Testing the Globalization-Driven Carbon Emissions Hypothesis: International Evidence

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Abstract: We empirically investigate the dynamic relationship between globalization and CO_2 emissions for 87 (high, middle and low-income) countries. We utilize the cross-correlation approach to examine the well-known EKC hypothesis between globalization and environmental degradation. The results validate the inverted U-shaped EKC hypothesis for 16 (approximately 18%) from the high- and middle-income countries only, thereby highlighting that a rise in globalization will decrease carbon emissions for these countries in the future. On contrary, the results also confirm the U-shaped relationship between globalization and environmental degradation for 8% of the countries. The remaining countries do not have a U- or an inverted U-shaped relationship between globalization and CO2 emissions. Policy implications are also discussed.

Keywords: Globalization; Carbon Emissions; Cross-correlation; EKC

JEL Classification: F6, Q5, Q0

1. Introduction

The well-known environmental Kuznets curve (EKC) hypothesis links carbon dioxide emissions with economic growth in the sense that environmental quality initially decreases with increases in economic growth but then improves as the economy grows after reaching a certain threshold level (Grossman and Krueger, 1995).[1] This hypothesis potentially implies that if the EKC argument holds, the country can prosper without hindering environmental quality (Beckerman, 1992; Bartlett, 1994; Mohapatra et al., 2016). Due to the relevance of the economic and environmental policy implications of this EKC hypothesis, many studies have been conducted with purpose of testing the EKC relationship between economic growth and environmental pollution across many countries. Moreover, the relevance of the effect of globalization on environmental degradation has been studied in the environmental economics literature. Taken together, the studies on the linkages between income level[2], globalization and carbon emissions have yielded mixed and contradictory results. In fact, the EKC-testing approaches have been criticized (e.g., Harbaugh et al., 2002) for the lack of insights regarding the efficiency/ inefficiency of countries' environmental policies and the inability of those studies to provide causal interpretations of the two pollution-related nexuses: the income-pollution, and the globalization-pollution.

In this context, Narayan and Narayan (2010) highlight that the time series and panel data regression models suffer from the issue of co-linearity or multi-collinearity when adding both the income level and the globalization index in the carbon emissions function. In this context, Narayan et al.

[1] The EKC (Environmental Kuznets Curve) hypothesis posits an inverted U-shaped relationship between pollution and income levels.
[2] See for example, Narayan and Narayan (2010), Wang (2012), Van Hoa and Limskul (2013), Yang and Zhao (2014), Mohapatra et al. (2016).

(2016) again stress this issue and propose the use of the cross-correlation estimation approach.[3] Motivated by the Narayan et al. (2016) seminal paper which gives a new methodological direction to testing the EKC hypothesis, our study uses the cross-correlation framework to examine the globalization--driven carbon emissions hypothesis for 87 countries categorized into high-, middle- and low-income groups. To the best of our knowledge, our study is the first attempt to examine the role of globalization in driving the evolution of CO_2 emissions and applying it to many categorized countries.

The issue of linking CO_2 emissions with globalization has been one of the passionately debated issues in the disciplines of economics and environmental studies since 1970. The debate on the degradation of environmental quality has produced mixed findings within the time series and panel frameworks (Christmann and Taylor, 2001). However, it is understood that climate change brings unexpected rain and environmental degradation which are harmful to human beings (Hawken et al., 2008). It has further been noticed that degradation in environmental quality is not only challenging the quality of life on the globe but also challenging academics, governments and policy makers of the world working in this area (Panayotou, 1997). On the other hand, globalization has brought a closer integration of developing and developed countries of the world by stimulating investments in innovations and green technology (Dreher, 2006). Eventually, globalization would enable both groups of economies to grow but at a high cost to the natural environment.[4] The proponents of globalization claim that this phenomenon is not harmful to countries because it contributes to a better environmental quality by lowering CO_2 emissions.[5] On the other hand, the

[3] A positive (negative) cross correlation between the current level of income and the past (future) level of CO_2 emissions indicates that carbon emissions will decline with an increase in income. This characterises the inverted U-shaped thesis.
[4] See Copeland and Taylor (2004), Aichele and Felbermayr (2012), Shahbaz et al. (2015a).
[5] See Christmann and Taylor (2001), Shin (2004), Lee and Min (2014); Ling et al. (2015), Shahbaz et al. (2015b).

opponents of globalization claim that it is harmful because it leads to a deterioration in the quality of the environment through increasing CO_2 emissions.[6] The opponents also argue that although globalization brings an expansion in the production process, it will degrade the environmental quality if both the production and consumption techniques remain unaltered. Moreover, although globalization boosts economic development particularly in developing economies, it has accelerated natural resource depletion and environmental devastation in those countries (Fridun, 2005; Wijen and Van Tulder, 2011).

Furthermore, Panayotou (1997) argues that newly industrialized and developing countries are more polluted today than 40 to 45 years ago, compared to developed countries. Although the theoretical nexus between globalization and environmental quality appears to be ambiguous, it seems that advanced economies have blamed developing countries for the growth of pollution-emitting industries. This is because dirty industries in developing economies damage environmental quality which comes in the name of producing greater output and higher employment in those economies. This scenario has also been statistically and clearly justified by the recent report of the World Resource Institute's CAIT Climate Data Explorer (WRI, 2014). The degradation in environmental quality mainly occurs due to the stupendous shifts in those countries' open economic policies (Panayotou, 1997; Baek et al., 2009). The loss of greater environmental quality mainly arises in developing nations due to their weak enforcement of environmental rules and regulations and the lax compliance of their pollution-intensive firms in the process of production activity. This implies that globalization enables developing countries to expand their industrial sector at the cost of environmental quality. On the other hand, it is argued that developed countries guard their environmental quality by enforcing stricter environmental regulations

[6]See Copeland and Taylor (2004), Feridun (2005), Wijen and Van Tulder (2011), Aichele and Felbermayr (2012).

(Copeland and Taylor, 1994, 2004; Copeland, 2006; Dean, 2002; Copeland 2005; Baek et al., 2009)). This concludes that higher economic growth, increasing energy consumption and loose standards of environmental regulations in developing countries are the primary causes of environmental damage.

Given the above background, our study investigates the following important research question: is globalization beneficial for the environment in high-, middle- and low-income countries? Our answers to this question bring two key contributions in two directions: (i) We investigate the cross-correlation relationship between globalization and carbon dioxide (CO_2) emissions for 87 countries categorized into high-, middle- and low-income groups; and (ii) we examine the cross-correlation estimates following Narayan et al. (2016) to understand how globalization and carbon emissions are correlated. This methodological approach is simple to understand and should help to have a critical assessment of the EKC hypothesis existence under the following axiom. If there is a positive cross-correlation between the current level of globalization and the past level of CO_2 emissions, and a negative cross-correlation between the current level of globalization and the future CO_2 emissions, then CO_2 emissions will decline with increases in globalization over time.

