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Environmental Kuznets Curve and Pollution Haven Hypothesis

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Abstract

There has been limited empirical work done in the recent past to test the hypotheses of EKC and PH. Results obtained in this paper validate EKC hypothesis for total carbon dioxide emissions and carbon dioxide emissions from liquid fuel consumption from a panel of countries. This is robust to inclusion of additional covariates and division of countries on the basis of income. Financial development increases total emissions in high income countries whereas it decreases emissions in non high income countries in the long run. Trade to GDP ratio does not affect emissions significantly in case of high income countries. In case of non high income countries, trade to GDP ratio increases the emissions from solid fuel in the long run. Also in case of non high income countries increase in trade to GDP ratio increases total emissions and emissions from liquid fuel consumption in short run. Therefore, there is evidence in favour of pollution haven hypothesis in short run.

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It is logical as we expect the emissions shifting aspect of trade to be operative in short run whereas in long run the trade should be determined by comparative advantages.

Keywords: Environment; CO2 emissions; Kuznets Curve; International Trade; Development

1 Introduction

Increasing concentration of carbon dioxide (one of the major anthropogenic greenhouse gas (GHG)) has been established as one of the major cause of increasing global temperature. It has been projected that if carbon emission continues to increase at the present rate [1], then the global mean temperature will increase by $4^{\cdot}C$ or more above pre-industrial levels by the end of 21st century. At the same time there has been a consensus among climate scientist that the global mean temperature should not be allowed to increase by more than $2^{\cdot}C$ above pre-industrial levels (Edenhofer et al. (2013)). Therefore, it becomes imperative to reduce anthropogenic greenhouse gas (GHG) emission. In light of this, the present paper tries to understand the relationship between energy usage, GDP per capita, trade, foreign direct investment and environmental pollution (carbon dioxide emission). Reducing carbon dioxide emissions plays an significant role in the current debate on environment protectionism and sustainable development.

The relationship between economic activity and carbon dioxide emissions is usually formulated in terms of the environmental (carbon) Kuznets curve (EKC). EKC is a reduced form relationship between per capita emissions and per capita income. The EKC hypothesis suggest that per capita carbon dioxide emissions initially increase with rising per capita income and decline after a threshold level of per capita income known as turning point. Grossman and Krueger (1995) argue that with change in income, environmental regulations, technology and industrial composition changes and therefore income

[1] Fifth assessment report of Intergovernmental Panel on Climate Change (IPCC, (2014))

should be able to capture these changes which are driving the environmental pollution.

EKC hypothesis for carbon dioxide emissions has been studied extensively for individual as well as panel of countries. Since the current work is related to panel data we briefly report few recent works for panel of countries. Farhani et al. (2014) and Omri et al. (2015) provide evidence for inverted U shape relationship for a panel of MENA countries whereas Ozcan (2013) suggests that there is no evidence of of EKC hypothesis for a group of Middle East countries. Chow and Li (2014) using a panel of 132 developed and developing countries over the period from 1992 to 2004 suggest that EKC hypothesis does not exist.

Beck (2006) suggests that financial development affects saving rates, investment, technological developments, long-run growth rates and hence energy consumption. Impact of Financial development on energy consumption have been studied by Tamazian et al. (2009), Jalil and Feridun (2011), Sadorsky (2010) and Sadorsky (2011). Since energy consumption and carbon dioxide emissions is closely related, it is not difficult to assume that financial development will affect carbon dioxide emissions too. According to Zhang (2011) developments in the financial system or a strengthening of financial indicators could lead to increase in GDP per capita and carbon dioxide emission. Shahbaz et al. (2012) and Aslan et al. (2014) suggest long-run bidirectional causalities are found between financial development and energy consumption,

Tamazian et al. (2009) suggest that financial development leads to adoption of new technologies and therefore decreases emissions [2]. Shahbaz et al. (2013a) suggest that financial development decreases emissions in both long and short run in South Africa whereas Shahbaz et al. (2013b) in context of Indonesia found only long run effect of financial development on emission. Shahbaz et al. (2013c) suggest that financial development reduces emissions in Malaysia. As we can see from above individual country specific studies, there is evidence that financial development reduces emission.

[2] In this paper we use CO2 emissions and emissions interchangeably.

According to Frankel and Romer (1999) higher level of financial development will lead to more foreign direct investment (FDI) that causes higher level of Research and Development (R&D). Higher level of research and development should lead to better environment. Talukdar and Meisner (2001), suggest that increase in FDI brings technological improvement that lead to lower emissions.

Pollution haven hypothesis have been widely discussed and explored in literature. According to Mani and Wheeler (1998) any polluting activity faces a higher cost in a high-income country than in a developing country. The difference arises due to differences in environmental protection and enforcement of environmental regulation. Based on this argument, it seems that polluting industries will have an obvious tendency to move to developing countries, Copeland and Taylor (1995), Cole (2004). If that happens, developing or non high income countries should emit more emissions as their trade increases keeping everything else constant.

In this paper, we add to the literature on pollution haven hypothesis, financial development and CO2 emissions in three ways. First, we use a panel of country to estimate the average effect of financial development on total emission. Hausman test suggest that long run relationship between emissions and per capita income is same across countries and therefore, panel data estimation is well suited for the problem in hand. Second, we estimate the impact of financial development on sub elements of carbon dioxide emissions such as emissions from gaseous fuel consumption, emissions from liquid fuel consumption and emission from solid fuel consumption. We estimate two sets of panel cointegrating regression, one basic EKC regression and other modified EKC in which we include energy consumption, foreign direct investment, trade to GDP ratio and financial development. Third, two provide robust evidence for pollution haven hypothesis we divide our set of countries in two groups, high income and non high income countries. Pollution haven hypothesis suggest that with increase in trade, emissions should increase in non high income countries.

Results obtained in this paper validate the EKC hypothesis for total emissions and emissions from solid and liquid fuel consumption in the long run. Even with the inclusion of additional variables the EKC hypothesis continues to hold. In case of country grouping into high and non high income countries, EKC hypothesis continues to hold for total emissions and emissions from liquid fuel consumption but vanishes for solid fuel consumption. Whereas for emissions from gaseous fuel consumption we find evidence in favour of U shaped relationship in long run. In case of high income countries there is evidence of U shaped relationship from solid fuel consumption in short run.

