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Environmental Kuznets Curve Revisit: Role of Economic Diversity in Environmental Degradation

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Abstract

Background: Unlike the classical view, a new path of economic growth and development among the emerging and developing nations seems to have distinct impact on environment. Customary patterns of production and consumption have undergone significant changes and the new "growth with non-smoke-staks" has put the developing economies on a path that can change Environmental Kuznets Curve (EKC) fundamentally. With this view, the current study attempts to examine how these growth patterns among developing world have impacted the degradation of environment. We argue that including income per capita and share of manufacturing would not capture the full growth dynamic of developing and emerging countries and therefore it masks the real impacts on environmental degradation. To this end, we introduce the Economic Complexity Index (ECI) to the model to reflect the full impacts of new growth approaches on CO2 emission levels by using a panel data analyses of 100 emerging and developing countries over 1963-2018 period.

Results: The results indicate that complexity of the economies of developing and emerging countries has added to the CO2 emission levels in absolute terms but it has helped to reduce the CO2 intensity.

Conclusions: The implications of the findings for developing and developed countries could be quite significant. For advanced economies, a downwardly-shifted Kuznets curve implies that, on one hand, technology transfers have been successful in curbing the environmental degradation of

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developing economies and, on the other hand, the economic transformation strategies of developing world is working in a sustainable way.

Keywords: Economic complexity, Structural change, Environmental Kuznets curve, Environmental degradation

JEL Classification: O10, O25, Q44, Q53

1. Background

Global warming is now considered as one of the biggest challenge that can pose an existential threat to human kind. Environmental issues represented by greenhouse gas emissions nowadays have led to a series of serious ecological problems, such as accumulation of CO2 emissions to an unprecedented level, and sea levels rising. Therefore, not surprisingly ecological treatments and climate change mitigation have taken center stage in the development agenda of both developed and developing countries as well as international organizations. As such, a global effort initiated by UN has been made through the establishment of Sustainable Development Goals (SDGs) to promote renewable and clean energy technologies, sustainable agriculture and food security, and mitigate climate change and its impact. Despite the pledges made, the efforts undertaken, and the funds earmarked, unfortunately, most of the signatory countries to United Nations Framework Convention on Climate Change (UNFCCC) are lagging behind in their obliged targets on climate change.

The growth pattern of courtiers can significantly change the landscape of fighting the climate change that can free up and/or lock in the limited resources that countries have for their adaptation and mitigation strategies. This is especially the case for developing countries who are more in need of extra fund and support to fight the unpredictable consequences of climate change. Climate change as a global commodity requires consolidated and coordinated efforts by both developed and developing countries.

The classical view on industrialization of economics pioneered by Nobel prize laureate, Arthur Lewis, was basically recommending on moving farmers from subsistence farms into factories and commercial farms. This view, however, has undergone considerable changes as the scope for "classic labour-intensive, export-oriented industrialisation" is narrower now. The model now is in between a classic manufacturing and a subsistence farming for many developing countries, labeled as "industries without smoke-stacks". Rodrik (2016) argues that automation, competition and shifting demand are closing the door to countries wanting to copy Asia's miracle. Economic transformation under this model is quite distinct from the Asian model and this has strong implications for green growth and climate change.

The pattern of industrialization has undergone serious changes in nature. The classical pattern of industrialization is not the common practice anymore in the way that the agriculture-manufacturing-services sequence shifted to agriculture-services-manufacturing or for some simply agriculture-services. In other words, many developing countries are jumping over the second stage of industrialization such that service sector constitutes more than 50 percent of the economy with a very thin manufacturing sector. This arguably influences the shape of the classical environmental Kuznets curve[4] (EKC) as manufacturing sector is the main contributor to the environmental degradation compared to other sectors. As service sector is less polluting than manufacturing, it is expected that developing countries experience a different version of the classical inverted U-shape curve.

According to EKC theory there is an inverted U-shaped relationship between environmental degradation and per capita income, simply indicating that at early stages of growth countries will be facing higher environmental degradation, but as the economy grows the intensity of environmental degradation will ease up.

Structural change and economic transformation to service and information-based economic activities which are less emission-intensive than physical production and the growing ecological efficiency of production and consumption by means of a 'greening' technical and technological progress are perceived to be the main channels of reducing the intensity of damages to the environment. On the other hand, product diversification, product complexity and economic complexity are the main driving forces of structural transformations in the economy. Therefore, economic growth and development with less adverse impact on the environment seems to be

[4] Kuznets (1955) was the first who introduced the hypothesis that income inequality increases to a maximum and then starts to decrease as per capita income increases. This hypothesis then extended to the environment labelled as Environmental Kuznets curve (EKC) hypothesis.

happening and the relationship between GDP per capita and environmental quality depends on scale, composition and technology effects of such transformation.

In this context, this study examines the Environmental Kuznets Curve for 100 emerging and developing countries over the period 1990–2018 from a different perspective than other studies had on the issue. More specifically, it attempts to see how changing the pattern of industrialization, in particular, and economic growth, in general, affect the inverted U-shape curve between environmental degradation and level of income of these countries.

To the knowledge of the authors of this study, this research is among the first studies to analyze the relationship between economic degradation and structural transformation. More specifically, our study is unique in the sense that it benefits from a highly cited indicator of economic transformation known as Economic Complexity Index (ECI) developed by Harvard University. To this end, this research aims at investigating the interactions between economic complexity and economic growth and it impact on environmental degradation.

The remainder of this paper is organized as follows: Section 2 provides a literature review. Section 3 surveys economic complexity and environmental degradation. Section 4 describes the data and variables definitions, as well as methods for empirical analysis. Section 5 presents the empirical results and discussions, and Section 6 concludes the paper with some key policy implications.

2. Literature review

As far as the authors of this study know, the majority of the exiting literature on environmental Kuznets curve has used share of manufacturing in GDP as a representation of industrialization to study the impacts of industrialization on economic degradation or they simply looked at the association between GDP per capita and environmental degradation without digging into on how the growth takes place. GDP per capita per se can not reflect the dynamics of the growth dynamics happening differently across countries.

A big body of theoretical models can be found in the literature aiming to explain the environmental Kuznets curve (EKC). The EKC hypothesis was empirically tested for many countries using different econometric methods and different indicators for environmental quality. Some has shown the influence of industry structure and technical change on the environment, and some others, more specifically, have shown that the structure of energy consumption been a significant factor in CO_2/ SO_2 emissions.

Buchholz and Cansier (1980) analyze the possibility of balanced growth with ecological constraints in a Harrod-Domar framework. They also allow for the case that environmental technical progress is not exogenous but requires expenditures. They find that the possibility of sustainable growth depends on its parametrization.

Grossman and Krueger (1991) focusing on trade liberalization and environmental degradation, used reduced form regression models to show that, for most air pollutants among 42 countries, a country will move along the U-shape curve as it becomes richer. In the context of trade, they have distinguished three mechanisms through which trade can influence air pollution including scale effect (i.e., expanding the scale of the economic activity due to trade and investment liberalization), composition effect resulting from trade policy changes, and technique effect (referring to the case that the pollution intensity of output does not necessarily remain the same before and after the liberalization).

