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HOW TRADE OPENNESS ALTERS ENVIRONMENTAL QUALITY

An analysis of 20 developed and developing countries using green house gas emissions as a proxy for environmental damage.

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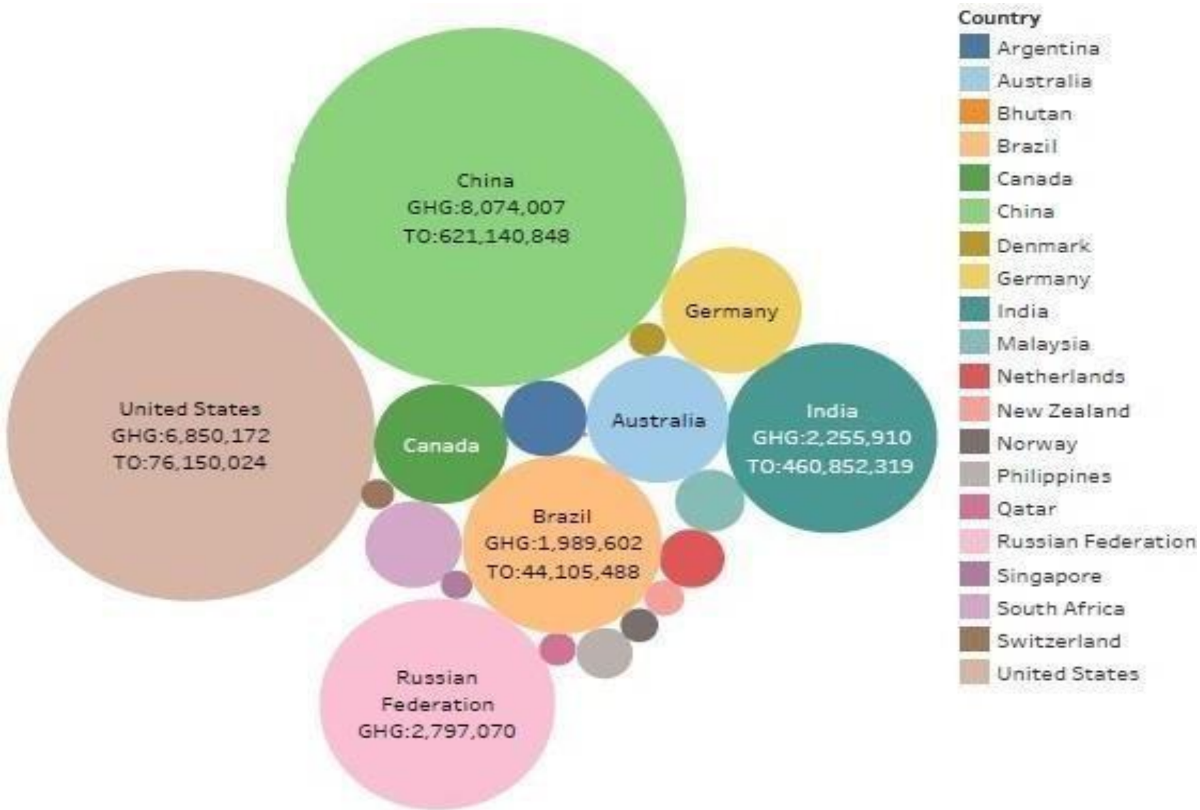
Introduction

The past half century has been marked by an unprecedented expansion of international trade. Since 1950, world trade has grown more than twenty-seven fold in volume terms. By way of comparison, the level of world GDP rose eight-fold during the same period. As a consequence, the share of international trade in world GDP has risen from 5.5 per cent in 1950 to 20.5 per cent in 2006. Economic growth resulting from trade expansion can have an obvious direct impact on the environment by increasing pollution or degrading natural resources. In addition, trade liberalisation may lead to specialisation in pollution-intensive activities in some countries if environmental policy stringency differs across countries – the so-called pollution haven hypothesis.



However, increased trade can in turn, by supporting economic growth, development, and social welfare, contribute to a greater capacity to manage the environment more effectively. More importantly, open markets can improve access to new technologies that make local production processes more efficient by diminishing the use of inputs such as energy, water, and other environmentally harmful substances.

As the figure above shows the extent of trade openness (TO) and green house gas emissions (we have taken green house gas emissions as a proxy for environmental damage) are different across different countries so in this paper we explore, *Whether economic growth throughout the world will have greater harm on the earth's environment? Or do the increase in income and wealth sew the seeds for amelioration of ecological problems? Whether trade is good or bad for the environment?*

Trade and investment liberalisation can provide firms with incentives to adopt more stringent environmental standards. As a country becomes more integrated within the world economy, its export sector becomes more exposed to environmental requirements imposed by the leading importers. Changes needed to meet these requirements, in turn, flow backwards along the supply chain, stimulating the use of cleaner production processes and technologies.

Many believe that openness harms the environment. Most widely discussed is the *race-to- the bottom hypothesis, which says that open countries in general adopt looser standards of environmental regulation, out of fear of a loss in international competitiveness.* Alternatively, poor open countries may act as pollution havens, adopting lax environmental standards to attract multinational corporations and export pollution-intensive good Less widely recognized is the possibility of an effect in the opposite direction, which we call the *gains-from-trade hypothesis. If trade raises income, it allows countries to attain more of what they want, which includes environmental goods as well as more conventional output*.

We will use the widely used framework developed to analyse the impact of the trade openness on the environment. This framework separates *the impact of trade liberalization into three independent effects: scale, composition and technique.* Apart from concentrating only on the relation between growth, trade openness and the emissions, this paper includes an analysis of trade with capital labor ratio and income at different levels to account for differences in factor endowment, environmental policies, scale and technique.

Furthermore, the type of institution and regime any country has may have a different impact on the relationship between Trade openness and greenhouse gas emissions. Generally developing countries have weaker and less efficient institutions and democratic and non- democratic countries may have different set of policies. Our paper incorporates this.

DEMOCRATIC		
Country	**AVERAGE TO**	**AVERAGE GHG**
Argentina	13396979.25	356940.4434
Australia	8675384.331	1009402.157
Brazil	44105488.33	1989601.876
Canada	22580056.75	896687.7397
Switzerland	7705999.79	54699.93165
Germany	57374689.25	992353.4433
Denmark	4885529.197	67374.40641
India	460852319.1	2255910.445
Netherlands	20167068.03	213361.5997
Norway	3281390.738	70376.73978
NewZealand	2497620.416	77664.68056
Philippines	69622141.98	158827.1852
UnitedStates	76150023.77	6850171.827

AUTOCRATIC		
Country	**AVERAGE TO**	**AVERAGE GHG**
Bhutan	369147.664	1902.119428
China	621140847.5	8074007.451
Malaysia	47590453.18	240748.5688
Qatar	1059506.17	67226.90194
Russian Federation	80826358.31	2797069.839
Singapore	16891696.28	49428.51644

Thus, the focus is on the complexities of trade induced composition effect as well as the scale-technique effect for 20 developed and developing countries.

