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The effect of import product diversification on carbon emissions: New evidence for sustainable economic policies

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Abstract

This study examines the effect of import product diversification and renewable energy consumption on CO_2 emissions across a panel of 35 developed and 93 developing economies. The empirical models utilize an environmental theoretical framework and yearly data for 1995–2014. The study makes use of common correlated effects—specifically mean group (CCE-MG) and augmented mean group (AMG) estimators. The overall results suggest that import product diversification has a substantial negative and positive impact on the carbon emissions of developed and developing economies, respectively. This study also finds that increasing renewable energy consumption helps to meet climate change targets by reducing carbon emissions. Thus, import product diversification and renewable energy could play an indispensable role in reducing carbon emissions in developed economies; while renewable energy is the only factor that assists developing economies meet their emission reduction targets at this stage.

JEL classification codes: F14; F18; Q42; Q56

Keywords: import product diversification; renewable energy; carbon emissions; AMG estimator

1. Introduction

Global warming is a problem shared by all countries regardless of their income level. Its effects can be seen in the form of an increasing number of natural disasters including rising sea levels, heavy storms, and extreme weather conditions (Boutabba, 2014). Consequently, governments are spending billions of dollars to cover the resulting losses. In other words, the problem of global warming brings with it both material and moral costs. To mitigate the effects of global warming, international organizations are attempting to reduce emissions of greenhouse gases by setting specific targets. For example, the United Nations (UN) emphasizes the need for intergovernmental cooperation and agreements to reduce the impact of global warming (Halicioglu, 2009). The European Union (EU) has declared that member countries will reduce petroleum-based energy consumption and increase the proportion of renewable energy in their total energy mix as part of its low carbon emission strategy (European Commission, 2010). As stated in the Commission of the European Communities report (2007), the EU has set a target of a 30% reduction of environmental pollutants by 2020.

In addition to international organizations, researchers and research institutes are also attempting to address the issue of global warming and to identify factors that harm the environment. In environmental economics literature, economic activities are singled out as one of the most important factors contributing to environmental degradation. Thus, researchers are seeking to explain the relationship between CO_2 emissions, economic growth, energy consumption, and trade factors. Among these variables, volume of trade (such as exports, imports, and/or trade openness) is the most frequently tested indicator in the literature. This is because increase in trade activity creates a considerably greater energy demand, which can lead to environmental degradation. However, in recent years, some scholars have argued that not only the volume of trade but also the diversification of products (for both exports and imports) leads to increase in trade activity, thereby raising CO_2 emissions.

Import product diversification is one of the most prominent parameters in international trade literature and can make a significant contribution to economic growth (e.g. Jaimovich, 2012; Parteka and Tamberi, 2013). Moreover, import product diversification is thought to affect a country's environment by affecting its energy consumption (Machado et al., 2001). The degree of impact depends on a country's level of development. For example, a nation may specialize in pollution-intensive manufacturing industries (e.g. cement and metal) in the early stages of its development (Hettige et al., 1995) to achieve higher growth by manufacturing more products, which leads to a greater demand for energy. The characteristics of such industries (such as scale, structure, and labour insensitivity) and their energy consumption can increase environmental pollution. However, once economic development reaches a certain level—for instance an income level of 8000 USD (Grossman and Krueger, 1995; Sengupta, 1996) —such countries switch to less polluting industries. This process leads to developed countries specializing in clean industrial products (technologically complex and sophisticated products), which play an indispensable role in reducing CO_2 emissions (Can and Gozgor, 2017; Lorente and Alvarez-Herranz, 2016). Moreover, in developed countries, considerable resources are devoted to meeting environmental regulations. Consequently, developed countries tend to specialize in products that cause less pollution and preferring to import from developing economies those goods whose manufacturing is pollution-intensive (Cole, 2004). This process, by which developing countries are subjected to increasing environmental pollution, is called the 'pollution haven hypothesis' (PHH) in the literature (Ren et al., 2014). In this respect, import product diversification may have a positive impact on the environment of developed countries.[1]

The situation is different for developing countries. One of the main targets of developing countries is to increase energy efficiency. However, technological developments that increase energy efficiency tend to first appear in developed countries. The transfer of new technology from developed countries, therefore, is of greater importance for developing

[1] For example, Li and Hewitt (2008) concluded that importing from China led to 11% reduction in the United Kingdom's potential CO_2 emissions in 2004.

countries given that it may contribute to reduce environmental pollution (Popp, 2011). In addition, technology used in production can be updated by means of importing new improved technology thus further greening production methods and further improving the quality of the environment (Dietzenbacher et al., 2012). But import product diversification also facilitates access to cheap intermediate goods (Carrere et al., 2011). If these intermediate goods include such products as construction materials, general machinery, electric appliances, and transportation equipment, CO_2 emissions will increase in developing countries (Kondo et al., 1998).