In long run financial development decreases total emissions and emission from liquid fuel consumption. Short run relationship between emission and financial development is weak but positive except in case of emission from gaseous fuel consumption. *There exist asymmetry between high and non high income countries. In case of high income countries, financial development increase total emissions whereas in case of non high income countries financial development decreases total emission.*

In case of foreign direct investment, our result differs from the argument by Talukdar and Meisner (2001). One expect that foreign direct investment should lead to lower emission in non high income countries, but our results suggest that emission increases with increase in foreign direct investment in non high income countries. But this is not surprising. Foreign direct investment to non high income countries are mostly coming in industries and sectors which have shifted form high income countries. These are mostly manufacturing industries including polluting Industry. Therefore, if trade is leading to high emission in non high income countries as we show in the paper, then foreign direct investment should also lead to high emission in non high income countries.

There is evidence in favour of pollution haven hypothesis. For all countries in our sample, with increase in trade, emissions from solid fuel and gaseous fuel increases in long run, whereas total emission and emissions from liquid fuel increases in short run. Thus, trade increase all types of emissions either in short run or in long run. Result suggest that trade does not effect emissions for high income countries (neither in short run nor in the long run). For non high income countries we find that trade increases emissions from solid fuel and decreases emissions from gaseous fuel in the long run, while in short run the total emissions and emissions from liquid fuel increases. *Therefore, our results suggest the existence of pollution haven hypothesis in the short run.*

In section 2 we provide brief description of the data and is followed by unit root test. Section 4 gives ARDL model being estimated in the paper. Section 5 presents results and is followed by concluding remarks.

2 Data

Following data series have been used in the paper: total CO2 emissions (kt [3]), CO2 emissions from solid fuel consumption (kt), CO2 emissions from liquid fuel consumption (kt), CO2 emissions from gaseous fuel consumption (kt), trade (% of GDP), domestic credit to private sector (% of GDP), GDP per capita (current US $) and foreign direct investment, net inflows (% of GDP). These data are from world bank. We have taken energy consumption in (MTOE [4]) from international energy statistics (EIA)[5]. We estimate four models: I) with total CO2 emissions, II) CO2 emissions from solid fuel consumption, III) CO2 emissions from liquid fuel consumption and IV) with CO2 emissions from gaseous fuel consumption. We create balance panel for each of these four models. Based on the data availability (I) and (III) model is estimated with data from 1980 to 2013 for 62 countries. Model (II) is estimated with from 1980 to 2013 for 28 countries. Model (IV) is estimated with from 1980 to 2013 for 24 countries.

[3]Kilo Tonne

[4]Million Tonne Oil Equivalent

[5]https://www.eia.gov/beta/international/data/browser/

Table 1: Summary Statistics of Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
GDP	2,108	7.64	1.64	4.73	11.54
GDP*GDP	2,108	61.09	26.10	22.40	133.24
Domestic Credit to GDP	2,108	3.30	0.94	0.47	5.73
Energy Consumption	2,108	1.42	2.53	-4.42	7.84
Foreign Direct Investment to GDP	2,084	2.72	4.29	-28.62	57.84
Trade to GDP Ratio	2,108	4.10	0.56	2.21	6.08
Emission: Total	2,108	9.10	2.57	3.60	15.57
Emission: Solid Fuel Consumption	952	2.39	1.42	-4.76	4.24
Emission: Liquid Fuel Consumption	2,108	8.71	2.32	3.60	14.71
Emission: Gaseous Fuel Consumption	816	9.39	2.25	2.69	14.14

Notes: All variables are in log except Foreign Direct Investment to GDP ratio as this can be negative also and we have many negative values in our sample. Small values of energy Consumption and Co2 emissions from solid fuel consumption can given negative minimum as above values are in log.

We group countries in our sample based on the world bank classification and create a separate group for high income countries. There are 15 high income countries in our sample (out of 62). We estimate model separately for high income and non high income countries to explore the differences in these two types of countries. Figure 1 to 7 in appendix gives average financial development, average per capita income, total emission, total emissions from solid fuel consumption, total emissions from liquid fuel consumption, total emissions from gaseous fuel consumption and total energy use over 1980-2013. Total emission from solid fuel consumption was almost stagnated in 90s but suddenly picked up with the Chinese entry in to WTO. Figure 8 to 19 gives relation between four emissions types and per capita income. We provide this relation for all countries, high income countries and non high income countries. Both linear and quadratic relations are given with scatter plot.

3 Unit Root Test

Since, we are estimating a long run relationship, first we look for the integration properties of our data. Results from Im–Pesaran–Shin unit toot test is given in table 2. All variables except trade to GDP ratio, foreign direct investment to GDP and emissions from solid fuel consumption have unit root at conventional 5 percent level of significance.

Table 2: Im–Pesaran–Shin Unit Root Test

Variable	No of Countries	No of Years	p value Level	p value First Difference
GDP	62	34	1.000	0.0000
GDP*GDP	62	34	1.000	0.0000
Domestic Credit to GDP	62	34	0.8683	0.0000
Energy Consumption	62	34	0.9975	0.0000
Foreign Direct Investment to GDP	62	34	0.0000	0.0000
Trade to GDP Ratio	62	34	0.0080	0.0000
Emission: Total	62	34	0.9993	0.0000
Emission: Solid Fuel Consumption	28	34	0.0000	0.0000
Emission: Liquid Fuel Consumption	62	34	0.8823	0.0000
Emission: Gaseous Fuel Consumption	24	34	0.0590	0.0000

Notes: Ho: All panels contain unit roots ; Ha: Some panels are stationary;. All variables are in log except Foregin Direct Investment to GDP ratio as this can be negative also and we have many negative values in our sample

Since trade to GDP ratio, foreign direct investment to GDP and Co2 emissions from solid fuel consumption are stationary, conventional cointegration tests are not applicable in cases involving these variables. There is another reason that conventional panel cointegration test would be inefficient in our case. Conventional panel cointegration test such as Kao tests, the Pedroni tests, and the Westerlund tests are based on a simple panel regression of the form given below.

$$y_{it} = x_{it}^{'}\beta_i + z_{it}^{'}\gamma_i + e_{it}$$

Where x_{it} contains the covariates of interest and z_{it} contains deterministic terms such as fixed effects and time trend. All above mentioned method of cointegration requires that covariates are not cointegrated between them for testing cointegratio[6]. In our case covariates include per gross domestic product, energy consumption and financial development. It would be very difficult to argue that there are no cointegration between these three variables especially between gross domestic product and energy use. Al-mulali et al. (2013) using a panel of countries suggest that 79 percent of countries in the sample have long run relationship between renewable energy consumption and GDP growth. Moreover, Tamazian et al. (2009), Jalil and Feridun (2011), Sadorsky (2010) and Sadorsky (2011) provide evidence of relationship between financial development and energy use. Therefore, we cannot use conventional methods of cointegration and adopt ARDL method of cointegration.

