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Examining Trade Mechanism of International Carbon Dioxide Emission: Evidence from Major Emitter Countries

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ABSTRACT

This study examines factors affecting the changes in the net exports of the carbon dioxide (CO_2) emissions embodied in global trade, conducting seemingly unrelated regression-based generalized least square (GLS) method. The study uses balanced panel data sets of 34 OECD and 7 major non-OECD countries in the G-20 and the period of 1996-2011. Along with various explanatory variables, we also add interaction terms between structural changes and income variables for crosschecking. Results reveal that trade openness leads to increase in emission exports, while GDP per capita has a slight negative effect. Net oil export per capita is the most important factor raising the emission export. The finding that structural changes also affect emission density affirms the importance of technological progress. Considering international trade pattern, overall results underline that nobody is responsible for global emission individually since countries emit for others. For trade mechanism of emission reduction, "ideal" and "global" green trade implications seem to be appropriate policy initiatives.

Keywords: Carbon Dioxide Emission, Emission Export, Kuznets Curve, SUR model, Structural Change
JEL Classifications: C33, F18, Q56

1. INTRODUCTION

Welfare or environment? This question is a longstanding debate concerning scholars. Now it seems to be understood well that this question is not about a choice, it in fact, implies sustainability. Even various actions have been already taken in global context, there is a well-supported evidence showing that environmental destructions are still occurring from different mechanisms and exposing significant risks for both human being and natural systems.

The key greenhouse gas emitted by human activities is carbon dioxide (CO_2). It is naturally a part of the atmosphere's carbon cycle but human activities have been altering its amount unnaturally, both by adding more CO_2 to the atmosphere and by destroying natural sinks, like forests. The main human activity that emits CO_2 is the combustion of fossil fuels (coal, natural gas, and oil) for energy and transportation. Both resource intensive and environment destructive industrial activities that accelerated with the industrial revolutions are also among the important factors emitting CO_2 (US-EPA, 2016). Measurements of different organizations (e.g., IPCC, 2016; US-EPA, 2016; IEA, 2016) show that in 2015, more than 80% of total greenhouse gas emission was the CO_2 and it was mostly caused by human activities globally.

There is an increasing awareness of the issue that interdisciplinary studies examining the effects of various pollutants have created an immense literature. Correspondingly, enormous progress has been made towards understanding the relationship between macroeconomic indicators and CO_2 emissions. Consequently, there is a strong evidence revealing economic indicators like growth, industrialization, energy consumption, production structure and non-economic factors like institutions, urbanization and population are among the major factors affecting the CO_2 emissions.

Trade theories in the literature seem to have centered around comparative and competitive advantages of countries based on natural resources abundance and structural change ignoring destructive impacts of trade on the nature. This is mainly because of the dense cross-border trade flows that make it hard to measure and internalize emission costs. Related to this, no country wants to consider the externality effects of emissions in the trade pattern and thus, numerous researchers have been trying to measure the emission for everyone to direct its reasons and consequences. One technical reason for this neglect comes from the unavailability of the multi-country input-output (MCIO) data required to measure CO_2 emissions specifically embodied in international trade.

There is a longstanding disconnection seen between trade and emission both theoretically and empirically in the literature. Some researches develop models connecting them (e.g., Stern, 2004; Carson, 2010; Jebli et al. 2016) and find trade represented by the proxy of trade openness is among the factors contributing to the emission (e.g., Ang, 2009; Sharma, 2011). However, most part of studies in the international trade is seen concentrated on the predictions of the neo-classical trade theories. Main interests center on the effects of natural resources to the global competitiveness and comparative advantages. Some studies deal with resource distribution, exhaustibility and dependency but still ignore the emission distribution effects of international trade. These two aspects in fact together associate a simple premise that environment (or resource endowments) affect the trade developments and trade affects the environment. Moreover, trade has a powerful channel with an important role in the diffusion of environment-friendly green goods, services and technologies among countries. In this context, best production practices spread all around the world through trade. All these bring a new green international trade pattern in which countries, especially developing ones, gain from green trade.