Literature Review

Trade theory suggests that a marginal change in trade affects the emission level through three major channels: the scale effect, the composition effect, and the technique effect. To study these effects, **Chong Hui Ling, Khalid Ahmed, Rusnah binti Muhamad and Muhammad Shahbaz (2015)** analyzed the impact of trade openness on CO2 emissions via scale, technique, composite and comparative advantage effects. They used time series data over the period of 1970 QI-2011 QIV employing ADF and PP unit root tests to examine the stationary properties of the variables. According to past literature, CO2 emissions are found with the highest concentration in the developing countries

i.e. Malaysia. It was shown that the relationship between linear (scale effect) and nonlinear (technique effect) in terms of real GDP per capita and CO2 emissions is inverted U-shaped which further confirms the existence of Environmental Kuznets Curve hypothesis. The impact of cns is negative and significant, hence trade openness has negative and significant effect on CO2 emissions. It reveals that the environmental friendliness of trade liberalization is a long-run phenomenon in case of Malaysia. Energy consumption affects CO2 emissions positively. The replacement of conventional energy sources with renewable energy may not necessarily reduce CO2 emission unless technique effect adequately supports the composition effect. To be more precise, **Matthew A. Colea, and Robert J.R. Elliott (2003)** examined whether the compositional effect of trade liberalization is driven by differences in endowments of capital and labor or due to differences in environmental standards and argued that pollution intensive sectors may be subject to opposing sources of comparative advantage. Due to the high correlation between a country's per capita income level and the stringency of its environmental regulations, the pure ERE implies that developing countries or regions (south) will become pollution havens, while the developed world (north) will specialize in clean production. The conclusions from the econometric analysis suggest that the trade-induced composition effect is small, relative to the scale, technique effects and direct composition effect. With regard to SO2, the authors find that capital labor effect and the environmental regulation affect both exist and cancel out each other. The results for BOD suggest further liberalization will reduce per capita emissions, while for NOx and CO2 trade liberalization is likely to increase emissions. For all four pollutants, trade liberalization reduces the pollution intensity of output.

Similarly, **Geoff McCarney and Vic Adamowicz (2006)** used a random effects model to evaluate the impact of trade liberalization on the environment while controlling for national characteristics that can distort the competing scale, technique and composition effects among 120 countries using CO2 and BOD emissions as the dependent variables. The results suggest that BOD emissions were worse in more open economies and the impact was significantly

different in strongly autocratic countries versus democratic or even weakly autocratic countries.They predicted that BOD emissions suggest that the promotion of democracy may help to improve the relationship between trade liberalization and environmental quality. On the other hand, for CO2 emissions, an increase in the democracy level of a country (or lessening of autocracy) marginally decreased emissions of CO2 but these effects were moderated for autocratic countries. The pollution haven hypothesis was found to be strongly significant for CO2 emissions and weakly for BOD emissions, however for relatively rich, autocratic countries, emissions were relatively constant as openness increased which can be accounted by the fact that BOD emissions increase for autocratic countries as free trade increases, likely negating any decline in emissions that may result from a pollution haven effect. On the other hand, **J.Bernard & S.K Mandal (2016)** analysed the impact of trade openness on environmental quality using a dynamic panel data for 60 emerging and developing economies for the period 2002 to 2012, employing Environmental Performance Index (EPI) and CO2 emissions as the two indicators of environmental quality. They analyse the effect of Governance and other socio economic factors affecting environmental quality. The fixed effects model elicits that trade openness improves EPI, albeit it increases CO2 emissions. When corrected for endogeneity, trade openness was found to have no significant impact on EPI, though it escalates CO2 emissions. GMM findings with EPI highlight that political factors improve environmental quality, whereas income and population have detrimental effects. In the GMM estimations with CO2 emissions, trade openness, income, energy consumption and population were found to have deleterious effects on environmental quality.

Faiz-Ur-Rehman, Amanat Ali and Mohammad Nasir (2007) focus on the impact of corruption and trade openness on the environmental quality for selected South Asian countries for the period 1984- 2003 using a Fixed Effects Model. The key independent variables of the study i.e. trade openness, corruption, and income levels have been used to test the interactions among institutions, economic growth and public policies. The study suggested that as the volume of trade increased and the corruption level fell, the level of CO2 emission decreased suggesting a positive impact of openness as well as reduced corruption on environmental protection. It is also observed from the interaction effect that as the level of corruption increased, the impact of trade on the stringency of the environmental regulations increased. The interaction effect corruption*GDP outlines that corruption distorts people's preferences to optimal policy formation showing that the idea of EKC depends on the level of corruption in the economy or it is not necessary that every country should follow the path of Kuznets curve in their emissions. **Sekrafi Habib & Snoussi Abdelmonen&Mili Khaled (2018)** analyze the total effect of corruption on the environmental quality for Africans countries for the period 1992 to 2013 using quantile regression analysis to account for different levels of corruption. Results indicate a negative effect of corruption on environmental quality for the lower quantiles and an absence of effect of corruption on the environmental quality for the higher quantiles. Specifically, the effect of corruption on CO2 emissions is significantly negative in the lower CO2 emission countries like Dem. Rep., Zambia, Kenya, Nigeria, Ghana, etc. At higher quantiles, countries that are characterized by high CO2 emissions like Angola, Morocco, Egypt, South Africa, etc., the effect was not significant.

It is also found that informal sector negatively and significantly affects the environmental quality for the lower quantiles but the effect was positive and not significant for the higher quantiles. The

EKCs for the African countries analysed by the authors take the form of an inverted-U whose values of the return point increase with increasing CO2 suggesting that African countries are still in the growing phase where an increase in GDP leads to increasing CO2 emissions. Apart from the direct negative effect of corruption on environmental quality, it has an indirect effect through two channels: economic growth and energy consumption.

To conclude, **Shunsuke Managi, Akira Hibiki and Tetsuya Tsurumi (2009)** study the relation between international trade openness and environmental quality using SO2 and CO2 emissions of 88 countries from 1973 to 2000 and the BOD emissions of 83 countries from 1980 to 2000 using a differenced GMM method. The results suggest that The Helsinki and Oslo Protocols were effective in reducing SO2 emissions while the Kyoto Protocol and Protocol on Water and were not effective at reducing emissions in their sample period studied. An increase in trade intensity results in a decrease in emissions in OECD countries and increase in emissions in non-OECD countries. The authors found that the short and long-term overall effects of trade openness on emissions are negative for all pollutants in OECD countries as the negative trade-induced scale-technique effect dominates the positive tradeinduced composition effect. While these effects are positive for SO2 and CO2 but negative for BOD in non-OECD countries since the trade-induced scale-technique effect and the tradeinduced composition effect are both positive in the cases of SO2 and CO2. Trade openness reduces BOD emissions both in OECD and non-OECD countries, while it reduces SO2 and CO2 emissions in OECD countries and increases them in non-OECD countries. The authors conclude that whether trade has a beneficial effect on the environment on average or not varies depending on the pollutant and the country.

The aim of this paper is to provide an analysis of the decomposed effect of trade openness on the environmental quality through scale, technique and composition effects as well as to determine the role of corruption, in particular, on having any intriguing effect on environment when interacted with trade liberalisation using a Random and fixed effects estimation technique.

Data & Methodology

- **Data and Variables**

To analyse the 20 major developing and developed countries in the world, the paper looks at 10 Developing nations namely China, India, Malaysia, Philippines, Argentina, Bhutan, Brazil, Qatar, Russia and South Africa along with 10 major developed countries namely Netherlands, New Zealand, Norway, Singapore, Australia, Canada, Denmark, Germany, Switzerland and United States of America. These nations were chosen based on their HDI ranking by the United Nations.

Since the greenhouse gas emissions (carbon dioxide, methane, nitrous oxide and fluorinated gases) from human activities are the most significant driver of observed climate change since the mid-20th century and have severe consequences on the environment, this paper aims to determine the impact of trade on the greenhouse gas emissions across these 20 major countries. The Kyoto Protocol, an international treaty which extends the 1992 United Nations Framework Convention on Climate Change (UNFCCC) committing the state parties to reduce greenhouse gas emissions was adopted in December 1997. Therefore, this paper spans over the period of 1998-2012. The focus of the paper is narrowed towards only greenhouse gas emissions since it is difficult to have a perfect indicator describing the several parts of the ecosystem that we care about (air, land, water).

The data for greenhouse gas emissions, imports and exports, GDP per capita, imports and exports of goods and services and labor are taken from the World Development Indicators, wWorld Bank. Trade openness is measured as the ratio of the sum of imports and exports to GDP. Physical capital stock is taken from Penn World tables. The Corruption Perceptions Index (CPI) is used as an indicator of corruption. CPI is an index published annually by Transparency International since 1995 which ranks countries "by their perceived levels of corruption, as determined by expert assessments and opinion surveys." The CPI defines corruption as "the misuse of public power for private benefit". It currently ranks 176 countries "on a scale from 100 (very clean) to 0 (highly corrupt)". The polity variable, representing the type of regime/government, is taken from Center for Systemic Peace (CSP) which is coded as polity IV index as -10 to 10. The negative scores denote autocracy and positive values denote democracy. This variable indicates the direct impact of governance on environmental quality.