In another study Grossman and Krueger (1995) find that for a number of environmental variables, the relationship between per capita income and environmental degradation takes an inverted U-shape confirming that environmental quality initially worsens but ultimately improves with income. As in their 1991 study, they proposed three major effects of international trade on environmental quality, including scale effect, structural effect and technical effect.

Andreoni and Levinson (1998) in a model for which the environment is assumed to be a normal good and households maximize their utility, argued that neither technical progress, nor changes of preferences or institutional regulations of the price system are necessary to obtain an EKC.

De Bruyn et al. (1998) estimated the individual EKC for the Netherlands, UK, USA and Western Germany, for the period of 1960 to 1993. They found that the EKC is not generally fit for all the countries, as each country has its own technological, structural, energy price and economic growth path, and therefore the emission situation and path would not be the same for all.

Lopez and Mitra (2000) used a theoretical model to examines the implications of corruption and rent-seeking behavior by the government on the shape of EKC. Their results suggest that corruption causes the turning point of EKC to rise above the social optimum.

Friedl and Getzner (2003) using time series data for 1960-1999 study the relationship between GDP and CO_2 emissions in Austria. By deploying a cubic functional form, they conclude that an

N-shaped relationship exists between GDP and CO2 emissions, claiming an increasing CO2 emission at the beginning, a stabilization or reduction in the middle of the period, and an increase at the end, and that a structural break occurred in the mid-seventies, more likely due to the oil price shock. The authors argue that the N-shape relationship could be the result of a “recovery effect” through which the initial shock of the oil crisis in mid 70s might have been reduced after one decade.

Dijkgraaf and Vollebergh (2005) examined EKC for 24 OECD countries from 1960 to 1997. They use both cursory comparison of the income and CO2 levels between countries and formal statistical tests investigating the differences in the coefficients for income-related terms in country-by-country EKC estimations. The homogeneity assumption across countries was rejected, somehow challenging the “poolability” of cross-country panel data in an EKC analysis and that EKC cannot be applied to a pool of countries.

Kijima et al. (2011) examine EKC-type transitions of pollutant levels not with respect to economic growth but more generally in time. According to this study, and assuming that each policy maker optimally deploy the two switching options of regulation and deregulation for pollution, the switching dynamics of environmental policy can be described by an alternating renewal process. It is shown that the double Laplace transform of transition density of a pollutant level can be obtained by a novel application of renewal theory. The expected level of overall pollutants is then calculated numerically and found to exhibit either an inversed U-shape or an *N*-shaped pattern over time.

Harbaugh et al., (2002) uses an updated and revised panel data set on ambient air pollution in cities world-wide to examine the robustness of the evidence for the existence of an inverted U-shaped relationship between national income and pollution. They examine the sensitivity of the pollution-income relationship to functional forms, to additional covariates, and to changes in the country samples, cities, and years. They find that the results are highly sensitive to these changes, and that there is little empirical support for an inverted U-shape relationship between several important air pollutants and national income in their data.

Ang (2007) found unidirectional Granger causality running from economic growth to energy consumption and pollution emissions. Olusegun (2009) using annual data of carbon dioxide per capita and GDP per capita from 1970 to 2005, found no evidence of EKC in the case of Nigeria.

Jalil and Mahmud (2009) using the autoregressive distributed lag (ARDL) method in their study confirmed that the relationship between carbon dioxide emissions and income per capita for China was an inverted U-shape.

Hooi and Smyth (2010) found that the long-run estimates in five ASEAN countries indicate that there is a statistically significant positive association between electricity and emissions and a non-linear relationship between emissions and real output, consistent with the EKC.

Turner and Hanley (2010) used a CGE model of the Scottish economy to consider the factors influencing the impacts of one form of technological change–improvements in energy efficiency–on absolute levels of CO2 emissions, and the carbon intensity of the economy (CO2 emissions relative to real GDP). They showed the key role played by the general equilibrium price elasticity of demand for energy, and the relative influence of different factors on this parameter.

Iwata et al., (2011) investigated whether the EKC hypothesis for CO2 emissions is satisfied using a panel data of 28 countries including OCED and non-OECD countries. They found the growth rate in CO2 emissions with income is decreasing in OECD countries and increasing in non-OECD countries and that CO2 emissions actually increase monotonically within the sample period in all cases.

Grunewald et al. (2012), find that the inequality in emissions varies with the level of income inequality. They showed that in countries with high income inequality, reductions in inequality yield lower emissions; in low inequality countries, less inequality yields higher emissions.

Deng et al. (2014) applied a generalized additive model to test the EKC in China and showed that not the traditional inverted U-shape but a monotonic increase of EKC is observed. In their study, the economic scale and technological advancements were key factors influencing carbon emissions.

Yin et al., (2015) examined the effects of environmental regulation and technical progress on CO2 emission level in china. The results indicated that there was a CO2 emission Kuznets curve observed for China for which energy efficiency, energy structure, and industrial structure exerted significant direct impact on CO2 emissions among the Chinese provinces.

Sinha and Bhattacharya (2016) investigated the EKC for 139 Indian cities using NO2 emissions as the proxy of environmental degradation for 2001–2013 period. The results confirm the EKC hypothesis, with reemphasis on the impact of growth-catalyzing economic policy decisions on environment.

Hao et al. (2018) examine EKC for coal consumption in China and found that there is strong evidence for the inverted U-shape EKC relationship between per capita coal consumption and the GDP per capita. Besides, the GDP per capita corresponding to the peak of coal consumption per capita is estimated to be higher when the spatial effects are accounted.

Wang et al. (2018) examined the relationship between industrial structure and pollutant emissions in a rapidly developing manufacturing-dominated city in China. They found a negative correlation between industrial concentration and pollutant emission. They also show that there is some other factors affecting the pollution in china including Pareto distribution of output value and pollutant emissions by divisions, groups and classes, increased industrial concentration, and the size of the firms.

Danish and Wang (2019) investigated the impact of energy consumption, urbanization and economic growth on emerging economies' ecological footprints over the period from 1971 to 2014. The findings suggested that urbanization and energy consumption cause higher ecological footprint.

More recently, Neagu (2019) argued that economic complexity can exert U-shape effects on the CO2 emissions. The author used COMTRADE data to compute the economic complexity index for the 25 European countries, and unlike the other studies he replaced the income per capita by Economic Complexity Index. The results suggested that in the first stage, the complexity of exports increases pollution (and according to the author, corresponding to the period of extensive use of resources to sustain the complexity of exported products), and after a threshold point, economic complexity suppresses the pollution level, corresponding to the stage of efficiency and effectiveness in the use of resources and adopting less pollutant technologies.

Ahmed et al., (2020) presented the influence of urbanization, trade openness and economic growth on the ecological footprint of G-7 economies using annual data from 1971 to 2014. The empirical analysis suggested that urbanization, trade, and growth level have bi-directional relationships with adverse environmental quality in developed countries.