Starting from the disconnection of these two aspects and interlinkages between trade and emission, this study investigates the determinants of net export of emission for main CO_2 emitter countries, namely 34 OECD countries and 7 major non-OECD countries (Argentina, Brazil, China, India, Indonesia, Russia and South Africa) in the G-20 over the period covering 1996-2011. The study differs from those in the related literature mainly in three ways: First, instead of total carbon emission, it concerns about net export of the emission calculated by OECD (2016) using both MCIO and CO_2 emissions data. Therefore, we carry the trade to the left-hand side of the model. Secondly, beside the environmental Kuznets curve, this study is motivated and inspired by the potential effects of technology - and quality-led structural changes in the export contents both over time (temporal dimension) and over countries (cross-section dimension). Third expected contribution of this study originates its method. Depending on the data availability and variable characteristics, considerable part of studies uses cointegration and causality analyses that some of them seem to be suffering from multicollinearity problem. In our model, we add different variables depending on the export emissions, together with four interaction terms. In order to hinder possible estimation biases we used seemingly unrelated regression (SUR) based GLS method that can still be efficient under the multicollinearity. In the rest of the study, next we outline theoretical framework together with some related evidence, and then introduce data sets, model and methodology under the empirical framework section. After results are presented, the study concludes with a summary of findings and their implications.

2. THEORETICAL BACKGROUND AND EVIDENCE

Most of attention on environmental debates centers on well-known inverted-U shaped environmental Kuznets curve, which is named so due to its resemblance to the Kuznets curve. Originally, Kuznets (1955) suggests that in the early stages of economic development/growth, inequality in income distribution and increase in GDP per capita proceed together and then beyond a certain income level (turning point), increases in GDP are followed by equality improvements in income distribution. This relationships path resembles inverted-U. In its environmental expression, the Kuznets curve postulates an inverted-U shaped relationship between pollutants measured by different indicators, and income per capita. Specifically, it depicts that CO_2 emission at first increases following the GDP per capita growth and then decreases as GDP per capita increases. The environmental Kuznets curve encourages optimistic projections on the relationship between environmental destructions and growths in economic activities, like production and export. In this context, the relationship between the stages of economic development/growth and environmental quality has become one of the major interests in the related literature (Dinda, 2004). Initial explanations associated relationships between pollution and natural resource use, industrial activities, growth and population (e.g., Grossman and Krueger 1995; Stern, 2004; Carson, 2010). More recent studies (e.g., Apergis and Ozturk, 2015; Jebli et al. 2016) approach to the issue exemplifying the environmental Kuznets curve.

Trade and environment linkage has become an increasingly important interest especially since 1980s, when developing countries' participations in the world trade started to have accelerated. This interest seems to have been reflected to the related literature that studies have started to add trade openness in their research models. Sharma (2011) investigated the determinants of CO_2 emissions for 69 countries and a period of 1985-2005 using a dynamic panel data model. To make the panel data analysis more homogenous, Sharma (2011) also clustered countries into three groups by their income levels: High, middle and low income. Main findings reveal that trade openness along with GDP per capita and energy consumptions increase CO_2 emissions, while urbanization is found to be leading to decrease in the emissions for all three sub-panels. For the global panel, only GDP and total primary energy consumption per capita are found to be statistically significant determinants increasing CO_2 emission, while urbanization, trade openness, and per capita electric consumption are negatively associated with the emissions.

One other study with sub-group panels is those of Saidi and Hammami (2015). They grouped countries by regions, not by income level. Differently, in their model dependent variable is energy consumption. They investigated the impact of economic growth and CO_2 emissions on energy consumption for a global panel of 58 countries using dynamic panel data model estimated employing the generalized method of moments for the period 1990-2012. They also estimated the relationship for different regional panels. Their results show that the effect of economic growth on energy use is significantly positive in the global panel. CO_2 emissions have a positive and statistically significant effect on energy consumption. They interpret this evidence as complementarity of the variables.