In general, developed countries aim to import high-quality products from developing countries (Cadot et al. 2014; Jaimovich, 2012).[2] As a result, developing countries' continually try to improve the quality of the products they manufacture. This effort may have a positive (Gozgor and Can, 2017b) or negative effect (Fang et al., 2019) on the country's environmental quality. The success of reducing CO_2 emissions is closely related to the environmental policies of governments in developing countries. If the governments do not implement environmental laws strictly, then the positive contribution of import product diversification to developing countries will remain low or negative in terms of improving the environment.[3]

In light of the above discussions, our goal in this paper is to investigate the effect of import product diversification on CO_2 emissions across a panel of 93 developing and 35 developed countries during the period of 1995-2014. This study contributes to the literature in four ways: i) to the best of our knowledge, this paper is the first of its kind to provide

[2] Mania (2019) utilized annual data, 1995-2013, and panel econometric techniques to investigate the impact of export diversification on CO_2 emissions in a sample of 98 developed and developing economies. The author confirmed the presence of an environmental Kuznets curve in this group of economies.

[3] In general, developing countries have low environmental standards. Hence, it can be expected that import product diversification will have a negative impact on the environment in developing economies. Moreover, the possibility increases because of PHH.

evidence on the impact of import product diversification on CO_2 emissions in developed and developing economies. The study period, 1995-2014, is determined by the availability of data; ii) the study also tests the effect of renewable energy consumption on CO_2 emissions; iii) the econometric techniques such as the common correlated effects – mean group (CCE-MG), augmented mean group (AMG) estimators - and a pooled-weighted approach are employed for the empirical investigation; (iv) finally, the empirical findings are expected to enhance our knowledge of sustainable environmental management in the context of developed and developing countries. The findings derived from this paper can consequently be useful inputs into designing appropriate policies in regards to the linked issues of product diversification, renewable energy use and environmental management for both developed and developing economies.

The remainder of this paper is organized as follows. The next section presents the relevant empirical literature. Section 3 describes the nature of the data, how the variables are measured and the methodology. Section 4 reports and discusses the empirical findings. Section 5 discusses relevant policy implications and Section 6 provides the paper's conclusions.

2. Literature Review

International trade has become an important factor in determining economic growth. There is a plethora of studies examining the effects of export, import, or trade openness on economic growth. The literature mostly concludes that international trade significantly contributes to economic growth (e.g., Buysse et al., 2018). Moreover, this type of trade provides an efficient system for resource allocation (Feenstra, 2003). In these studies, international trade was discussed in terms of ‘volume’. However, in the past decade, scholars have frequently stated that new variables need to be used for international trade apart from ‘volume'.[4]

International trade as a vital parameter for the environment is often examined in the literature. According to scholars, international trade significantly affects the environment in three ways. The first is the technology effect. Increasing trade allows countries to import new technologies that improve energy efficiency, thereby helping reduce emissions. The second is the scale effect. More trade leads to more production, which degrades the quality of the environment. The third is the composition effect. The characteristics of industries have a significant impact on the environment. If countries have polluting industries, it will harm the environment (Shahzad et al., 2017).

By considering the above factors, a number of researchers tested the effects of international trade on the environment for different countries or country groups. For example, Al-Mulali and Ozturk (2015) analysed the effect of trade openness on ecological degradation in a sample of 14 Middle Eastern and North African (MENA) countries over the period 1996–2012. The results from Perdoni’s co-integration test revealed that series are co-integrated in the long run, while the regression result concluded that trade deteriorates environmental quality. Likewise, considering Turkey as a case study, Ozatac et al. (2017) tested the effects of trade openness on CO_2 emissions for the period 1960–2013. The result from the autoregressive distributed lag (ARDL) bound test suggested that trade openness increases the CO_2 emissions in Turkey. Using the ARDL approach, Shahzad et al. (2017) examined the effects of trade openness on CO_2 emissions in the case of Pakistan for the period 1971–2011.

[4] These new variables for international trade can be listed as export product diversification (Cadot et al., 2011; Gozgor and Can, 2017a), import product diversification (Parteka and Tamberi, 2013), export market diversification (Juvenal and Monteiro, 2013), import market diversification (Jaimovich, 2012), export quality (Can and Gozgor, 2018; Henn et al., 2017), export sophistication (Hausmann et al., 2007; Jarreau and Poncet, 2012) and economic complexity (Hausmann et al., 2011), respectively.

They concluded that trade has a harmful impact on the environment. Likewise, Shahbaz et al. (2017) examined the relationship between trade openness, economic growth, and carbon emissions across panels of high, middle, and low-income economies. Their results showed a feedback nexus between trade openness and carbon emissions in the middle-income economies, and a one-way causality from trade openness to emissions in high- and low-income countries. Similarly, Lv and Xu (2019) investigated the effect of trade openness and urbanization on CO_2 emissions in middle- income countries. By using yearly data from 1992–2012 on 55 countries and a pooled mean group (PMG) estimator, the study confirmed that the impact of trade openness on emissions is more alarming in the long run than in the short run, whereas urbanization significantly reduces CO_2 emissions both in the short run and long run, which implies that urbanization is promoting environmental quality in these economies.

In a sample of 12 Middle Eastern countries, Al-Mulali (2012) explored the effect of total trade (import plus export) on CO_2 emissions over the period of 1990–2009. The empirical findings showed that trade increases CO_2 emissions in the selected country group. Using data on new EU members and candidate countries, Kasman and Duman (2015) reported that trade openness raised CO_2 emissions over the period 1992–2010. Boutabba (2014) tested the impact of trade openness on CO_2 emissions. The findings revealed that trade openness is harmful to the environment in India. In the case of Turkey, Halicioglu (2009) investigated the effects of trade openness on CO_2 emissions over the period 1960–2005. The empirical result demonstrated that trade openness raises CO_2 emissions. Zhang (2018) also confirmed the same results in the context of South Korea over the period 1971–2013. Ertugrul et al. (2016) examined the effect of trade on environmental degradation in the case of China, India, South Korea, Brazil, Mexico, Indonesia, South Africa, Turkey, Thailand, and Malaysia separately for the period of 1971–2011. The empirical findings showed that trade are harmful to the environment in Turkey, India, China, and Indonesia.