Our findings reveal that for only 16 (high (6) and middle (10) income countries) out of the 87 countries in the sample (18%), a rise in globalization is positively and negatively cross-correlated with lags and leads of carbon emissions, respectively. That is, the inverted U-shaped EKC hypothesis supports for the globalization and carbon emissions nexus. On contrary, we find that for only 7 (led by all income categories of high (3), middle (2) and low (2) income economies) out of the 87 countries (8%), there is a U-shaped relationship between globalization and carbon emissions, which indicates that a rise in globalization will eventually increase CO_2 emissions in the future. The remaining countries do not show a U- or an inverted U-shaped relationship between

globalization and CO2 emissions. On a final note, the overall finding suggests that some high- and middle-income countries in the world have benefitted from globalization due to the larger role this phenomenon plays in improving the quality of the environment by lowering carbon emissions. Along such lines, the current study discusses key policy implications in the conclusion section.

The remainder of this study is organized in the following ways. Section 2 presents related studies in the literature. Section 3 provides the theoretical understanding, the empirical method and the data description. Both the summary statistics and the results are discussed in Section 4. Finally, Section 5 concludes and provides suggestions of future directions.

2. Related studies

The Environmental Kuznets Curve (EKC) hypothesis[7] establishes the existence of both linear and non-linear relationships between economic growth and environmental degradation. (Kuznets, 1995; Grossman and Krueger, 1991, 1995). Such a defining relationship between economic growth and environmental degradation is called an inverted U-shaped curve. This EKC hypothesis has been criticized by many researches since it does not hold equally across developed and developing countries (Mohapatra et al. 2016). This argument again underscores that the findings of the EKC hypothesis across developed and developing countries are mixed and inconclusive in the time series and panel data frameworks. Despite that, many countries have exerted their good efforts in implementing policies towards the protection of environmental health.

[7]This hypothesis originates from Kuznets (1955) which initially links a causal relationship between economic growth and income inequality.

As a result, more stringent environmental regulations have been strengthened over the years to protect the environment (Jena and Grote, 2008). Despite the tireless efforts of developed and developing countries in reducing the environmental consequences on the well-being of human beings through stringent environmental regulations, it seems that people in developed and developing countries suffer significantly from climate change and global warming caused by a higher course of economic development. In this context, most of the literature hypothesizes that globalization can minimize the environmental consequences on developed and developing countries. In such logic, it is argued that trade openness can cause the dynamics of environmental quality (Grossman and Krueger, 1995; Copeland and Taylor, 2004). In the study of Grossman and Krueger (1991), it is further viewed that the effect of international trade on the environment in developed and developing countries truly depends on the kind of policies they implement towards the protection of the environment, irrespective of their levels of economic growth and development.

In such a direction, two contrasting views seem to be prominent about the environmental impacts of trade openness. The proponents of the openness postulate that trade openness not only benefits countries but also provides them with a platform of participation in the international trading market. This access would result in a greater production efficiency of the trade-participating countries by allocating the given scarce resources among the competing uses through a better management. According to Runge (1994), trade openness provides opportunities to most of the countries on the globe to have a better environmental quality by lowering CO_2 emissions through utilizing cleaner technologies in economic activities. Furthermore, trade openness benefits economies in terms of environmental management by enabling them to have access to environmentally sound technology (Jayadeappa and Chhatre (2000).

Similarly, few studies also argue that a win-loss position is naturally present for developing countries but not for advanced countries because trade openness stimulates economic growth of developing countries more than that of developed countries and in turn deteriorates environmental quality mainly for developing economies (Copeland and Taylor 1994, 2000; Christmann and Taylor, 2001; Copeland, 2005; Shin, 2004). This suggests that the pollution-haven hypothesis is likely to take place when industries from developed countries enter developing countries under lax environmental regulations. This hypothesis is understood when the growth of these industries happens in developing countries at the cost of environmental health. As a result, developing countries are becoming havens for pollution-intense and dirty industries, whereas developed economies import from the developing countries the products produced with a high pollution content. Moreover, with more opportunities to improve environmental quality, rich countries can sustain a better quality of life. However, the transnational environmental problems affect the global ecologic and economic systems. These environmental problems like global warming, ozone depletion, deforestation and acid rain have cross-border effects, and therefore they affect all countries. Consequently, rich countries might not sustain a higher quality of life due to a deterioration in environmental resources globally. This implies that the nature of economic growth and development created by multinational firms is not environment-friendly (Copeland and Taylor, 2003, 2004). Given that, it is finally argued by other studies (Shahbaz et al., 2012; Schmalensee et al., 1998; Chaudhuri and Pfaff, 2002) that because of trade openness, natural resources are relatively depleted in developed and developing economies.

Despite the relevance of globalization to the evolution of carbon dioxide emissions, there only are few studies available on the nexus between globalization and environmental degradation within the framework of time series and panel data analysis. However, the recent studies of Ahmed et al.,

(2015) and Ling et al. (2015) have also examined the trade and CO_2 emissions nexus but found mixed findings. In a similar vein, Antweiler et al. (2001) have introduced the composition, scale and technological effects within the trade framework. They argue that trade openness improves environmental quality if clean technology is being used in an effective management of the environment where economic activities are taking place. Copeland and Taylor (2003, 2004) in their pollution haven hypothesis argue that international trade improves environmental quality only if stringent environmental regulations are implemented. Managi (2004) reveals that trade openness is not healthy for environmental quality for 63 developed and developing countries. In contrast, Shin (2004) considers trade openness to be conducive to the environment of Chinese cities. McCarney and Adamowicz (2006) further argue that improved environmental quality through trade openness is only possible through an effective implementation of government policies. Managi and Jena (2008) also argue that strong implementation of environmental regulations can only bring possible environmental quality. Jena and Grote (2008) also find a beneficial effect of trade on environmental quality in India.

Subsequently, Baek et al. (2009) validate the environmental Kuznets curve hypothesis and praise trade openness as the key for environmental quality improvement for 50 developed and developing countries. Saboori et al. (2012) and Ling et al. (2015) find trade openness as one of the factors that help the improvement of environmental quality in Malaysia. Solarin (2014) finds that Malaysia's exports to Singapore deteriorates environmental quality. Chang (2012) argues that the type of pollutants matters in examining the environmental quality effects of trade openness and foreign direct investment in China. Machado (2000) shows that foreign trade is harmful for environmental quality in Brazil. Shahbaz et al. (2012) reveal that environmental quality improvement is the cause of trade openness in Pakistan. In line with environmental quality, Kanzilal and Ghosh (2013)

support the trade openness framework for the Indian economy but this is not the case in Tiwari et al. (2013), which has found that trade openness is harmful to environmental health in India.

Considering the newly developed Dreher globalization index (Dreher, 2006), few studies have applied this index with its financial, political and social aspects in an international setting. Christmann and Taylor (2001), for example, consider globalization as a beneficial factor for improved environmental health of China. In their findings, the authors argue that only an effective implementation of environmental quality regulations can bring an improved environmental quality to the Chinese economy. Subsequently, Lee and Min (2014) consider broadly defined globalization as one of the determinants in enhancing the environmental health for developed and developing countries. Shahbaz et al. (2015b) find globalization to be helpful for the Australian economy as far as the environmental quality is concerned. Concerning the Indian economy, Shahbaz et al. (2015a) do not find any positive effects of globalization on environmental quality.

After reviewing the above literature, we have arrived at the conclusion that many studies use trade openness as a proxy for globalization while focusing on its impact on environmental health of developing and developed economies. The only problem with the usage of trade openness is that it just captures the trade intensity while ignoring the financial, political and social aspects of globalization. In such circumstances, it suffers from important limitations. The narrowly defined trade liberalization is unable to produce the dynamic behaviour of environmental degradation happening in developed and developing countries, and thereby it produces mixed evidences. To address this issue, Dreher (2006) has developed the globalization index by using sub-indices covering the economic, political and social aspects of globalization. The Dreher-based globalization is a primary source of engineering sustainable economic growth and development, and thereby it affects environmental quality by influencing CO_2 emissions.

