO_2 emissions per capita from 8.9 tons (1990) to 9.1tons (2010), ranking the second to Australia in 2010 in our sample countries.

As one of three high income developed economies (Australia, Japan and New Zealand) with minor increases in income inequality and CO2 emissions that have taken place at the reduced rates of GDP growth during 2000–2010, Japan's income inequality has worsened compared with other high income developed economies as shown by a rise of its quintile ratio from 5.7 (1995) to 6.2 (2009) (Table 15). But according to Ohtake *et al.*, Japanese attitudes towards income redistribution policies have not changed in the 2000s and the impact of income redistribution policies using income tax has been small (Ohtake *et al.*, 2013).

What is unique about Japan's growth and income inequality is its exceedingly largest value of income-Gini elasticity of all, which can be accounted for by its small increase in the Gini index as against its limited growth rate of GDP (Fig. 7, Table 8 and 15).

Japan aims to reduce CO_2 emissions by about 20% from 2013 levels by 2030–a much lower target than other major developed economies due largely to the shutdown of all the nuclear power plants in Japan, forcing them to burn more fossil fuels, although in earlier climate talks it pledged a more ambitious reduction of 25% by 2020 from 1990 levels (Lies and Reklev, 2014; McCurry, 2015; Ministry of the Environment, Japan, 2014).

The varying need for policy implementation by the development stage. As we have seen, the two relationships (that is, one relation between income and income disparity, and the other relation between income and environmental degradation) are found to be relatively stable for the countries for the low income range, in the sense that income inequality and the level of environmental decay are generally limited. These two relationships can be delineated as an inverted *U*- curve for the income range up to the lower level of high income. The environmental policy is often non-existent for the economies at the low level of industrialization and ambient pollution since the first priority for a low income country is generally placed on poverty eradication rather than environmental protection. However, it will become increasingly necessary for a developing country to cope with environmental preservation as further industrial development advances brings about environmental degradation. As income further increases to the higher level of income, our survey indicates that the levels of income inequality and environmental degradation do not seem to decline monotonically to the lowest level, contrary to the Kuznets hypothesized Inverted *U*-curve. In our Asian case, varied forms of the two relationships can be observed among the high income countries, presenting irregular patterns in the Kuznets type curves. Since these two relationships are so diverse for the countries for the high income range, policies introduced for environmental protection and income redistribution can be varied, and that the complexities in the relationship between the above mentioned two factors appear to grow as income rises. Generally speaking, since economic performances of individual countries largely depend on the type of economic policies formulated principally based on their economic conditions, resource endowments, technological level, irregular patterns in the Kuznets' type inverted U-curves observed among high income countries could largely be attributable to their policies and economic conditions that are distinctively different between the countries. Whereas among countries for the lower income range, differences of income inequality and environmental decay are rather limited, hence, generating less irregular patterns in the inverted *U*-curve.

It thus seems quite probable that the results of many of econometric analyses that cast doubt on the validity of EKC hypothesis seem to have been led by their inability to account for the irregular segments in the EKC observed among countries within the high income range.[27] Thus, the varying roles of policies that could substantially differentiate economic growth and environmental quality among countries, especially high income economies may need to be taken into account in the evaluation of the two Kuznets related hypotheses.

Concluding remarks

The diverse results of numerous empirical studies undertaken to examine the validity of two Kuznets related hypotheses still largely remain inconclusive. The results of our reassessment of the above two hypotheses as applied to Asia with updated data show that both Asian trends in income inequality and in environmental degradation appear, by and large, to follow Kuznets' hypothesized curve up to the lower level of high income as income rises, whereas divergent trend could be observed among the economies in the higher income range, generating second inverted *U*-curves with frequent irregularities toward the terminal range. Irregularities in the curves seem to be reflecting changing relationships (that is, the relationship between income and income inequality, and the relationship between income and CO_2 emissions) that appear to become increasingly complex as income increases for the countries within the high-income range, though the irregularities appear to be more frequent in the EKC pattern rather than in the Kuznets inverse-*U* type.