Table 1: Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
country	300	10.5	5.775916	1	20
year	300	2005	4.327713	1998	2012
totalgreen~s	300	1322668	2284251	0	1.20e+07
gdppercapita	300	25480.75	23763.08	409.194	101668
relativegdp	300	3.340823	2.833758	.077747	10.3246
trade_open~s	300	88.11709	77.87997	16.4386	441.604
kl_ratio	300	.1705309	.1170872	.009868	.475017
polity	300	5.853333	6.405356	-10	10
corruption	300	63.33487	25.89254	21	100
rkl	300	5.412405	3.630553	.368419	13.3472

- **Background**

Trade theory suggests that a marginal change in trade affects the emission level through three major channels: the scale effect, the composition effect, and the technique effect:

Scale effect: An increase in inputs to satisfy the increasing level of production generated by the economic development of a country caused by trade on the environment. Greater energy use is required to increase economic activity and therefore may lead to higher emissions.

Technique effect: The impact of trade on the environment due to a change in production technologies. The discovery of pollution-reducing technologies which comes as a result of research and development (R&D) reduces pollution per capita. Thus studies have argued that the technique effect has a positive impact on environmental quality.

Composition effect: The comparative advantage a country possesses in terms of factor endowments and differences in environmental regulations has implications on the Environment. If comparative advantage exists due to factor endowment (capital-labor ratio), then the factor endowment hypothesis suggests that high income countries with high capital- labor ratio will have comparative advantage in pollution-intensive goods and hence environmental degradation might result as compared to developing countries. However, since regulations increase the cost of producing dirty goods and also pollution abatement is costly, developed countries suffer from comparative disadvantage in pollution- intensive goods. Developing countries enjoy comparative advantage in pollution-intensive industries, hence becoming pollution haven. Thus, it is predicted that developing countries with laxer environmental regulations would be made dirtier whiles developed countries become clean (gain). Therefore, the composition effect is ambiguous and depends on the relative size of the capital-labor ratio effect and pollution haven effect.

The *Environmental Kuznets Curve* (EKC) is a hypothesized relationship between various indicators of environmental degradation and income per capita. It states that at low levels of income, the scale effect outweighs the composition and technique effects. Thus, as a poor country begins to grow, there is a net increase in environmental damage. Over time, income reaches some critical level, and the latter two effects outweigh the former. Growth then leads to a net reduction in environmental damage. This implies that the environmental impact indicator is an inverted U-shaped function of income per capita and the net impact of trade on the environment depends on the relative size of scale, technique and composition effect.

To analyse this decomposition, our paper studies three major hypothesis. The *Pollution Haven Hypothesis* posits that jurisdictions with weak environmental regulations, 'pollution havens' will attract polluting industries relocating from more stringent locales. This is because environmental regulations raise the cost of key inputs to goods with pollution-intensive production, and reduce jurisdictions' comparative advantage in those goods. Thus firms will seek to avoid the cost of stringent environmental regulations by locating production in countries where environmental norms are laxer. While the *Factor Endowment Hypothesis* claims that countries that are relatively abundant in capital will have comparative advantage in the production of capital-intensive (dirty) goods and hence tend to export pollution-intensive

goods. This suggests that pollution will fall for developing countries since they do not have comparative advantage in pollution-intensive goods.

- **Generalized Method of Moments (GMM)** is a parameter estimation strategy which nests the classic method of moments, linear regression and maximum likelihood.

The method requires a certain number of moment conditions which are functions of the model parameters and the data, such that their expectation is zero at the parameters' true values. It is an estimation procedure that allows economic models to be specified while avoiding often unwanted or unnecessary assumptions, such as specifying a particular distribution for the errors and therefore can be used in situations where maximum likelihood estimation is not applicable.

The GMM estimators are known to be consistent, asymptotically normal, and efficient in the class of all estimators that do not use any extra information aside from that contained in the moment conditions. GMM is practically the only estimation method which can be used in endogeneity problems.

The model in matrix form is: $Y = X\beta + \epsilon$ where $E(X'\epsilon) \neq 0$ The moment conditions are:

$E(Z'\epsilon) = 0$ where Z is some other variable.

Due to more moment conditions than parameters, throwing out extra moment conditions would not lead to a unique estimated value of β . Instead, the following minimization is carried out:

Min $[(Z'\epsilon)'W(Z'\epsilon)]$ where W is an L x L weighting matrix. Substituting for ϵ gives :

Min $[(Z'(Y-X\beta)'W(Z'(Y-X\beta)]$

The solution for the optimal would be:

estimated $\beta = (X'ZWZ'X)^{-1}X'ZWZ'Y$

Reason for choosing GMM over other methods of estimation:

Including a lagged dependent variable as a regressor violates strict exogeneity, since the lagged dependent variable is necessarily correlated with the idiosyncratic error. Hence, when the strict exogeneity assumption is violated, panel data techniques such as fixed effects estimators are inconsistent which usually require the estimators to be strictly exogenous. Anderson and Hsiao (1981) first proposed a solution by utilising instrumental variables (IV) estimation. However, the Anderson Hsiao estimator is asymptotically inefficient, as its asymptotic variance is higher than the Arellano Bond estimator, which uses a similar set of instruments, but uses generalized method of moments estimation rather than instrumental variables estimation.

In the Arellano Bond method, first difference of the regression equation is taken to eliminate the fixed effects. Further, deeper lags of the dependent variable are used as instruments for

differenced lags of the dependent variable (which are endogenous). In traditional panel data techniques, adding deeper lags of the dependent variable reduces the number of observations available. This creates a trade-off: adding more lags provides more instruments, but reduces the

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sample size. The Arellano Bond method circumvents this problem. Moreover, the dynamic generalized method of moments (GMM) estimation of panel data is useful both to correct for serial correlation and to analyze both short- and long-term effects of trade openness on the environment.

Empirical Model I

To estimate the impact of trade openness on greenhouse gas emissions, the following equation is estimated using Arellano Bond GMM estimation:

$GHG\ it = \alpha + GHG\ it{-}1 + \beta\ 1GDP\ it + \beta\ 2GDP\ ^{2}it + \beta\ 3K/L\ it + \beta\ 4K/L\ ^{2} + \beta i\ t\ 5(K/L)\ itGDP\ it + \beta$ $6TO\ it + \beta$

$7RGDP\ itTO\ it + \beta\ 8(RGDP)\ ^{2}\ TO\ it\ i{+}_{t}\ \beta\ 9RK/L\ itTO\ it + \beta\ 10(RK/L)\ 2\ itTO\ it + \beta\ 11RGDP$ $itRK/L\ it + \beta\ 12$

$Polity + \beta\ 13(Polity)\ GDP\ it + \varepsilon\ it$

…..(1)

Where $\varepsilon\ it = u\ i + v\ it$ where $u\ i$ is the fixed effect reflecting the time-invariant country specific characteristics and $v\ it$ is the random noise variable.

The above equation can be decomposed into following categories.

1. Scale Technique Effect
2. Trade induced composition Effect

The Scale technique effect is captured by using the GDP per capita current US. This is in sync with the study by Cole and Elliot (2003). Following McCarney and Adamowicz (2005), the study argues that the scale technique effect (STE) would be influenced by democratic governance. Thus, the STE is specified as

$STE\ it = \alpha\ 1GDP\ it + \alpha\ 2GDP\ ^{2}it + \alpha\ 3(Polity)GDP\ i\ t$

….
.(2)

From EKC theory, $\alpha\ 1$ is expected to be positive and $\alpha\ 2$ negative. The positive coefficient on GDP coupled with the negative coefficient for $GDP\ ^{2}$ indicates that a representative country in our sample may follow an EKC path. The interaction between per capita income (GDP) and the polity variable gives additional technique effect. $\alpha\ 3$ is expected to be negative since democratic countries are responsive to high environmental quality as income grows.