3. Theoretical understanding and empirical method

3.1. Theoretical understanding

Before we embark on the empirical strategy used in our analysis, it is crucial to understand the significance of globalization and highlight how it influences carbon emissions through the various channels existing in developing and developed countries in a globalized world. It is also currently believed that this phenomenon is a current economic tool which improves economic growth and welfare through relaxing restrictions on trade and investment flows across country boundaries. But at the same time, there are those who consider globalization as a vehicle that affects CO_2 emissions and economic activity via different channels. Having a country engaged in trade and investment activities, then higher amounts of energy usage are required in producing goods and services, which eventually releases more carbon emissions to the environment. Globalization brings an improvement in environmental health by reducing those CO_2 emissions through technology and knowledge transfers. For instance, the use of cleaner technology by international firms requires lesser energy and also generates higher economic growth, all without undermining the quality of the environment. Channels such as trade, investment and technology have many implications for the environment and economic activity. First, if a country continues to release a greater amount of CO_2 emissions, it then hampers environmental quality by increasing those emissions. Second, environmental degradation depends on the nature of technology that is used in economic activities. In this case, if firms use dirty, energy-intensive production techniques, then there will be no doubt that economic growth will increase but those techniques will also weaken environmental quality, along with impacting climate change and global warming.

Different dimensions of globalization also command importance in impacting CO_2 emissions. Globalization connects various countries through trade and financial integration. The growth of each economy requires large amounts of energy to stimulate economic growth and increase carbon emissions. Social globalization occurs via connecting personal contacts, information spillover and cultural sharing. For instance, social globalization enables a country to access the environmental management knowhow of other countries. Accordingly, a country will be able to reduce energy consumption generated in the process of economic activities. Subsequently, it helps individuals, and economies as a whole to protect the quality of the environment. The number of embassies and memberships in key international missions and treaties also come under political globalization.

Furthermore, globalization is considered a tool of integration among countries' social and cultural fabrics as well as their institutions that determine the quality of the environment (Tamazian and Rao, 2010). Tamazian and Rao (2010) also argue that quality institutions through globalization play a significant role in improving the quality of the environment with a strict implementation of environmental rules and regulations. As far as the greater role of globalization is concerned, this phenomenon also affects environmental quality via the *scale effect*, the *technique effect* and the *composite effect* (Tsurumi and Managi, 2010). Trade openness induces economic growth which requires more energy, and thereby leads to a deterioration in environmental quality. This is termed the *scale effect* which is visible in the increasing phase of the EKC curve. Globalization through trade openness enables developing economies to import energy efficient hybrid technology from advanced countries, which helps them to reduce energy consumption without undermining their production processes. The reduction in energy consumption will improve environmental quality by lowering carbon emissions. From such a perspective, it can be argued that globalization affects

energy demand and enhances environmental quality using energy efficient technology. This is called the *technique effect*. Globalization through trade changes the structure of production of goods by changing the capital-labour ratio, which affects negatively and positively the environmental quality (Cole, 2006, Jena; Grote 2008). This is known as the *composite effect*.

As far as the adverse effect on environmental quality is concerned, globalization deteriorates environmental quality in the industrial phase of developing economies. For instance, if business firms in developing countries do not import and use advanced energy-saving production techniques and do not follow strict environmental rules and regulations, while advancing their growth for profit-making purposes, they will deteriorate environmental health through releasing increased carbon emissions to the atmosphere. Moreover, in the presence of globalized world, environmental quality also deteriorates if the mind-set of the people in developing countries does not change towards ethical environmental quality. As the positive effect of globalization on environmental quality is concerned, this phenomenon improves environmental quality through trade openness. It will also change the production structure only if business firms in developing countries use imported energy-efficient production techniques in the presence of a changing globalized world. Furthermore, globalization helps developing economies to change their production structure from the industrial to the service sector. Since the service sector is less energy-consuming due to the use of imported hybrid energy-efficient technology from the advanced nations, this helps developing economies to improve their environmental quality through trade.

3.2. Empirical method and data description

We utilize the cross-correlation approach for EKC testing, as recently applied by Narayan et al. (2016). The coefficient of cross-correlation (CCC) between globalization (G_t) and CO_2 emissions (E) is as follows:

$$CCC = \frac{\sum (G_t - \overline{G})(E_{t+k} - \overline{E})}{\sqrt{(G_t - \overline{G})^2 (E_{t+k} - \overline{E})^2}} \quad (1)$$

where $\overline{G}$ and $\overline{E}$ stand for the mean of globalization and carbon emissions, respectively. Since, we have 43 annual observations, the time series of the considered variables are therefore $G_1, G_2, ...G_{43}$ and $E_1, E_2, ...E_{43}$. In order to avoid the spurious correlation, we first de-trend all the time series using the Hodrick–Prescott (HP) filter. The correlations between globalization and carbon emissions are the contemporaneous (CCC_0) when k = 0. A lag order k = 1 implies that the CCC_1 between G_t and E_{t+1}, one-period lead or the future value of E and so on. In contrast, if the lag order is k = -1, the CCC_{-1} is between G_t and one-period lagged values of E,.

For a short- to a long-run perspective, we estimate the CCC's for k = $\mp$20 as these lags (20) are sufficient to gauge the behaviour of carbon emissions in response to changes in globalization, with annual time series data. Our estimation regarding the relationships between globalization and carbon emissions is of paramount interest for policy-makers because Eq. (1) is estimated for all 87 high, middle and low income countries. In doing so, we use annual time series data over the period 1970-2012 for carbon dioxide emissions and globalization. We show the details the names of the sampled countries in the Appendix (see Table 1A). Due to the availability of annual data, our final sample includes 87 countries, which are sufficient to do a comparison exercise. For a better comparison, we categorize the sample countries in terms of economic development. This

classification is relevant because countries with different fundamentals are at different stages of economic development, and hence the analysis will offer more insights for better policy implications (see summary statistics presented in Table 1). Moreover, the concept or the empirical validity of the EKC hypothesis may not be generalized across all countries. With this background, we categorize the 87 countries into the three income country groups: 30, 48 and 9 countries from high, middle- and low-income groups, respectively.

Our study uses the annual data over the period 1970-2012. This period is dictated by the availability of data along with the actual availability of the overall globalization index.[8] Moreover, the annual carbon emissions data are taken from the *World Development Indicators* (CD-ROM, 2014) which are measured in metric tons and also converted into per capita units by dividing over the total population. Our study uses the overall globalization index as an influential variable in the dynamics of carbon emissions in the context of the 87 countries. For this purpose, we use only the overall globalization index which is estimated by Dreher (2006).[9]

4. Descriptive statistics and discussion

Table 1 reports the descriptive statistics and the correlation estimates (i.e., unconditional correlation) between globalization and carbon emissions (Column 6). Specifically, it shows the mean and standard deviation of globalization and carbon emissions. The null hypothesis which states that the "unconditional correlation between globalization and carbon emissions is equivalent

[8] The overall globalization index data are sourced from the Swiss Federal Institute of Technology, Zurich. This data for all countries is updated annually.