Country grouping is a big challenge panel data studies face as in the cases of Sharma's (2011) and Saidi and Hammami's (2015) studies. Their results seem to be varying over countries and county groups. However, our study takes advantage of the heterogeneities that wide intervals in cross sections (i.e. low-high income country and small-large country or industrialized-deindustrialized county) allow us to capture the effects of the cross-section characteristics. This is more beneficial since we have a cross-section dominant panel structure in which identical countries would lead misleading results. We believe that panel results with possible aggregation biases are still better than those of generalized results of the country-specific studies. An example of studies investigating individual countries is Friedl and Getzner's (2003) study that tests the validity of the environmental Kuznets curve for Austria using time series regressions and data for the period of 1960-1999. They explored a significant so-called N-shaped relationship between economic development and CO_2 emissions. This cubic path exhibits a similar pattern as the inverted-U curve initially, but beyond a certain income level, the relationship turns into positive again. The second increase opens doors to debate on threshold and sustainability of the emission-reducing growth for developed countries. They found that import shares that reflect to exporting emitting industries (the pollution haven hypothesis), and the share of the tertiary (service) sector of total production (GDP) representing the structural changes reduce the CO_2 emissions. Ang (2007) examined the dynamic causal relationships between pollutant emissions, energy consumption, and output for France's data of the period 1960-2000, using cointegration and vector error-correction modeling techniques. The results support the evidence that economic growth has a causal influence on growth of energy use and growth of pollution in the long-run. The results also point to a unidirectional causality running from growth of energy use to output growth in the short run.

Country-specific researches are not restricted to developed countries that recently there are studies investigating the issue for developing countries. China is a target for its so-called non-environmental production and export growth. Ang (2009) showed that exceptional growth performance of China accelerated especially since the early 1990s has come with rapid environmental deterioration. CO_2 emissions in China are negatively related to research intensity, technology transfer and foreign technology adoption. Their findings also indicate that more energy use, higher income and greater trade openness tend to cause more CO_2 emissions. Related to our case, the negative affect of the trade openness can be explained by the import contents of China. China is main importer of intermediates from and main exporter of final products to all around the world. Another example of the studies on developing countries is that of Halicioglu's (2009) Turkey case. Halicioglu (2009) examined the dynamic causal relationships between carbon emissions, energy consumption, income, and foreign trade using Turkey's time-series data for the period 1960-2005 and conducting the bounds testing approach to cointegration procedure. The empirical results suggest that income is the most significant variable, which is followed by energy consumption and foreign trade in explaining the carbon emissions in Turkey.

Initially strong evidence of destructive impacts of economic growth and industrialization on the environment has started to be ambiguous as the empirical relationships weaken. This is in fact expected that when considered the process of rapid industrialization and growth in a global context, the destruction would be much more than those of we have today. What makes the growth less destructive is another debate in the literature. One explanation for the diminishing emission effect of the growth is technology level. There are both views that some suggest technology is neutral and even mildly beneficial factor, while some environmentalists assert that technology itself is a destructive force (Carson, 2010). Supporting the latter view, there are various environmental taxes on the new technologies similar to emission taxes in some countries. However, technological progress that leads to an increase in efficiency and productivity saves resources and reduces pollution. Key factor for this is technological progress in high-tech production that our study specifically focuses on. Technological progress is the engine of a green economy and one of the main contributors to reduce emissions. It does not only bring new ones, it also drive down prices of current environmental technologies. One concern about green technology dissemination is that developing countries remain disadvantaged since most of them lack the sophisticated regulatory and institutional frameworks, as well as the business environments that needed to be promoted for technology transfer (UNCTAD, 2011). One of the technology transfer channels is foreign direct investment that also increases trade openness of countries. It is now acknowledged that trade has a function that it can reduce the green technology gap between developed and developing countries through know-how, imitation and knowledge spillovers as the trade between them increases.

Theoretical origins of this study are based on the integration of premises of Grossman and Helpman's (1991) quality ladder, Pearson's (1994) export ladder, and Klinger and Lederman's (2004) nexus between new product discovery and development into the environmental Kuznets curve. The key factor is structural change triggered by technological progress, which implies that negative effects of the growth can decline, even turn into positive. Economic rationale behind this premise is that as a country grows its production structure changes from resource-driven to efficiency driven first and then finally shifts to innovation driven structure. Using Pearson's (1994), and Grossman and Helpman's (1991) terms we can describe these process as "quality based-export ladder." In the low-level rungs, i.e. resource driven stages, countries are expected to increase the emission directly in their export. In the medium-level rungs, efficiency-driven structure, the resource dependency of exports weakens and income levels of the countries increase but however countries still increasingly emit due to intensive manufacturing activities for meeting both domestic and export demands. However, in the innovation and knowledge-based stages, high-level rungs of the export ladder, countries export cleaner product and more services that lead to decreases in the net export of emissions. These three stages and transition phases between the stages are capable to explain different evidence over countries and periods in the literature.

