



Research article

Production-based and consumption-based approaches for the energy-growth-environment nexus: Evidence from Asian countries

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ABSTRACT

The number of studies that highlight demand-side and supply-side of environmental degradation are quite limited in the literature. The aim of this study is to analyze the energy-growth-environment nexus in cooperation with globalization, urbanization, life expectancy and biocapacity as control variables by using both consumption-based and production-based approaches in an Environmental Kuznets Curve (EKC) framework for Asian countries over the years of 1971–2014. The empirical results show that globalization improves environmental quality while urbanization, life expectancy, biocapacity and energy consumption increase environmental degradation. While the EKC hypothesis is validated for supply-side analysis, it is not validated for demand-side analysis for the panel of Asian countries. The governments should take initiatives to invest in research and development for the usage, promotion, development and adoption of clean energies. The policymakers should emphasize on the development of urban planning strategies of Asian countries to overcome the negative effects of urbanization on the environment. Further implications are discussed in the study.

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List of abbreviations

BC	biological capacity
EC	energy consumption
EF	ecological footprint
EF_C	ecological footprint from consumption
EF_P	ecological footprint from production
EKC	Environmental Kuznets Curve
GDP	gross domestic product
GI	globalization index
LE	life expectancy
MENA	Middle East and Northern Africa
URB	Urbanization

1. Introduction

The linkages between economic growth and environmental degradation have been under scrutiny by many studies in the literature. Their roots mainly rely on the Environmental Kuznets Curve (EKC) hypothesis, which links the economic development to

the environment. This relationship is found to be an inverted U-shaped or a U-shaped depending on characteristics of an economy. An inverted U-shape suggests that environmental degradation increases as income per capita increase, but this relationship is inverted as economies grow and technologies to build cleaner energy sources are established (Stern, 2004; Kasman and Duman, 2015; Shahbaz and Sinha, 2019). An N-shaped relationship, on the other hand, refers to the case where environmental degradation escalates after a specific income level threshold (Poudel et al., 2009). Despite the existence of a vast number of empirical papers, the findings are conflicting on the existence or non-existence of the EKC, on the shape of the curve, the main hypothesis with an inverted U-shape suggests that economic growth is both the underlying cause and the alleviating factor for environmental degradation (Galeotti et al., 2006). The argument supports the deduction in emission targets suggested by the Kyoto Protocol and the recent Paris Agreement.

Global warming and environmental degradation are considered as among the most crucial problems in the world, so outcomes of the Paris Climate Conference in 2015 and the United Nations in 2017 have called for several policy implications to mitigate environmental problems, rising global temperature and emissions. The literature investigates different kinds of emissions; such as, CO₂ emissions (Ikram et al., 2020; Mendonca et al., 2020), SO₂ (Selden and Song, 1994), NO_x (Janke et al., 2009; Zhang et al., 2018) and

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PM_{2.5} (Ouyang et al., 2019). These papers mostly link economic growth and pollutant relationship in an EKC framework to evaluate the possible relationship in both developed and developing countries. Despite the wide recognition of hazardous pollutants, a comprehensive measure is necessary to assess environmental degradation. These emissions may stand as a weak indicator of environmental degradation since they do not represent the degradation of resources like forests, croplands, and mines, etc. (Ulucak and Apergis, 2018).

Ecological footprint (EF) is a comprehensive measurement of environmental degradation and economic sustainability (Chen et al., 2010), and is put forth by Wackernagel and Rees (1995), which defines it as a measure determining the area of biologically productive land and water required to produce the renewable sources consumed by humans and to absorb human waste. EF provides more transparent evaluations for the policy makers, since it offers a criterion for evaluating ecological impacts of decisions (Wackernagel and Rees, 1995).

This study considers a panel group of Asian countries. These countries represent most rapidly growing economies in the world and parallel to their growth, the majority of these countries emit more carbon emissions compared to the resources they produce. The GDP of these countries showed a tremendous increase over the analyzed period, with an average growth rate of 5.30%, whereas the world average was only 3.13% (WDI, 2020). These high growth rates are followed by an intensive amount of pollution and environmental degradation. The EF per capita of these countries has increased gradually over the past 50 years, while the average per capita biological capacity has been gradually declining. Analysis of EF for Asian countries is of crucial importance since the energy systems in these countries are carbon-intensive and have not yet reached to a point in terms of technological enhancements to promote a sustainable economic development (Menegaki and Tugcu, 2018). These countries are famous for exporting its manufacturing to high-income countries (Liddle, 2018a). China, alone, is responsible for half of the total carbon emissions in the world. Thus, the analysis of the EKC considering both the consumption-based (demand-side) and the production-based (supply-side) of EF will provide significant outcomes.