[9] In addition, details on the globalization index are discussed in the study of Dreher (2006). The weighted average of the overall globalization index is maintained by ETH Zurich (http://globalization.kof.ethz.ch/).

to zero" is also tested. The t-statistics are reported in the final column of Table 1. The results of the 87 countries are reported in this table and also are categorized into three income groups to help with the interpretation and comparison of the results[10]. The average and standard deviation values of the globalization index provide useful information on the degree of social, economic and political integration of the sample countries. As evident, high income countries are generally more integrated/globalized with the rest of the world's economies, compared to the middle- or low-income countries. Contrary to that, low income countries are less globalized. This is an expected outcome knowing that globalization is higher in high economic countries.

The unconditional correlation analysis between globalization and carbon emissions provides very interesting empirical findings for all groups of countries. In the case of high income countries, 16 out of the 30 countries (53.3%) show a positive and significant correlation between globalization and carbon emissions. This indicates that on average globalization leads to an increase in carbon emissions over the period 1970-2012. In 13 out of those 30 high income countries (43.3%), globalization is negatively and significantly correlated with the CO_2 emissions. This indicates that globalization on average leads to a decline in carbon emissions in these countries over the period 1970-2012.[11] In the middle income countries, globalization on average is positively (negatively) correlated with carbon emissions in 36 out of the 48 countries, i.e. 75% (6 out of the 48 countries, i.e. 12.5%) but globalization is insignificantly linked with CO_2 emissions in 6 out of the 48 countries i.e. 12.5%. In the low income countries, carbon emissions are on average positive for 5 out of the 9 countries or 55.5%, and globalization is negatively and significantly correlated with

[10] The classification of the countries into three distinct income groups is based on the recent World Bank Atlas method (https://datahelpdesk.worldbank.org/knowledgebase/articles/906519).
[11] In one out of 30 countries (0.3%), globalization is negatively but insignificantly linked with CO_2 emissions.

carbon emissions in 33.3% of the sample countries (3 out of the 9 low income countries)[12]. Overall, we note that the correlation between globalization and carbon emission is positive (negative) and significant in 65.50% (25.30%) of all the 87 countries. However, this correlation is positive or negative but statistically insignificant for 9.2%% (or 8 out of the 87 countries).

Table 1: Summary Statistics and Correlation Coefficients.

	Globalization		Carbon emissions			
Countries	Mean	Standard deviation	Mean	Standard deviation	Correlation	t-statistics
Panel A: High Income						
Angola	38.6084	4.9575	0.7199	0.3243	0.4550	3.2714***
Australia	73.8216	7.8775	15.4199	1.7335	0.9275	15.883***
Austria	78.9142	11.6470	7.6866	0.5681	0.6008	4.8122***
Albania	36.3952	10.7613	1.7327	0.7302	-0.5157	-3.8538***
Belgium	82.5889	8.9622	11.3587	1.4368	-0.7889	-8.2209***
Canada	81.4735	5.3917	16.4481	0.9769	-0.1423	-0.9207
Cyprus	58.3698	14.3644	5.7081	1.5369	0.7893	8.2298***
Denmark	79.3470	8.2357	10.5567	1.4411	-0.6005	-4.8080***
Finland	71.7346	12.6987	10.6220	1.1431	0.4357	3.0996***
France	72.4675	10.0095	6.9982	1.3734	-0.9300	-16.1986***
Greece	62.6568	14.0258	1.2969	0.7246	0.9755	28.3692***
Hungary	64.4332	17.1415	6.5742	1.1305	-0.8850	-12.1720***
Iceland	61.8536	11.6065	7.3919	0.6745	-0.3067	-2.0633**
Israel	59.9941	10.1706	7.4924	1.6618	0.7908	8.2715***
Italy	66.1751	12.4414	7.0579	0.6894	0.7984	8.4907***
Kuwait	60.8165	8.2501	25.1904	7.2035	0.5052	3.7485***
The Netherlands	82.7754	8.3858	10.8461	0.8615	-0.5708	-4.4508***
Luxemburg	76.6146	5.2689	26.1411	6.4222	-0.6899	-6.1031***
New Zealand	68.9857	8.7304	7.0299	1.0885	0.8468	10.1934***
Norway	76.1418	7.3292	8.3787	1.1427	0.4742	3.4485***
Oman	51.4345	5.5589	8.5730	5.0164	0.8613	10.8526***
Portugal	66.2559	15.1139	4.0952	1.4791	0.9074	13.8280***
Saudi Arabia	56.0212	8.5516	14.1690	2.4564	0.5185	3.8825***
Spain	68.3237	14.9130	5.9148	1.1192	0.8056	8.7076***

[12] In 12% of the sample countries (or 1 out of 9 countries), the correlation between globalization and carbon emission is positive but insignificant.

Sweden	80.0059	8.4231	7.2258	1.9324	-0.9380	-17.3316***
Switzerland	44.2655	3.4428	5.9428	0.6048	-0.8751	-11.5758***
Trinidad and Tobago	50.0622	7.6180	18.9246	8.7176	0.6795	5.9302***
United Kingdom	76.2575	7.8549	9.6591	1.1552	-0.8678	-11.1813***
United Arab Emirates	61.7938	9.7263	36.3471	16.8033	-0.7246	-6.7321***
Unites States	69.3616	6.4801	19.6761	1.3136	-0.6422	-5.3649***
Panel B: Middle Income						
Algeria	41.6399	6.5034	2.8366	0.6014	0.2389	1.5753
Argentina	52.5716	7.8497	3.7987	0.3803	0.3639	2.5012**
Bolivia	43.3499	7.9420	1.0459	0.3418	0.8849	12.1659***
Botswana	44.1913	5.1076	1.5419	0.8486	0.8392	9.8806***
Brazil	49.2209	8.1164	1.5869	0.3057	0.8765	11.6610***
Bulgaria	51.1481	13.8210	7.6267	1.5541	-0.7223	-6.6884***
Cameroon	33.6413	6.3279	0.2771	0.1625	0.0424	0.2717
Chile	58.5494	9.8756	2.9645	0.9145	0.8716	11.3856***
China	38.6483	16.0331	2.7285	1.6344	0.8667	11.1254***
Colombia	44.3347	9.1574	1.5352	0.1333	-0.0251	-0.1609
Congo Rep	37.8285	5.2067	0.4901	0.2085	-0.2200	-1.4440
Costa Rica	52.4537	7.7919	1.2378	0.3389	0.8672	11.1520***
Cote D'Ivoire	39.3453	6.6680	0.4995	0.1337	-0.6548	-5.5470***
Cuba	39.9894	6.2652	2.7897	0.4559	-0.2992	-2.0075*
Ecuador	42.3076	9.5879	1.7444	0.5104	0.6023	4.8314***
Egypt	44.9891	10.0688	1.5336	0.6005	0.9265	15.7601***
El Salvador	47.3397	10.0172	0.7253	0.2924	0.9277	15.9077***
Gabon	42.9440	4.3372	4.4517	3.1276	-0.6585	-5.6021***
Ghana	40.0223	8.6066	0.3117	0.0625	0.8183	9.1170***
Guatemala	44.9011	9.3702	0.6438	0.1683	0.7664	7.6406***
Honduras	42.6612	11.7904	0.7088	0.2472	0.7201	6.6460***
India	35.2492	9.9725	0.8711	0.3978	0.9496	19.3973***
Indonesia	40.7663	11.7359	1.0356	0.5277	0.9749	28.0531***
Iran	30.9783	6.5099	4.8386	1.5580	0.5150	3.8469***
Ireland	78.3870	8.6193	8.6738	1.3715	0.8652	11.0486***
Jamaica	51.9333	7.2981	3.4805	0.7490	0.4291	3.0417***
Japan	50.5138	10.0921	8.6801	0.8255	0.8858	12.2232***
Jordan	53.4175	12.4192	2.8420	0.8741	0.8261	9.3876***
Mexico	51.0099	7.6642	3.5698	0.5182	0.7593	7.4717***
Morocco	44.4452	10.2381	1.0441	0.3789	0.9714	26.2176***
Nicaragua	41.8011	8.2289	0.6809	0.1288	0.3209	2.1695**
Nigeria	41.9357	8.1667	0.6510	0.1832	0.9035	13.4968***