Hence, the policies introduced for environmental protection and income redistribution can vary in each country to cope with the challenges that are respectively different among high income economies, while the environmental policy is often non-existent for the economies at the lower stage of industrialization since the first priority for a low income economy is generally placed on poverty eradication rather than on environmental protection. It follows then that growth (income) impacts on income inequality, and that on environmental deterioration differ substantially among the high income countries, whereas both growth impacts generated in the countries with lower income are generally small. Hence, varying types of policies are devised reflecting differences in economic conditions, resource endowment and technological standards especially among high income countries. Thus, irregular patterns in the Kuznets' type inverted *U*-curves could largely be attributable to their policies and economic conditions that are distinctively different between the countries in the upper-income range, which would make it difficult to estimate the impacts of economic growth from the trends in inequality development and pollution degradation. Whereas among countries with lower income level, differences of income inequality and environmental decay are rather limited, hence, generating less irregular patterns in the inverted *U*-curve. As we have seen, for the reasons stated above, the levels of income inequality and environmental degradation do not seem to decline monotonically to the lowest level as income further increases to the higher level of income, contrary to the Kuznets hypothesized Inverted *U*-curve. It is quite probable that the results of many of econometric analyses that have cast doubt on the validity of EKC hypothesis seems to have been led by their inability to account for the irregular segments in the EKC curve observed among countries within the high income range, since irregular patterns in the Kuznets Inverted *U*-curve seem most likely to be generated by varied types of policies, economic conditions, and technology among high income economies. Thus, the varying roles of policies capable of substantially differentiating economic growth and environmental quality among countries, especially high income economies may need to be take into account in the evaluation of the two Kuznets related hypotheses.

This study raises the question whether it is possible to promote equitable income growth that could reconcile with environmental protection. The governments of high income countries, the largest emitters by income group, may need to cope with the issue by devising policies that seek a proper link between development and environment.

Notes

1 Kuznets himself admits that his hypothesis is based on 95% speculation, and 5% empirical information because of the meagerness of reliable information. His data on developed countries are limited to those of the United States, England and Germany in the late nineteenth and the first half of the twentieth century, while data on developing countries are of India, Ceylon and Puerto Rico for limited time periods before 1950 (Kuznets, 1955). Piketty also denounces Kuznets hypothesis for its limited applicability to the specific time periods (Piketty, 2013). To quote some

examples that agree with Kuznets inverted *U*-curve hypothesis, Ahluwalia (1976) and Barro (2008) both found support for it using cross-sectional data, while those who did not support the hypothesis were Saith (1983), and Anand and Kanbur (1993), and one example that has a limited applicability is study by Cornia *et al.* (2003).

2 World Bank's World Development Report 1992 observed that some environmental problems "initially worsen but then improve as incomes rise," and claimed that "most forms of air and water pollution" fit into this category (World Bank, 1992: 10).

3 For example, out of eight studies reviewed that incorporated the CO2 emissions in the model (that is, Holtz-Eakin and Selden (1995), Tucker (1995), Cole *et al.* (1997), Hill and Magnani (2002), Lantz and Feng (2006), Shafik (1994), De Bruyn *et al.* (1998), Friedl and Getzner (2003)), three papers (from Shafik to Friedl and Getzner) failed to identify the EKC pattern, although each of the eight studies had different data samples and time effects observed for various lengths of time periods during 1960–2000. The results of following studies in which sulphur dioxide (SO2) is used as a surrogate for pollutant emissions appear to be more supportive of the existence of the EKC; for example, Shafik and Bandyopadhyay (1992), World Bank (1992), Selden and Song (1994), Grossman and Krueger (1995), De Bruyn *et al.* (1998), Torras and Boyce (1998) and List and Gallet (1999), whereas Perman and Stern (2003) found no statistical support for the EKC in their studies using the SO2 as pollutants. One empirical study that dealt with the case of CO2 emissions for only developed 24 OECD countries over the period 1960–2002 showed the results that the EKC hypothesis is supported in only 5 out of 24 countries (Galeotti *et al.*, 2008).

4 A sample of 20 countries are all regional member countries of Asian Development Bank (ADB) from South Asia (4 countries), Southeast Asia (8), East Asia (5), ADB developed members (Australia, New Zealand, and Japan).
Two other ADB member regions (Central and West Asia (10 countries), and the Pacific (14) were excluded from the sample due largely to the differences of economic and social structure as well as data problem.