4 Methodology

We use ARDL method of cointegration. This has several benefits. First, in case of both $I(0)$ and $I(0)$ variables, traditional methods of cointegration are not applicable. They require all variables to be $I(1)$. In our case emissions from solid fuel consumption is stationary in levels. Moreover, traditional methods of panel cointegration is not suited in our case as argued above. Second, ARDL specification estimates both long and short run equations and therefore also allows us to infer both long and short run causality. Third, ARDL method allows us to estimate short and long run dynamics separately. This is important because EKC hypothesis is expected to hold in the long run as it is a long run phenomenon. Fourth, The panel ARDL approach used in this paper allows us to statistically test whether the long run relationship between carbon emissions and per capita income across countries are same or not. The panel ARDL method had been used by Binder & Offermanns (2007), Bildirici & Kayıkcı (2012a, b) and Bildirici & Kayıkcı (2013). Our baseline model is a panel ARDL (p, q) given by:

$$y_{it} = \sum_{j=1}^{j=p} \lambda_{ij} y_{i,t-j} + \sum_{j=0}^{j=q} \delta_{ij}^{'} X_{i,t-j} + u_i + \epsilon_{it}$$

[6]See Stata manual on xtcointtest.

Where $i = 1, 2, ..., N$ is number of groups, $t = 1, 2, ..., T$ is time period. u_i are country fixed effects, X_{it} is $k \times 1$ vector of explanatory variables, δ_{ij} is $k \times 1$ vector of coefficients. We can write the above equation as:

$$\Delta y_{it} = \phi_i \left(y_{i,t-1} - \theta' X_{it} \right) + \sum_{j=1}^{p-1} \lambda_{ij}^* \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta_{ij}^* \Delta X_{i,t-j} + u_i + \epsilon_{it}$$

$$\phi_i = -\left(1 - \sum_{j=1}^{p} \lambda_{ij}\right) \quad \theta = \frac{\sum_{j=0}^{j=p} \delta_{ij}'}{(1 - \lambda_{i1} - \lambda_{i2} - \lambda_{i3} - ... - \lambda_{ip})}$$

$$\lambda_{ij}^* = -\left(\sum_{m=j+1}^{p} \lambda_{im}\right) \quad j = 1, ..., p-1$$

$$\delta_{ij}^* = -\left(\sum_{m=j+1}^{p} \delta_{im}'\right) \quad j = 0, ..., q-1$$

The model for $p = 1$ and $q = 1$ is given by

$$\Delta y_{it} = \phi_i \left(y_{i,t-1} - \theta' X_{it} \right) + \delta_i^* \Delta X_{i,t} + u_i + \epsilon_{it}$$

Stacking the terms for a given i across time, we can write the above equation as

$$\Delta y_{it} = \phi_i \xi_i(\theta) + \delta_i^* \Delta X_{i,t} + u_i + \epsilon_{it}$$

Where

$$\xi_i(\theta) = \left(y_{i,t-1} - \theta' X_{it} \right)$$

$$\phi_i = -\left(1 - \lambda_{i1}\right) \quad \delta_{i0}^* = -\delta_{i1}' \quad \theta = \frac{\delta_{i0}' + \delta_{i1}'}{(1 - \lambda_{i1})}$$

ϕ_i is the error correction term and for long run relationship this must be negative. The above model is estimated with maximising the log likelihood.

$$L\left(\theta^{'},\sigma^{'}\right)=-\frac{T}{2}\sum_{i=1}^{N}ln\left(2\pi\sigma_i^2\right)-\frac{1}{2}\sum\frac{1}{\sigma_i^2}\left(\Delta y_i-\phi_i\xi_i\left(\theta\right)\right)^{'}H_i\left(\Delta y_{it}-\phi_i\xi_i\left(\theta\right)\right)$$

Where

$$H_i=I_T-\Delta X_i\left(\Delta X_i^{'}\Delta X_i\right)\Delta X_i$$

We use Pesaran, Shin, and Smith (1997, 1999) PMG (pooled mean group) estimator that combines both pooling and averaging. This intermediate estimator allows the intercept, short-run coefficients, and error variances to differ across the groups (as would the MG (mean group) estimator) but constrains the long-run coefficients to be equal across groups (as would the FE estimator). Starting with an initial estimate of the long-run coefficient vector, θ, the short-run coefficients and the group-specific speed of adjustment terms can be estimated by regressions of Δy_i on (ξ_i , ΔX_i). These conditional estimates are in turn used to update the estimate of θ. The process is iterated until convergence is achieved. We also estimate mean group estimator and conduct a Hausman test for the validity of long-run coefficients to be equal across groups. As it is clear from the above discussion that PMG estimator has additional restriction of long-run coefficients being equal across groups. We estimate all models with $p = 1$ and $q = 1$. Our data is annual and one lag should be sufficient to capture the dynamics of the model[7].

We estimate two sets of model. First set of models is estimated with taking income and square of income as covariates. We estimate another extended EKC model in which we bring additional covariates to explore the role of trade on carbon dioxide emission.

4.1 Turning Point

Since we use natural log of emissions and income, our model for calculation of turning point is given by where we have only considered the income and income square term on the right hand side:

[7] To the best of our knowledge, there is no test available to determine the optimal number of lag in PMG and MG estimator.

$$ln(e_{it}) = \beta_1 ln(y_{it}) + \beta_2 \left(ln(y_{it})\right)^2 + \epsilon_{it}$$

Where e_{it} is emissions in country i at time t and y_{it} is per capita income in country i at time t. Turning point is obtained as point of maxima or minima and that implies that $\frac{de_{it}}{dy_{it}} = 0$. Differentiating both sides with respect to y_{it} gives us:

$$\frac{1}{e_{it}}\frac{de_{it}}{dy_{it}} = \beta_1 \frac{1}{y_{it}} + \beta_2 \times 2 \times ln(y_{it}) \times \frac{1}{y_{it}}$$

Substituting e_{it} to the right obtain:

$$\frac{de_{it}}{dy_{it}} = \left(ln(y_{it}) + (ln(y_{it}))^2 + \epsilon_{it}\right)\left(\beta_1 \frac{1}{y_{it}} + \beta_2 \times 2 \times ln(y_{it}) \times \frac{1}{y_{it}}\right)$$

Since $ln(y_{it}) + (ln(y_{it}))^2 + \epsilon_{it} \neq 0$ and

$$\frac{de_{it}}{dy_{it}} = 0 \implies \beta_1 \frac{1}{y_{it}} + \beta_2 \times 2 \times ln(y_{it}) \times \frac{1}{y_{it}} = 0$$

$$\beta_1 \frac{1}{y_{it}} + \beta_2 \times 2 \times ln(y_{it}) \times \frac{1}{y_{it}} = 0 \implies \beta_1 + \beta_2 \times 2 \times ln(y_{it}) = 0$$