Pakistan	36.6834	9.8143	0.6282	0.2199	0.9497	19.4164***
Panama	58.8851	4.8521	1.7639	0.4072	0.3414	2.3260**
Paraguay	40.3210	10.7238	0.5837	0.1884	0.5731	4.4780***
Peru	45.3687	11.6386	1.2568	0.2579	-0.2450	-1.6179
Philippines	44.0989	10.4395	0.7810	0.1118	0.2968	1.9899*
Senegal	41.2601	7.4865	0.4487	0.0863	0.0230	0.1476
South Africa	47.4313	11.5811	8.7323	0.9315	0.4448	3.1800***
Sudan	26.5405	5.4336	0.2300	0.0785	-0.6176	-5.0275***
Syria	34.1308	6.6941	2.6551	0.7083	0.8610	10.8382***
Thailand	43.9445	14.5969	2.1360	1.4240	0.9812	32.5975***
Tunisia	50.3589	6.3108	1.7207	0.4985	0.9802	31.6932***
Turkey	50.9519	13.6089	2.6975	0.9050	0.9568	21.0687***
Uruguay	55.6427	7.3418	1.7425	0.3669	0.5572	4.2967***
Venezuela	49.3926	7.5646	5.9237	0.7481	0.6395	5.3266***
Vietnam	29.3064	10.6070	0.6830	0.5006	0.9233	15.3919***
Zambia	42.5855	7.5675	0.4070	0.2568	-0.9423	-18.0178***
Panel C: Low Income						
Bangladesh	24.3503	10.0065	0.1736	0.1011	0.9716	26.3117***
Benin	27.6478	9.3801	0.2224	0.1413	-0.2648	-1.7585*
Congo Dem Rep	37.8285	5.2067	0.4901	0.2085	0.0291	0.1862
Ethiopia	27.7118	6.1330	0.0597	0.0143	0.6249	5.1255***
Kenya	36.3584	7.8993	0.2855	0.0549	0.3284	2.2260**
Mozambique	32.7379	10.2777	0.1468	0.0960	-0.8418	-9.9843***
Nepal	25.4723	8.3205	0.0752	0.0479	0.9098	14.0395***
Togo	37.8189	6.2517	0.2282	0.0685	0.8083	8.7899***
Zimbabwe	36.4326	8.8571	1.2184	0.3296	-0.8294	-9.5064***

Note: As usual ***, ** and * indicate significance at the 1%, 5% and 10% levels.

Table 2: Cross-Correlation Analysis.

Countries	Lag		Lead	
	Sum of correlations	Average of correlations	Sum of correlations	Average of correlations
Panel A: High Income				
Angola	-0.7766	-0.0388	10.6771	0.5339
Australia	6.9038	0.3452	5.3621	0.2681
Austria	2.7297	0.1365	9.7382	0.4869
Albania	-10.2859	-0.5143	-1.8397	-0.0920
Belgium	-5.9589	-0.2979	-6.4597	-0.3230

Canada	-3.0397	-0.1520	-8.0951	-0.4048
Cyprus	9.8424	0.4921	2.3194	0.1160
Denmark	-2.4574	-0.1229	-9.2039	-0.4602
Finland	8.4067	0.4203	3.9789	0.1989
France	-6.6525	-0.3326	-5.9603	-0.2980
Greece	6.1047	0.3052	6.9453	0.3473
Hungary	-4.6410	-0.2321	-8.1563	-0.4078
Iceland	-0.6661	-0.0333	-9.8470	-0.4924
Israel	9.7493	0.4875	2.8518	0.1426
Italy	9.1353	0.4568	3.1198	0.1560
Kuwait	2.5364	0.1268	9.5871	0.4794
The Netherlands	-6.1186	-0.3059	-5.8581	-0.2929
Luxemburg	-9.4558	-0.4728	-2.3013	-0.1151
New Zealand	8.0324	0.4016	4.7028	0.2351
Norway	2.9881	0.1494	8.7570	0.4379
Oman	4.2988	0.2149	7.3083	0.3654
Portugal	8.7352	0.4368	4.2222	0.2111
Saudi Arabia	4.8078	0.2404	6.6655	0.3333
Spain	6.7813	0.3391	6.1554	0.3078
Sweden	-6.9911	-0.3496	-5.2008	-0.2600
Switzerland	-6.5312	-0.3266	-5.7907	-0.2895
Trinidad and Tobago	3.3996	0.1700	8.5864	0.4293
United Kingdom	-4.6356	-0.2318	-7.7811	-0.3891
United Arab Emirates	-9.4799	-0.4740	-2.2252	-0.1113
Unites States	-5.2194	-0.2610	-6.8280	-0.3414
Panel B: Middle Income				
Algeria	10.6668	0.5333	-0.4381	-0.0219
Argentina	-0.8616	-0.0431	10.7139	0.5357
Bolivia	5.5779	0.2789	7.2497	0.3625
Botswana	7.0894	0.3545	5.6113	0.2806
Brazil	5.1913	0.2596	7.5963	0.3798
Bulgaria	-6.0187	-0.3009	-6.2874	-0.3144
Cameroon	5.1513	0.2576	-6.0590	-0.3029
Chile	3.7451	0.1873	8.3873	0.4194
China	4.3333	0.2167	7.9223	0.3961
Colombia	7.7949	0.3897	-7.2357	-0.3618
Congo Rep	-5.2016	-0.2601	-7.2566	-0.3628
Costa Rica	4.8470	0.2424	7.9336	0.3967
Cote D'Ivoire	-4.6455	-0.2323	-7.2319	-0.3616