5 The average GDP growth rates of "East Asia and the Pacific" region for two decades are 7.2% (1990–2000) and 9.4% (2000–2010),the highest of all six world developing regions, and those of "South Asia" was 5.6% and 7.4%, respectively both second highest, followed by the rest of four world developing regions; "Europe and Central Asia", "Sub-Saharan Africa", "Middle East and North Africa" and "Latin America and Caribbean" when ranked by their average growth rate of (2000–2010). World Bank (1992, 2002). (Table 8).

6 ADB study demonstrates that the trend of rising inequality is widespread in the developing Asia as follows.
The average Gini for the 36 economies with available data in 2000s is 37.0. 13 had a Gini coefficient at or greater than 40.0. Eleven of the 28 economies with comparable data show an increase (worsening) in the coefficient in the last 2 decades. ADB (2012b: 38, 45–46).

7 The following table shows the Gini coefficients of the six global regions estimated by Ortiz and Cummins (2011). Source: Ortiz and Cummins (2011: 26)
According to our sample data, the average Gini coefficients of the 20 countries were lower than Asia-wide's Gini values for 38 Asian developing countries that had increased from 39.0 in the mid 1990s to 46.0 (ADB, 2012b) in the late 2000s. Our lower values of the Gini are due largely to inclusion of three high income

Gini Index in six world regions: 1990–2008

Global regions	*1990*	*2000*	*2008*
Asia	36.4	40.1	40.4
Eastern Europe and Central Asia	26.7	33.2	35.4
Latin America and the Caribbean	46.9	49.2	48.3
Middle East and North Africa	39.2	39.2	39.2
Sub-Saharan Africa	49.1	46.1	44.2
High income countries	27.4	30.8	30.9
Number of observations	137	149	141

developed ADB member countries in the sample. Thus an increase in the Gini coefficient in Asia is much larger than the average increase in the Gini of the developing countries that showed 11% between 1990 and 2010 (UNDP, 2013b: 3).

8 High taxes and transfers are key reasons for their low income inequality. Twenty OECD countries had a Gini coefficient before taxes and transfers greater than 40.0 in the mid 2000s (ADB 2012b: 51).

9 According to the ADB data, OECD's Gini coefficients indicated 0.25–0.35 instead of 25–35.
Asia region's proportion of the population living on or below the $1.25-a-day poverty line fell from 54% (1990) to 22% (2008), lifting 716 million people out of poverty. The substantial growth in Asia was accompanied by rising income inequality as demonstrated by the fact that 11 (accounting for about 82% of developing Asia's population) out of the 28 countries experienced rising inequality as measured by the Gini coefficient (ADB, 2012b: 38).

10 Because of income increase during 1990–2010, the number of countries in each of four income groups changes between the classifications of economies of the 1990 and 2010. The classification of economies into four income groups is based on the World Bank definition from World Bank (1992) and (2012a, b).

11 The highest income-Gini elasticity of Japan is caused by a much lower growth rate of GDP per capita against a relatively higher rate of increase in Gini coefficient during the 1990s–2000s. In fact, Japan's average growth rates of GDP per capita during the two decades ranked the lowest (1.0% (1990–2000) and 0.9% (2000–2010)) among high income countries (Table 1).

12 Quintile ratio is the ratio of the per capita expenditure of the top 20% to that of the bottom 20%.
In the late 2000s, 13 out of the 33 economies with available data had a quintile ratio of or above 7; that is, the average per capita expenditure of the richest 20% households was at least seven times as high as that of the poorest 20%. These include the PRC, Malaysia, the Philippines, Singapore, Thailand, Fiji, Georgia, Kiribati, Nauru, Palau, Samoa, Solomon Islands, and Vanuatu. The mean quintile ratio for the 33 economies was 7.2. The Gini coefficient presents an aggregate measure of inequality in a distribution, but it may hide detailed patterns of differences across different levels of income (ADB, 2014: 27).

13 This ratio would increase to 6.7 and 7.1 respectively once three developed ADB member countries with lower Gini coefficients are excluded from the sample.

14 Hong Kong's quintile ratio for the 2000s is missing in the Table 8 as there was no corresponding data in ADB (2014: 153). However, since Hong Kong's Gini coefficient is among the highest for both 1990s and 2000s, Hong Kong's quintile ratio for the 2000s is estimated to be ranked, at least, within the top eight quintile ratio country rankings. In fact, Hong Kong's Gini index distribution of family income was 53.7 in 2011, according to The World Factbook. https://www.cia.gov/library/publications/the-world-factbook/rankorder/2172rank.html.