On the other hand, some scholars observed a beneficial effect of trade on environmental quality. For example; Shahbaz et al. (2013) explored the effect of trade openness on CO_2 emissions in the case of South Africa over the period of 1965–2008. The evidence indicated that trade openness is beneficial for the environment. Al-Mulali et al. (2015a) investigated the impact of trade openness on CO_2 emissions in the case of 23 selected European countries from the period 1990–2013. The panel result suggested that trade openness improved environmental quality in these countries. Employing a different time series approach, Zhang et al. (2017) examined the impact of trade openness on CO_2 emissions in a sample of ten newly industrialized countries over the period 1971–2013. The results confirmed that trade openness reduces CO_2 emissions. Pie et al. (2018) tested the impact of exports and imports on CO_2 emissions over the period 1992–2012 in the case of the European Union (EU) separately. The empirical findings showed that exports raise CO_2 emissions while imports reduce them. Shahbaz et al. (2019) investigated the effect of trade openness on CO_2 emissions in the case of the United States of America over the period 1965–2016. The findings revealed that trade openness is not harmful to the environment. Using the ARDL approach, Onafowora and Owoye (2014) tested the effect of trade on the environment for Brazil, China, Egypt, Japan, Mexico, Nigeria, South Korea, and South Africa for the period of 1970–2010. The researchers concluded that trade has a mixed effect on the environment. The empirical findings revealed that trade is beneficial for Brazil, China, and Japan, while it is harmful to Mexico, Nigeria, and South Africa. Ozturk and Acaravci (2013) analysed the effect of trade on the environment in Turkey using data from 1960 to 2007. The ARDL findings suggested that trade contributes to reducing CO_2 emissions. In a sample of 69 countries and using generalized methods of moments (GMM), Sharma (2011) examined the effects of trade on CO_2 emissions over the period 1985–2005. The empirical findings provided evidence that trade decreases CO_2 emissions.

The above literature suggested that trade may have had a positive or negative impact on the environment. However, other scholars could not establish any significant association between trade and environment. For example, using the ARDL bound test approach, in a case study of Tunisia, Farhani et al. (2014) examined the effect of trade on CO_2 emissions over the period 1971–2008. The findings confirmed that trade has no impact on environmental degradation. Using data on China and India, Jayanthakumaran et al. (2012) reported that trade openness has no significant adverse effect on CO_2 emissions for the period 1971–2007. Jalil and Mahmud (2009) analysed the effect of trade on environmental quality in China for the period 1975–2005. The ARDL bound test suggested that trade has no impact on CO_2 emissions. In a sample of 129 countries, classified by their income levels, Al-Mulali et al. (2015b) tested the effect of trade on environmental quality for the period 1980–2011. The empirical findings revealed that trade is helpful for decreasing CO_2 emissions in the upper-middle and high-income countries, whereas it has no significant impact on environmental quality in low-income countries.

However, as we mentioned before, these indicators (e.g. trade openness, export, and import) are based on the 'volume' of trade. In the second group of studies, scholars started to use new indicators as a proxy for international trade. These are export product diversification, export market diversification, export concentration, economic complexity, export quality, and trade potential, etc. For example, using the dynamic ordinary least square method (DOLS), Gozgor and Can (2016) tested the impact of export product diversification on CO_2 emissions in the case of Turkey for the period 1971–2010. The empirical findings provided evidence that export product diversification increases CO_2 emissions. Employing the Fixed Effect panel estimation method, Hongbo (2018) explored the impact of export product diversification and export market diversification on CO_2 emissions in the case of 125 countries. The findings revealed that both export product diversification and export market diversification reduce CO_2

emissions. Considering Korea, Japan, and China as a case study, Liu et al. (2018) investigated the effects of export product diversification and export market diversification on environmental degradation for the period 1990–2013. The findings suggested that both export product diversification and export market diversification positively affect, i.e. help reduce, the ecological footprint of the related countries.

Likewise, Apergis et al. (2018) analysed the effects of export concentration on CO_2 emissions in a sample of 19 high-income countries over the period 1962–2010. The empirical findings confirmed that export concentration contributes to decreasing CO_2 emissions. Can and Gozgor (2017) examined the impact of economic complexity (sophisticated production) on CO_2 emissions in France. By covering the period from 1964–2014, the empirical findings showed that economic complexity decreases CO_2 emissions. Neagu and Teodoru (2019) tested the effects of economic complexity on the environment in the context of EU countries. Empirical findings demonstrated that economic complexity increases CO_2 emissions in the EU. In another study, Gozgor and Can (2017b) analysed the impact of export product quality in China over the period 1971–2010. The empirical results concluded that export product quality contributes to decreasing CO_2 emissions. On the other hand, Fang et al. (2019) investigated the effects of export product quality on CO_2 emissions in the case of 82 developing countries over the period 1970–2014. The empirical findings revealed export product quality increases CO_2 emissions in developing countries. Gozgor (2017) explored the impact of trade potential index on CO_2 emissions over the period 1960–2013 in the case of 35 countries which are the members of Organization for Economic Cooperation and Development (OECD). The study proved that trade potential decreases CO_2 emissions.