Cuba	-0.6208	-0.0310	-5.7603	-0.2880
Ecuador	8.7178	0.4359	2.9323	0.1466
Egypt	5.7358	0.2868	7.1434	0.3572
El Salvador	7.1251	0.3563	5.4677	0.2734
Gabon	-6.2238	-0.3112	-6.7600	-0.3380
Ghana	4.1507	0.2075	7.8479	0.3924
Guatemala	6.5644	0.3282	6.1959	0.3098
Honduras	4.0528	0.2026	8.1214	0.4061
India	6.6986	0.3349	6.0754	0.3038
Indonesia	5.8219	0.2911	6.9428	0.3471
Iran	7.3401	0.3670	-1.5328	-0.0766
Ireland	8.1737	0.4087	4.4121	0.2206
Jamaica	2.3324	0.1166	7.9033	0.3952
Japan	7.3292	0.3665	5.8619	0.2931
Jordan	8.9338	0.4467	3.2209	0.1610
Mexico	8.8016	0.4401	2.0040	0.1002
Morocco	6.8147	0.3407	5.6163	0.2808
Nicaragua	-0.2953	-0.0148	8.9791	0.4490
Nigeria	-8.2546	-0.4127	-4.3108	-0.2155
Pakistan	7.4000	0.3700	5.5638	0.2782
Panama	1.0756	0.0538	7.4959	0.3748
Paraguay	9.4612	0.4731	3.0272	0.1514
Peru	-5.9577	-0.2979	8.3854	0.4193
Philippines	2.3970	0.1198	9.4703	0.4735
Senegal	3.0661	0.1533	5.7902	0.2895
South Africa	9.7244	0.4862	-2.7684	-0.1384
Sudan	-6.6019	-0.3301	7.5541	0.3777
Syria	10.1952	0.5098	-0.0770	-0.0038
Thailand	6.1851	0.3093	6.7662	0.3383
Tunisia	7.3484	0.3674	5.4303	0.2715
Turkey	6.0226	0.3011	6.9841	0.3492
Uruguay	-8.1295	-0.4065	8.1576	0.4079
Venezuela	3.7399	0.1870	8.8371	0.4419
Vietnam	2.4596	0.1230	8.0376	0.4019
Zambia	-8.7794	-0.4390	-3.6104	-0.1805
Panel C: Low Income				
Bangladesh	5.9407	0.2970	6.5922	0.3296
Benin	3.8896	0.1945	8.0012	0.4001
Congo Dem Rep	-5.2016	-0.2601	-7.2566	-0.3628

Ethiopia	6.5506	0.3275	5.9286	0.2964
Kenya	-10.6108	-0.5305	3.4761	0.1738
Mozambique	-10.0037	-0.5002	-0.6196	-0.0310
Nepal	6.3068	0.3153	6.6699	0.3335
Togo	6.4571	0.3229	5.5798	0.2790
Zimbabwe	-3.4837	-0.1742	-8.6454	-0.4323

The prime objective of the current paper is to examine whether globalization is positively or negatively correlated with carbon emissions, covering 20 lags and 20 leads of cross correlations. If globalization is positively and negatively correlated with lags and leads of carbon emissions, respectively, this confirms the presence of an inverted U-shaped relationship between both variables, which supports the Environmental Kuznets Curve (EKC) hypothesis. This hypothesis reveals that globalization is positively linked with carbon emissions initially, but after a threshold level of globalization, CO_2 emissions will decrease with increases in globalization, as the technique effect dominates the scale effect[13]. This simply exposes that globalization in the past leads carbon emissions, but in the future it improves environmental quality by lowering carbon emissions. On contrary, if the scale effect dominates the technique effect then globalization is negatively and positively correlated with the lags and leads of carbon emissions, respectively. This shows that environmental quality deteriorates in the future due to massive production, compared to the initial stages of globalization.

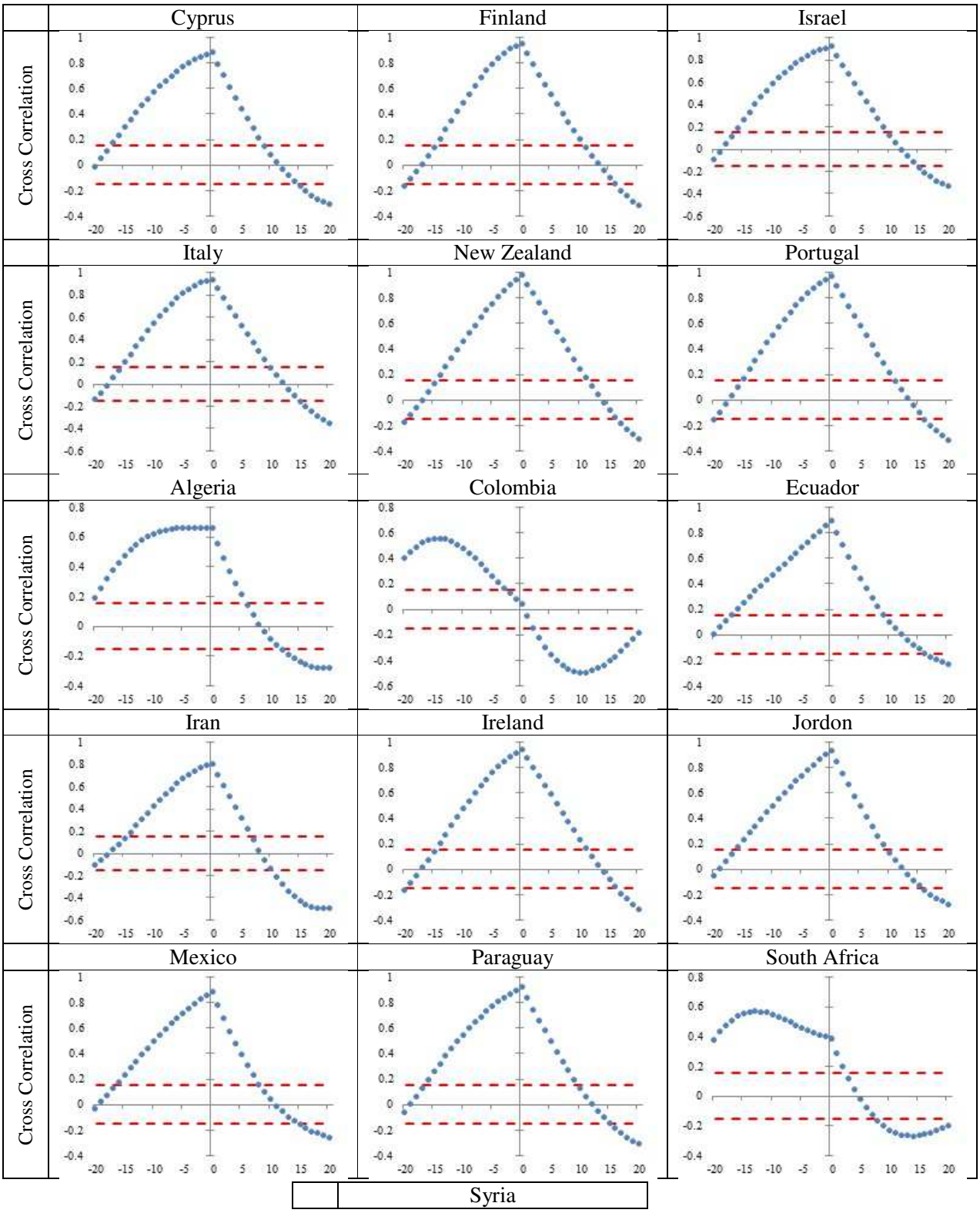
The results are reported in Table 2. The sum of lag and lead correlations is shown in Columns 2 and 4 over the 20 lags and 20 leads. The average of the correlations is reported in Columns 3 and 5 for the 20 lags and 20 leads of CO_2 emissions. We note that an inverted-U shaped relationship