15 Two Asian regions, that is, South Asia, and the East Asia & Pacific hold the 35% of world CO2 emissions in 2010.
World Bank (2014a).

16 The term "CO2 emission efficiency" is used by Lipford and Yandle (2010) in the similar meaning to author's CO2-GDP elasticity in this paper. Lipford and Yandle (2010: 434).

17 A smaller value of the elasticity can be observed also even when income per capita increased at a faster rate than that of CO2 emissions.

18 N-shaped curve for the EKC relationship is argued, for example, by Martinez-Zarzoso and Bengochea-Morancho (2004) Friedl and Getzner (2003), and Aslanidis (2009), that is, the threshold of the trough point at the high income level.

19 Of the 36 Asian developing economies with available data in 2000s, eleven economies that cover 82% of the region's population show a worsening income inequality in the last two decades. See also notes 6 (ADB, 2012b).

20 Earlier IMF work has shown that income inequality matters for growth and sustainability. According to the analysis of Dable-Norris *et al.*, income distribution itself matters for growth as well. For example, an increase in the income share of the bottom 20% (the poor) is associated with higher growth, whereas an increase in income share of the top 20% (the rich) is associated with decline in GDP growth over the medium term (Dabla-Norris *et al.*, 2015).

21 In developed democratic countries equipped with information feedback system, efficient technologies are used to ensure that practices are more sustainable to meet the people's demand for better environment. Torras = Boyce's findings indicate that efforts to achieve a more equal distribution of power via more equitable income distribution, and greater political liberties, for example, can positively affect environmental quality (Torras and Boyce, 1998).

22 In Asia, the reginal average emissions on a per capita basis grew rapidly by 97% while that for the world grew by only 18%.

23 Though the level of CO2 emissions of high income countries is the highest among the four income groups, their average income elasticity (0.041) (Table 14) is at the lowest, indicating their successful reduction of CO2 emission per capita. In contrast, the average income elasticity of low income group was by far the largest (0.675).

24 China's carbon dioxide emissions in 2010 rose to 8287 million tons which far exceeded second ranking United States (ADB, 2014: 114). World Four biggest emitters of CO2 were China (8287 metric tons), United States(5433), India(2009), Japan(1171) as of 2010. ADB (2013): 150.

25 Singapore is the only country that reduced CO2 emissions by nearly 85% largely because of policy interventions in phasing down higher-polluting fuels (ADB 2014: 113). Actually Singapore has dramatically expanded the role of natural gas as a lower-emission alternative to previous fuel sources, and has also made major investments in in utilizing smart grids.

26 There has been a small tendency for emissions in the energy sector to decrease, but still substantial emissions generated from the expansion of the coal seam gas industry in Australia. (Milman, 2013).

27 Kuznets presented evidence for his hypothesis from the United Kingdom, the United States and some other developed economies during the late nineteenth and first half of the twentieth century when these economies demonstrated the downward part of the inverted *U*-curve (Magnani, 2000). Though the later test of Kuznets inverse-*U* for developing countries by Ahluwalia (1976) supported the hypothesis by using cross-

sectional data, subsequent rigorous econometric testing by Anand and Kanbur (1993) did not support the inverse-*U* in cross-country data.

28 Criteria of income range of four income groups: 1990–2000–2010

Income classification	*1990*	*2000*	*2010*
Low-income (LIC)	$610 or less	$755 or less	$1,005 or less
Lower Middle-Income (LMC)	$610–$2,465	$756–$2,995	$1,006–$3,975
Upper Middle-income (UMC)	$2,466–$7,619	$2,996–$9,265	$3,976–$12,275
High-income (HIC)	$7,620 or more	$9,266 or more	$12,276 or more

Source: World Bank. World Development Report (1992, 2002, 2012a)

References

Angel DP and Rock MT (2001) *Policy Integration: Environment and Development in Asia*. The Bureau for Economic Growth, Agriculture and Trade, The United States Asia Environmental Partnership. Mar, https://rmportal.net/library/content/tools/environmental-policy-and-institutional-strengthening-epiq-iqc/epiq-environmental-policy-and-institutional-strengthening-cd-vol-1/epiq-cd-1-technical-area-environmental-financing/policy-integration-environment-and-development-in-asia/view?searchterm=energy%2520needs (accessed 10 April 2015).