In light of the above discussions and considerations, the fundamental aim of this study is to analyze the energy-growth-environment nexus by using both consumption-based and production-based approaches in a strong and widely adopted EKC theory for a panel of Asian countries for the period between 1971 and 2014. There are several contributions of the current study to the existing literature. First, this study is a first attempt in the literature to analyze the energy-growth-environment nexus in the EKC model using both demand-and-supply sides of environmental pollution. The literature mostly attributes the industrial production side of the economy as being liable for the distortion of the environment but the existence of a possible pollution havens it is necessary to allocate the distortion with the consumption side of the economy (Rothman, 1998; Bagliani et al., 2008). The production-side approach deals with the environmental damage related to the production processes, while consumption-side approach related the environmental degradation to the consumption behavior of individuals. Second, this study uses a comprehensive proxy for the environment (ecological footprint) rather than a single indicator such as CO₂ emissions. Third, this study uses a set of control variables, urbanization, globalization, life expectancy and biocapacity, in the modeling the energy-growth-environment nexus. Fourth, the empirical analysis takes into account possible existence of cross-sectional dependence for analyzed dataset and thus apply second-generation econometric methods.

The remainder of the paper is as follows: Section 2 presents a brief literature review, Section 3 specifies the methodology and the

data, and shows empirical results, finally Section 4 presents conclusions and policy implications.

2. Literature review

Energy, economic growth and environment relationship is a highly investigated phenomenon in the literature. Especially, EKC hypothesis, that links the environmental degradation with the phase of economic growth (Grossman and Krueger, 1991), attracted much attention in the literature. EKC hypothesis states that at the earliest stage of economic development a country faces environmental deterioration and as the level of development increases deterioration slows down and even improves, leading to an inverted-U shape (Shahbaz and Sinha, 2019). The use of proxies used for environmental degradation and the applied methodologies vary, thus the outcomes of the EKC analysis diverge. Many papers note the existence of the EKC hypothesis in Asian countries. Guangyue and Deyong (2011) analyze carbon emissions by using provincial level data for 1990–2007 period and their findings favor the EKC Hypothesis in eastern region and the central region of China. Jalil and Feridun (2011) also support the existence of the EKC hypothesis in their paper, in which they considered the lessening impact of financial development on environmental pollution as well. Shahbaz et al. (2013) for Malaysia also verify the EKC. They note a feedback relationship between CO₂ emissions, energy consumption, economic growth and financial development. The EKC hypothesis is verified for China and India for 1965–2013 period in the work of Solarin et al. (2017) and a long-run relationship between CO₂ consumption, hydroelectricity consumption, urbanization and the GDP. Rahman et al. (2020) examine the EKC hypothesis in Bangladesh, China, India, Myanmar and they report the validity of the EKC in India and China when they consider structural breaks. Some papers cannot find evidence of the EKC in Asian countries. Du et al. (2012) investigate the CO₂ emissions in provinces of China and note that economic development, technological progress and industry structure as significant factors affecting emissions. They further assert that their results do not support an inverted U-shape between emissions and economic development. Chandran and Tang (2013) assess the impact of transportation industry on energy consumption, foreign direct investments and CO₂ emissions and they fail to find evidence of the EKC Hypothesis. Solarin and Lean (2016) analyze the natural gas consumption, income and urbanization on carbon emissions in China and India. A support for the EKC is not found in both of the countries. The analyzed period, the methodology applied and the use of different control variables stand as the reasons for conflicting results.

A limited amount of literature considers EF as a measure of environmental degradation in EKC framework (Al-Mulali et al., 2015; Acar and Aşici, 2016; Ulucak and Bilgili, 2018). EF stands as one of the most efficient indicator to evaluate sustainable development and it has attracted much attention of the academics and policy makers. It is an aggregate measure of environmental quality that is structured to evaluate the environment by treating the factors as the inputs and outputs (Haberl et al., 2001; Nijkamp et al., 2004; Solarin and Bello, 2018). Six factors are considered in EF calculation; forestland, carbon footprint, fishing grounds, cropland, grazing land, and built-up land (W. Lin et al., 2018). Recent environmental problems arouse since the consumption exceeds the reproduction capacity of the natural resources and the supply-demand mismatch creates the environmental distortion (Ewing et al., 2010; Galli et al., 2012). EF is not only an indicator of the total consumption of resources (Costanza, 2000) but also stands as a proxy to indicate the distribution resource use and calculate sustainability referring to Borucke et al. (2013). Many empirical papers consider ecological footprint as a way of representing pollution and environ-

mental sustainability (Ozcan et al., 2019). Dogan et al. (2020) consider EF in their EKC analysis for BRICST countries and they do not find evidence of EKC hypothesis. Rather they note the significance of energy intensity and energy structure as elements of environmental degradation. Bilgili and Ulucak (2018) investigate the convergence of environmental degradation in G20 countries, by proxying EF as the best indicator of degradation, they point to environmental convergence across G20 countries. Solarin et al. (2018) and Solarin et al. (2019) prove that EF display non-stationarity in 96 countries, thus it stands as a robust indicator for environmental degradation and policy outcomes on EF will provide long-term results.