Previous literature indicates that most of the studies examined the relationship between trade openness and carbon emissions. Further, previous studies mostly used the conventional econometric approach. Therefore, in this paper, we address these issues by looking at the effect of import product diversification on carbon emissions. The study also applies robust panel econometric techniques that account for cross-sectional dependence and estimates models by classifying the countries into two groups such as 35 developed and 93 developing countries. Therefore, our estimates are expected to provide reliable results and may offer constructive policy and practical implications.

3. Data, Empirical Model, and Econometric Methodology

3.1 Data and empirical model

In this study, our main goal is to examine the effects of import product diversification and renewable energy consumption on total CO_2 emissions (kiloton). We use annual data from 1995 to 2014 on 35 developed and 93 developing countries separately.[5] Based on previous literature, we use a number of factors that are major determinants of carbon emissions. Specifically, we use the following variables in the model: total population (POP) in millions; per capita gross domestic product (PI) in constant 2010 US$; total renewable energy consumption (REC) in terajoule; and import product diversification (IMP) index[6], which is the key determinant of CO_2 emissions in this paper. The data on CO_2, POP, PI, and REC were sourced from the World Bank, while data on IMP were collected from the United Nations Conference on Trade and Development (UNCTAD) database. Before we begin our investigation, all variables are transformed into logarithmic form as recommended by a number of previous studies (Paramati et al., 2016; Paramati et al., 2017; Ummalla and Samal, 2019). We model CO_2 emissions as a function of the variables under consideration, as follows:

$$CO_{2,it} = f\left(POP_{i,t}^{\beta_1}, PI_{i,t}^{\beta_2}, REC_{i,t}^{\beta_3}, IMP_{i,t}^{\beta_4}\right) + \mu_{i,t}$$

[5] The grouping of the countries according to the level of development is based on the United Nations (UN) World Economic Situation and Prospects (2018) report. The list of the countries is presented in Appendix-1.

[6] A higher level value of the IMP means a higher level of import product diversification. In the UNCTAD database, some of the missing import products' values are estimated by the related institution's staff.

$$CO_{2,it} = \beta_0 + \beta_1 POP_{i,t} + \beta_2 PI_{i,t} + \beta_3 REC_{i,t} + \beta_4 IMP_{i,t} + \mu_{i,t}$$

Where *i* refers to country; *t* refers to time; and CO_2, POP, PI, REC and IMP indicate total carbon dioxide emissions, total population, per capita income, renewable energy consumption, and import product diversification respectively. The error term is represented by μ.

Hypothesis development: According to previous literature, population ($\beta_1 > 0$) and per capita income ($\beta_2 > 0$) are expected to increase CO_2 emissions, while renewable energy consumption ($\beta_3 < 0$) is expected to decrease CO_2 emissions. As discussed previously, import product diversification is expected to decrease ($\beta_4 < 0$) CO_2 emissions in developed countries, whereas it is expected to increase ($\beta_4 > 0$) them in developing countries. More specifically, higher population and per capita income lead to a higher demand for energy; hence, they will increase carbon emissions. By contrast, expanding the share of renewable energy is expected to mitigate emissions. Finally, due to differences in environmental standards, import product diversification is expected to decrease and increase CO_2 emissions in developed and developing economies, respectively.

3.2 Econometric Methodology

The recent literature increasingly highlighted the significance of the econometric methods that account for cross-sectional dependence in the analysis. This is particularly important as most of the conventional panel econometric methods do not account for cross-sectional dependence. Hence, the findings obtained from the methods that do not address the issue of cross-sectional dependence may not be reliable. So, we apply the methods that account for cross-sectional dependence in the estimation.

First, with the cross-sectional dependence (CD) test, our main goal is to observe if the given series have cross-sectional dependence. Thus, the cross-sectional dependence of the series is examined with the CD test developed by Pesaran (2004), which is important before applying a panel unit root test. As a consequence of having low power, the conventional unit root tests are inefficient when employed in series with cross-sectional dependence (Bhattacharya et al. 2016). In this context, we use cross-sectionally augmented IPS (CIPS) unit root test of Pesaran (2007) which is effective under the assumption of cross-sectional dependence. This unit root test is used to investigate the order of integration of the considered variables. If all of the variables are integrated in the same order, that is, I (1), it implies that all the variables have a unit root at the level data series. Moreover, they are stationary in first-order differentials.

To achieve the objectives of this research paper, we employ econometric techniques that are robust and reliable in the presence of cross-sectional dependence. Hence, this study makes use of two robust panel econometric techniques, such as Common Correlated Effects – Mean Group (CCE-MG) and Augmented Mean Group (AMG) methods, to examine the effect of renewable energy and import product diversification on CO_2 emissions by accounting for other key determinants in the model. Pesaran's (2006) CCE-MG estimator allows empirical configuration to identify cross-sectional dependence to variables that cannot be observed as variable over time, which has a heterogeneous effect among panel members and specification problems. The CCE-MG estimator is highly effective against structural deteriorations and lack of co-integrated relationships (Kapetanios et al., 2011; Sadorsky, 2013). Finally, the AMG estimator is an alternative to the CCE-MG (Pesaran, 2006) approach (Eberhardt and Bond, 2009; Eberhardt and Teal, 2010). The AMG approach takes cross-sectional dependence into account by adding a "common dynamic process" into the country regression (Sadorsky, 2013; Magazzino, 2012). This method expresses cross-sectional dependency and provides heterogeneous slope coefficients among panel members (Paramati and Roca, 2019). Additionally, as this estimation method predicts the arithmetic mean of cointegration coefficients by weighing on them, it is stronger than other coefficient estimation methods (Sadorsky, 2014).