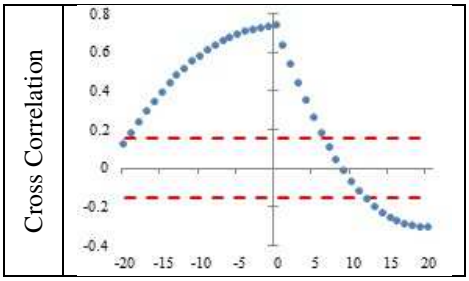
[13] Please see our theoretical understanding section where we have extensively discussed the role of globalization in affecting environmental quality via the *scale effect*, the *technique effect* and the *composite effect*.

between globalization and carbon emission (as represented by the cross-correlation coefficient) is found in the case of six high-income countries including Cyprus, Finland, Israel, Italy, New Zealand, and Portugal, and ten middle-income countries including Algeria, Colombia, Ecuador, Iran, Ireland, Jordan, Mexico, Paraguay, South Africa, and Syria (see Figure 1). In the statistical sense, Figure 1 indicates that both high-income and middle-income countries support the EKC hypothesis for globalization. This implies that each of the sixteen countries supporting the EKC comes under the high-income and middle-income groups. Again, the finding shows that for each 6 out of the 30 high-income countries (20%) and 10 out of the 48 middle-income countries (20.8%), both high and middle income countries can benefit from globalization to reduce carbon emissions in the future. This highlights that the rise in globalization is positively and negatively cross-correlated with the lags and leads of carbon emissions, confirming the presence of the EKC effect between both globalization and carbon emissions.

This result implies that a rise in globalization will decrease the level of carbon emissions in the future. In other words, it shows that globalization mostly benefits both high- and middle-income countries in terms of improving environmental quality via reducing carbon emissions. From a policy perspective, it is suggestive that the governments of these economies should give top priority to greater trade and financial integration with the rest of the world because of the carbon emissions-reducing effect of globalization as a whole. In addition, policy-makers should also add globalization in the carbon emissions function while designing their sustainable long-run environmental policy.

Figure 1. Plots of Cross-Correlations for Countries Consistent with the EKC Hypothesis.



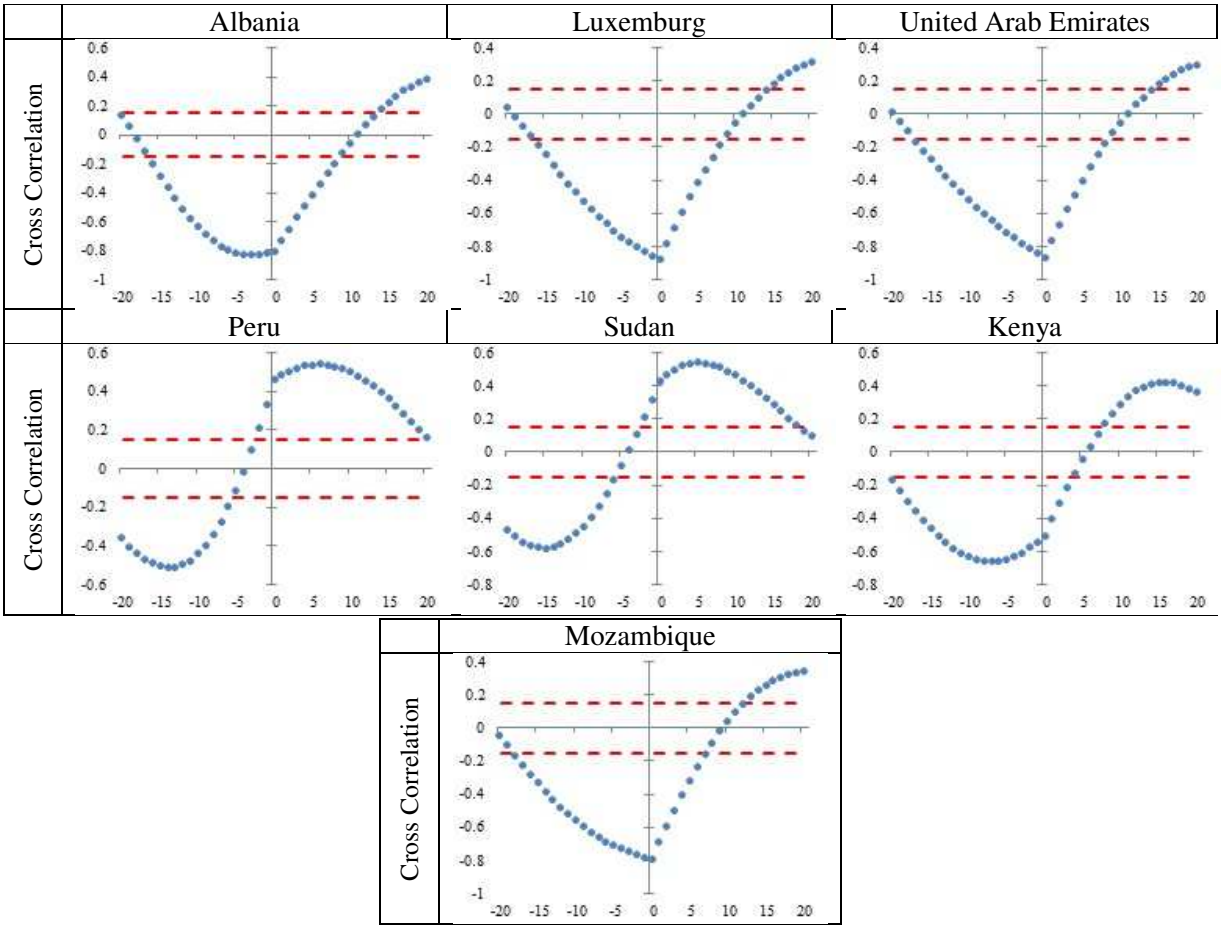


On the contrary, Figure 2 also shows that a rise in globalization is negatively and positively linked with lags and leads of carbon emissions for certain countries. This implies that globalization decreases carbon emissions initially, but then it increases those emissions in the latter stages of economic development, as the scale effect dominates the technique effect. This association between globalization and carbon emissions is termed as a U-shaped relationship of globalization with environmental degradation. It reveals that carbon emissions are positively linked with globalization in the future in the case of three high-income countries including Albania, Luxemburg, and United Arab Emirates, two middle-income countries including Peru and Sudan, and Kenya and Mozambique among low-income countries.

In the statistical sense, Figure 2 shows that for 7 out of the 87 countries (8%) led by (3) high, (2) middle and (2) low income countries, the U-shaped EKC relationship between globalization and carbon emissions exists which indicates an increasing effect of globalization on the CO_2 emissions in the future. Similarly, the results for 3 countries out of the 30 high-income countries (10%), 2 out of the 48 middle-income countries (4%) and 2 out of the 9 low-income countries (22%) support the U-shaped EKC relationship between globalization and carbon emissions, indicating that these countries are not benefitting from the wholesale model of globalization as this phenomenon adds to carbon emissions in the future.

In such logic, a key policy implication that emerges from this analysis is that fiscal governments in these high, middle and low income countries should not be too passionate about a massive globalization process because it impedes a sustainable improvement in environmental quality in the long-run by increasing carbon emissions. Moreover, policy advisers should give importance to the environmental consequences of globalization when designing their policies of steadying environmental quality. Hence, it is very important for both environmental policymakers and fiscal governments of these economies to have a better coordination while designing their policies and advancing their global integration with the rest of the countries.