Urbanization is considered as a significant factor in determining environmental degradation. Industrial production processes are undertaken in urban areas and consumption levels of natural resources are elevated in those areas. Thus, urbanization is associated with the consumption of bio-productive factors in production (Munksgaard et al., 2000) and represents the shift of population from their towns to industrialized cities and stands for industrialization from agriculture. This process results in increases in economic output and often causes environmental distortions like an increase of emissions, pollution, deforestation, etc. (Liddle and Lung 2010; Kasman and Duman, 2015). Still, a few papers note that the demands of the residents may require the green practices to increase, so urbanization can mitigate environmental degradation Chikarashi et al. (2015).

Globalization is additionally regarded as a triggering factor intensifying the impact of sectors that rely on non-renewable energy and produce pollutants especially in emerging economies in which environmental regulations are not strictly determined (Copeland and Taylor, 2004). Globalization has an immense effect on the environment (Borghesi and Vercelli, 2003), but the adverse impacts on the environment can be eliminated, even enhanced with strict policy interventions (Stern, 2004). Moreover, Liddle (2015) suggests that the country will shift towards cleaner technologies in the generation processes of products and services if the constraints on foreign investments are diminished. On the other hand, Figge and Martens (2014) assert that increased level of globalization may not always result in better EF and a more globalized country may put large pressures on the ecosystem either in its own country or elsewhere. Sabir and Gorus (2019) focus on the impacts of globalization on EF in South Asian countries for the period between 1975 and 2017 and report that FDI, trade openness and KOF index enhance EF.

The literature focusing on EF investigates biological capacity/bioproductivity as a determining factor, too. Borucke et al. (2013) define biological capacity as the area of biologically productive land and sea, which will influence ecological footprint and environmental sustainability. Many countries in the world have biological capacity deficits, suggesting that they are not environmentally sustainable given their biological capacity and their limited regenerative capacity (Aşici and Acar, 2015). EF and biological capacity gap diminish the productive capacity of the world and result in the change in climate, food shortage, and loss of biodiversity (Rashid et al., 2018). Last, some recent papers in the literature investigate the life expectancy as a significant factor in explaining environmental degradation. Mariani et al. (2010) note that in countries where life expectancy is higher the willingness to care for the environment increases. Charfeddine and Mrabet (2017) point to the significant impact of life expectancy in an EKC framework using EF as an indicator in 15 MENA countries. Hervieux and Darne (2016) report a diminishing impact of life expectancy on EF for some emerging economies.

The number of studies that marks the consumption-based and production-based approach is very scarce; both approaches contemplate almost the same environmental data but production-

based approach allocates the environmental influence on each economy based on the location of the sources, whereas the consumption-based approach considers the consumer responsibility (Proops et al., 1999; Bastianoni et al., 2004; Mikayilov et al., 2020). One strand of literature studies the EKC hypothesis from a consumption-based approach. Ekins (1997) stress that change in consumption patterns may not necessarily affect the green structural composition of the economy whilst the economic growth increases. The rise in the demand for environmental quality may not change the consumption patterns but may lead the production outside of the country rather than shifting to cleaner production processes. Rothman (1998) favors the consumption-based indicators and examines EF to the real income per capita relationship for 52 countries. The results fail to report evidence of an inverted U-shape. Some papers fail to find an EKC type relationship between EF and growth (York et al., 2004; Bagliani et al., 2008; Caviglia-Harris et al., 2009). Al-Mulali et al. (2015) accept the validity of EKC only under the condition that renewable energy technologies are existent. Hervieux and Darne (2016) note a positive impact of energy use on ecological footprint for Colombia and Argentina whereas biological capacity has a positive and life expectancy have a negative impact. Ahmed and Wang (2019) investigate the influence of human capital on EF in India and report a negative contribution of it, concluding that improvement of human capital might enhance EF. On the other hand, another strand of literature considers the EKC hypothesis from a production-side. Aşici and Acar (2016) investigate the production-based component of EF and income relationship for a panel of 116 countries and report evidence of EKC for most of the countries in the sample. Uddin et al. (2017) investigate EF and real income relationship in 27 highest emitting countries and they report the existence of a long-run relationship. Hervieux and Darne (2016) provides inconclusive results for the sample applying the EKC hypothesis, such that the production-side approach reveals a positive effect of ecological footprint for Sweden and an opposite effect for Spain and Portugal. The study also reports a diminishing impact of openness and financialization on the footprint. Wang and Dong (2019) report a positive impact of economic growth for a panel of Sub-Saharan countries. Bello et al. (2018) validate the EKC hypothesis for Malaysia considering the 1971–2016 period using STIRPAT model and report a feedback hypothesis between real GDP and all degradation indices. Moreover, they note the insignificant impact of urbanization on environmental degradation. Finally, Acar and Aşici (2017) adopts cointegration techniques for the 1961 and 2008 period for Turkey and note an inverted U-shape when production-side of EF is used.