The composition effect (COMP) is ascertained by ignoring the$GDP\ it$,$GDP\ ^{2}it$ and the polity variables in equation (1). This gives us equation (3)

$COMP\ it = \alpha\ 3K/L\ it + \alpha\ 4K/L\ ^{2} + i\alpha t\ 5(K/L)\ itGDP\ it + \alpha\ 6TO\ it + \alpha\ 7RGDP\ itTO\ it +$

$\alpha\ 8(RGDP)\ ^{2}itTO\ it + \alpha\ 9RK/L\ itTO\ it + \alpha\ 10(RK/L)\ ^{2}\ itTO\ it + \alpha\ 11RGDP\ itRK/L\ it$ ……(3) In particular, the trade-induced composition effect (TCOMP) reflects the relative opposing magnitudes of factor endowment effect and pollution haven effect. The trade induced composition effect is formalized by Cole and Elliot (2003) as:

$TCOMP\ it = \alpha\ 6TO\ it + \alpha\ 7RGDPitTO\ it + \alpha 8(RGDP)\ ^{2}itTO\ it + \alpha\ 9RK/L\ itTO\ it + \alpha\ 10(RK/L)\ ^{2}itTO\ it$

$+ \alpha\ 11RGDP\ itRK/L\ it$…..(4)

In the above model (equation 4), Antweiler, Copeland and Taylor (2001) theory predicts **α6** to be zero. Since developed countries with high income have more strict regulations than developing countries with low income, it is expected that free trade will cause a damaging impact on environmental quality for countries with low per capita income but improve the environment of countries with high per capita incomes. This is because first, dirtier industries will relocate to low income countries that also have comparative advantage in the pollution intensive production processes. This impact (pollution haven hypothesis) is captured by the interaction of relative real GDP per capita and trade openness (i.e. RY*TO). The quadratic term is included to account for differences in RK/L and RY, where RK/L denotes relative capital-labor ratio.We therefore expect **α7** to be positive and **α8** to be negative. Factor endowment hypothesis predicts that countries with low capital- labor ratio will have a comparative disadvantage in pollution-intensive industry and hence pollution will be low. However, countries with high capital-labor ratio tend to have comparative advantage in dirty industry and hence pollution might increase. This argument is captured by the interaction of relative capital-labor ratio and trade openness (i.e. RK/L*TO) and its quadratic term. **α9** and α_{10} are therefore expected to be negative and positive respectively. Finally,**α11** can be either positive or negative.

Empirical Model II

To estimate the impact of corruption and trade openness on greenhouse gas emissions, the following equation is estimated using Arellano Bond GMM:

GHGit = αo+α1Opennessit +α2 Corruptionit +α3GDPit+α4GDPit ^{2}+ α5Corruptionit*openness it +α6 Corruption it *GDP it +α7Corruptionit *Di + eit …..(5)

Trade openness affects the environmental quality through two effects; the direct impact on greenhouse gas emissions and the through an interaction term with corruption (i.e corruption* openness). Theoretically, corruption levels should have a greater absolute impact on environmental protection as compared to openness. Nevertheless, its total impact depends on its direct effect and its interaction effect with openness.

The sign and significance of the GDP and GDP^2 tells us about the shape of Environmental Kuznets Curve (EKC) which should be an inverted u-shaped curve implying that **α3** is expected to be positive and **α4** is expected to be negative showing the EKC path followed by the countries. The coefficient of the interaction variable (corruption*GDP) represents how people's demand for environmental quality changes as their income level rises implying the sign of **α6** to be negative. The coefficients of the other interaction term (corruption*openness) show the impact of trade on the stringency of the environmental regulations as the level of corruption rises according to which the sign of **α5** is expected to be negative. Thus, the interaction coefficient provides a sense of the effects of governmental corruption level under different trade regimes with corruption and protection being complements in the creation of environmental policy distortions in developing countries. Further, an interaction of corruption with a dummy (D=1 for developed; 0 for developing countries) is added to represent the impact separately on developed vis-a-vis developing countries.

Preliminary Analysis

A common assumption in many time series techniques is that the data is stationary. The stationary property implies that the mean, variance and autocorrelation structure do not change over time, with constant variance over time, a constant autocorrelation structure and no periodic fluctuations. Non stationary time series often result in spurious correlation in regression analysis. To check stationarity in our data, the unit root test is used on greenhouse gas emissions, trade openness, GDP per capita and its square variables. By employing the Fisher type unit root test based on Augmented Dickey Fuller (Choi, 2001), it was inferred that the variables were not stationary in their level terms but became stationary after their first difference. Hence, the model is tested using the first differences of these variables. Table A1 (appendix) shows the same, suggesting that the null hypothesis of no stationairity is rejected when the variables are specified in their first differences.

To overcome the problem of both autocorrelation and endogeneity, a GMM technique is used. A more efficient approach is to use the Arellano-Bond GMM technique which naturally corrects the problem of endogeneity by exploiting all possible instruments for each lagged dependent variable until orthogonality is reached.

In addition, the Sargan test is utilized for testing the validity of over-identifying restrictions or the validity of the instruments used. The Sargan test is based on the assumption that model parameters are identified via a priori restrictions on the coefficients.

The null hypothesis is that the instruments employed in the regression are not correlated with the error terms; hence failing to reject the null means the instruments as a group are exogenous. Alternatively, the null hypothesis is to test whether the restrictions are overidentified. If the model passes these tests (i.e. null hypothesis is rejected), then Arellano-Bond estimator is asymptotically efficient.

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Log-linear functional form using the first difference of variables (equation 6) is chosen for the first model over the other possible functional forms; having the highest Chi2 value for the Sargan test (figure A2).

Hence, the log-lin model estimated with one lagged value of the dependent variable is:

lnGHG it = α + *GHG it*−1 + β 1*GDP it* + β 2*GDP* 2*it* + β 3*K/L it* + β 4*K/L* 2*it* + β 5*TO it* + β 6*RGDP itTO it* + β 7(*RGDP*) ^{2}*itTO it* + β 8*RK/L itTO it* + β 9(*RK/L*) ^{2}*itTO it* + β 10*RGDP itRK/L it TO it* + β 11 *Polity* + β 12(*Polity*) *GDP it* + ε *it* …..(6)

For the second model, the same exercise is repeated and according to the results of the sargan test (appendix table A3), log-lin model (equation 7) having the highest chi2 value is chosen for estimation. GHGit = αo + α1 Opennessit + α2 Corruptionit + α3 GDP it + α4 GDPit^{2}+ α5 Corruptionit*opennessit + α6Corruptionit *GDPit +α7Corruptionit *Di + eit (7) where, Di represents a dummy variable for country which takes a value 1 for a developed country and 0 for a developing country.

Fixed effects regression was estimated for the same equations (6 and 7), however, due to the presence of endogeneity in the model, the results were inefficient. For other functional form specifications of Arellano-Bond GMM, the results turned out to be insignificant with unexpected signs and are presented in table A4 & A5 (appendix).