Ahluwalia M (1976) Income distribution and development: Some stylized facts. *American Economic Review*; **66** (2): 128–135.

Anand S and Kanbur R (1993) Inequality and development: A critique. *Journal of Development Economics*; **41** (1): 19–43.

Asian Development Bank (ADB). (2012a) *Key Indicators for Asia and the Pacific 2012*, 43th EditionSpecial Chapter Green Urbanization in Asia, Asian Development Bank: Manila, Philippines.

Asian Development Bank (ADB). (2012b) *Asian Development Outlook 2012*. Asian Development Bank: Manila, Philippines.

Asian Development Bank (ADB). (2013) *Key Indicators for Asia and the Pacific 2013*, 44th EditionSpecial Chapter, Asia's Economic Transformation: Where to, How, and How Fast? Asian Development Bank: Manila, Philippines.

Asian Development Bank (ADB). (2014) *Key Indicators for Asia and the Pacific 2014*, 45th EditionSpecial Chapter, Poverty in Asia: A Deeper Look Asian Development Bank: Manila, Philippines.

Asian Development Bank (ADB). (2014) ADO *Asian Development Outlook 2014*. Asian Development Bank: Manila, Philippines.

Aslanidis N (2009) "Environmental Kuznets Curves for Carbon Emissions: A Critical Survey", *Nota Di Lavoro, 75 2009*, Fondazione Eni Enrico Mattei, https://core.ac.uk/download/pdf/6300531.pdf (accessed 8 July 2016).

Barro RJ (2008) Inequality and Growth Revisited. ADB Working Paper Series on Regional Economic Integration No.11, Asian Development Bank, January. https://aric.adb.org/pdf/workingpaper/WP11%20Inequality and Growth_Revisited.pdf (accessed 8 December 2016).

Cao J (2010) Reconciling economic growth and carbon mitigation: Challenges and policy options in China. *Asian Economic Policy Review*; **5** (1)June 110–129.

Chen S and Santos-Paulino AU (2013) Energy consumption and carbon emission based industrial productivity in China: A sustainable development analysis. *Review of Development Economics*; **17** (4): 644–661.

Cole MA, Rayner AJ and Bates JM (1997) The environmental kuznets curve: An empirical analysis. *Environmental and Development Economics*; **2** (4)November 401–416.

Cornia GA, Addison T and Kiiski S (2003) Income Distribution Changes and Their Impact in the Post-World War II period. WIDER Discussion Papers//World Institute for Development Economics (UNU-WIDER) No.2003/28, March, http://hdl.handle.net/10419/52822.

Dabla-Norris E, Kochhar K, Suphaphiphat N, Ricka F and Tsounta E (2015) *Causes and Consequences of Income Inequality: A Global Perspective*. IMF Staff Discussion Note, Strategy, Policy, and Review Dept. June, IMF, Washington D. C. www.imf.org/external/pubs/ft/sdn/2015/sdn1513.pdf (accessed 5 April 2016).

De Bruyn SM, van den Bergh J.C.J.M. and Opschoor JB (1998) Economic growth and emissions: Reconsidering the empirical basis of environmental kuznets curves. *Ecological Economics*; **25** (2): 161–175.

Deolalikar AB (2002) *Poverty, Growth, and Inequality in Thailand*. ERD Working Paper Series No.8, Economics and Research Department, Asian Development Bank, Manila, Philippines, April.

Friedl B and Getzner M (2003) Determinants of CO2 emissions in a small open economy. *Ecological Economics*; **45** (1): 133–148.

Galeotti M, Manera M and Lanza A (2008) "On the Robustness of Robustness checks of the Environmental Kuznets Curve". *Working Paper no.11*, Istituto di Economia e Politica dell'Energia e dell'Ambiente, IEFE, Universita Commerciale Luigi Bocconi, 27 May, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1137584 (accessed 15 May 2016).

Grossman GM and Krueger AB (1991) "Environment impacts of a North American Free Trade Agreement", Working Paper No.3914, National Bureau of Economic Research, Cambridge, MA, pp.1–39.

Grossman GM and Krueger AB (1995) Economic growth and the environment. *The Quarterly Journal of Economics*; **110** (2): 353–377.

Hill RJ and Magnani E (2002) An exploration of the conceptual and empirical basis of the environmental kuznets curve. *Australian Economic Papers*; **41** (2): 239–254.