3. Methods and results

3.1. Model specification and data

To accomplish the aim of this study, following Figge and Martens (2014), Hervieux and Darne (2016), and Dogan et al. (2020), and considering the detailed discussion in the preceding section, this study builds on the EKC model for consumption-based and production-based approaches:

$$\ln EF_{-C_{it}} = \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{it}^2 + \beta_3 \ln EC_{it} + \epsilon_{it} \quad (1)$$

$$\ln EF_{-C_{it}} = \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{it}^2 + \beta_3 \ln EC_{it} + \beta_4 \ln BC_{it} + \beta_5 \ln LE_{it} + \epsilon_{it} \quad (2)$$

$$\ln EF_{-P_{it}} = \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{it}^2 + \beta_3 \ln EC_{it} + \epsilon_{it} \quad (3)$$

Table 1
Descriptive Statistics.

	EF_C	EF_P	BC	Y	LE	EC	URB	GI	EF_Ratio
Mean	2.030	1.790	1.058	6303.235	66.302	1066.864	41.415	47.726	1.106
Median	1.263	1.270	0.704	1606.436	67.112	487.178	33.081	46.750	1.062
Maximum	6.208	5.023	4.978	46,249.210	83.332	5248.520	92.104	80.700	1.803
Minimum	0.459	0.409	0.247	161.735	41.457	86.765	4.005	15.300	0.554
Std. Dev.	1.567	1.212	0.862	10,249.900	8.474	1116.493	24.069	15.981	0.198
Observations	660	660	660	660	660	658	660	660	660

$$\ln EF_{P_{it}} = \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{it}^2 + \beta_3 \ln EC_{it} + \beta_4 \ln URB_{it} + \beta_5 \ln GI_{it} + \epsilon_{it} \quad (4)$$

where EF_C is ecological footprint from consumption, EF_P is ecological footprint from production, Y is per capita gross domestic product, Y^2 is the square of per capita gross domestic product, EC is energy consumption, BC is biological capacity, LE is life expectancy, URB is urbanization and GI is globalization index and, i represent countries, t indicates time period. Last, β_i are the coefficient estimates, and ϵ is the residuals.

The distinction between consumption-side and production-side is trade:

$$EF_{P_{it}} = EF_{C_{it}} + EF \text{ of Exports}_{it} - EF \text{ of Imports}_{it}$$

Regarding the dataset, ecological footprint of consumption is measured as gha per person, ecological footprint of production is measured as gha per person, the GDP per capita is gross domestic per capita in constant 2010US\$, biological capacity is calculated gha per person, life expectancy at birth is in total years, and energy use (kg of oil equivalent per capita), urban population is the share of urban population to total population, and globalization index. The data for ecological footprint of consumption, ecological footprint of production and biological capacity are collected from the Global Footprint Network. The data of GDP per capita, urbanization and life expectancy are borrowed from the World Development Indicators. In addition, the KOF index of globalization, consisting of economic, political, and social globalization, is taken from KOF Swiss economic institute (Dreher 2006; Gygli et al., 2019) to measure globalization. The Asian countries are Bangladesh, China, India, Indonesia, Israel, Japan, Malaysia, Myanmar, Nepal, Pakistan, Philippines, South Korea, Sri Lanka, Thailand and Turkey. The data period is 1971–2014. The sample of countries and time period are selected based on the data availability.