3.3. Preliminary investigation

Figure 1 displays the share of global CO_2 emissions for each developed and developing economy. It shows that the share of global CO_2 emissions from developed economies has been declining over the years while it is rapidly increasing in developing countries. It further suggests that the CO_2 emissions from these two groups of economies converged in 2004 and has since diverged. The share of global CO_2 emissions from developed economies has reduced from 48.24% in 1995 to 29.68% in 2014, whereas the share from developing economies has grown from 34.73% in 1995 to 55.22% in 2014. The overall share of developed and developing economies has increased from 82.97% in 1995 to 84.90% in 2014. This graph implies that the share of global CO_2 emissions from developing economies is increasing over the years while it is reducing in developed economies. This further indicates that there might be a significant difference between these two groups of nations in terms of the nature of energy use, as well as their energy and environmental policies. As a result, their global share of emissions has been moving in opposite directions over the years.

[Insert Figure 1 here]

Table 1 reports unconditional correlations on the selected variables of both the developed and developing economies. The correlation results on developed economies show that the CO_2 emission is positively correlated with population, per capita income, renewable energy, and total energy consumption, while it is negatively correlated with import product diversification. These correlations suggest that CO_2 emissions are highly correlated with total energy consumption and population. Likewise, the correlations on developing economies reveal that CO_2 emissions are positively correlated with population, per capita income, renewable energy, and total energy consumption, whereas it has a negative correlation with import product diversification. All of these correlations are also statistically significant at the 1% level. These correlations overall imply that CO_2 emissions have a negative correlation with import product diversification across the panels of developed and developing economies. However, we further confirm their association in the following empirical investigation.

[Insert Table 1 here]

4. Empirical findings and discussion

The recent empirical literature has paid considerable attention to the issue of cross-sectional dependence in the panel data set. This is because the conventional panel econometric techniques usually assume cross-sectional independence in the estimation. However, in reality, most of the panel data sets have cross-sectional dependence. Hence, the findings derived from the techniques that assume cross-sectional independence may be unreliable. Given this fact, it is important to explore whether the selected data series is cross-sectionally dependent or independent. To do this, we begin by applying Pesaran (2004) CD test on the panel data series of both the developed and developing economies. The results of CD test are reported in Table 2. The findings across the variables and economies suggest that the null hypothesis of cross-sectional independence is strongly rejected at the 1% significance level. Hence, these results indicate that the selected variables have significant cross-sectional dependence during the study period, 1995–2014.

[Insert Table 2 here]

Given the evidence of cross-sectional dependence across the variables, we apply a panel unit root test that accounts for cross-sectional dependence in the estimation. Specifically, we apply Pesaran (2007) CIPS test. The estimated results from CIPS test are displayed in Table 3. The findings on level data across the variables and economies suggest the evidence of a unit root. On the other hand, the estimates on first order difference data series confirm the rejection of the null hypothesis of a unit root at the 5% and 1% significance levels for all of the variables. This evidence implies that the selected variables are non-stationary at the level and stationary at their first order differences.

[Insert Table 3 here]

Given the presence of a unit root at the level data across the selected variables and panels, we proceed further to empirically investigate the impact of import product diversification on carbon emissions. To do this, we first apply the CCE-MG estimator. The results are presented in Table 4. They indicate that per capita income growth is a major driver of carbon emissions across the panels of developed economies, developing economies, and the full sample. Further, the results suggest that renewable energy and import product diversification have a lowering and escalating effect on carbon emissions, respectively but the results are statistically insignificant in all the panels. We also estimate the same models by replacing renewable energy with total energy consumption. The results show that an increase in per capita income and total energy consumption increases carbon emissions across the panels. The results of import product diversification show that it decreases and increases emissions in developed and developing economies, respectively. These findings suggest that import product diversification is not helpful for reducing carbon emissions in developing economies, while its impact in developed economies is insignificant.

[Insert Table 4 here]

We again estimate these models by making use of a robust panel econometric technique such as the AMG estimator. The results of AMG estimator are reported in Table 5. The results show that both population and per capita income considerably increase carbon emissions across the panels. Renewable energy has a lowering effect on all the panels but the effect is statistically insignificant. Results on import product diversification indicate an escalating effect on emissions in all the panels but a significant effect only in the case of developed economies. The other set of estimates, by replacing renewable energy with total energy consumption, also confirm that both per capita income and total energy consumption substantially increase emissions, whereas import product diversification is positive but insignificant in all the cases. Overall, the results from CCE-MG and AMG estimates suggest that in most cases both renewable energy and import product diversion are statistically insignificant, while per capita income and total energy consumption clearly play an important role in driving carbon emissions both in developed and developing countries.