3. Economic Complexity and Environmental Degradation- A review

In recent years, the analysis of countries' economic complexity (ECI) has attracted increasing interest and discussion, mainly because it offers a way to rank countries in the correct global order in terms of their competitiveness. ECI has attracted significant attention from researchers and policymakers as it can explain more variation in country income per capita and economic growth than other variables commonly employed in growth regressions such as governance, institutional quality, education, and competitiveness. In a nutshell, economic complexity index (ECI) provides important insights into patterns of economic development and its dynamics.

Despite the importance of the nexus between an economy's complexity and its environmental implications, it has so far received very little attention in the case of environmental studies. In regard to the role of complexity, Alvarez et al. (2017) argued that the relevance of economic complexity in economic systems could be gauged by understanding the connection between energy consumption and economic growth, where innovation processes offer a new approach with applications and crucial implications for policymaking. Governments have started promoting energy and environmental regulations to reduce the dependency on fossil fuel and its energy intensity. These actions may be influenced by the sophistication of several aspects such as the social, technical, economic or environmental features of energy systems, and their complex social and technological dynamics (Bale et al., 2015).

In this context, the introduction of measures of 'economic complexity' have expanded the ability to quantify a country's productive structure and have revived interest in the macroeconomic role of structural transformations, in general, and in environmental discussion, in particular. On one hand, the country's product manufacturing structure and economic complexity might affect the environment more severely, as the complexity level of products depends on the consumption of resources, which could adversely impact the environment, mainly due to the fact that productive structure and manufacturing activities require energy consumption of both non-renewable and fossil fuels. On the other hand, higher economic complexity does not necessarily mean higher use of fossil fuels and it can represent a low-emission intensive sophisticated technology that requires less fossil fuel consumption. The final outcome of economic complexity on emission and environmental degradation, therefore, depends on the relative importance and size of these two competing effects.

The current study benefits from the complexity index developed by Harvard University team at Harvard's Growth Lab at the Center for International Development (CID). The index is calculated using two indicators of "diversity" and "ubiquity". Diversity refers to the number of products that a country is connected to, and ubiquity is related to the number of countries that a product is connected to.[5]

4. Methodology

The earliest EKCs were simple quadratic functions of the levels of income which shows the relationship between CO2 emission and economic growth (GDP per capita) as defined in the following formula:

$$lnC_{it} = \beta_0 + \beta_1 lnY_{it} + \beta_2 (lnY_{it})^2 + \varepsilon_{it} \qquad (1)$$

Where i indicates the country samples (i=1, 2, 3 … ,100), t indicates the study period, β_0 represents the fixed effect, C_{it} is CO2 emission per capita, Y_{it} represents GDP per capita of country i in year t and ε_{it} is the standard error term. When $\beta_1 > 0.$ and $\beta_2 < 0$ then an inverted U-shape EKC will be obtained.

Our model is different from the other studies in the way that it uses economic complexity in addition to the income per capita and share of manufacturing to GDP to capture the full transformation happening in the economies of developing and emerging economies and its impacts on environmental degradation represented by CO2 emission levels.

The empirical model that will be tested is shown in the following form:

$$ED_{it} = \alpha + \beta_1 Inc_{it} + \beta_2 Inc_{it}^2 + \delta ECI_{it} + \theta_1 ECI_{it} * Inc_{it} + \theta_2 ECI_{it} * Inc_{it}^2 + \varphi Z_{it} + \varepsilon_{it} \qquad (2)$$

Where;

ED_{it} : represents the environmental degradation represented by log of CO2 per capita and log of CO2 in kilo tonnes,

Inc_{it}: is the log of income per capita as the natural logarithm of GNI per capita at 2011 international prices,

ECI_{it}: is Economic Complexity Index for country i, in time t,

[5] For more information on ECI, please see: https://growthlab.cid.harvard.edu/files/growthlab/files/harvardmit_atlasofeconomiccomplexity.pdf

Z_{it}: represents the other factors influencing the environmental degradation including economic openness, share of manufacturing in GDP and population growth.

In addition to have the manufacturing share in GDP we decided to include another variable who can better represents the overall dynamics of growth in the economies. We believe that a simple share of industry sector in GDP can not capture the full dynamics inside the whole economy and the interactions among various sectors of the economy. Furthermore, a mere income per capita s a measure of economic growth is not a good representation of the tremendous changes and transformation that are happening within the economics of developing world. To this end, Economic Complexity Index (ECI) and its interaction with the income level have been introduced to the model to capture the probable impacts of ECI on the shape of the Kuznets curve. The model also includes region dummies to capture any region-specific effects.

The effect of ECI on the shape of the EKC will be assessed by derivate of the equation (2) above with respect to Income per capita as follows:

$$ED'_{it} = Constant + (\beta_1 + \theta_1 ECI_{it}) + 2 * (\beta_2 + \theta_2 ECI_{it})\ Inc_{it} \qquad (3)$$

For which, any significant figures for $\theta_1 ECI_{it}$ and/or $\theta_2 ECI_{it}$ indicates a change in either intercept or the slope (or both) of the EKC.

A random Generalized Least Square Model was used on an unbalanced panel data covering 100 developing and emerging economies across the globe over 1963-2018.[6] The availability of the data for various variables dictated the choice of the countries include in the model.

It is worth noting that in our model and for the Emerging group we included most populous countries of BRICS plus Malaysia, and Turkey called BRICS+. The reason for adding these countries to the BRICS is that their economies are different from their counterparts in their regional grouping either size-wise and or economic-structure-wise.

[6] The countries included are: Albania, Algeria, Argentina, Armenia, Azerbaijan, Bangladesh, Belarus, Benin, Bolivia, Botswana, Brazil, Brunei Darussalam, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Chad, Chile, China, Colombia, Comoros, Costa Rica, Cote d'Ivoire, Croatia, Cyprus, Djibouti, Dominican Republic, Ecuador, Egypt, El Salvador, Ethiopia, Gabon, Gambia, Georgia, Ghana, Guatemala, Guinea, Guinea-Bissau, Honduras, Hungary, India, Indonesia, Iran, Jamaica, Jordan, Kazakhstan, Kenya, Kyrgyz Republic, Lebanon, Liberia, Madagascar, Malawi, Malaysia, Maldives, Mali, Mauritania, Mauritius, Mexico, Moldova, Morocco, Mozambique, Myanmar, Namibia, Nepal, Nicaragua, Niger ,Nigeria, Oman, Pakistan, Panama, Paraguay, Peru, Philippines, Puerto Rico, Romania, Russian Federation, Rwanda, Senegal, Serbia, Sierra Leone, Slovak Republic, Slovenia, South Africa, Sri Lanka, Suriname, Tajikistan, Tanzania, Thailand, Togo, Tunisia, Turkey, Turkmenistan, Uganda, Ukraine, Uruguay, Uzbekistan, Vietnam, Zambia, and Zimbabwe.