3.2. Methods and empirical results

We start with presenting information related to the dataset. Table 1 presents the detailed information related to the dataset for a panel of Asian countries for the years of 1971–2014. The mean value of ecological footprint of consumption is 2.02 gha per person while mean value of ecological footprint of production is 1.78 gha per person. The standard deviation is also high for ecological footprint consumption as compared to ecological footprint of production. The mean value of biological capacity is 1.06 gha per person with a standard deviation 0.86. The maximum value of biocapacity is 4.97 gha per person, which is less than maximum value of ecological footprint of consumption (6.20 gha per person) and production (5.20 gha per person), indicating ecological deficit in the sample countries. The mean value of real income is US\$6303.24 with minimum and maximum values are US\$161.74 and US\$46,249.21, respectively, and have high standard deviation among the group of countries.

The mean value of life expectancy is 66.30 years while the lowest value and highest values are 41.45 years and 83.33 years, respectively. The mean of energy consumption is 1066.86 (kg of oil equivalent per capita) with standard deviation 1116.49 indicating

Table 2
Results from CD-test and panel unit root tests.

	CD-test	CIPS Level	Difference	CADF Level	Difference
LEF_C	44.417***	-1.205	-6.013***	-2.253**	-3.391***
LEF_P	29.716***	-1.822	-5.946***	-2.06	-3.461***
LY	63.171***	-1.336	-4.499***	-1.151	-2.757***
LY ²	63.2***	-1.137	-4.370***	-0.971	-2.662***
LBC	31.108***	-2.084	-6.018***	-2.092	-3.927***
LEC	66.634***	-1.226	-5.477***	-1.083	-2.833***
LLE	50.981***	-2.222*	-2.814***	-1.877	-2.223**
LURB	56.047***	-1.634	-1.589	-2.278**	-2.152*
LGI	65.135***	-2.084	-5.588***	-1.921	-3.728

*** statistical significance at 1 percent, ** statistical significance at 5 percent, * statistical significance at 10 percent.

Table 3
Results from Westerlund (2007) cointegration test.

Statistic	Consumption-based approach			Production-based approach		
	Value	Z-value	P-value	Value	Z-value	P-value
Ga	-3.362	-4.431	0.00	-2.58	-2.263	0.00
Gt	-10.619	0.557	0.14	-5.851	2.194	0.68
Pa	-10.198	-2.382	0.02	-7.695	-1.131	0.06
Pt	-10.439	-1.172	0.04	-3.642	1.309	0.68

high dispersion or variation of energy consumption among Asian countries. The minimum and maximum levels of urbanization are 4 percent and 92 percent, respectively, with a mean of 33 percent and a standard deviation of 24.06, indicating huge variation of urbanization level among sample countries. The mean value of globalization index is 46.75 with a maximum value of 80.70 and a minimum of 15.30. Interestingly, the EF_ratio indicates the ratio of ecological footprint of consumption to ecological footprint of production. The mean value is 1.11 gha per person is greater than one, which basically implies that the panel of Asian countries are importers of environmental pollution (Liddle, 2018a).

First of all, the cross sectional (CD) test proposed by Pesaran (2004) has been used in the study to show possible dependence among the variables across Asian countries: ecological footprint of production, ecological footprint of consumption, biological capacity, energy use, life expectancy, urbanization and globalization index. Table 2 presents the outcome of Pesaran's CD-test. The result indicates that the null hypothesis of cross-sectional independence is rejected for all the dataset. Since, the CD-test indicates the existence of cross-sectional dependence in the panel data series, we should use the CIPS and the CADF panel unit root tests, which are robust to cross-sectional dependence, to investigate stationarity properties of the analyzed data. The result indicates that all analyzed data end up stationary at first differences and the results are statistically significant. Since we are sure that all series are integrated of order one and there exist cross-sectional dependence in panel data series, we apply bootstrap Westerlund (2007) cointegration technique to investigate possible cointegration among the variables. As shown in Table 3, the analyzed variables have a long-run relationship for both demand-side and supply-side.

Table 4
Results from long-run estimates from consumption-based approach.

Variables	Model I			Model II		
	SUR	OLS with robust error	DOLS	SUR	OLS with robust error	DOLS
LY	0.06	0.06**	−0.09	−0.15***	−0.15***	−0.22
LY ²	0.01***	0.01***	0.02	0.02***	0.02***	0.03**
LEC	0.52***	0.52***	0.48***	0.44***	0.44***	0.44***
LBC	—	—	—	0.14***	0.14***	0.12
LLE	—	—	—	0.13**	0.13	0.20
Constant	−3.72***	−3.73***	—	−3.08***	−3.08***	—
F-stat	—	3426.24***	—	—	17,366.27***	—
Chi-square	12,572.62***, —	364.16***	17,139.70*** —	458.22***	—	—

*** statistical significance at 1 percent, ** statistical significance at 5 percent, * statistical significance at 10 percent.