Therefore

$$ln(y_{it}) = -\frac{\beta_1}{2\beta_2} \implies y_{it} = e^{-\left(\frac{\beta_1}{2\beta_2}\right)}$$

One can ignore the log on both sides and treat the log term as a new variable and write

$$E_{it} = \beta_1 Y_{it} + \beta_2 Y_{it}^2 + \epsilon_{it}$$

In this case the turning point is given by

$$\frac{dE_{it}}{dY_{it}} = 0 \implies \beta_1 + 2\beta_2 Y_{it} = 0$$

$$Y_{it} = \frac{-\beta_1}{2\beta_2}$$

Since this is turning point in log the level turning point is given by $e^{-\left(\frac{\beta_1}{2\beta_2}\right)}$. This is the turning point for E_{it} i.e. natural log of e_{it}, but since log is a monotonic transformation the turning point for E_{it} and e_{it} are same. We provide turning point in case of first model. In extended model emissions does depend on other factors and therefore the turning point obtained would be not of much meaning in strict sense of EKC hypothesis. The extended model is used for testing pollution haven hypothesis which is one of the main objectives of the paper.

5 Results and Analysis

5.1 Environmental Kuznets Curve

The baseline environmental Kuznets curve regressions are given in table: 3 and table: 4. PMG estimator gives evidence of existence of environmental Kuznets curve for total CO2 emission, emissions from solid fuel consumption and emissions from liquid fuel consumption (inverted U shape). Both PMG and MG estimator[8] suggest long run relationship as the error correction coefficient is negative and significant. MG estimator does not give significant long run coefficient in any case. This is possible because MG estimator takes average of coefficients from each country and calculates standard error using delta method. Both MG and PMG estimator gives insignificant coefficients for short run. We need to compare these two estimator and same is reported in table 5. In all four cases, there is evidence in favour of PMG estimator. This implies that long run relation between carbon dioxide emissions and income is similar across these countries whereas in short run the relation between carbon dioxide emission and income varies. This inference is based on statistical test and mere observance of different turning point from individual country regression can not be given as an argument against our finding, because one need to test whether these different turning points are statistically different or not. Our result suggest that these are not statistically different. In case of all countries the turning point for solid fuel is estimated at very low level of income (table: 3) while turning point

[8]MG estimator is given by average of the individual country estimates. This implies that we estimate an ARDL model for each country and take average of coefficients.

for liquid fuel consumption is estimated at 31128. Turning point for overall emissions is estimated at 39163.

Table 3: CO2 Emission: Total and From Solid Fuel Consumption: All Countries

	PMG Estimate	MG Estimate	PMG Estimate	MG Estimate
	Total	Total	Solid Fuel	Solid Fuel
Long Run				
Log GDP	2.003***	13.78	0.517***	-0.817
	(15.02)	(0.44)	(3.57)	(-0.10)
Log GDP*Log GDP	-0.0947***	-0.639	-0.0408***	0.178
	(-14.59)	(-0.29)	(-4.47)	(0.27)
Turning Point	39163.5***		564.4***	
Short Run				
Error Correction	-0.181***	-0.294***	-0.253***	-0.362***
	(-6.81)	(-8.39)	(-5.69)	(-7.91)
D.Log GDP	-0.414	0.949	-2.332	-2.311
	(-0.90)	(1.28)	(-1.50)	(-1.24)
D.Log GDP*Log GDP	0.0269	-0.0558	0.151	0.155
	(0.86)	(-1.11)	(1.15)	(1.08)
Constant	-0.176*	1.961	0.235***	2.345
	(-1.78)	(1.01)	(2.80)	(0.32)
N	2046	2046	924	924

Notes: *, **, *** gives significance at 1, 5 and 10 percent significance level respectively. We only report turning point associated with significant coefficient.

Table 4: CO2 Emission: Liquid and Gaseous Fuel Consumption

	PMG Estimate	MG Estimate	PMG Estimate	MG Estimate
	Liquid Fuel	Liquid Fuel	Gaseous Fuel	Gaseous Fuel
Long Run				
Log GDP	3.021***	-9.901	0.327	62.91
	(27.09)	(-0.75)	(0.79)	(0.93)
Log GDP*Log GDP	-0.146***	0.888	0.00390	-4.238
	(-26.30)	(0.86)	(0.19)	(-0.93)
Turning Point	31128.9***			
Short Run				
Error Correction	-0.201***	-0.354***	-0.170***	-0.215***
	(-6.64)	(-9.37)	(-4.78)	(-4.85)
D.Log GDP	0.731	1.325	-2.847	0.331
	(1.21)	(1.56)	(-1.31)	(0.17)
D.Log GDP*Log GDP	-0.0558	-0.0825	0.168	-0.0193
	(-1.39)	(-1.45)	(1.42)	(-0.16)
Constant	-1.235***	1.234	1.094***	11.06**
	(-5.37)	(0.67)	(5.44)	(2.37)
N	2046	2046	792	792

Notes: *, **, *** gives significance at 1, 5 and 10 percent significance level respectively. We only report turning point associated with significant coefficient.

Table 5: Hausman Test for PMG vs. MG Estimator

Model	χ^2	p value
Total Co2 emissions	2.27	0.3216
Co2 emissions from solid fuel	0.64	0.7275
Co2 emissions from liquid fuel	1.04	0.5934
Co2 emissions from gaseous fuel	0.99	0.6101

Notes: Rejection of null hypothesis implies that the restriction on long run coefficient being same across countries is valid and PMG estimator is favoured.

5.2 Extended Environmental Kuznets Curve

We extend our baseline environmental Kuznets curve regressions by adding additional covariates. Only PMG estimation is done as argued above and results are given in table 6. Adding additional controls only changes the magnitude of income and income square term, this is expected as now other variables also explain variation in carbon dioxide emission. But the evidence in for environmental Kuznets curve obtained from baseline regression continues to hold. All error correction terms are negative and significant, thus giving is long run relationship. Coefficient associated with log trade to GDP ratio, log energy consumption and log domestic credit to GDP are elasticities. long run energy elasticity of carbon dioxide emissions is positive except in case of emission from solid fuel emission. This could be due to the fact that increase in energy use would be mostly through increase in liquid and gaseous fuel at the expense of solid fuel. Short run energy elasticities are positive but significant only for total emissions and emissions from liquid fuel. Foreign direct investment has no significant short run effects in any model. In long run the FDI decrease the emissions from liquid fuel and increase emissions from gaseous fuel.