5. Findings

5.1. Descriptive statistics

Among the countries covered under this study Comoros has the minimal amount of CO2 in million kilo tonnes at 66.8 compared to China at 3,097,583 kilo tonnes of CO2 as the most pollutant country in our study. However, on CO2 per capita, the countries change their places; Burundi with 0.03067 CO2 per capita as the less pollutant country per person, as opposed to Brunei Darussalam with 21.034 CO2 per capita as the most pollutant country.[7]

According to Table 1 below the average ECI for our sample of 100 countries is -0.357 on a scale of -5 as minimum and +5 as maximum. Among countries under study, Slovak Republic, has seen highest ECI, followed by Hungary and Croatia with an average of 1.39, 1.04 and 0.77, respectively. On the other end, Nigeria, Guinea and Cameron all from Africa with -1.99, -1.52 and -1.35 have had the lowest complex economy. On average, the trend of ECI during 1964-2018 shows a slight upward trend during 1963-1985, but a stable trend afterward, indicating that, on average, the complexity of the economies of the sample countries have experienced an advancement for the first 20 years or so but afterwards have not seen any particular progress (see Figure 1 below).

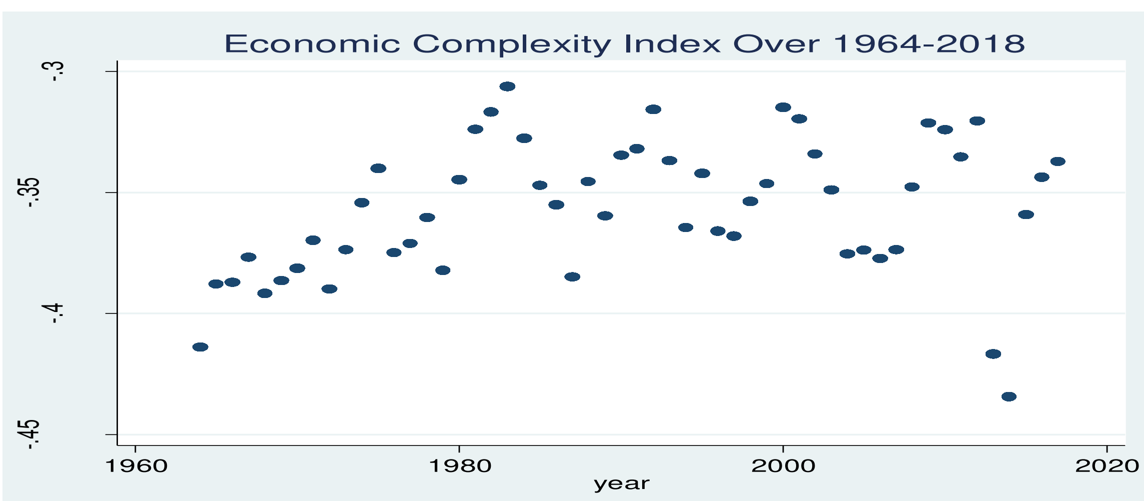


Figure 1: Average of ECI for the sample countries

[7] Due to space limitation it was decided to remove the country-specific statistics for 100 countries included in the study.

As shown in Table 1 below, on a grouping basis, Africa with an average ECI of -1.002 has the lowest score of ECI, followed by South Asia with -0.6063, Central Asia with -0.3308, and MENA with -0.3155. On the other end, Eastern Europe with 0.4455 has the highest score of ECI, followed by , BRICS with 0.1767 and South America with -0.2335.

Table 1: Region-wise statistics of ECI and environmental degradation indicators

	Average CO2 per capita	Average CO2 in million kilo tonnes	Average ECI
Africa	4734044	3783.51	-1.018
BRICS+	3.796266	840155.4	0.17667
Central Asia	4.766142	56988.82	-0.3308
Eastern Europe	5.19309	58890.9	0.4455
MENA	2.913515	60325.21	-0.3155
South America	1.742803	33071.2	-0.2335
South Asia	. 2.19842	39900.5	-0.6063

It is interesting to see the very low correlation between the level of income per capita and the economic complexity index at 0.45 as shown in Table 2, confirming our view that some countries despite having high level of economic growth (income per capita) they have not experienced a relatively diversified and complex economy. Put simply, income per capita masks the dynamic of economic activities within countries economies.

Table 2: Correlation matrix of the model variables

	(1)	(2)	(3)	(4)	(5)	(6)
Log of Income per capita (1)	1					
Log of Population Growth (2)	-0.4249	1				
Log of industry share in GDP (3)	0.5579	-0.153	1			
Log of Trade Openness (4)	0.131	-0.1158	0.1664	1		
Log of Income per capita-squared (5)	0.998	-0.4273	0.5521	0.1372	1	
ECI (6)	0.3983	-0.3025	0.0486	0.0279	0.4029	1

At first glance and as it can be seen in Figure A.1 in appendix, ECI is associated with higher environmental degradation evidenced by the simple two way scatter diagrams. Our model below investigates this correlation in a more rigorous way.

5.2. Model results

Table B.1 in appendix presents the result of our panel model for a group of 100 developing countries. Overall, the results indicate that the well-known Environmental Kuznets Curve (EKC) still is applicable to the developing countries economies evidenced by the positive and significant relationship between the level of income per capita and the indicators of environmental degradation and the negative association with the second degree of income per capita. This is true for both models with CO2 per capita and kilo tonnes of CO2 as the dependent variables.

Higher degree of economic openness has been associated with higher level of environmental damage indicating that the more open the economy, the lower the environmental quality will be. This result can be an indication of environment haven hypothesis for which the polluting industries facing challenging and strict environmental regulations in developed countries migrate to developing countries with no or relaxing environmental regulations.

Population growth, as expected, has led to more environmental damage when the damage represented by the kilo tonnes of CO2, but it does not show the same worsening pattern when the dependent variable is CO2 per capita implying that the intensity of environmental degradation has been slowed as far as the population growth concerned.

Industry share in GDP surprisingly shows a negative impact of economic degradation. At first glance, this finding is in contrast to the many previous studies and to some extent to the main hypothesis of EKC. One possible reason can be relatively high correlation of the variable with the level of income per capita (at 55%). This can also signal that simple share of manufacturing in GDP cannot capture the full effect of economic transformation of developing countries.

5.3. Effect of ECI on the EKC

Our variable of interest, ECI, has been associated with more adverse environmental impacts, implying that the whole growth dynamics of developing countries have worsened the environment.

In other words, the economic transformation process of developing economies, on average, have deteriorated their environment.

To dig more into the case, we included the interaction of ECI and income per capita. It is interesting to see that ECI has flatten the Kuznets curve by downward shifting of the EKC evidenced by negative sign of the interaction term between ECI and the income per capita and more clearly presented in Figure 2 below. Put it simply, the economic dynamics of developing and emerging economies has still led to inverted U-shape curve but it has shifted the curve downward, implying that the process of environmental degradation has been lessened and reduced. The change is significant evidenced by its t-value. This impact is only observed for the case where CO2 per capita is used as the proxy for degradation.