The results of long-run estimates using two models and three methods for demand-side (consumption-based) analysis are given in Table 4. The result found shows positive coefficients of the income and the square of income, which indicates a monotonically rising relationship when the base Model-I is evaluated. In addition, the results of long-run estimators indicate that coefficients of income and square of income is negative and positive, respectively, which indicates a U-shaped nexus between ecological footprint of consumption and economic growth in Asia referring to the advanced Model-II. Both models similarly imply that after the threshold level ecological footprint of consumption is increasing with the increase in economic growth, showing the non-existence of the EKC hypothesis. The finding is in line with Destek and Sarkodie (2019), which finds a U-shaped relation for some Asian countries (India, China, Thailand and Turkey) while using ecological footprint as the dependent variable. While comparing the base and the advanced models of demand-side analysis, Model-I indicates monotonically rising relationship between EF_C and economic growth and Model-II reveals a U-shaped relationship between EF of consumption and growth. However, the turning point for the U-shaped is around US\$40–70 for the panel of Asian countries which is less than the minimum value of income, US\$ 161 as shown in Table 1, which overall indicates that all countries are on the upward portion of the U-shaped curve. Therefore, as far as consumption-based approach is concerned, Asian countries have rising ecological footprint with rising income.

The coefficient value of energy consumption is statistically significant and positive ranging from 0.44 to 0.52 across econometric methods and models. This output states that ecological footprint of consumption increases with rising EC. The result of biocapacity is positive and significant from the SUR and the OLS with robust error and positive but insignificant from the DOLS method of estimation. The positive coefficient value of BC means that population care less about environment if the environment ends up with more resources. Hervieux and Darne (2016) argues that people with relatively scarce resources use and treat the environment nicer than those with relatively abundant resources when two group of people are given the same level of income. In this study, inhabitant in sample countries are insensitive towards rising pressure of EF, even though they have ecological deficit, may be because they have not been able to meet the basic needs of their population and they are focusing on growth variables. As stated in Bagliani et al. (2008), the surplus income can be used for taking care of environmental resources when simple needs such as food, water and health are met. The sample countries are so much busy in productive activities that they do not care for environment. Regarding the other control variable, life expectancy has a positive and significant coefficient through the SUR model but positive and insignificant coefficient from the other two methods. Similarly, the coefficient of LE indicates that a higher life expectancy increases the burden on environment leading higher level of ecological footprint of consumption. Thus, the life expectancy is deteriorating ecological footprint

of consumption. The worsening EF with rising life expectancy indicates that though quality of life is improving but lack of awareness of environmental issues among inhabitants is prevalent.

The result of long-run estimates using two models and three approaches is given for the supply-side analysis in Table 5. The results from the base Model-III and the advanced Model-IV show a positive coefficient of income and a negative coefficient of the square of income using the three econometric methods. This output yields an inverted U-shaped nexus between economic growth and the environment, and thus the existence of the EKC hypothesis. The main outcome is consistent with Acar and Aşici (2015), Mrabet and Alsamara (2017), Charfeddine and Mrabet (2017), and Ulucak and Bilgili (2018). The EKC holds for ecological footprint of production, may be because of the better enforcement of environmental regulations and technological innovations through research and developments in production process Stern (2003). Supply-side analysis indicates an inverted U-shaped nexus between EF of production and income for both the base and the advanced models. Consumption-based ecological footprint consists of ecological footprint from domestic production plus ecological footprint from imports minus exports, thus avoiding a pollution haven bias prevalent in production-based footprint analysis.

If the consumption-to-production emissions ratio is greater than one, then a country effectively imports carbon emissions (Liddle, 2018b). Considering the panel of Asian economies, most of the countries' ratio is higher than 1, indicating that in majority countries ecological footprint from consumption is more than ecological footprint from what that they produce at home. The production-based analysis confirms the EKC hypothesis, reflecting that sample countries are moving towards environment friendly domestic production process. However, the monotonically rising consumption ecological footprint with ongoing growth reflects that trade among Asian countries is not focused on environment friendly goods. The production-based analysis usually delivers significant advantage to the economies which deploy their pollution to emerging countries and provides incomplete picture (Karakaya et al., 2019). Therefore, demand-side analysis emphasizes the need of proper co-ordination among countries to reduce the negative impact of consumption activities on ecological footprint. Responsibilities for reducing pollution will be larger for developed countries than un-developed economies in case they are distributed with respect to the consumption-based approach. We can claim continuous economic growth as a track to end up less environmental pollution only if countries show the existence of EKC hypothesis between income and EF of consumption (Bagliani et al., 2008).