Holtz-Eakin D and Selden TM (1995) Stoking and fires? CO2 emissions and economic growth. *Journal of Public Economics*; **57** (1): 85–101.

IMF. (2007) Globalization and Inequality*World Economic Outlook*. IMF: Washington DC, pp 31–65.

Kuznets S (1955) Economic growth and income inequality. *American Economic Review*; **45** (1): 1–28.

Lantz V and Feng Q (2006) Assessing income, population and technology impacts on CO2 emissions in Canada: Where's the EKC? *Ecological Economics*; **57** (2): 229–238.

Lies E and Reklev S (2014) *Japan Slashes CO2 Emissions Targets At UN Climate Talks, Prompting Criticism*. *Huffington post*, 23 Jan, http://www.huffingtonpost.com/2013/11/15/japan-co2-emissions-targets_n_4280593.html (accessed 3 July 2016).

Lipford JW and Yandle B (2010) Environmental kuznets curves, carbon emissions and public choice. *Environment and Development Economics*; **15** (4): 417–438.

List JA and Gallet CA (1999) The environmental kuznets curve: Does one size fit all? *Ecological Economics*; **31** (3): 409–424.

Low Carbon Singapore. (2009) *Singapore's Carbon Dioxide Emissions Per Capita and Carbon Intensity*. 14 May, http://www.lowcarbonsg.com/2009/05/14/singapores-carbon-dioxide-emissions-per-capita-and-carbon-intensity/ (accessed 3 August 2016).

Magnani E (2000) The environmental kuznets curve, environmental protection and income Distribution. *Ecological Economics*; **32** (3): 431–443.

Martinez-Zarzoso I and Bengochea-Morancho A,((2004) Pooled mean group estimation for an environmental kuznets curve for CO2. *Economic Letters*; **82** (1): 121–126.

McCurry J (2015) "Can Japan's climate policy get back on track after Fukushima? *The guardian*, 17 April, https://www.theguardian.com/environment/2015/apr/17/can-japans-climate-policy-get-back-on-track-after-fukushima (accessed 13 September 2016).

Milman O (2013) "Australia worst carbon emitter per capita among major western nations". *The Guardian*, 19 November, https://www.theguardian.com/environment/2013/nov/19/australia-worst-carbon-emitter-per-capita-among-major-western-nations (accessed 3 November 2016).

Ministry of the Environment. (2014) *Japan's Climate Change Policy*. Japan's Ministry of the Environment, 18 March, http://www.reuters.com (accessed 10 October 2016).

Nielson L *Australia's greenhouse gas emissions*, Economics Section, Parliament of Australia, http://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/BriefingBook43pemissioncontrol (accessed 15 January 2016).

Ohtake F, Kohara M, Okuyama N and Yamada K (2013) *GINI Growing Inequalities' Impacts—Growing Inequalities and Their Impacts in Japan*. Country Report for Japan, April, http://gini-research.org/system/uploads/449/original/Japan.pdf?1370090592 (accessed 10 December 2016).

Ortiz I and Cummins M (2011) *Global Inequality: Beyond the Bottom Billion—A Rapid Review of Income Distribution in 141 Countries*. Social and Economic Policy Working Paper, UNICEF POLICY AND PRACTICE. April, UNICEF, New York https://www.unicef.org/socialpolicy/files/Global_Inequality.pdf (accessed 15 December 2016).

Ota T (2000) "Empirical study: Transformation of political regime and economic growth in Asia", (original Japanese title "Kensho: Ajia no seijitaisei no henka to keizaiseicho") *Keiei Kenkyusho Ronshu (Management Research Institute Papers), Vol.23*. Department of Management, Toyo University: Tokyo, Japan, pp 109–144.

Ota T (2002) "Industrial policy and economic development in Asia" (original Japanese title "Ajia Keizai Hatten niokeru Sangyo Seisaku no Tenkai"*Keiei Ronshu (Management Review), Vol.56*. Department of Management, Toyo University: Tokyo, Japan, pp 95–106.

Ota T (2003a) "Development of Political Regime and Economic Growth" (Part I) (original Japanese title "Ajia no Seiji Seido to Keizai Hatten") *Keiei Ronshu (Management Review), Vol.58*. Department of Management, Toyo University: Tokyo, Japan, pp 145–158.