Estimation and Results

- **Decomposed impact of trade openness on greenhouse gas emissions**

Variables	Model A	Model B	Model C	Model D
logGHG	.46649704***	.37800297***	.33118898***	.28360987***
GDP	.00001138**	.00001804***	0.000009633	-0.000009335
GDP2	-8.308e-11*	-1.274e-10**	-6.561E-11	8.239E-11
Polity		.02902483***	.0256785***	.01810704**
PO_GDP		-4.600e-07**	-5.380e-07***	-5.636e-07**
KL			3.5423312**	8.7722953***
KL2			-5.167797*	-10.245585**
TO				.00453609**
RGDP_TO				.00386542**
RGDP2_TO				-0.00013467**
RKL_TO				-.0022859***
RKL2_TO				.00013157***
RGDP_RKL_TO				-0.00019221
Constant	6.5793959***	7.4938606***	7.8789212***	7.9648444***
chi2	76.190001	111.44432	128.24179	153.24543
N	250	250	250	250

* p<.05; **p<.01; ***p<.001

Table 3: Dynamic GMM estimation results for greenhouse gas emissions

Model A presents the basic EKC model with GDP and its square term. It can be observed that the sign of GDP is positive and its square term is negative as expected, and this result holds for all 4 models (however, the squared term is insignificant for the other models). This suggests that in the early stage of economic development, a small portion of excess income is allocated for environmental problems, at this stage, the industrialization process is likely to be accompanied by environmental problems. When GDP per capita increases and exceeds a certain threshold, the level of pollution typically decreases. This effect gives an inverted U-shaped relationship between GDP and greenhouse gas emissions, which is consistent with EKC literature suggesting that environmental quality is a normal good. **This is in the same lines as we read while reviewing the paper by Chong Hui Ling et al (2015), which also confirms the EKC hypothesis. As compared to them we have done a panel analysis instead of time series to better understand the result.** Hence the income elasticity of demand for environmental quality

is greater than zero or even one i.e. if the income increases, the society pays more attention to the environmental quality (Beckerman, 1992).The EKC hypothesis indicates that environmental degradation initially exaggerates when a country's per capita income is low, and as the economy grows, environmental degradation falls. There is confirmation of the linear (scale effect) and nonlinear (technique effect) relationship between real gdp per capita and green house gas emissions.

Model B includes the political variables to capture the role of governance in determining greenhouse gas emissions. It can be noted that the signs of polity are positive for all models theoretically implying that a democratic country results in a greater amount of emissions as compared to autocracy. However, many scholars debate the effects of democracy on environmental degradation both theoretically and empirically. Some theorists have claimed that democracy reduces environmental degradation; others argued that democracy may not reduce environmental degradation or may even harm the environment. One argument claims that democracies are more likely to comply with environmental agreements because they respect the rule of law and this in turn raises environmental quality. **Sen (1994)** argues that famines promote environmental degradation because they divert attention away from long-run environmental concerns and famines usually occur in democracies because democratic governments are more responsive to the needs of the people. Hence, environmental degradation will be higher in autocracies than in democracies. Another argument expects that the elite in an autocracy will be less pro-environment than the masses or the public at large in a democracy **(Congleton, 1992).**

This is because with the prevailing technologies and materials, environmental regulation lowers production and consumption which imposes a higher cost on the elite in an autocracy than on the masses in a democracy. An opposite argument suggests that democracies tend to be market economies where business interest groups have considerable clouts and hence there is asymmetric influence of profit-oriented corporate interests in capitalist democracies. Moreover, as a result of budget constraints, democracies may not be responsive to environmental imperatives but to more pressing issues of the economic subsistence of major portions of the voting public **(Midlarsky, 1998).** Hence the impact of the polity variable on greenhouse gas emissions can be either positive or negative.

In addition, the interaction of polity and GDP per capita confirm the argument espoused by **McCartney and Adamowicz (2005)** that autocratic governance will result in a lower emission of greenhouse gases as compared to democratic governance when the income grows. The results indicate that autocratic countries are 4.6% more responsible to demands for reducing greenhouse gas emissions as the per capita GDP grows by 1% in comparison to democratic countries. This hence indicates a high scale-technique effect from trade in autocratic countries.

Model C includes the capital-labor ratio and its squared term, explaining the composition effect. International trade permits a country's production patterns to diverge from its consumption patterns, as its citizens consume goods produced in other countries and produce goods consumed elsewhere and hence imply composition effect of rising per capita incomes i.e. capital accumulation has a diminishing marginal impact on the pollution emissions. The results suggest a positive sign of capital-labor ratio and a negative significant sign of capital-labor squared term

thereby confirming that countries with higher capital-labor ratio tend to produce more pollution. Results show that a 1% increase in the composition effect leads to a 5.16% decline in the greenhouse gas emissions other things remaining constant. J.Bernard& S.K Mandal (2016) analysed the impact of trade openness on environmental quality using a dynamic panel data for 60 emerging and developing economies for the period 2002 to 2012, employing Environmental Performance Index (EPI) and CO2 emissions as the two indicators of environmental quality. They analyse the effect of Governance and other socio economic factors affecting environmental quality. The fixed effects model elicits that trade openness improves EPI, albeit it increases CO2 emissions. When corrected for endogeneity, trade openness was found to have no significant impact on EPI, though it escalates CO2 emissions. GMM findings with EPI highlight that political factors improve environmental quality, whereas income and population have detrimental effects. In the GMM estimations with CO2 emissions, trade openness, income, energy consumption and population were found to have deleterious effects on environmental quality. This confirms with the GMM approach that we have used as it corrects the problem of endogenity as compared to other dynamic models for studying environmental relations.

Model D includes trade openness and its interaction terms, explaining the trade-induced composition effect which determines the relative strength of the pollution haven hypothesis and the factor endowment hypothesis. The lagged emissions terms for all specifications are statistically significant with a positive sign, but their values are less than one. These results imply that changes in explanatory variables, such as trade openness, at a specific point in time would also influence

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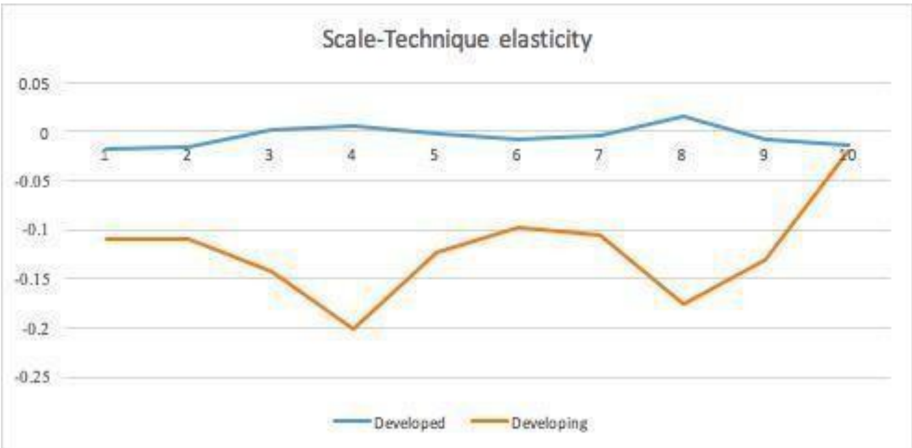
emissions after the current period. It can be seen that trade openness is significant and positively related to greenhouse gas emissions. The first interaction term between trade openness and relative GDP per capita is significant and positive and the interaction of trade openness with relative GDP per capita square is negative and significant indicating that the pollution haven hypothesis is satisfied. This suggests that through trade, rich countries are able to relocate their jurisdiction of tighter environmental regulations to a less stringent jurisdiction. Hence developed (high income) countries experience lower emissions compared to developing (low income) countries. **The paperby Matthew A. Colea, and Robert J.R.Elliott (2003), also confirms the same result but they classified there country on the basis of north and south to categories them into developing and developed but in our paper we have taken countries randomly to get a more robust result.** The interaction of trade openness with relative capital labor ratio is significant and negative and with relative capital labor ratio square is positive and significant. The signs are as expected, satisfying the factor endowment hypothesis. Countries with low capital-labor ratio will have a comparative disadvantage in pollution-intensive industry and hence pollution will be low. However, countries with high capital-labor ratio tend to have comparative advantage in dirty industry and hence pollution might increase. Thus, the total effect of trade-induced composition effect will depend on the relative magnitude of pollution haven effect and factor endowment effect as well as the final interaction between relative income, relative capital-labor ratio and trade openness which turned out to be negative.