The effect is opposite for the case where CO2 in kilo tonnes represents the environmental degradation; higher level of economic complexity is associated with an upward shift in CO2 in Kilo tonnes as it can observed in Figure 3 . Combining these two opposite observations implies that economic transformations of developing economies have overall increased the levels of CO2 in kilo tonnes, but on a relative basis the level of normalized CO2 (through dividing by population) has been reduced. In other words, the emission intensity of the economies of our sample of emerging and developing countries have been reduced by the increased complexity of their economies overall.

Figure 2: Impact of ECI on EKC for Log of CO2 per capita

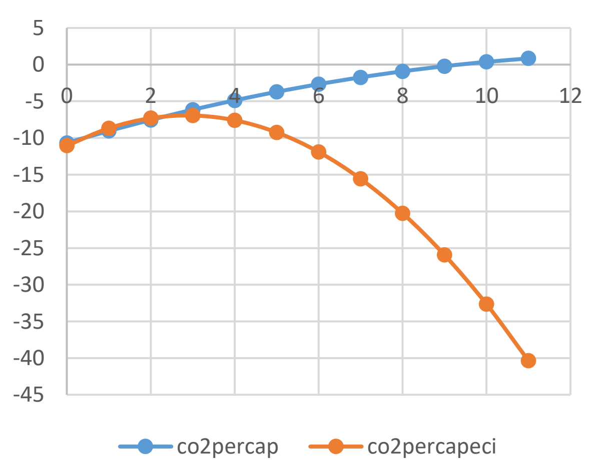
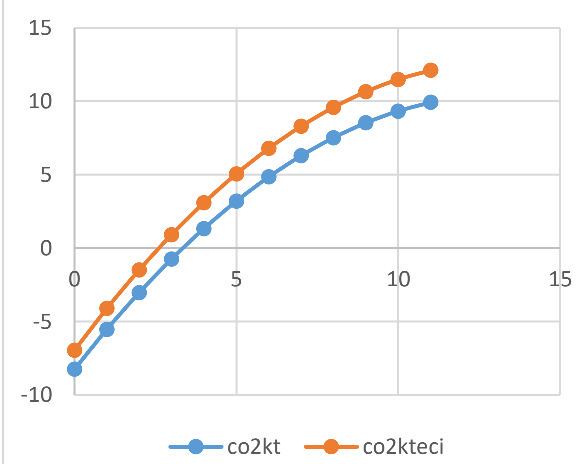


Figure 3: Impact of ECI on EKC for Log of CO2 in milllion kilo tonnes



Then the next question that comes to mind is that what can be the reasons for a shifted flatten Kuznets curve by ECI? And what does that imply for environment policy making?

It appears that the developing countries have taken a different route and path to grow their economies which in turn is cleaner than the old classic view of industrialization. This unconventional less-emission intensive growth can offer great opportunities in the way that the economy can grow while the environment will not be as damaged as previously thought. Likely, economic diversity represented by ECI has flattened and shifted the curve as countries adopt new less polluting technologies and thus avoided the degradation that would have had happened otherwise.

6. Results and Discussion

The implications of the findings for developing and developed countries could be quite significant. For advanced economies, a downwardly-shifted Kuznets curve implies that, on one hand, technology transfers have been successful in curbing the environmental degradation of developing economies and, on the other hand, the economic transformation strategies of developing world is working in a sustainable way.

Developed countries have pledged billion of dollars to aid developing countries through mitigation and adaptation policies through funds such as Green Fund. The result of this study can provide a hint to the developed countries in considering diverting and/or targeting their funds in some other possible ways to aid developing countries in their economic transformation process. If economic diversification is helping developing countries limit the environmental degradation, then by helping developing countries in their diversification efforts could lead to a win-win situation for both developed and developing nations.

7. Conclusion

policy implication for advanced economies is that pollution havens might provide a short-term release of transferring the dirty polluted industries to developing worlds but in long-term such strategies will fireback in those countries and in the end they should pay much higher costs to curb the (sometimes irreversible) environmental degradation. The international institutions such as the World Bank and IMF has a very big role in supporting the developing countries efforts to continue on their sustainable economic growth.

More research is needed to explore and identify the details of the transformations that have happened that led to such relatively sustainable growth strategies of developing world with the aim of fostering and promoting those efforts and replicating in other developing countries.

Declarations

□ Ethics approval and consent to participate
Not applicable

□ Consent for publication
Not applicable

□ Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

□ Competing interests
The authors declare that they have no competing interests

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□ Authors'
Mohammad Sharif Karimi and Raza Ghazal estimated the econometrics model and results and theoretical framework as well. Bakhtiar Javaheri performed literature review and some contributor in writing the manuscript and collected data and edited manuscript . All authors read and approved the final manuscript.

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Not applicable

□ Authors' information (optional)

Not applicable

References

Ahmed, Z., Zafar, M.W., Ali, S., 2020b. Linking urbanization, human capital, and the ecological footprint in G7 countries: An empirical analysis. Sustain. Cities Soc. 55, 102064. https://doi.org/10.1016/j.scs.2020.102064

Agosin, M.R., 2009. Export diversification and growth in emerging economies. CEPAL Rev. (97), 115–131.

Alvarez, A., Balsalobre, D., Cantos, J.M., Shahbaz, M., 2017. Energy innovations-GHG emissions nexus: fresh empirical evidence from OECD countries. Energy Policy. 101, 90–100.

Andreoni, J., Levinson, A., 1998. The Simple Analytics of the Environmental Kuznets Curve. NBER Working Paper series. No. 6739.

Ang, JB., 2007. CO2 emissions, energy consumption and output in France. Energy Policy 2007. 35, 4772–8.

Bale, C.S.E., Varga, L., Foxon, T.J., 2015. Energy and complexity: new ways forward. Apply Energy. 138, 150–159.

Bourguignon, F., 2004. The Poverty-growth-inequality triangle (Indian Council for Research on International Economic Relations, New Delhi Working Paper No. 125). Indian Council for Research on International Economic Relations, New Delhi, India. Retrieved from https://ideas.repec.org/p/ind/icrier/125.html

Buchholz, W., Cansier, D., 1980. Modelle o kologisch begrenzten Wachstums. Zeitschrift fur Wirtschafts und Sozialwissenschaften. 100, 141-161.

Danish, wang, Z., 2019. Investigation of the ecological footprint's driving factors: What we learn from the experience of emerging economies. Sustain. Cities Soc. 49, 101626. https://doi.org/10.1016/j.scs.2019.101626

De Bruyn, S.M., van der Bergh, J.C.J.M., Opschoor, J.B., 1998. Economic growth and emissions: reconsidering the empirical base of environmental Kuznets curves. Ecological Economics. 25, 161–175.

Dijkgraaf, E., Vollebergh, H.R.J., 2005. A test for parameter homogeneity in CO2 panel EKC estimates. Environmental and Resource Economics. 32, 229–239.