The coefficient value of energy consumption is 0.64 from the SUR and the OLS, and 0.61 from the DOLS, respectively and significant at one percent level of significance indicating rise in ecological footprint with rising energy use. The results for EC in both demand side analysis and supply side analysis indicates a negative impact of EC on ecological footprint and the results are consistent

Table 5
Results from long-run estimates from production-based approach.

Variables	Model III			Model IV		
	SUR	OLS with robust error	DOLS	SUR	OLS with robust error	DOLS
LY	0.45***	0.45***	0.3	1.04***	1.04***	0.87***
LY ²	−0.03***	−0.03***	−0.01	−0.06***	−0.06***	−0.05***
LEC	0.64***	0.64***	0.61***	0.68***	0.68***	0.65***
LURB	—	—	—	0.11***	0.11***	0.15**
LGI	—	—	—	−0.59***	−0.60***	−0.52***
Constant	−5.65***	−5.65***	—	−6.50***	−6.50***	—
F-stat	—	14,937.05***	—	—	4440.55***	—
Chi-square	5291.87***	—	248.62***	6541.41***	—	359.90***

*** statistical significance at 1 percent, ** statistical significance at 5 percent, * statistical significance at 10 percent.

Table 6
Result of Dumitrescu-Hurlin panel causality for consumption-based approach.

	LEF_C	LY (LY ²)	LBC	LLE	LEC
LEF_C	—	12.61*** (18.16)	3.93*** (3.14)	7.87*** (9.96)	15.53*** (23.20)
LY (LY ²)	8.13*** (10.40)	—	6.99*** (8.44)	15.64*** (23.41)	6.40*** (7.41)
LBC	6.13*** (6.95)	5.57*** (5.98)	—	7.45*** (9.23)	1.84 (−0.46)
LLE	4.55*** (4.21)	4.88** (4.79)	7.30*** (8.97)	—	4.20*** (3.61)
LEC	6.27*** (7.19)	2.13 (0.02)	5.01*** (5.00)	7.06*** (8.56)	—

*** statistical significance at 1 percent, ** statistical significance at 5 percent, * statistical significance at 10 percent.

with Mrabet and Alsamara (2017), and Destek and Sarkodie (2019). For energy consumption, the elasticity from both demand side and supply side analysis are positive and highly significant indicating massive production and consumption of energy intensive products leading to worsening EF. Energy efficiency maybe executed by imposing energy-saving projects, energy conservation regulations and energy infrastructure outsourcing (Haseeb et al., 2018) to decrease pressure on ecological footprint in these sample countries. The government should take the initiative to invest in research and development for the usage, promotion, development and adoption of clean technology.

Urbanization has a positive and significant coefficient implying rising EF of production with rising urban population. The coefficient value of urbanization is 0.11 and significant from both the SUR and the OLS regressions, and 0.15 and significant from the DOLS. The result is in consistent with Charfeddine (2017), implying urbanization deteriorates environment through increased ecological footprint of production. The policy makers should emphasize on development of urban planning strategies of these countries to overcome the negative effects of urbanization on the environment. Also, the government in these countries should emphasize on creating environment friendly urban cities and proper steps should be taken to create awareness among its citizens about worsening environmental issues. Globalization Index used in the study has coefficient value of −0.59 from the SUR technique, −0.60 from the OLS method, and −0.52 from the DOLS. The coefficient of GI is negative and significant at one percent level of significance from all the methods used and indicates that globalization may help in reducing EF of production. Lastly, globalization index is reducing ecological footprint of production in these countries implying that GI may yield a clean environment through composition, scale and income effects (Haseeb et al., 2018). Globalization causes the adoption of environment friendly technology in production process, engagement of countries in international treaties to reduce environmental degradation through political and social pressure, which results in reduction of ecological footprint of production.

Further, Granger non-causality test proposed by Dumitrescu and Hurlin (2012) is employed to test the causal relationship among the variables. The results shown in Table 6 (demand-side analysis) indicates existence two-way relationship between income and EF

of consumption; biocapacity and EF of consumption; energy consumption and EF of consumption; biocapacity and income; biocapacity and life expectancy; economic growth and life expectancy; life expectancy and energy use. Moreover, the findings indicate one-way causation from energy consumption to biological capacity, energy use to economic growth. To conclude from findings, we can say that economic growth, biological capacity, life expectancy and energy consumption causes ecological footprint of consumption. The results of panel causality for supply-side analysis is shown in Table 7. The result indicates two-way causation between EF of production and economic growth; EF of production and urbanization; EF of production and globalization index; EF of production and energy consumption; globalization index and energy consumption; urbanization and income. The finding further indicates one-way causality running from growth to globalization and energy use.