Inter-stages relations have brought a convergence process that as the trade increases between countries with different development stages, export structures of developing countries become increasingly similar to those of developed countries. This convergence pattern can be tracked from export similarity indices (IMF, 2011) and can be supported by Pearson's export ladder phenomenon. Klinger and Lederman's (2004) evidence that originally indicates an inverted-U shaped curve between economic discovery and GDP per capita can link "quality based-export ladder" and environmental Kuznets curve. These relationships comprise the empirical motivations of the study.

3. EMPIRICAL FRAMEWORK

3.1. Variables and Data

Even there is an increasing awareness of the trade mechanism of the emission; studies do not directly investigate the emission export. One reason for this is data unavailability that input-output tables, main sources capable to capture the emission export, are not systematically provided by countries. In this context, OECD (2016) harmonizes international input-output data and calculates the emissions embodied in the global trade.

Our dependent variable is net export of CO_2, calculated by OECD (2016) as the difference between production- and consumption-based of CO_2 emissions within the environmentally extended inter-country input-output (ICIO) framework. Therefore, net export of CO_2 also allows us to track who and how emit for whom in the global production networks. OECD estimates production-based emissions (PBE) by allocating the International Energy Agency (IEA)'s fuel combustion-based CO_2 emissions to the 34 industries in ICIO and, to final demand for fuels, by both residents and non-residents. Therefore, PBE of country *j* can be written as in the equation 1.

$$PBE_j = \sum_{i=1}^{N} \varepsilon_j^i X^i + \sum_{i=1}^{N} \rho_j^i X^i + \sum_{i=1}^{N} \sigma_j^i X^i + \sum_{i=1}^{N} \theta_j^i F_j^i + \sum_{i=1}^{N} \phi_j^i F_j^i \qquad (1)$$

Where ε_j^i, ρ_j^i and σ_j^i are emissions intensities in country *j*, caused by sectors *i*'s electricity generation, road transportation (fuel consumption) and other industrial activities, respectively. θ_j^i and ϕ_j^i respectively refers to emissions factors of final consumption related to road transportation (e.g., petroleum consumption of passenger cars) and other final consumption of fuel (e.g., natural gas consumption for heating and cooking at households). *N* is number of sectors, X^i is output of sector *i* and F_j^i is final expenditure of country *j* for product of sector *i*.

OECD (2016) calculates consumption-based CO_2 emissions (CBE) by multiplying the intensities of the PBE with the global Leontief inverse $(I-A)^{(-1)}$ and global final demand matrix (*Y*) from ICIO, taking the column sums of the resulting matrix and adding residential and private road emissions (*FNLC*). Consequently, it gives a *1*x*N* vector of direct emissions due to final demand: *Column sum* [*diagonal* (*PBE*) (*I-A*)$^{(-1)}$*Y*] +*FNLC*. This expression can be extended as in the equation 2.

$$CBE_j = \sum_{i=1}^{N} \sum_{p=1}^{R} (h_j^i F_{p,j}^i) + (e_1^1 \cdots e_1^N \mid e_R^1 \cdots e_R^N) B \begin{pmatrix} F_{1,j}^1 \\ \vdots \\ F_{1,j}^N \\ \hline F_{R,j}^1 \\ \vdots \\ F_{R,j}^N \end{pmatrix} \qquad (2)$$

Where h_j^i is emission factor of final consumption of the products in country *j*'s sector *i*, $(h_i^j = \theta_j^i + \phi_j^i)$, e_j^i is industrial emissions intensity of country *j*'s sector *i* $(e_j^i = \varepsilon_j^i + \rho_j^i + \sigma_j^i)$, *R* is number of countries, *B* is Leontief inverse, *N* is number of sectors and $F_{1,j}^i$ is final expenditure by country *j* for the country 1's product of sector *i*.

Along with the factors like trade openness and income per capita (for testing environmental Kuznets curve) whose effects have been immensely investigated, we introduce different explanatory variables. Product diversification and discovery can alter emission intensities in both production- and consumption-based measurements, and eventually net export of carbon emission. In our case, the economic rationale for the effect of product diversification in the export basket is based on Klinger and Lederman's (2004) evidence suggesting an (one more) inverted U-shaped relationship between economic discovery and economic development. Their economic discovery measurement was the number of the new products entered in the export basket. Since the new products come up with the productivity, one can expect negative relationship between new product discoveries and emission. There is a fallacy challenge while measuring product diversification that it is hard to determine the extent of "newness" for products since they can be just imitation or slightly differentiated. We adapted it to our case as structural change taking the shares of high-tech products (information and communication technology goods), low-tech products and service exports in total manufactures exports. For crosschecking, we also added net oil exports as proxy of resource abundance presenting the factor-driven production and export structures.