Ota T (2003b) "Development of Political Regime and Economic Growth" (Part II), (original Japanese title "Ajia no Seiji Seido to Keizai Hatten") *Keiei Ronshu (Management Review), Vol.59*. Department of Management, Toyo University: Tokyo, Japan, pp 93–100.

Ota T (2003c) *Asian Development Path - The role of Industrial Policy under Changing Political Systems, (original Japanese title "Ajia no Seiji-seido to Sangyou Seisaku no Yakuwari")*. Bunshindo Publishing Co: Tokyo, Japan.
Ota T (2007) Special economic zones in China's economic development as compared with asian export processing zones (chapt.6). In: Shastri RP (ed) *Special Economic Zones - Global and Indian Experiences*. The Icfai University Press: Hyderabad, India, pp 71–105.
Panayotou T- (1997) Demystifying the environmental kuznets curve: Turning a black box into a policy tool. *Environment and Development Economics*; **2** (4): 465–484.
Perman R and Stern DI (2003) Evidence from panel unit root and cointegration tests that the environmental kuznets curve does not exist. *Australian Journal of Agricultural and Resource Economics*; **47** (3)September 325–347.
Piketty T (2013) *Capital in the 21st Century*. Harvard University Press: Cambridge, MA.
Saith A (1983) Development and distribution: A Critique of the Cross-country U-hypothesis *Journal of Development Economics*; **13** (3): 367–382.
Selden TM and Song D (1994) Environmental quality and development: Is there a Kuznets curve for air pollution? *Journal of Environmental Economics and Environmental Management*; **27** (2): 147–162.
Shafik N (1994) Economic development and environmental quality: An econometric analysis. *Oxford Economic Papers*; **46**, Oct. Special Issue on Environmental Economics, 757–773.
Shafik N and Bandyopadhyay S (1992) *Economic growth and Environmental Quality:Time Series and Cross- Country Evidence*. Background Paper for the World Development Report 1992, The World Bank.
Stern DI (2003) The rise and fall of the environmental kuznets curve. *World Development*; **32** (8): 1419–1439.
Taiwan National Development Council. (2015) *2015 Taiwan Statistical Data Book*. National Development Council: Taipei, R.O.C.
Torras M and Boyce JK (1998) Income, inequality, and pollution: A reassessment of the environmental kuznets curve. *Ecological Economics*; **25** (2): 147–160.
Tucker M (1995) Carbon dioxide emissions and global GDP. *Ecological Economics*; **15** (3): 215–223.
UNDP. (2013a) Cooperation with Middle Income Countries Concept Note. United Nations Programme for Development, *Human Development Report 2013*. The Rise of the South, http://effectivecooperation.org/wordpress/wp-content/uploads/2013/10/MICconceptnotev23sept.pdf (accessed 15 October 2016).
UNDP. (2013b) *Humanity Divided: Confronting Inequality in Developing Countries, Bureau for Development Policy, United Nations Development Programme*. November, UN: New York.
US Environment Protection Agency. *Global Greenhouse Gas Emissions Data*, https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data (accessed 10 December 2016).
World Bank. (1992) *World Development Report 1992: Development and the Environment*. Oxford University Press: New York.
World Bank. (2002) *World Development Report 2002: Building Institutions for Markets*. Oxford University Press: New York.
World Bank. (2010) *East Asia and Pacific Economic Update 2010. vol.2*. World Bank: Washington DC.
World Bank. (2012a) *World Development Report 2012: Gender Equality and Development*. Oxford University Press: New York.
World Bank. (2012b) *2012 World Development Indicators*. World Bank: Washington DC.
World Bank. (2014a) *World Development Indicators*, http://data.worldbank.org/data-catalog/world-development-indicators. (accessed 28 September 2014).
World Bank. (2014b) *World Development Report –Risk and Opportunity; Managing Risk for Development*. The World Bank: Washington DC.
World Factbook. https://www.cia.gov/library/publications/the-world-factbook/rankorder/2172rank.html (accessed 28 May 2016).
Yandle B, Madhusudan Bhattarai M and Maya Vijayaraghavan M (2004) Environmental Kuznets Curves: A review of findings, methods, and policy implications. *Research Study*; **2**, 1–16.

Data availability

All datasets analysed in this study are included in the article.

Additional information

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