4. Conclusions and policy implications

This study investigates the EKC hypothesis for a panel data of Asian countries using ecological footprint of consumption and ecological footprint of production as proxy of environmental indicator for the period 1971–2014. A basic model and an advanced model with more variables are used for both demand-side and supply-side analysis. We use the cross-sectional dependence test to check the independence of dataset across the panel of Asian economies; the CIPS and the CADF panel unit root test to check for their stationarity; Westerlund cointegration test to check a long-run relationship among variables; SUR, OLS with robust standard errors, and DOLS methods to estimate long-run coefficients; Dumitrescu-Hurlin causality test to analyze the causal relationship among variables.

For Asian countries, we find rising consumption-based ecological footprint with on-going growth in these economies and a decline in production-based ecological footprint after reaching threshold level of growth, reflecting an entirely different environment-income relation depending on how ecological footprints are calculated. The demand-side EF comprises of EF based on domestic production plus EF from imports minus exports, thus, it takes into consideration the burden on ecological footprint caused by trade in these economies. The consumption to

Table 7
Result of Dumitrescu-Hurlin panel causality for production-based approach.

	LEF_P	LY (LY ²)	LURB	LGI	LEC
LE_P	—	9.07*** (12.04)	3.93*** (3.14)	3.82*** (2.95)	14.15*** (20.81)
LY (LY ²)	6.11*** (6.91)	—	5.50*** (5.85)	3.91*** (3.10)	6.40*** (7.41)
LURB	4.77*** (4.60)	3.12** (2.56)	—	6.38*** (7.38)	3.45** (2.32)
LGI	3.53** (2.46)	2.79 (1.18)	6.43*** (7.46)	—	4.04*** (3.33)
LEC	5.81*** (6.39)	2.13 (0.02)	4.44*** (4.02)	5.71*** (6.22)	—

*** statistical significance at 1 percent, ** statistical significance at 5 percent, * statistical significance at 10 percent.

production based ecological footprint ratio of the majority of the Asian countries is greater than one, revealing that these economies are raising the burden on their ecological footprint via trade. The long-run estimates indicate that the EKC hypothesis is confirmed for production-based analysis and not confirmed for consumption-based analysis. Therefore, it cannot be claimed that economic growth alone can provide solution for clean environment and the respective government of Asian countries should emphasize on policies that can guarantee an actual reduction in environmental degradation instead of focusing on growth alone. Comparing the results of demand-side and supply-side analysis, the difference in the relationship between ecological footprint and growth may be attributed to the fact that through various international treaties and agreements these economies are focusing on reducing environmental pressure in domestic production process while completely neglecting the pressure on biological capacity through trade flows. Though the Asian economies are moving towards environment friendly domestic production process, yet the trade among Asian countries is not focused on environment friendly goods. The main policy implication emerging from the findings exhibits that the environmental regulation in countries whose consumption-based EF is greater than production-based EF should be based on demand-side analysis to encourage mitigation strategies based on trade activities (Liddle, 2018a). The finding suggests that these economies should put forward a comprehensive policy to negotiate and cooperate for green trade by minimizing emission-intensive and energy-intensive imports along with reducing ecological footprint through environmentally- efficient domestic production process. A holistic approach to reduce ecological footprint through emphasizing on green domestic consumption is needed.

Our empirical findings further indicate that energy consumption, biological capacity, urbanization and life expectancy are worsening ecological footprint. These economies should put emphasize on switching over to energy-efficient production process, environmentally friendly urban cities and creating awareness among people to inculcate energy-efficient consumption habits among its inhabitants along with improving their quality of life. The need is to emphasis on dual role of minimizing the negative externalities emerging from urbanization, such as environmental pressure due to industrialization, transportation, congestion and maximizing the positive externalities from urbanization such as public provisioning of waste management, environment-friendly transportation and infrastructure, sustainable smart cities and so on. Through workshops, advertisements and awareness programs at public places, government should try to create a nudge among its urban population to shift their consumption habits towards energy-efficient electronic products, saving water, using public transport, using solar energy and using eco-friendly goods. Further, the negative impact of energy consumption on ecological footprint accentuates that energy mix of these economies needs to be altered with more of renewable energy use and less of non-renewable energy use in the production process. The government in these economies should put emphasis on allocating budget towards research & development on energy-efficient technology in industries and renewable energy projects.

Last, we find that globalization, which is a combination of economic, social and political variables, is improving ecological footprint of production. The Asian governments can use this in offsetting the negative impact of economic activities on environment through putting efforts in improving institutional qualities, international commitments and agreements to reduce environmental pressure.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.spc.2020.06.006.

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