In the long run financial development decreases total emissions and emission from liquid fuel consumption. Short run relationship between emission and financial development is weak but positive except in case of emission from gaseous fuel consumption. In short run financial development would lead to higher growth and thus higher emission, whereas in long run it is expected that financial development will lead to investment in efficient technologies with lesser emission.

Trade to GDP has a significant and positive long run elasticity with emissions from solid fuel and gaseous fuel consumption. One percent increase in trade increase the emissions from solid and gaseous fuel by .34 and .21 percent respectively in the long run. Trade to GDP has no significant long run relationship with total emissions and emission from liquid fuel. But trade to GDP has significant short run relationship with total emissions and emissions from liquid fuel.

Table 6: CO2 Emission: All Countries

	(1) Total	(2) Solid Fuel	(3) Liquid Fuel	(4) Gaseous Fuel
Long Run				
Log GDP	0.611***	1.229***	1.104***	0.00523
	(9.13)	(4.03)	(10.39)	(0.02)
Log GDP*Log GDP	-0.0355***	-0.0789***	-0.0568***	0.0136
	(-9.57)	(-4.70)	(-10.65)	(1.12)
Log Domestic Credit to GDP	-0.0448***	0.0784	-0.0986***	-0.0641
	(-3.81)	(1.28)	(-7.46)	(-1.11)
Log Energy Consumption	0.924***	-0.254***	0.700***	0.768***
	(43.58)	(-2.84)	(18.94)	(7.32)
Log Trade to GDP	-0.0267	0.337***	0.0326	0.206**
	(-1.31)	(2.81)	(0.92)	(2.36)
Foreign Direct Investment	0.00139	0.00738	-0.00800***	0.0181**
	(0.65)	(0.77)	(-3.04)	(2.25)
Short Run				
Error Correction	-0.292***	-0.266***	-0.258***	-0.235***
	(-10.36)	(-5.65)	(-9.49)	(-5.54)
D.Log GDP	0.630	-2.887	1.483**	-0.917
	(1.16)	(-1.49)	(2.17)	(-1.27)
D.Log GDP*Log GDP	-0.0362	0.159	-0.0970**	0.0586
	(-0.94)	(1.18)	(-2.13)	(1.23)
D.Log Domestic Credit to GDP	0.0415	0.0782	0.0575*	-0.0833
	(1.57)	(0.64)	(1.80)	(-0.67)
D.Log Energy Consumption	0.164**	0.245	0.229***	0.488
	(2.54)	(0.96)	(3.40)	(1.35)
D.Log Trade to GDP	0.0774***	-0.164	0.0797***	0.130
	(2.92)	(-1.02)	(2.63)	(0.62)
D.Foreign Direct Investment	0.00213	-0.00524	0.00118	0.00524
	(0.94)	(-0.74)	(0.42)	(0.47)
Constant	1.643***	-0.857***	0.758***	1.184***
	(10.14)	(-4.58)	(9.26)	(6.06)
N	2017	903	2017	784

Notes: *, **, *** gives significance at 1, 5 and 10 percent significance level respectively. Y is per capita income in ('000).

Based on these results, we conclude that all countries regression suggest that trade is harmful for environment as it increase the carbon dioxide emissions from a range of sources, both in the short as well as in the long run. To understand the aspect of trade in a better way in next section we report results from two sub sample regressions which has been obtained from country grouping based on their world bank income classification.

5.3 High Income Countries vs. Non High Income Countries

We divide our sample countries in two groups on the basis of income. We use world bank classification [9]. We separate out high income countries and make one group of high income countries and rest of the countries are put in another group called as non high income countries. The pollution haven hypothesis suggest that trade should increase pollution in low income countries but it should not have effects in high income countries.

Table 7 gives the result for high income countries. All error correction terms are negative and significant, thus giving us long run relationship. Long run environmental Kuznets curve hold for total emissions and emission from liquid fuel. But for emissions from gaseous fuel consumption, there is evidence of U shape. Moreover, the evidence also suggest short run U shape curve for emissions from solid fuel consumption.

Energy consumption has both long as well as short run positive elasticity but short run elasticity in case of emissions from solid and gaseous fuel consumption is not significant. Financial development measure by domestic credit to GDP ratio increase total emissions and emission from solid fuel in long run. Financial development decrease emission from liquid fuel in long run but decreases in short run. *Interestingly trade to GDP ratio has no significant effect on emission, neither in the short run nor in the long run.*

Table 8 gives the result from non high income countries. All error correction terms are negative and significant, thus giving is long run relationship. Long run environmental Kuznets curve hold for total emissions and emissions from liquid fuel. But for emissions

[9] https://datahelpdesk.worldbank.org/knowledgebase/articles/906519

from gaseous fuel consumption, there is evidence of U shape.

Energy consumption has significant long run positive elasticity except in case of emissions from solid fuel in which it is negative and significant. Energy elasticity for emissions from gaseous fuel consumption is greater than one. Contrary to high income countries, financial development has negative elasticity with emissions in the long run. Both high and non high income countries have positive emissions elasticity of solid fuel consumption with respect to financial development but the elasticity in case of high income countries is significantly higher than the one for non high income countries. Also, contrary to high income countries, in case of non high income countries, in short run financial development does not increase emissions from liquid fuel consumption. *Thus one can conclude that financial development increases emissions in high income countries whereas it decreases emissions in non high income countries in the long run.*

One percent increase in trade to GDP ratio increase the emissions from solid fuel by 1 percent in the long run. One percent increase in trade to GDP ratio decreases the carbon dioxide emissions from gaseous fuel by .41 percent in the long run. Increase in trade to GDP ratio increases total emissions and emissions from liquid fuel consumption in short run. Since, increase in trade to GDP ratio increase emissions in non high income countries and does not affect emissions in high income countries, there is evidence in favour of pollution haven hypothesis in short run.