[Insert Table 5 here]

Since the above estimates provide inconclusive evidence particularly on the role of import product diversification on carbon emissions both in developed and developing economies, we again estimate the models by making use of panel fully modified least squares (FMOLS) technique. This is also a robust panel econometric technique to handle the issues of heterogeneity in the estimation (Pedroni, 2000, Kao and Chiang, 2000). Specifically, this approach uses long-run covariances from the cross-section estimates and reweights the data to account for heterogeneity in the estimation. Given the significance of this approach, we apply panel FMOLS method to estimate long-run parameters. The results of panel FMOLS are displayed in Table 6. The results on developed economies show that the increase in renewable energy consumption leads to reduce carbon emissions across the panels of developed, developing, and full sample economies. Similarly, the results also advise that increasing import product diversification helps developed economies reduce the growth of carbon emissions, while it has an insignificant effect in the case of developing countries. The other estimates suggest that both population and per capita income have a positive effect on carbon emissions across the panels. Likewise, the second part of results, where we replace renewable energy with total energy consumption, show that rise in total energy consumption has a substantial positive impact on CO_2 emissions, while import product diversification has a negative and positive impact on emissions of developed and developing economies, respectively. Given these estimates, the findings seem to be consistent with our hypothesis.

[Insert Table 6 here]

5. Policy implications

We provide a number of relevant policy discussions based on the evidence from panel FMOLS method because both CCE-MG and AMG techniques gleaned insignificant results, in most cases, on the variables of our interest such as renewable energy and import product diversification. Our results showed that expanding the share of renewable energy in total energy consumption has a significant positive impact on the environment; it reduces carbon emissions across the economies of developed and developing countries. This evidence has an important policy and practical relevance. It shows that replacing conventional energy sources with renewable energy has positive environmental outcomes. Thus, we recommend that the authorities responsible for creating policies to promote renewable energy and reduce fossil fuel use consider the following points while designing appropriate initiatives. First, energy and environmental policies must aim to extensively boost the generation and use of renewable energy across economic activities. Second, it is also equally important to implement strict policies to discourage the use of carbon-intensive energy sources such as coal and oil. Such new initiatives can not only help economies meet their climate change targets but also facilitate a smooth transition for sustainable economic development.

Other findings showed that import product diversification significantly decreases and increases carbon emissions in developed and developing economies, respectively. These results also have important policy and practical relevance for both developed as well as developing economies. Import product diversification has an important role, particularly in developed economies, to reduce carbon emissions. Therefore, we suggest the policymakers of developed economies to look at the significance of import product diversification in the context of energy use and the environment. There are two ways in which higher import product diversification benefits developed economies. First, the higher import product diversification is an indication that these countries are trying to import products that are energy intensive while manufacturing. This helps these economies avoid higher energy consumption and carbon emissions. Second, because of the import product diversification of developed economies, the developing countries are manufacturing more and more energy-intensive products, which not only raises their fossil fuel energy consumption, which is a major source of energy in these economies, but also leads to environmental degradation. Hence, we argue that import product diversification has a greater positive impact on developed economies in terms of energy saving and environmental protection. On the other hand, import product diversification does not help developing economies reduce carbon emissions. It can be speculated that developing economies may not be importing products that are energy intensive in the production process. Hence, their import product diversification does not reduce their carbon emissions but further contributes to pollution because of domestic transportation and/or using those imports as manufacturing raw materials. Given these arguments, we suggest the policymakers of developed and developing economies to consider the impact of import product diversification while designing policies on international trade, energy, and environment.

6. Conclusion

In the recent period, global economies, both developed and developing, are under significant pressure to reduce their share of global emissions. This is because the world has been facing severe climate change issues since the recent past due to increasing carbon emissions. Hence, both developed and developing economies have adopted a number of initiatives to tackle the issue of climate change and/or carbon emissions. For instance, since the major cause of climate change is carbon emissions, which is mainly caused by fossil fuel energy consumption, nations have made efforts to replace conventional energy with renewable energy sources to mitigate the growth of carbon emissions. Further, developed economies have significantly diversified their import products, which are mostly energy intensive, to reduce their energy consumption and carbon emissions. Given this background, this empirical study was designed to examine the impact of import product diversification and renewable energy on carbon emissions across the panels of developed and developing countries. To do that, we applied a number of robust panel econometric techniques such as CCE-MG, AMG, and panel FMOLS methods and annual data from 1995 to 2014.

The overall empirical findings suggested that import product diversification substantially decreases and increases carbon emissions in developed and developing economies, respectively. Further, our results indicated that renewable energy consumption plays an important role in reducing the growth of carbon emissions across these economies. Given these empirical outcomes, it is important to note that import product diversification and renewable energy are the two essential factors that are helping developed economies to minimize their share of global emissions in the recent period. In the case of developing economies, the import product diversification is not reducing carbon emissions, rather it slightly adds to it. It is because the developing economies may not be importing the products that are more energy intensive in the manufacturing stage. However, increasing the share of renewable energy in developing economies has an important role in fighting the growth of carbon emissions.