One other variable is oil prices that increasing oil prices can encourage countries to invest in research and development on less oil-dependent new products or upgrades of current ones. There are studies (e.g. Blanchard and Riggi, 2013) pointing to the a smaller share of oil in production and consumption compare to the time of 1970s to explain why more recent oil price shocks have not caused economic crises as they did in 1970s. Consistently, in case of Austria, Friedl and Getzner (2003) found that before the oil price shocks in the mid-1970s, increases in CO_2 emissions and economic growth were strongly correlated. For the post-crisis period, 1975-1999, growth of CO_2 emissions was significantly smaller than economic growth. Again, Shapiro and Walker (2015) showed that reductions by 60% in air pollution emissions from U.S. manufacturing between 1990 and 2008 are primarily driven by within-product changes in emissions intensity rather than changes in output or in the composition of products produced. In our case, this is supposed to reflect to export baskets and so, a negative relationship is expected between oil prices and emission. The best data would be those of ex-post 1970s but the input-output data do not allow us to extend the period backwards. However, our time span also has considerable oil price shocks that can capture these kinds of shifts in the production structures.

Our last explanatory variable is import of goods produced in so-called dirty industries that together with the exports of services test the validity of the pollution haven hypothesis from different aspects. Pollution haven or dirty industry hypothesis is a flow of so called "dirty" industries from the developed countries with relatively more stringent regulations on the environmental standards to the developing countries where environmental regulations are relatively laxer. In the global trade pattern, this displacement have simultaneously resulted in both industrialization and deindustrialization for developing countries and developed countries, respectively. We determined most pollutant sectors according to their pollution elasticities calculated by Shapiro and Walker (2015). So the sectors (and ISIC, Rev. 3 codes) are wood products (20), paper and publishing (21-22); coke, refined petroleum, fuels (23); other non-metallic minerals (24) and basic metals (27). Export share of services also well presents the dirty industry/pollution haven hypothesis through deindustrialization process. We use annual data modified from different sources as summarized in Table 1.

3.2. SUR Model

In the related literature, characteristics of model specifications may lead to misleading results that commonly used explanatory variables like urbanization, GDP per capita and energy consumption are in fact highly correlated that may distort the results because of multicollinearity. Moreover, it is seen that dependent variables can replace explanatory variables, and *vice versa*. For example, in Sharma's (2011) study, the dependent variable, CO_2 emission, determined by energy consumptions and GDP per capita is an explanatory variable together with economic growth affecting energy consumption in Saidi and Hammami's (2015) study. Multicollinearity problem is expected in our case not only theoretically but also technically since the model has interaction terms together with the main terms, otherwise, the interaction effect may be significant due to omitted variable bias.

One explanatory variable that significantly tends to causes the multicollinearity is income. It can be explained by other right-hand side variables like trade openness or high-tech export. Again, for an oil-exporter, oil prices directly affect its income level. Therefore, our variable characteristics imply a system of simultaneous equations.

Zellner's (1962) seminal study suggests that regression coefficients obtained from whole system of equations are at least asymptotically more efficient than those of obtained by an equation-by-equation application of least squares. In this context, SUR system embodies several individual relationships reflecting the fact that heir disturbances are correlated. Considered y_{it} is dependent variable related to the t^{th} observation of the i^{th} equation in the system; x_{it} is a K_i-vector of explanatory variables for observational unit i, and u_{it} is an unobservable error term, following Moon and Perron's (2006) presentation, basic linear SUR model can be expressed as in the equation 3.

$$\begin{aligned} y_{1t} &= \beta_1' x_{1t} + u_{1t} \\ \vdots \quad & \quad \vdots \\ y_{Nt} &= \beta_N' x_{Nt} + u_{Nt} \\ & (i=1,\dots,N;\quad t=1,\dots,T) \end{aligned} \tag{3}$$