Erkan, B., Yildirimci, E., 2015. Economic complexity and export competitiveness: the case of Turkey. Procedia Environ. Sci. Eng. Manag. 195, 524–533.

Friedl, B., Getzner, M., 2003. Determinants of CO2 emissions in a small open economy. Ecological Economics. 45, 133–148.

Grossman, G.M., Krueger, A.B., 1991. Environmental Impacts of a North American Free Trade Agreement. National Bureau of Economic Research.

Grossman, G.M., Krueger, A.B., 1994. Economic growth and the environment. NBER Working Paper Series. Working Paper. 4634.

Grunewald, N., Klasen, S., Martínez-Zarzoso, I., Muris, C., 2012. Income inequality and carbon emissions. Discussion Paper No. 92. Courant Research Centre, University of Göttingen.

Hao, Y., Liu, Y., Weng, J-H., Gao, Y., 2016. Does the Environmental Kuznets Curve for coal consumption in China exist? New evidence from spatial econometric analysis. Energy. 114, 1214-1223.

Harbaugh, W. T., Levinson, A., Wilson, D. M., 2002. Re-examining the empirical evidence for an Environmental Kuznets Curve. The Review of Economics and Statistics,. 84(3), 541-551.

Hidalgo, C.A., Hausmann, R., 2009. The building blocks of economic complexity. Proc. Natl. Acad. Sci. U.S.A. 106 (26), 10570–10575.

Hidalgo, C.A., Klinger, B., Barabasi, A.L., Hausmann, R., 2007. The product space conditions the development of nations. Science. 317 (5837), 482–487.

Hooi, L., Smyth, R., 2010. CO2 emissions, electricity consumption and output in ASEAN. Apply Energy. 87, 1858–64.

Iwata, H., Okada, K., Samreth, S., 2011. Note on the environmental Kuznets curve for CO2: A pooled mean group approach. Applied Energy. 88, 1986–1996.

Jalil, A., Mahmud, S., 2009. Environment Kuznets curve for CO2 emissions: A cointegration analysis for China. Energy Policy. 37(12), 5167-5172.

Kijima, M., Nishide, K., Ohyama, A., 2011. EKC-type transitions and environmental policy under pollutant uncertainty and cost irreversibility. J. Econ. Dyn. Control 35 (5), 746–763.

Kuznets, S., 1955. Economic growth and income inequality. American Economic Association. 45(1), 1-28.

Lopez, R., Mitra, S., 2000. Corruption, pollution, and the Kuznets environment curve. J. Environ. Econ. Manag. 40, 137–150.

Mealy, P., Farmer, J.D., Teytelboym, A., 2019. Interpreting economic complexity. Sci. Adv. 5 (1), eaau1705.

Neagu, O., 2019. The link between economic complexity and carbon emissions in the European

Union countries: A model based on the Environmental Kuznets Curve (EKC) approach. Sustain. 11. https://doi.org/10.3390/su11174753

Olusegun, O. A., 2009. Economic growth and environmental quality in Nigeria: Does environmental Kuznets curve hypothesis hold? Environment Research Journal. 3(1), 14-18.

Ravallion, M., 2004. Pro-Poor Growth: A Primer (Policy Research Working Paper No. ID 610283). World Bank. Retrieved from http://dx.doi.org/10.1596/1813-9450-3242

Rodrik, D., 2016. An African growth miracle? Journal of African Economies. 1-18.

Tacchella, A., Cristelli, M., Caldarelli, G., Gabrielli, A., Pietronero, L., 2013. Economic complexity: conceptual grounding of a new metrics for global competitiveness. J. Econ. Dynam. Contr. 37 (8), 1683–1691.

Wang, Z., Jia, H., Xu, T., Xu, C., 2018. Manufacturing industrial structure and pollutant emission: An empirical study of China. Journal of Cleaner Production. 197, 462-471.

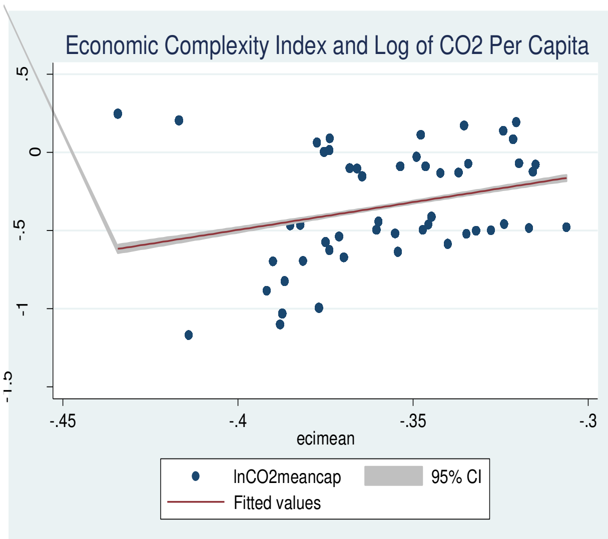
Appendices

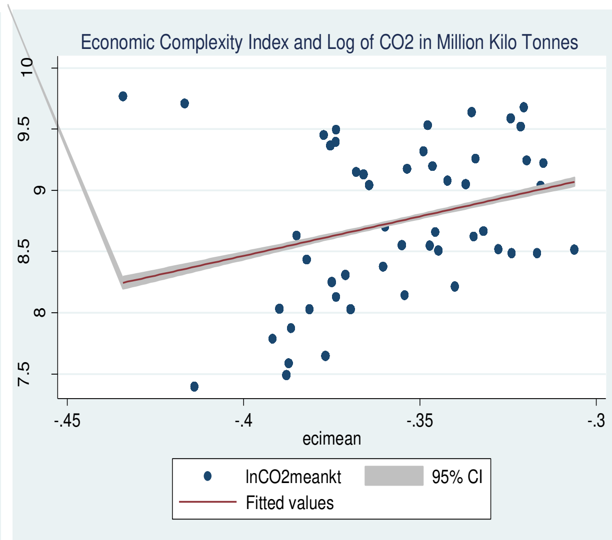
Appendix A: Descriptive statistics

Table A.1: Variables statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Log of CO2 per capita	4,825	-0.37124	1.611071	-5.4415	4.20783
Log of CO2 in million Kilo Tonnes	4,825	8.703362	2.341822	1.299374	16.14687
Log of Income per capita	2,332	8.642303	1.030086	5.828973	11.37261
Square Log of Income per capita	2,332	75.75002	17.70419	33.97693	129.3363
Log of Trade Openness	4,623	4.010093	0.641149	-1.78726	5.927935
Log of industry share in GDP	4,484	3.212438	0.4416	1.176528	4.505493
Log of Population Growth	5,495	0.599496	0.731731	-5.49056	2.398596
Economic Complexity Index (ECI)	3,535	-0.35657	0.713632	-2.76425	1.55648
ECI and Income per capita interaction	1,732	-2.74322	6.439474	-23.297	15.32273
ECI and square of Income per capita interaction	1,732	-22.0048	57.96658	-196.346	153.0578