Given these evidences, the policy makers of developed economies need to continue to strengthen the policies on import product diversification as it is playing an important role in reducing the growth of carbon emissions. While the policymakers of developing economies need to be aware that import product diversification has no significant energy and environmental benefits. Hence, both developed and developing economies need to work out policies that are aimed at increasing the implementation of renewable energy plants. Increasing the share of renewable energy in total energy use not only replaces fossil fuel energy but also reduces carbon emissions. Given all of these factors, we suggest that policymakers of developed economies focus on import product diversification and renewable energy projects, whereas developing economies should strengthen their position in terms of renewable energy generation and use to meet their climate change targets. Finally, we suggest that the future studies may do a similar exercise for individual countries, particularly the major import-dependent countries as it can help them redesign their trade portfolio policies to meet their climate change targets.

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Declaration of competing interest

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

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Figure 1: Global share of CO_2 emissions from developed and developing economies

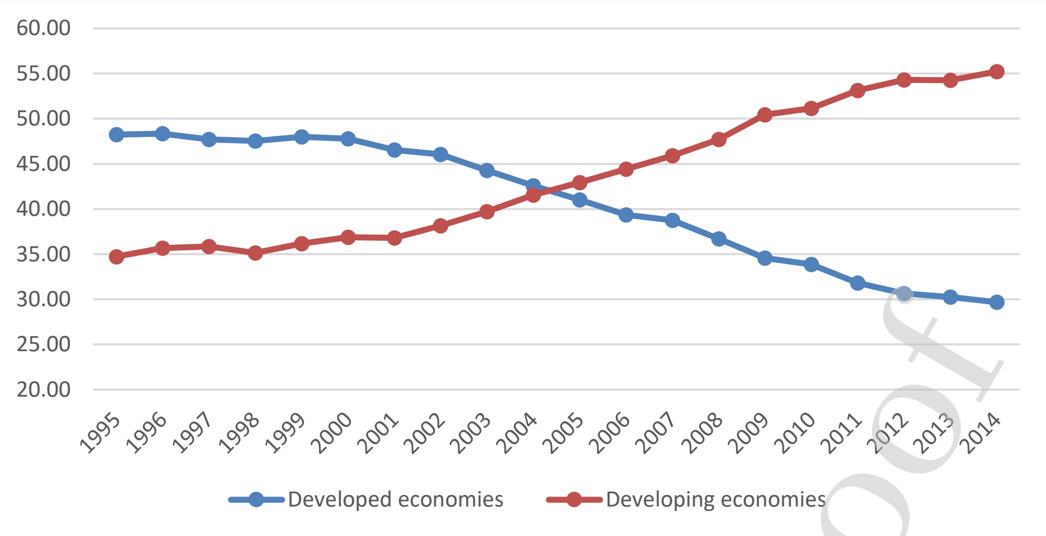

Table 1: Estimates of unconditional correlations on panel data sets

	CO_2	POP	PI	REC	TEC	IMP
Developed economies						
CO_2	1.000					
POP	0.965***	1.000				
PI	0.209***	0.073*	1.000			
REC	0.705***	0.731***	0.269***	1.000		
TEC	0.975***	0.952***	0.306***	0.797	1.000	
IMP	-0.683***	-0.673***	-0.296***	-0.631	-0.721***	1.000
Developing economies						
CO_2	1.000					
POP	0.678***	1.000				
PI	0.467***	-0.086***	1.000			
REC	0.386***	0.771***	-0.293***	1.000		
TEC	0.832***	0.895***	0.285***	0.632***	1.000	
IMP	-0.564***	-0.276***	-0.622***	-0.154***	-0.490***	1.000

Notes: The unconditional correlation were estimated using 'natural log' data; ***, ** and * indicate the significance levels at the 1%, 5% and 10%, respectively.

Table 2: Cross-sectional dependence (CD) test results

	Developed economies		Developing economies	
Variables	CD-test	Prob.	CD-test	Prob.
CO_2	31.200***	0.000	199.390***	0.000
POP	20.970***	0.000	281.010***	0.000
PI	97.460***	0.000	162.250***	0.000
REC	81.790***	0.000	98.690***	0.000
TEC	27.640***	0.000	196.010***	0.000
IMP	26.620***	0.000	5.190***	0.000

Note: *** indicates the rejection of the null hypothesis of a cross-sectional independence at the 1% significance level.

Table 3: Panel Unit Root test (CIPS) results

	Developed economies				Developing economies			
	Level		First difference		Level		First difference	
Variables	Zt-bar	Prob.	Zt-bar	Prob.	Zt-bar	Prob.	Zt-bar	Prob.
CO_2	0.741	0.771	-8.003***	0.000	4.961	1.000	-10.973***	0.000
POP	-0.837	0.201	-1.806**	0.035	3.635	1.000	-7.426***	0.000
PI	2.323	0.990	-2.703***	0.003	4.929	1.000	-8.180***	0.000
REC	0.525	0.700	-9.213***	0.000	3.501	1.000	-10.932***	0.000
TEC	4.328	1.000	-7.928***	0.000	-1.329	0.092	-10.626***	0.000
IMP	5.823	1.000	-9.538***	0.000	4.220	1.000	-16.174***	0.000

Notes: *** and ** indicate the rejection of the null hypothesis of a unit root, under cross-sectional dependence, at the 1% and 5% significance levels, respectively.