- **Elasticity comparison between developing and developed countries** *Figure : Scale-Technique elasticity for developed and developing countries*



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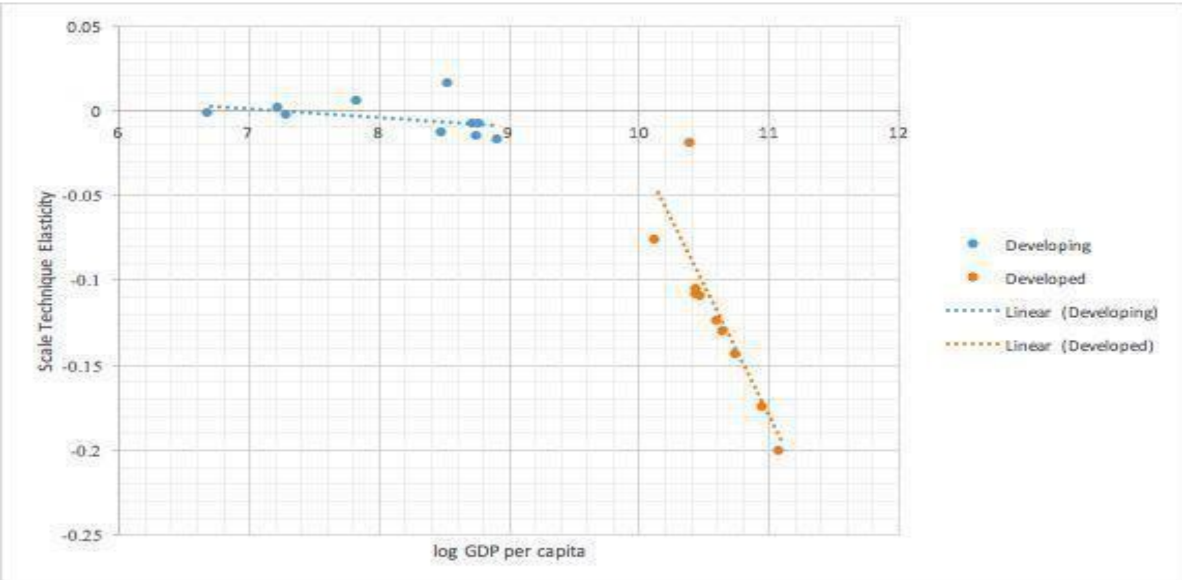
The scale-technique and composition elasticities have been computed by estimating the log-lin GMM model; equations 2 and 4 respectively.

The above figure graphs the scale-technique elasticity[1] for the developed and developing countries. It suggests that the trend line is higher and positive for developing countries while it is negative for the high income or developed countries. Since greenhouse gases are a major source of pollution globally, and a by-product from industrial processes or activities, it is expected that developing countries experience high positive scale effect and emit more pollution. Thereby, this confirms that the economies with higher per capita incomes enjoy an advantage of diverting their pollution intensive goods to the developing countries and reduce pollution.

Figure : Scale-Technique elasticity against GDP per capita for developed & developing countries



Above figure plots the scale-technique elasticity for developed and developing countries against their log GDP per capita. It shows that the scale-technique effect is downward sloping for both sets of countries and is more negative (steeper) for developed countries than the developing countries as the income (GDP per capita in logarithmic terms) increases. This means that the favorable technique effect outweighing the scale effect is more apparent in developed countries than developing countries. The negative technique effect via the role of government enacts stiffer environmental policies to curb increasing pollution more in the developed countries. This negative effect is in line with the effect of environmental treaties on greenhouse gases such as the Oslo Protocol (1994), the Kyoto Protocol (1997), and more recently the Paris Agreement (2016) in improving the environmental quality (i.e. reduction in emissions).

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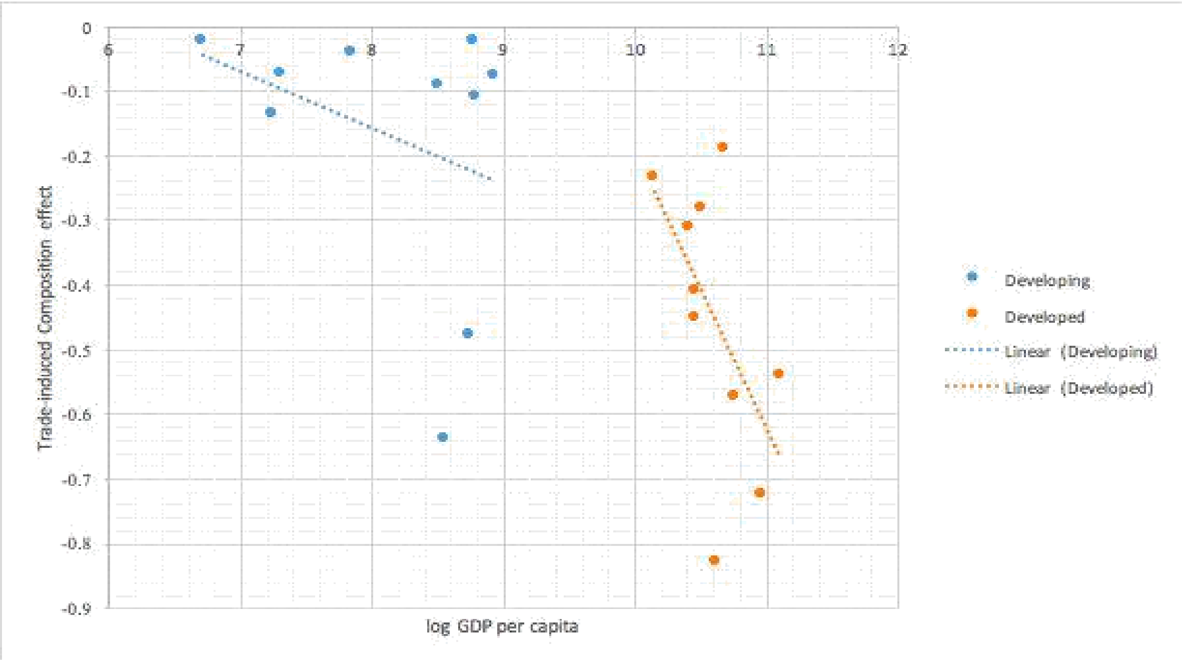
[1] $(\partial GHG/\partial POGDP)/(GHG/POGDP) = \alpha3\ (POGDP)$

Figure: Trade-Composition elasticity for developing & developed countries



Above figure plots the trade-induced composition elasticity[2] against the log GDP per capita for each country. The results reveal a downward trend in the trade-induced composition effect for both developed and developing countries. This suggests that the comparative advantage gained by the factor endowment do not make these countries dirtier; implying that both the developed and developing countries are more labor-intensive and have a comparative disadvantage in pollution-intensive industry and hence produce less pollution. A country which enforces relatively strict environmental policies is likely to have less of a comparative advantage in capital-intensive goods following an increase in trade intensity, thereby decreasing its emissions as its relative production of these goods decreases. The results show that the effect is more negative (steeper) for developed countries than the developing countries with an increase in the per capita GDP.

- **Impact of corruption on greenhouse gas emissions**

Table : GMM Estimation Results for greenhouse gas emissions

Variable	loglin
logemission	0.37378832***
gdppercapita	0.00002973***
tradeopeness	0.00333281*
corruption	0.16939952***
gdp2	-1.015e-10**
corrto	-0.000034793**
corrgdp	-2.147e-07*
corrDU	0.0044557**
constant	6.8326544***
chi2	103.42004
N	250

Above table summarises the findings of regressions when greenhouse gas emissions are used as a proxy for environmental quality. To study the impact of openness on Greenhouse gas emissions, trade openness variable is used as an indicator of free economy.