Figure A.1: ECI and Environmental Degradation





Appendix B. Model results

Table B.1: Random-effects GLS regression results

	Dependent variable: Log of CO2 in Kilo Tonnes		Dependent variable: Log of CO2 per capita	
Variable Name	Coefficient (p-value)			
Income per capita - Log	2.756095* (0.00)	2.817914* (0.00)	1.678194* (0.00)	1.746978* (0.00)
Income per capita-squared - Log	-0.1011* (0.00)	-0.10609* (0.00)	-0.05744* (0.00)	-0.06297* (0.00)
Openness - Log	0.320037* (0.00)	0.325666* (0.00)	0.209262* (0.00)	0.217031* (0.00)
Industry share in GDP- Log	-0.08841† (0.09)	-0.11568+ (0.027)	-0.09275+ (0.017)	-0.1179* (0.002)
Population Growth -Log	0.00202 (0.901)	0.001142 (0.944)	-0.00285 (0.816)	-0.00416 (0.733)
ECI	0.077128* (0.001)	2.791388+ (0.033)	0.024269 (0.159)	2.09537+ (0.033)
Region one- Africa	Omitted category			
Region 2 – BRICS+	3.775884* (0.00)	3.774773* (0.00)	1.534339* (0.00)	1.532833* (0.00)
Region 3- Central Asia	1.888085* (0.00)	1.872007* (0.001)	2.20804* (0.00)	2.190181* (0.00)
Region 4- Eastern Europe	0.721841† (0.099)	0.745284† (0.09)	1.637411* (0.00)	1.662758* (0.00)
Region 5 – MENA	1.114552* (0.007)	1.084091* (0.009)	1.24129* (0.00)	1.209426* (0.00)
Region 6 – South America	0.228152 (0.487)	0.198901 (0.546)	0.690077* (0.00)	0.663112* (0.00)
Region 7 – South Asia	2.06952* (0.00)	2.047083* (0.00)	0.386202+ (0.029)	0.365625+ (0.04)
Constant	-8.12556*	-8.18558*	-11.1965*	-11.49*

	(0.00)	(0.00)	(0.00)	(0.00)
ECI and Log of Income per capita- Interaction term	-0.56967† (0.066)			-0.41497† (0.073)
ECI and Log of Income per capita squared- Interaction term	0.029231 (0.107)			0.020066 (0.139)
R-square: Within Between Overall	 0.62 0.53 0.55	 0.63 0.53 0.55	 0.53 0.87 0.85	 0.54 0.87 0.85
# of Obs.	1291	1291	1291	1291
Wald chi2(14)	2029	2065	1944	1991

Note: *, + and † represent 1%, 5%, and 10% level of significance, respectively.