Table 4: Common Correlated Effects Mean Group (CCE-MG) estimator

	Developed economies		Developing economies		Full sample	
	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
CO_2 = f (POP, PI, REC, IMP)						
POP	1.815*	0.090	3.225	0.170	2.192	0.133
PI	1.013***	0.000	0.884***	0.000	0.878***	0.000
REC	-0.080	0.232	-0.182	0.546	-0.218	0.391
IMP	0.007	0.862	0.126	0.219	0.071	0.359
Cross-section averaged regressors						
CO_2	0.816***	0.000	0.922**	0.013	1.022***	0.001
POP	-2.096	0.395	-2.585	0.316	-3.115	0.147
PI	-0.994***	0.002	-0.945*	0.058	-0.751***	0.006
REC	0.148	0.101	0.151	0.545	-0.076	0.739
IMP	-0.125	0.381	0.111	0.748	-0.029	0.916
Constant	5.659	0.892	-3.476	0.867	20.651	0.196
CO_2 = f (POP, PI, TEC, IMP)						
POP	0.716	0.260	3.337	0.119	2.155	0.156
PI	0.469***	0.010	0.540***	0.003	0.439***	0.001
TEC	0.794***	0.000	0.996***	0.000	1.004***	0.000
IMP	-0.018	0.628	0.244***	0.008	0.161**	0.020
Cross-section averaged regressors						
CO_2	0.781**	0.017	0.818**	0.018	0.700**	0.011
POP	0.387	0.838	-3.214	0.173	-1.650	0.404
PI	-0.534**	0.047	-0.222	0.567	-0.344	0.197
TEC	-0.680**	0.031	-0.340	0.481	-0.531	0.163
IMP	-0.092	0.431	-0.165	0.568	-0.129	0.605
Constant	-17.159	0.551	-7.277	0.657	-11.728	0.378

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

Table 5: Augmented Mean Group (AMG) estimator

	Developed economies		Developing economies		Full sample	
	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
$CO_2 = f(POP, PI, REC, IMP)$						
POP	0.980**	0.028	1.033***	0.008	1.329***	0.000
PI	0.794***	0.000	0.781***	0.000	0.834***	0.000
REC	-0.088	0.155	-0.149	0.625	-0.105	0.652
IMP	0.095*	0.093	0.040	0.683	0.052	0.476
Constant	-12.247	0.100	-11.366**	0.021	-17.233***	0.000
$CO_2 = f(POP, PI, TEC, IMP)$						
POP	0.090	0.828	0.225	0.384	0.610***	0.010
PI	0.189**	0.014	0.350***	0.004	0.390***	0.000
TEC	0.917***	0.000	0.958***	0.000	0.949***	0.000
IMP	0.004	0.902	0.098	0.285	0.079	0.243
Constant	-5.068	0.451	-8.702***	0.004	-15.277***	0.000

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

Table 6: Panel Fully Modified Least Squares (FMOLS) with weighted estimation

	Developed economies		Developing economies		Full sample	
Variable	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
$CO_2 = f(POP, PI, REC, IMP)$						
POP	1.063***	0.000	1.244***	0.000	1.470***	0.000
PI	0.152***	0.000	0.826***	0.000	0.676***	0.000
REC	-0.185***	0.000	-0.097***	0.000	-0.244***	0.000
IMP	-0.210***	0.000	-0.001	0.417	-0.151***	0.000
$CO_2 = f(POP, PI, TEC, IMP)$						
POP	0.052***	0.000	0.831***	0.000	0.841***	0.000
PI	-0.219***	0.000	0.655***	0.000	0.422***	0.000
TEC	0.897***	0.000	0.383***	0.000	0.495***	0.000
IMP	-0.234***	0.000	0.032***	0.000	-0.158***	0.000

Note: *** indicates the significance level at the 1%.

Appendix 1

Developed countries	**Developing countries**		
Australia	Algeria	Guinea-Bissau	Philippines
Austria	Angola	Guyana	Rwanda
Belgium	Argentina	Haiti	Saudi Arabia
Bulgaria	Bangladesh	Honduras	Senegal
Canada	Barbados	Hong Kong SAR[c]	Sierra Leone
Croatia	Benin	India	Singapore
Cyprus	Bolivia	Indonesia	South Africa
Czech Republic	Botswana	Iran	South Korea
Denmark	Brazil	Iraq	Sri Lanka
Estonia	Burkina Faso	Israel	Sudan
Finland	Burundi	Jamaica	Thailand
France	Cabo Verde	Jordan	Togo
Germany	Cameroon	Kenya	Trinidad and Tobago
Greece	Central African Republic	Lebanon	Tunisia
Hungary	Chad	Lesotho	Turkey
Iceland	Chile	Liberia	Uganda
Ireland	China	Madagascar	United Arab Emirates
Italy	Colombia	Malawi	Uruguay
Japan	Comoros	Malaysia	Venezuela
Latvia	Congo	Mali	Viet Nam
Lithuania	Costa Rica	Mauritania	Yemen
Luxembourg	Côte d’Ivoire	Mauritius	Zambia
Netherlands	Democratic Republic of the Congo	Mexico	Zimbabwe
New Zealand	Djibouti	Morocco	
Norway	Dominican Republic	Mozambique	
Poland	Ecuador	Myanmar	
Portugal	Egypt	Namibia	
Romania	El Salvador	Nepal	
Slovakia	Equatorial Guinea	Nicaragua	
Slovenia	Ethiopia	Nigeria	
Spain	Gabon	Pakistan	
Sweden	Gambia	Panama	
Switzerland	Ghana	Papua New Guinea	
United Kingdom	Guatemala	Paraguay	
United States	Guinea	Peru	