Table 1: Variables, descriptions and sources

Series	Variables	Descriptions*	Sources**
Dependent variable			
Net exports of CO_2 emissions	*NCEX*	The difference between production and consumption of CO_2. Million tons	OECD, 2016
Explanatory variables			
Trade openness	*TROP*	Total trade as a percentage of GDP	UNCTAD, 2016
Income per capita	*INC*	Real GDP per capita, US Dollars at 2005 prices and 2005 exchange rates	OECD, 2016; UNCTAD, 2016
Global crude oil prices	*OILP*	Crude oil prices as US dollars at 2005 prices and 2005 exchange rates	Author's calculations from US-EIA (2016)
Resource abundance	*OILA*	Net oil exports (including refined products) as barrel per capita	Author's calculations from US-EIA (2016)
High-tech exports	*HTEX*	Share of information and communication technology goods (ISIC 30, 32-33)*** exports in total manufactures exports	UN COMTRADE, 2016
Low-tech exports	*LTEX*	Share of primary goods and commodities (ISIC 1-14)*** exports in total manufactures exports	UN COMTRADE, 2016
Imports of dirty products	*DPIM*	Share of commodities produced in dirty industries (ISIC 20-24, 27)*** import in total manufactures import	Author's computations from UN COMTRADE
Exports of services	*SREX*	Share of services (ISIC 40-95) exports in total manufactures import	UNCTAD, 2016

*All variables are expressed in annual percentage changes. **Sources listed in the table are the main databases. In some series, except *NCEX*, for the years with missing value, different sources' data were applied harmonizing them with those of main sources. ***For detailed explanations on ISIC codes, UN, 2016

The next step is clustering the observations either in the *t* dimension or for each *i*. Consistently with our case, if we cluster for each observation *t*, we have the final expression seen in the equation 4.

$$Y_t = \tilde{X}_t'\beta + U_t \quad (4)$$

Where, $Y_t = [y_{1t},\ldots,y_{Nt}]'$, $\tilde{X}_t$ is a block-diagonal matrix with $x_{1t}, x_{2t}, \ldots, x_{NT}$ on its diagonal ($\tilde{X}_t = diag(x_{1t}, x_{2t}, ..., x_{NT})$), $U_t = [u_{1t},\ldots,u_{Nt}]'$ and $\beta = [\beta_1', ..., \beta_N']'$. However, for a better efficiency, explanatory variables are not supposed to be "highly" correlated (Zellner, 1962; Moon and Perron, 2006 and Baltagi and Pirotte, 2010, for further explanations on the SUR model).

In order to hinder lost-effect and serious multicollinearity problems we specify four different models with one interaction term per each, as seen in the equation 5. These models are also those that have no heteroscedasticity and autocorrelation.

$$\begin{aligned}
i)\ NCEX_{it} &= \alpha_0 + \beta_0 TROP_{it} + \beta_1 INC_{it} + \beta_2 HTEX_{it} + \beta_3 OILP_{it} \\
&\quad + \beta_4 OILA_{it} + \beta_5 (INC_{it} \times HTEX_{it}) + \varepsilon_{it} \\
ii)\ NCEX_{it} &= \alpha_1 + \theta_0 TROP_{it} + \theta_1 INC_{it} + \theta_2 LTEX_{it} + \theta_3 OILP_{it} \\
&\quad + \theta_4 OILA_{it} + \theta_5 (INC_{it} \times LTEX_{it}) + u_{it} \\
iii)\ NCEX_{it} &= \alpha_2 + \delta_0 TROP_{it} + \delta_1 INC_{it} + \delta_2 DPIM_{it} + \delta_3 OILP_{it} \\
&\quad + \delta_4 OILA_{it} + \delta_5 (INC_{it} \times DPIM_{it}) + E_{it} \\
iv)\ NCEX_{it} &= \alpha_3 + \lambda_0 TROP_{it} + \lambda_1 INC_{it} + \lambda_2 SREX_{it} + \lambda_3 OILP_{it} \\
&\quad + \lambda_4 OILA_{it} + \lambda_5 (INC_{it} \times SREX_{it}) + U_{it} \\
&\qquad (i = 1...41; \quad t = 1996...2011)
\end{aligned} \quad (5)$$

Since cross-section units (N:41) are numerous than temporal units (T:16), we have a cross-section dominant (N>T) balanced panel data sets. All the variables are as previously defined in Table 1. In the literature, increase in GDP is usually found main reason for the CO_2 emissions since the increase in income are accompanied by increasing energy consumption. However, in our case this relationship is not certain that high-income countries specialize in high-tech components in their production and exports, and carry their resource and labor-intensive production and/or production stages to developing countries where environmental regulations are relatively laxer. This process, that is called deindustrialization, can result in leaving dirty industries and improving the service sectors. In order to track these effects we add four mutual interaction terms of high-tech exports, low-tech exports, import of 'dirty' products and exports of services with income per capita. These observation-by-observation interaction terms are expected to capture the moderating effects of the income increases over the relationships.