Table 7: CO_2 emissions : High Income Countries

	(1) Total	(2) Solid Fuel	(3) Liquid Fuel	(4) Gaseous Fuel
long Run				
Log GDP	2.743**	0.711	2.736***	-3.779***
	(2.53)	(0.47)	(10.61)	(-3.55)
Log GDP	-0.150***	-0.0643	-0.132***	0.188***
	(-2.75)	(-0.87)	(-10.63)	(3.74)
Log Domestic Credit to GDP	0.0922*	0.244**	-0.0919**	0.147
	(1.80)	(2.41)	(-2.54)	(1.58)
Log Energy Consumption	0.913***	0.442***	0.275***	0.959***
	(8.10)	(2.97)	(4.41)	(6.52)
Log Trade to GDP	0.0177	0.258	0.0302	0.0866
	(0.16)	(1.49)	(0.55)	(0.61)
Foreign Direct Investment	-0.00278	0.00970	-0.00854***	0.0107
	(-0.77)	(1.18)	(-2.86)	(1.56)
Short Run				
Error Correction	-0.162***	-0.207***	-0.301***	-0.270***
	(-3.75)	(-4.16)	(-4.77)	(-2.91)
D.Log GDP	-0.0848	-5.554*	0.892	-0.922
	(-0.08)	(-1.88)	(0.59)	(-0.70)
D.Log GDP*Log GDP	0.00488	0.289*	-0.0422	0.0631
	(0.09)	(1.94)	(-0.52)	(0.76)
D.Log Domestic Credit to GDP	0.0364	0.176	0.131*	-0.123
	(0.79)	(0.66)	(1.73)	(-0.47)
D.Log Energy Consumption	0.484***	0.607	0.453***	0.0344
	(3.49)	(1.59)	(2.82)	(0.06)
D.Log Trade to GDP	-0.0305	-0.185	0.0636	0.333
	(-0.50)	(-0.50)	(0.82)	(0.69)
D.Foreign Direct Investment	0.00467	0.00434	0.00194	-0.00380
	(1.24)	(1.08)	(0.51)	(-0.37)
Constant	-0.850***	-0.281***	-1.461***	6.487***
	(-3.63)	(-3.57)	(-4.24)	(2.96)
N	525	360	525	327

Notes: *, **, *** gives significance at 1, 5 and 10 percent significance level respectively.

Table 8: CO_2 emissions : Non High Income Countries

	(1) Total	(2) Solid Fuel	(3) Liquid Fuel	(4) Gaseous Fuel
Long Run				
Log GDP	0.570***	0.00674	1.378***	-3.348***
	(5.23)	(0.05)	(8.53)	(-4.00)
Log GDP*Log GDP	-0.0328***	0.00269	-0.0900***	0.209***
	(-4.76)	(0.28)	(-8.62)	(4.26)
Log Domestic Credit to GDP	-0.0338**	0.0666*	-0.0805***	-0.0316
	(-2.31)	(1.69)	(-3.79)	(-0.63)
Log Energy Consumption	0.911***	-0.130***	0.855***	1.692***
	(41.01)	(-4.77)	(25.94)	(12.46)
Log Trade to GDP	-0.0237	0.0961***	-0.0140	-0.411***
	(-1.11)	(2.88)	(-0.42)	(-3.04)
Foreign Direct Investment	0.00715**	-0.0337***	-0.000157	0.0398**
	(2.29)	(-3.44)	(-0.05)	(2.27)
Short Run				
Error Correction	-0.323***	-0.346***	-0.281***	-0.269***
	(-9.57)	(-5.00)	(-9.65)	(-4.28)
D.Log GDP	0.974	-2.466	1.086	0.0228
	(1.55)	(-0.99)	(1.47)	(0.02)
D.Log GDP*Log GDP	-0.0558	0.203	-0.0748	0.0200
	(-1.16)	(0.96)	(-1.39)	(0.30)
D.Log Domestic Credit to GDP	0.0317	0.0309	0.0379	-0.0278
	(0.98)	(0.31)	(1.03)	(-0.30)
D.Log Energy Consumption	0.0655	-0.0305	0.132*	0.591
	(0.94)	(-0.10)	(1.86)	(1.35)
D.Log Trade to GDP	0.115***	-0.123	0.0802***	0.0542
	(4.15)	(-1.14)	(2.73)	(0.37)
D.Foreign Direct Investment	0.000701	-0.00288	-0.000232	0.0104
	(0.25)	(-0.26)	(-0.06)	(0.62)
Constant	1.867***	0.672***	0.798***	5.176***
	(9.36)	(3.38)	(9.13)	(4.11)
N	1492	543	1492	457

Notes: *, **, *** gives significance at 1, 5 and 10 percent significance level respectively. Y is per capita income in ('000).

Badri Narayanan et al. (2017) using an computable general equilibrium model suggest that trade liberalisation increases emission at the regional level (Asia Pacific). Substantial increase in global trade has happened due to shift of industries to non high income countries from high income countries. China is an important example for this shift and increasing trade. At the same time carbon emission has significantly increased in China and is one of the biggest emitter today. There is a possibility that trade may reduce emission if there is a decrease in price of renewable energy due to trade (Mani et al. (2018), Steinbuks and Narayanan (2015)). Our results suggest that this channel may not be working significantly enough to reduce emission. Our results suggest that trade is shifting emission significantly to non high income countries. It is not bringing other benefits significantly enough to reduce emission. =

6 Conclusion and Policy Implications

EKC hypothesis for CO2 emissions has been analysed extensively for individual countries. Results using panel of countries are relatively few. There has always been concern that relationship between emission and per capita income would be different across countries even after controlling for country fixed effects. Using Hausman test we provides evidence that the long run relation between emissions and per capita income is same across countries. Results obtained in this paper validate the EKC hypothesis for total emission, emissions from solid and liquid fuel consumption in the long run. Even with the inclusion of additional variables the EKC hypothesis continues to hold. Even with division of countries as high and non high income countries, EKC hypothesis continues to hold for for total emission, and emissions from liquid fuel consumption.

Financial development increases emissions in high income countries whereas it decreases emissions in non high income countries in the long run. Trade to GDP ratio does not affect emissions significantly in case of high income countries. In case of non high income countries, one percent increase in trade to GDP ratio increases the emission from solid fuel by .1 percent in the long run. Trade also increases total emissions and emissions from liquid fuel consumption in short run in non high income countries. Therefore, there is evidence in favour of pollution haven hypothesis in short run. It is logical as we expect the emissions shifting aspect of trade to be operative in short run whereas in long run the trade should be determined by comparative advantages.

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Appendix

List of Countries used for Total C02 emissions and Co2 emissions from liquid Fuel Consumption

1)Antigua and Barbuda 2)Australia 3)Burundi 4)Benin 5)Bangladesh 6)Bahrain 7)Belize 8)Bolivia 9)Central African Republic 10)Switzerland 11)Chile 12)Cameroon 13)Costa Rica 14)Dominica 15)Denmark 16)Dominican Republic 17)Algeria 18)Ecuador 19)Gabon 20)Gambia 21) Guatemala 22)Honduras 23)Indonesia 24)India 25)Iceland 26)Israel 27)Jamaica 28)Jordan 29)Japan 30)Kenya 31)Sri Lanka 32)Madagascar 33)Mexico 34)Mali 35)Malawi 36)Malaysia 37)Niger 38)Nigeria 39)Nicaragua 40)Norway 41)Nepal 42)Pakistan 43)Peru 44)Paraguay 45)Rwanda 46)Saudi Arabia 47)Sudan 48)Senegal 49)Singapore 50)Sierra Leone 51)El Salvador 52)Sweden 53)Seychelles 54)Chad 55)Togo 56)Thailand 57)Tunisia 58)Turkey 59)Uruguay 60)United Kingdom 61)United States 62)Vanuatu;