Alternative model specifications are computed where trade is used as a measure of openness (Appendix). Loglin specification turns out to be the preferred specification on the basis of the Sargan Test performed (results shown in the appendix). The empirical results provide coefficient estimates that are consistent with the theory and statistically significant at the 5% level, trade openness was found to have positive impact on GHG emissions **which is in line with the results estimated by Tamazian and Rao and Omri et al.** This provides evidence for the developing and emerging economies becoming Pollution Havens with greater volumes of trade. The signs

and statistical significance of GDP and GDP^2 confirms the inverted U-shaped Environmental Kuznets Curve**, also tested by Deacon and Norman (2004), and Khana and Plassman (2004).**

There are two ways through which trade openness affects the environmental quality.

1. Through its direct impact on GHG emissions.
2. Through an interaction term with corruption.

The marginal effect is estimated as $\partial GHG/\partial TO = GHG(\alpha + \alpha \text{ Corruption}) = 0.00005987$. This suggests that as the trade openness increases by one standard. Corruption has always been accused of having adverse effects on growth since it decreases productivity, leads to accumulation of additional costs and discourages investment.

Corruption plays a substantial role in increasing pollution emissions level. The effect of corruption on GHG emissions indicates that as the corruption index falls (corruption level increases), GHG emissions increase as indicated by the significance of the corruption coefficient at 5% level. The results suggest that corruption level has a greater absolute impact on environmental protection as compared to openness (coefficient 0.16934 being greater than 0.0033), **which is also analysed by Damania, et al (2003), Pellegrini and Gerlagh (2006).** Hence, it is suggested that countries should put more emphasis on its institutions on curbing the corruption level. However, its total impact depends on its direct effects and its interaction effects

with ∂GHG/∂Corruption = GHG(α+α5Tradeopenness + α6GDP + α7Di)= 0.5871 for developing countries and 0.4937 for developed countries (where Di=1 for developed country and Di=0 for a developing country). This suggests that corruption further aggravates the problem in developing countries which are already faced with high levels of emissions relative to the developed countries.

The statistically significant coefficient of the interaction variable corruption*GDP confirms the theory that people's demand for environmental quality increases as their income level rises, but this income effect is offset by high level of corruption in the economy. On the other hand, the estimates of the interaction term corruption*openness is highly significant supporting the results of the theoretical model. The sign of this interaction effect is positive suggesting that as the level of corruption rises, the impact of trade on the greenhouse gas emissions increases. **As also confirmed by Sekrafi Habib & SnoussiAbdelmonen&Mili Khaled (2018) and Faiz-Ur- Rehman, Amanat Ali and Mohammad Nasir (2007) in their paper.**

Literature points to the fact that corruption has a potential to undermine the positive effects of democracy on achieving pollution emission reductions and intensify the negative effects that democracy might have on curbing emissions. Hence, combining the results of both our models would imply that developing countries being more corrupt are hence detrimental for the environmental quality and pollute more.

Conclusions and Suggestions

The debate over trade liberalization and the environment is prevalent since quite some time and suggests that as the world's population grows and trade expands further, future trade and environment conflicts are bound to arise.

This paper examines the empirical evidence of the link between trade and environment while paying special attention to the role of government. The impact of trade openness is decomposed into scale-technique and trade-induced composition effect to analyse the impact for 20 major developing and developed countries of the world. The Arellano-Bond GMM estimation technique corrects for endogeneity issues between trade and income and serial correlation problems in the dynamic panel model.

If environmental quality is a normal good, and if environmental regulation is responsive to consumer demand, then the stringency of environmental regulation increases with improvements in income which is shown by EKC hypothesis in all specified models suggesting that an increase in growth results in an initial increase in emission following a subsequent fall in the emissions with further growth. The results render support for factor endowment hypothesis and pollution haven hypothesis as well as the role of government. The pollution haven hypothesis asserts that liberalizing trade barriers will induce polluting industry to migrate to countries with relatively weaker environmental policy. If poor countries lack adequate and enforceable environmental regulations, then trade liberalization driven by pollution haven forces is likely to increase total world pollution and may lower welfare in low-income countries. Such a process could justify concerns about the possibility of a "race to the bottom." That is, if rich countries deal with their environmental problems by shifting dirty goods production to poor countries, then eventually the world will run out of new places to shift such production to. Long run abatement costs would therefore increase, and poor countries may not be able to grow their way out of environmental problems. Therefore, developing countries who are comparatively poor, in their quest for economic development and poverty reduction are expected to put economic growth, energy for all and industrialization at the fore front of their goals before giving consideration to environmental issues. So, compelling developing countries in order to pursue environmental goals, particularly reduction in CO2 emissions, should be given substantial economic, technological and financial support from developed countries and the international community to compensate for the economic losses associated with reducing pollution and help them to continue working and producing efficiently.

It is inferred that trade is detrimental to the environment quality (considering the greenhouse gases as a proxy for environment) and increases the greenhouse gas emissions in the set of countries studied. It is indicated that autocratic countries tend to produce less pollution in comparison to the democratic countries. In addition, the decomposition shows that scale- technique effect also depends on the role of government and show a higher scale elasticity effect for developed countries than developing countries. The negative technique effect via the role of government enacts stiffer environmental policies to curb increasing pollution more in the

developed than the developing countries. Moreover, the elasticities for trade-induced composition effect suggests a comparative disadvantage in pollution intensive goods tends which decreases the greenhouse gas emissions in these countries. The positive impact of trade openness on the greenhouse gas emissions suggests that effective environmental policies and institutional frameworks are needed at the local, regional, national, and international levels. Stringent environmental policies regarding the pollution level permits are required since they are compatible with a trade openness regime as they create markets for environmental goods that can subsequently be exported to countries that follow suit on environmental standards which is called first-mover advantage. Hence, each should develop a set of policy indicators on trade and environment to help monitor progress towards more policy coherence, and to identify policy priorities at the intersection of trade and environment.

Kelsey Jack and Greenstone, analyze the puzzle underlying enviro-devonomics and propose the possible explanations for the poor environmental quality in developing countries. **The key points they have tried to emphasise on are**:

Firstly, poverty and low incomes of the population takes away most of the incomes towards immediate consumption needs. **Secondly**, weak policy design, implementation and enforcement raise the cost of environmental improvements. Policymakers who don't place the needs of their constituents ahead of their own cause problems further being fueled by corruption. **Thirdly**, market failures, such as weak property rights and poor access to credit, also distort the costs of improvements to environmental quality. According to them, all these factors are further enhanced by the threat of climate change. This suggests that most developing countries have established laws and formal governmental structures to address their serious environmental problems, but only few have been successful in alleviating those problems. The conflicts between different user groups of natural resources, especially from different income groups in many cases cause agents to adopt unsustainable practices which in turn marginalizes some of the groups which eventually fall into the poverty group. The conflicts to a large extent are either initiated or encouraged by institutional or market failure. Certain groups benefit while others suffer. Unsustainable use of natural resources inevitably causes poverty and there is not just one- way impact but it's a both sided way relation of poverty and environmental degradation. So, to solve the problem, policy must be focused on environmental policies and not poverty alleviation policies. Environmental degradation can be caused by poverty. However, to resolve the problem, the first objective is to first identify if it is indigenous or exogenous poverty. If it is indigenous poverty, then policies must be focused on environmental policies. However, if it is exogenous poverty, then poverty alleviation policies need to be formulated and implemented.

The replacement of conventional energy sources with renewable energy may not necessarily reduce greenhouse gas emissions unless technique effect adequately supports the composition effect. It therefore means that adoption of updated technology is equally important while shifting from conventional to renewable energy sources in order to maintain efficiency level.

Improving energy efficiency is a highly effective way to reduce GHG emissions. It is hence recommended that policies should focus on major efficiency improvement opportunities, support research and development, and provide incentives for consumer and industry adoption of new energy and resource efficiency measures. They must include incentives for use of GHG-saving products and materials; focus on scale, cost and implementation speed; and support research and development in innovation. One such policy is the Paris Climate Change Agreement within the United Nations Framework Convention on Climate Change (UNFCCC) which deals with greenhouse gas emissions mitigation, adaptation and finance starting in the year 2020. The Agreement aims to respond to the global climate change threat by keeping a global temperature rise in this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius.