The interaction term between income per capita and high-tech exports (*INC* × *HTEX*) is expected to be negative since as income levels go up high-tech exports increase as well and so net emission exports go down. The coefficient of the interaction term here shows how the high-tech exports affect the net exports of the carbon emission, when GDP per capita increases one-unit. On the contrary, as income decreases high-tech export decreases and net export of emission (*NCEX*) increases. Again, the interaction term between income per capita and low-tech exports (*INC* × *LTEX*) is expected to have positive sign since as *INC* increases (decreases) *LTEX* decreases (increases) and consequently *NCEX* decreases (increases). With the same interpretations, the interaction terms *INC* × *SREX* and *INC* × *DPIM* are expected to have negative and positive signs respectively, which provide information to infer pollution haven hypothesis from. However, for better interpretations, coefficients of interaction terms need to be considered together with those of main terms beside the notice of variables are expressed in growth terms.

4. ANALYSIS AND RESULTS

We estimate models for a panel of 34 OECD countries and 7 major non-OECD countries (Argentina, Brazil, China, India, Indonesia, Russia and South Africa) in the G-20 over the 16-year period covering 1996-2011. The countries included in the sample are major emitters and the period is determined under the data restrictions. In 2014, total share of the sample countries in both world export and world import was more than three-quarters in the world (UNCTAD, 2016). Again, total share of these countries in CO_2 emissions from fuel combustion is more than 80% in 2013 as IEA (2016) statistics say. China individually has shares around 13% and 10% in world export and import, respectively, while its share in world CO_2 emissions is more than 28% which equals three-quarters of the total emission emitted by OECD countries. The difference between trade and emission shares points out the non-environmental production structures. Considering the export and import contents of China, also it can be evaluated as a symptom of pollution haven hypothesis.

In order to determine appropriate analysis procedure to follow, first we checked each series for stationarity. Unreported results from various panel unit root tests affirmed that all the variables are stationary at level. This is expected since all the variables are expressed in growth terms. Finally we use SUR based GLS method to estimate the models in equation-5. Estimated coefficients are reported in Table 2.

Results indicate that increases in trade openness (*TROP*) also lead to increases in the net export of carbon emission (*NCEX*) for all model specifications, while income (*INC*) represented by GDP per capita has a slight but significant negative effect on the *NCEX*, for all specifications. Against our expectations, international oil price (*OILP*) does not have any significant effect. However, oil abundance (*OILA*) proxied by net oil exports per capita, is the most important factor raising the *NCEX*. Structural change indicators, high-tech (*HTEX*) and low-tech exports (*LTEX*) consistently have negative and positive signs, respectively. Supporting the effects of structural change and pollution haven hypothesis, import of dirty products (*DPIM*) positively associated with the *NCEX* while exports of services (*SREX*) has negative effect. Findings on the interaction terms confirm that increase of income level not only tends to reduce the emissions directly, but also does indirectly by leading the structural changes: Increases in the income levels and progress in the export basket towards higher technology move together. Finally, countries with higher income growth have also

Table 2: Factors affecting the net export of carbon dioxide emission (*NCEX*)

Specification i		Specification ii		Specification iii		Specification iv	
Variables	Coefficients	Variables	Coefficients	Variables	Coefficients	Variables	Coefficients
TROP	0.719 (3.238)*	*TROP*	0.765 (2.951)*	*TROP*	0.793 (3.367)*	TROP	0.851 (4.744)*
INC	–0.001 (–2.601)*	*INC*	–0.001 (–2.743)*	*INC*	–0.001 (–2.941)*	INC	–0.001 (–2.869)*
OILP	0.111 (1.222)	*OILP*	0.0559 (0.574)	*OILP*	0.007 (0.077)	OILP	0.076 (0.431)
OILA	2.319 (4.010)*	*OILA*	2.027 (4.173)*	*OILA*	-	OILA	1.210 (2.753)*
HTEX	–0.525 (–3.874)*	*LTEX*	0.860 (2.588)*	*DPIM*	1.180 (2.409)*	SREX	–0.137 (–2.652)*
INC×HTEX	–0.578 (–3.340)*	*INC×LTEX*	1.186 (2.587)*	*INC×DPIM*	0.0003 (5.269)*	INC×SREX	–0.177 (–2.697)*
Constant	–0.994 (–0.275)	Constant	0.177 (1.297)	Constant	1.804 (2.660)*	Constant	0.997 (1.919)
R^2	0.565	R^2	0.669	R^2	0.701	R^2	0.555
Adj. R^2	0.561	Adj. R^2	0.666	Adj. R^2	0.697	Adj. R^2	0.549
P (F-st.)	0.000	P (F-st.)	0.000	P (F-st.)	0.000	P (F-st.)	0.000
D-W stat.	1.842	D-W stat.	1.972	D-W stat.	1.945	D-W stat.	1.797