List of Countries used for Co2 emissions from Solid Fuel Consumption

Country Name 1)Algeria 2)Australia 3)Burundi 4)Bangladesh 5)Chile 6)Denmark 7)Iceland 8)Indonesia 9)India 10)Israel 11)Japan 12)Kenya 13)Madagascar 14)Malawi 15)Mexico 16)Malaysia 17)Nepal 18)Niger 19)Nigeria 20)Norway 21)Pakistan 22)Peru 23)Sweden 24)Switzerland 25)Thailand 26)Turkey 27)United Kingdom 28)United States

List of Countries used for Co2 emissions from Gaseous Fuel Consumption

Country Name; 1)Australia 2)Bangladesh 3)Bahrain 4)Bolivia 5)Switzerland 6)Chile 7)Algeria 8)Ecuador 9)Gabon 10)United Kingdom 11)Indonesia 12)India 13)Israel 14)Japan

15)Mexico 16)Malaysia 17)Nigeria 18)Norway 19)Pakistan 20)Peru 21)Saudi Arabia 22)Tunisia 23)Turkey 24)United States

High Income Countries Based on World Bank Classification

Country Name 1)Antigua and Barbuda 2)Australia 3)Bahrain 4)Switzerland 5)Chile 6)Denmark 7)United Kingdom 8)Iceland 9)Israel 10)Japan 11)Norway 12)Saudi Arabia 13)Singapore 14)Sweden 15)Seychelles 16)United States