Figure 2. Plots of Cross-Correlations for Countries: An increase in Globalization Increases Emissions in Future.



5. Conclusions and policy discussions

Although several empirical attempts have been made to study the relationship between globalization and environmental degradation known as the EKC hypothesis, with the application of conventional time series and panel techniques for developing and developed countries, the results have been mixed and inconclusive (Baek et al. 2009; Shahbaz et al. 2015a, b). Based on this argument, our main contribution in the current paper is that we employ a recently applied cross-correlation dynamic test of Narayan, Saboori and Soleymani (2016), which examines the nexus between economic growth and environmental degradation by considering the lags and leads of the cross-correlations between those variables. Our attempt postulates that if the current level of globalization is positively and negatively cross-correlated with the past and future levels of CO_2 emissions of countries, respectively, then these emissions will decline with an increase in globalization over time, thereby bestowing desired benefits on globalization in terms of improving environmental quality. Such a relationship therefore if exists supports the EKC hypothesis between globalization and carbon emissions.

In addition, the methodology we apply in the current paper can also be seen as an extension of the earlier Narayan and Narayan (2010) approach. Though the Narayan and Narayan (2010) approach tests the EKC hypothesis via comparing the estimated elasticity values, this is not used in this study because of the newer and better methodology used by Narayan et al. (2016), which is rooted in our study of considering the lags and leads of the cross-correlation between globalization and carbon emissions in order to decide whether the EKC hypothesis exists or not at the international level. In the laymen perspective, it is very easy to implement the cross-correlation test to support or reject the EKC hypothesis. It is also equally interesting that one can discern that the EKC

hypothesis is supported for an economy if globalization is positively cross-correlated with past emissions and negatively cross-correlated with future emissions.

Since the environmental consequences of globalization in a connected world seem to be larger than in a segmented world, this has motivated us to investigate the cross-correlation between globalization and CO_2 emissions for the 87 high, middle and low income countries using the annually available data. In doing so, our empirical results reveal that for 16 ((6) high-income and (10) middle-income) countries out of the total 87 countries (18.4%), a rise in globalization is positively and negatively cross-correlated with the lags and leads of carbon emissions, thereby supporting the existence of the EKC hypothesis between globalization and environmental degradation for those countries. This implies that for only 18.4% of the total country sample, a rise in globalization would decrease carbon emissions in the future.

On contrary, we find that for 7 out of the 87 countries (8%), led by (3) high, (2) middle and (2) low income countries, the U-shaped relationship between the series holds, which underscores the increasing effect of globalization on environmental degradation in the future, therefore invaliding the EKC hypothesis between globalization and carbon emissions. From these results, we note that out of the 87 sampled countries, only 16 high and middle-income countries are in a position to reduce the level of carbon emissions due to a greater role of globalization, whereas 7 (high, middle and low income) countries do not benefit from globalization as the long as environmental quality is concerned. Finally, the results show that although both high and middle income countries support the inverted–U shaped EKC hypothesis, the carbon dioxide emissions-reducing effect of globalization benefits middle-income countries relatively more, compared with high-income countries. This is probably so because the middle-income countries enable foreign investors to invest and produce output in the host countries. These investors may have been given strict and

clean environmental assessments to follow while producing the desired output level. This however may not be the case for the high-income countries, and thus an improvement in environmental quality due to wholesale globalization is much higher in the case of the high-income countries. In this context, this study suggests that those countries should not be de-globalized in the years to come because of their lesser environmental quality enhancing content. Rather the high-income countries should explore the environmental assessment mechanism which can strengthen the strong and positive relationship between globalization and environmental quality in the long-run.

Our key findings show that for almost 16 high and middle economies out of our total sampled countries, a rise in globalization will improve environmental quality by reducing carbon emissions in the future. From a policy perspective, it is suggestive that the fiscal governments of these economies should give top priority to a stronger trade and financial integration with the rest of the world due to the carbon emissions-reducing benefits of globalization as a whole. In addition, policymakers should also add ‘‘globalization’’ as a key environmental quality-inducing parameter in the carbon emissions function while designing their sustainable long-run environmental and growth policies.

Our findings further reveal the evidence of a U-shaped EKC relationship between globalization and environmental quality for 7 high, middle and low income countries. From a forecasting point of view, this implies that a rise in globalization will add to carbon emissions in future for these countries. In such case, a key policy implication is indicative of the fact that fiscal governments in these countries (high, middle and low income) should not be crazy about a massive globalization process because it hurts sustainable environmental quality in the long-run by increasing carbon emissions. Moreover, policymakers in these countries should not underestimate the environmental

consequences of globalization while designing their policies of maintaining or improving environmental quality.

Based on our overall empirical evidence, we find that the results are mixed across the 87 sampled countries. This implies that for some countries, the EKC hypothesis holds well, while for others it does not hold in our analysis. The key expected question that arises here is: what to do about globalization? Can globalization help the other countries suffering from the pollution consequences of globalization? The root of this question speaks about reality, indicating that globalization is not good for everyone. In this context, our study suggests that those high- and middle-income countries, for which globalization is not good, need to think seriously about the effective process of globalization rather than be too unwise about the wholesale volume of globalization. This is because some of the high and middle income countries in the name of globalization are connecting themselves with the rest of the countries in terms of trade and financial investments. Thus, high and middle income countries eventually encourage a larger set of both domestic and foreign investments in order to produce a greater scale of output at the cost of their sustainable environmental quality. This finally indicates that although globalization stimulates economic growth, but it also impedes improvements in the long-run environmental quality. In this context, the only suggestive way out for high and middle income countries that are suffering from the greater environmental consequences of globalization is that an environmental assessment policy needs to be implemented effectively at their domestic levels before they allow domestic and foreign investors in for the purpose of expanding production and consuming greater energy. As a result, we finally believe that the countries could be escaped from an increasing stage of pollution accompanied by globalization.

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Appendix

Table A.1: List of countries by income category.

Panel A: 30 high income countries	**Panel B: 48** middle income countries	**Panel C: 9** low income countries
Angola	Algeria	Bangladesh
Australia	Argentina	Benin
Austria	Bolivia	Congo Dem Rep
Albania	Botswana	Ethiopia
Belgium	Brazil	Kenya
Canada	Bulgaria	Mozambique
Cyprus	Cameroon	Nepal
Denmark	Chile	Togo
Finland	China	Zimbabwe
France	Colombia	
Greece	Congo Rep	
Hungary	Costa Rica	
Iceland	Cote D'Ivoire	
Israel	Cuba	
Italy	Ecuador	
Kuwait	Egypt	
The Netherlands	El Salvador	
Luxemburg	Gabon	
New Zealand	Ghana	
Norway	Guatemala	
Oman	Honduras	
Portugal	India	
Saudi Arabia	Indonesia	
Spain	Iran	
Sweden	Ireland	
Switzerland	Jamaica	
Trinidad and Tobago	Japan	
United Kingdom	Jordan	
United Arab Emirates	Mexico	
Unites States	Morocco	
	Nicaragua	
	Nigeria	
	Pakistan	
	Panama	

	Paraguay	
	Peru	
	Philippines	
	Senegal	
	South Africa	
	Sudan	
	Syria	
	Thailand	
	Tunisia	
	Turkey	
	Uruguay	
	Venezuela	
	Vietnam	
	Zambia	