It is also possible for developing countries to take care of both economic development and environmental conservation simultaneously. For example, through promotion of ecotourism. The Amazon rainforest is being promoted as a destination for ecotourism, natural park are set-up to conserve the forest while controlled number of tourist are allowed to visit the rainforest for sight-seeing. In this way, both economic growth and environmental conservation is taken care of. In conclusion, though it is important for developing countries to strive for economic development, environmental conservation must not be neglected. Doing so, will result is even more undesired outcome brought by environmental degradation. The ultimate goal should be trying to find a balance between them and achieving both simultaneously.

It has also been estimated that corruption has a significant impact on increasing the greenhouse gas emissions. Not only is its direct impact positive, but its indirect impact on emissions through the interaction with trade openness is also positive suggesting that as the level of corruption increases, the impact of trade on greenhouse gas emissions increase further. This shows that corruption is a substantial challenge for sustainable economic development since higher degree of corruption results in a greater deviation from socially acceptable standards. Moreover, corruption induces degradation of environmental quality through the trade policies channel since the level of corruption affects the impact of trade liberalisation on the stringency of environmental policies. It points to an urgent need to curb the level of corruption at the very outset which requires enabling identification of any misuse of funds in projected initiatives as well as increasing transparency of government institutions and proper implementation of policies with stricter punishments in case of violation and cheating.

Thus, good governance with a broad commitment to the rule of law is crucial for environmental sustainability and a way to put an end to the devastating impact of corruption on the environment. While corruption in itself is a very broad concept with various indirect impacts on the environmental quality, there is further scope to analyse its impact and determine ways to curb this issue worldwide.

Apart from the factors that we have considered in this paper to study the impact of trade openness on environmental degradation mainly air pollution. Other kinds of pollutions can also be considered for further studies as environmental degradation doesn't only refer to atmospheric pollution. Other ways such as ground water levels going down with each passing year, rivers getting dirtier , fires in lakes, forest encroachment, social crimes such as public defecation (even in cities), bad garbage dumping practices, smoking in public areas , all contribute to environment degradation and also social degradation which can be studied further.

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Appendix

Table A1 : Unit Root Tests

```
Fisher-type unit-root test for D.ImportsExports
Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots           Number of panels  =    10
Ha: At least one panel is stationary        Number of periods =    14

AR parameter: Panel-specific                Asymptotics: T -> Infinity
Panel means:  Included
Time trend:   Not included
Drift term:   Not included                  ADF regressions: 0 lags

                                  Statistic      p-value

 Inverse chi-squared(20)    P      159.8192       0.0000
 Inverse normal             Z       -9.9614       0.0000
 Inverse logit t(54)        L*     -14.0302       0.0000
 Modified inv. chi-squared Pm       22.1074       0.0000

 P statistic requires number of panels to be finite.
 Other statistics are suitable for finite or infinite number of panels.
```

```
Fisher-type unit-root test for D.YY
Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots           Number of panels  =    10
Ha: At least one panel is stationary        Number of periods =    14

AR parameter: Panel-specific                Asymptotics: T -> Infinity
Panel means:  Included
Time trend:   Not included
Drift term:   Not included                  ADF regressions: 0 lags

                                  Statistic      p-value

 Inverse chi-squared(20)    P       68.0167       0.0000
 Inverse normal             Z       -4.9769       0.0000
 Inverse logit t(54)        L*      -5.4744       0.0000
 Modified inv. chi-squared Pm        7.5921       0.0000

 P statistic requires number of panels to be finite.
 Other statistics are suitable for finite or infinite number of panels.
```

```
Fisher-type unit-root test for D.GDPpercapitacurrentUS
Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots           Number of panels  =    10
Ha: At least one panel is stationary        Number of periods =    14

AR parameter: Panel-specific                Asymptotics: T -> Infinity
Panel means:  Included
Time trend:   Not included
Drift term:   Not included                  ADF regressions: 0 lags

                                  Statistic      p-value

 Inverse chi-squared(20)    P       71.7838       0.0000
 Inverse normal             Z       -5.4914       0.0000
 Inverse logit t(54)        L*      -6.0409       0.0000
 Modified inv. chi-squared Pm        8.1877       0.0000

 P statistic requires number of panels to be finite.
 Other statistics are suitable for finite or infinite number of panels.
```

```
Fisher-type unit-root test for D.GDPpercapitarelativetoworld
Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots           Number of panels  =    10
Ha: At least one panel is stationary        Number of periods =    14

AR parameter: Panel-specific                Asymptotics: T -> Infinity
Panel means:  Included
Time trend:   Not included
Drift term:   Not included                  ADF regressions: 0 lags

                                  Statistic      p-value

 Inverse chi-squared(20)    P       84.3819       0.0000
 Inverse normal             Z       -5.9913       0.0000
 Inverse logit t(54)        L*      -7.0291       0.0000
 Modified inv. chi-squared Pm       10.1797       0.0000

 P statistic requires number of panels to be finite.
 Other statistics are suitable for finite or infinite number of panels.
```

Figure A2: Sargan test of overidentifying restrictions for model I

Models	Linear	Lin-log	Log-lin	Log-log
Chi2	176.9921	166.491	195.2943	170.4986
p-values	0	0	0	0

Figure A3: Sargan test of overidentifying restrictions for model II

Models	Linear	Lin-log	Log-lin	Log-log
Chi2	178.38022	169.3085	182.6127	168.6498
p-values	0	0	0	0

Figure A4 and A5: Different functional forms for GMM estimation of model I and II

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Variables	linear	loglin	linlog	loglog
GHG lag	.85033734***		.59293062***	.26919087***
lnGDP			12709.251	-0.12251798
lnGDP2			-1218.7831	-0.00087379
polity	27612.971	.01810704**	451380.62***	.13240736***
PO_lnGDP			-58551.593***	-.01681674**
lnKL			1120513.1	0.83039342
lnKL2			-21894.335	0.08050424
lnTO			329393.98	.27903142*
lnRGDP_TO			35018.497	0.08326219
lnRGDP2_TO			-31667.106	-.02474108*
lnRKL_TO			-56296.923	-0.04597056
lnRKL2_TO			-97582.877	-0.04691625
lnRGDP_RKL_TO			79528.668	0.03664826
logGHG lag		.28360987***		
gdppercapita	-6.8880088	0.000009335**		
GDP2	0.00011389	-8.24E-11		
PO_GDP	-0.52163122	-5.636e-07**		
kl_ratio	10007814*	8.7722953***		
KL2	-14966706	-10.245585**		
trade_open~s	8576.3125*	.00453609**		
RGDP_TO	3392.5486	.00386542**		
RGDP2_TO	-217.27207	-0.00013467		
RKL_TO	-2939.1517**	-.0022859***		
RKL2_TO	175.88474*	.00013157***		
RGDP_RKL_TO	-154.93239	-0.00019221		
constant	-1100433.7**	7.9648444***	3486612.1	10.319591***
chi2	984.26841	153.24543	1425.523	213.66588
N	260	250	250	250

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Variable	loglin	loglog	linlog	linlin
logemissions	0.37378832***	0.30593493***		
gdppercapita	0.00002973***			38.567251**
tradeopeness	0.00333281*			9417.5027
corruption	0.16939952***			15347.497
gdp2	-1.015e-10**			-0.00013955
corrto	0.00003479**			-90.892644
corrgdp	-2.147e-07*			-0.27945488
corrDU	0.0044557**			7397.1897
loggdp		.91731171***	1557165.6**	
loggdp2		-.0693899***	-113696.82*	
logtrade		1.0469238	2645881.2	
logcorruption		0.19831046	943214.85	
logcorrtrade		-0.25782499	-654902.04	
logcorrgdp		0.12157894	195694.85	
logcorrDU		-0.43952275	24024.091	
GHGemissions			.77233232***	.87759475***
constant	6.8326544***	1.9644361	-15364513	-1618261.4
chi2	103.42004	174.58325	1112.1097	971.93586
N	250	250	250	250