Figures

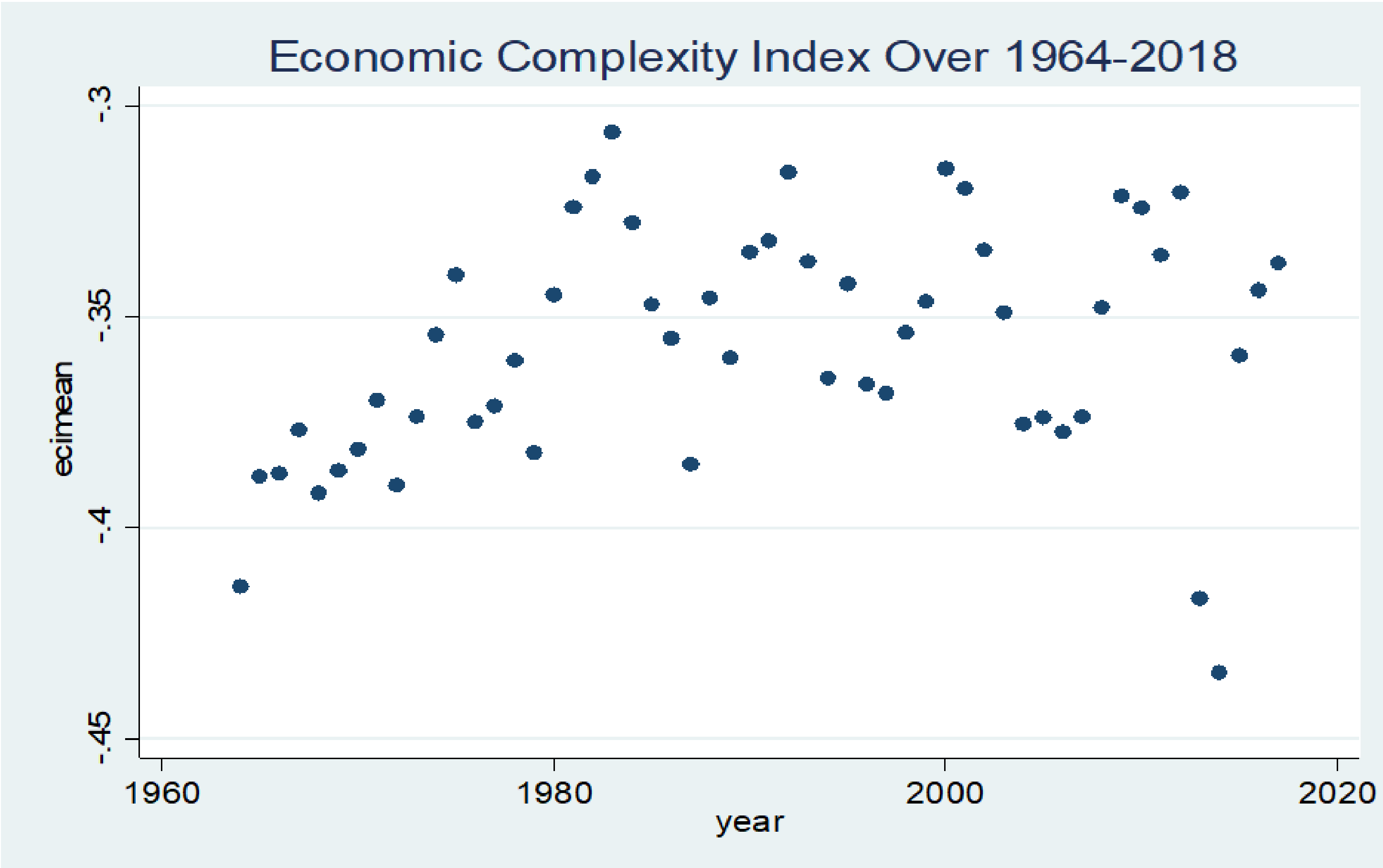


Figure 1

Average of ECI for the sample countries

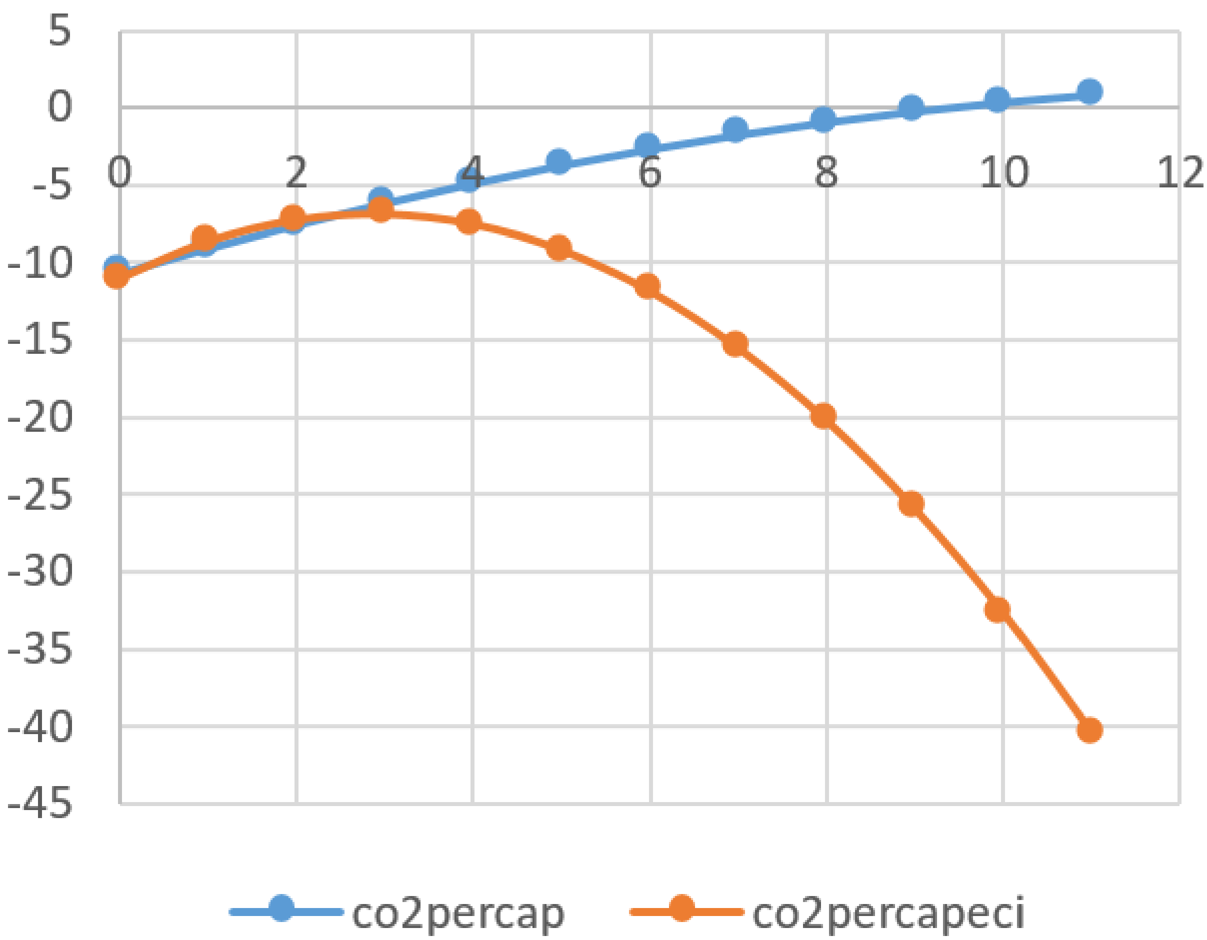


Figure 2

Impact of ECI on EKC for Log of CO2 per capita

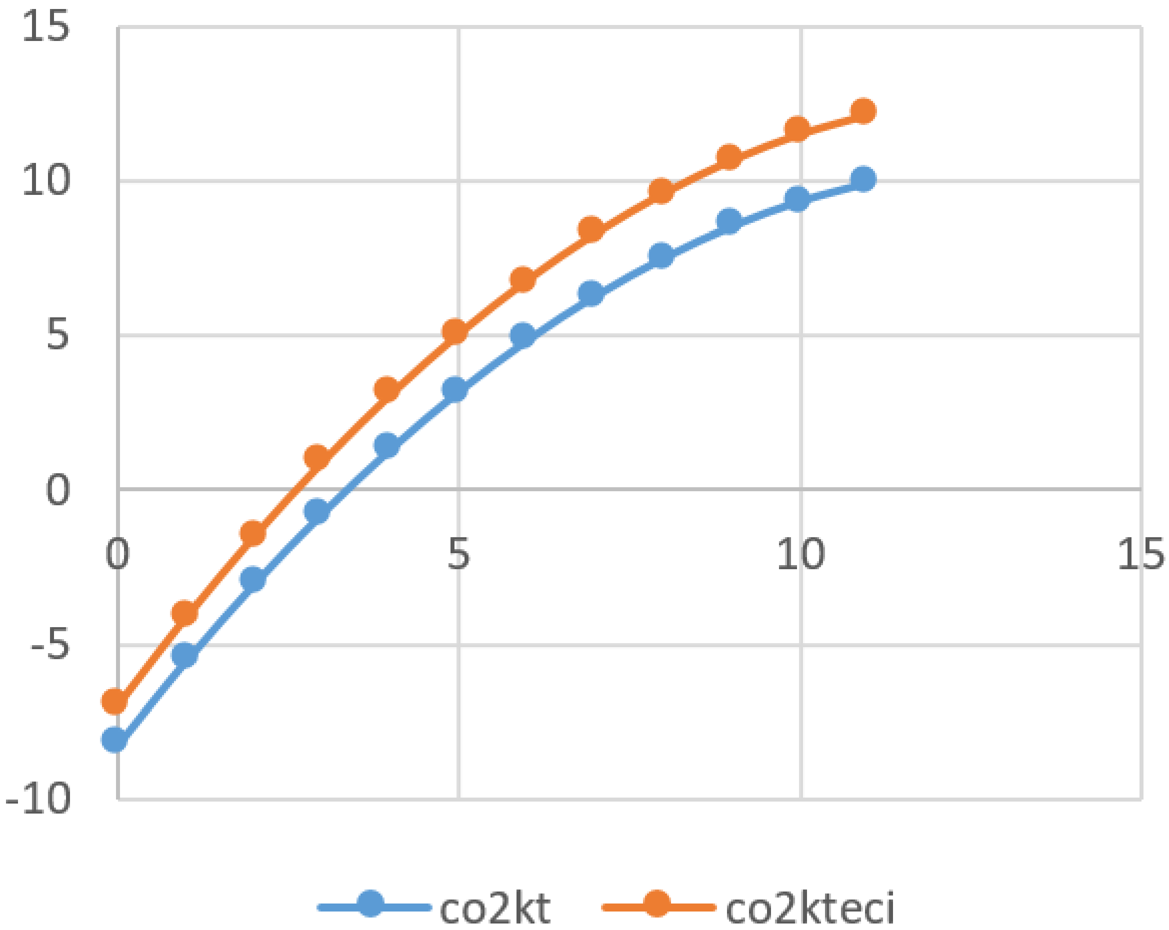


Figure 3

Impact of ECI on EKC for Log of CO2 in milllion kilo tonnes