*Denotes significance at 5% levels. t-statistics are in the parentheses

higher growth in service shares in their export and therefore have decreasing net export of emission.

5. CONCLUSION

There is a certainty that CO_2 emissions emitted mostly by human activities have been polluting the environment. Who and how emits are big challenges that studies in the literature focus on. Recently there is a considerable attempt among scholars for exploring the determinants of the carbon emission using both time series and panel data. Along with the destructive effects of economic growth under the environmental Kuznets curve pattern, energy consumption, population and urbanization indicators are found responsible for carbon emission in the studies. Even it is now well known that trade and CO_2 emission are increasingly entwined, the interest on the trade mechanism of the carbon emissions is relatively weak and seen restricted to the trade openness in the related literature. This restriction also causes a neglect of the fact that international trade has a powerful channel having important roles in the diffusions of environmentally-friendly green goods, services, technologies and production methods among countries. In this context, best production practices spread all around the world via trade mechanism. Starting from this negligence and multidimensional effects of the trade, this study examined potential factors affecting the changes in the net exports of the CO_2 emissions measured by OECD using environmentally extended ICIO tables and the International Energy Agency's fuel combustion-based CO_2 emissions data. Explanatory variables are percentage changes in trade openness, income, high-and low-tech export shares, international crude oil prices, resource abundance, dirty products imports and services exports. For crosschecking, we also added interaction terms between structural change indicators and income in the model.

We conducted SUR-based GLS method on the balanced panel data sets of 34 OECD and 7 major non-OECD countries in the G-20 for the period of 1996-2011. Several noteworthy findings of the study can be summarized as follows: (i) Higher trade openness causes increases in emission exports. This is not surprising since our dependent variable is net export of emission. We added it in the model for having robust estimation and seeing the interactions. (ii) GDP per capita growth has a slight negative effect. This is consistent with the trade-adaptation of the environmental Kuznets curve since our sample consists of countries that have mix of middle- and high income levels. (iii) Rise in the net oil exports per capita is the most important factor contributing the emission export. This evidence is one reason why we imply ambiguity for blaming individual countries for emitting, since some countries' emission intensive exports are the sources of growth for the others. Supporting this evidence, we found that so-called dirty product imports (exports of others) are strongly and positively associated with the emission exports. (iv) Even we expected oil price rises encourage countries to export more environment-friendly goods, oil-prices are found insignificant. (v) For structural changes, export shares of high-tech and services are found easing the emissions, while consistently low-tech exports and import of dirty products increase the emission. (vi) Significant coefficients of interaction terms between income and structural change indicators embody important implications that open doors to the debates for further studies. Rises in income growth are followed by high-tech and service export augmentations that reveal the indirect contributions and moderating roles of the income growth for reducing the net export of emissions. Supporting the pollution haven hypothesis, both import shares of dirty products that are positively correlated with income growth and export shares of low-tech products that are negatively correlated with income growth increase the emission exports. This is the other strong support highlighting the importance of the necessity for setting an international and environmental trade system operated by the green trade policies. In this context, green tariff, green non-tariff measures and more environmental global standards are seen efficient policy implications. These international initiatives need to consider the challenges originate from the lacks of financial sources, technical capacities and human capital stocks that many developing countries have been facing. Some researchers in the international trade literature seem to have replaced the standard quantity-based competitiveness measurements by quality-based ones that also need to be updated through more-environmental indicators. This awareness can help developing countries especially those seeming pollution havens, transform their export structures along an environmental trajectory.

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