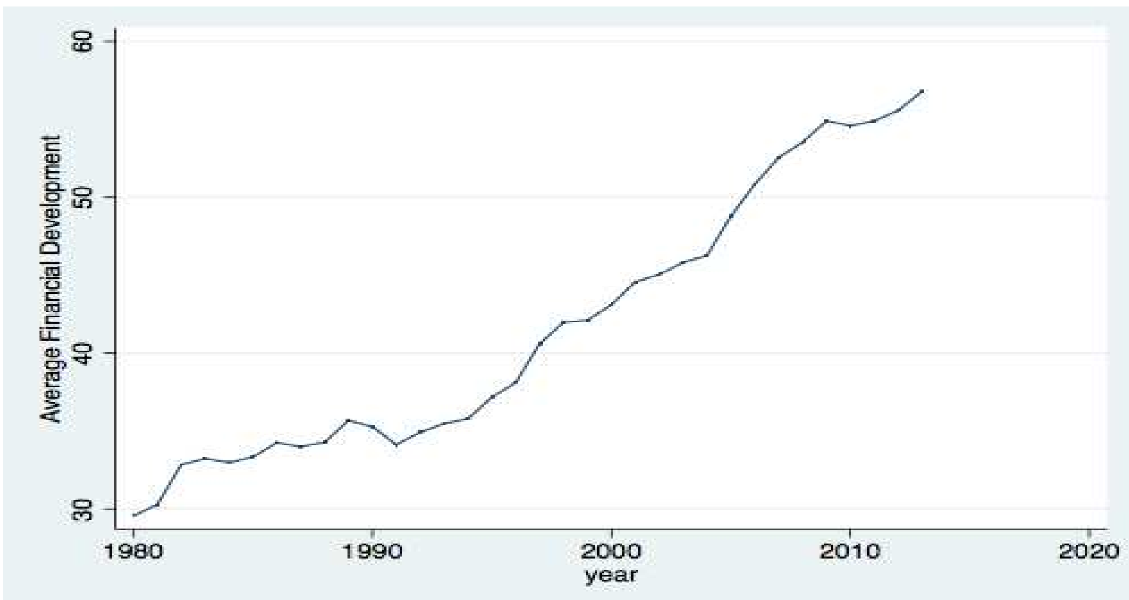

Figure 1: Average Financial Development Across Countries

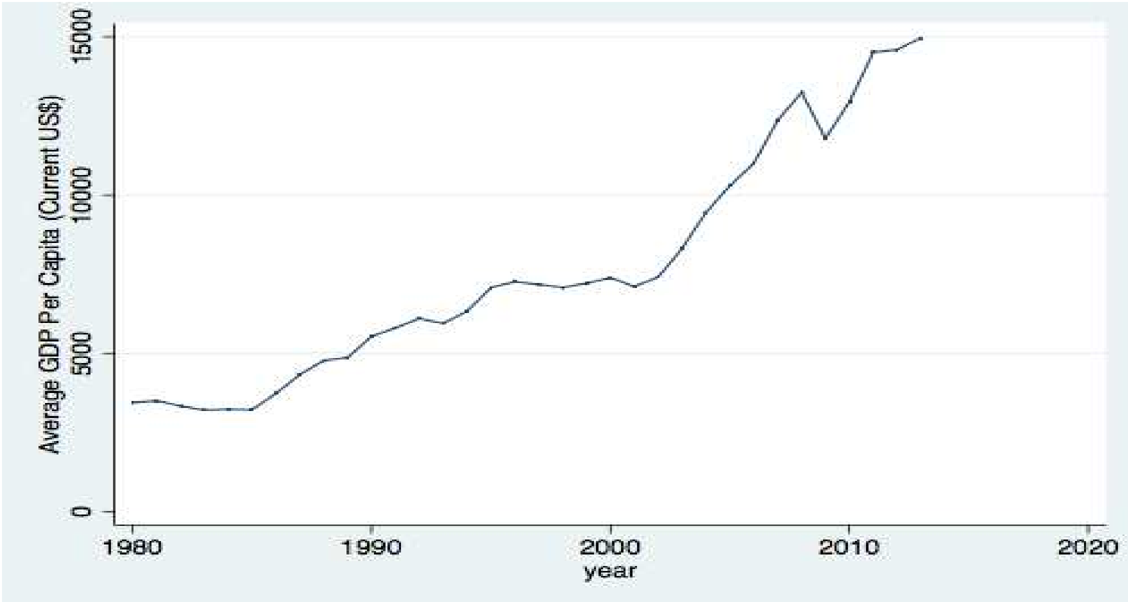

Figure 2: Average Per Capita Income Across Countries

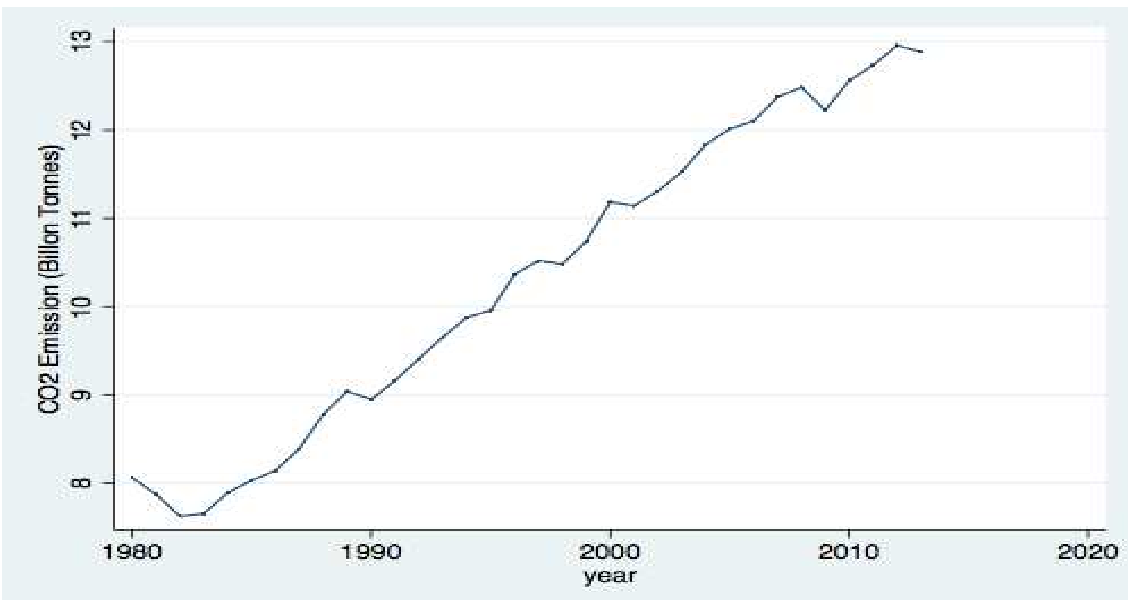

Figure 3: Total CO2 emissions Across Countries

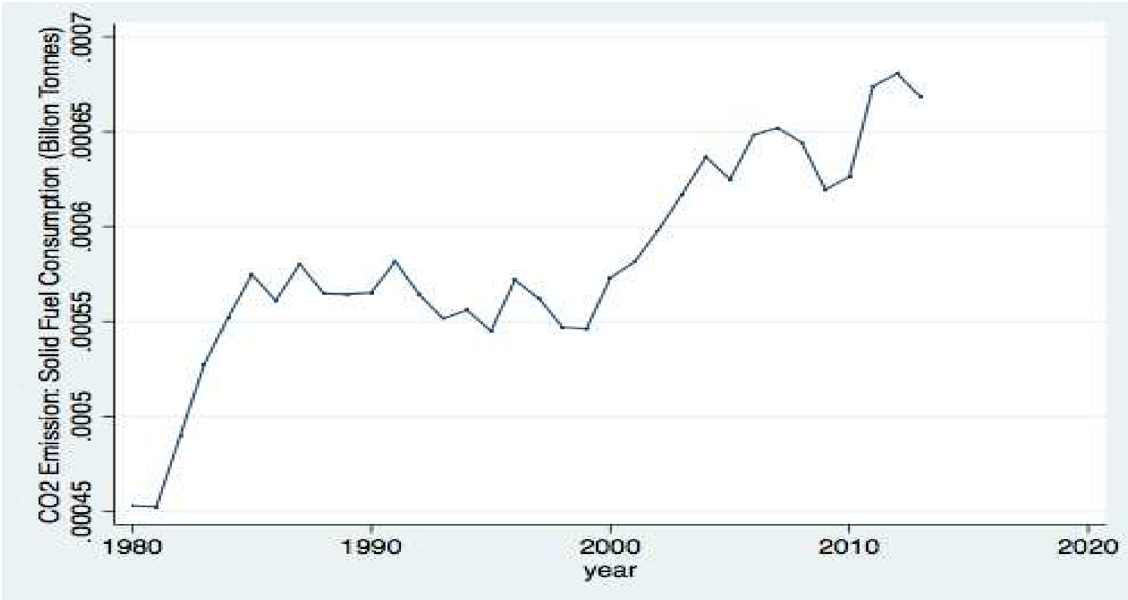

Figure 4: Total CO2 emissions From Solid Fuel Consumption Across Countries

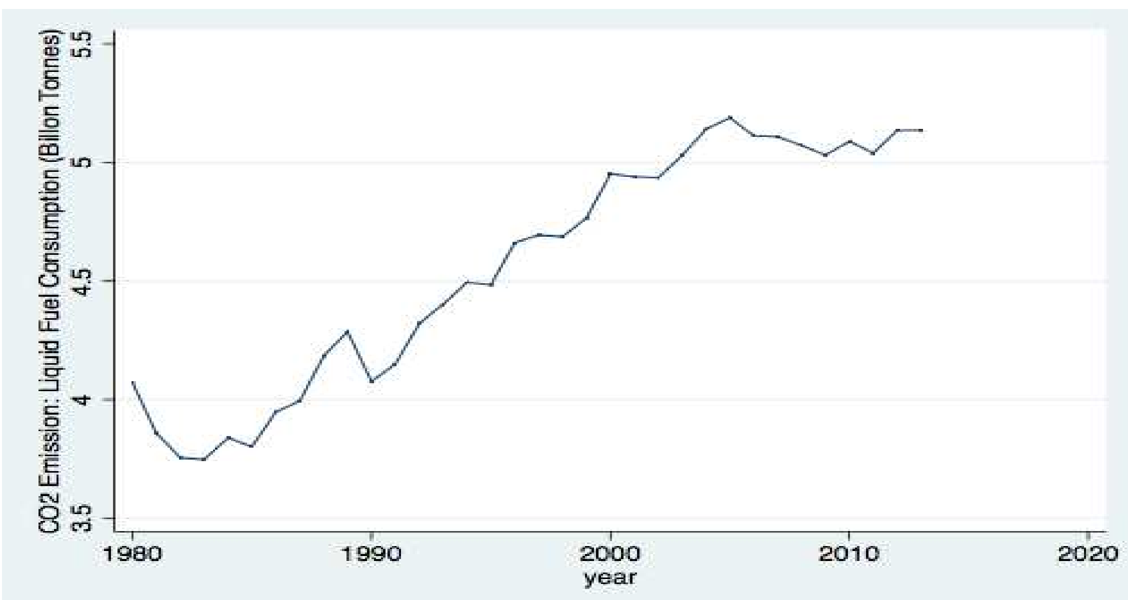

Figure 5: Total CO2 emissions From Liquid Fuel Consumption Across Countries

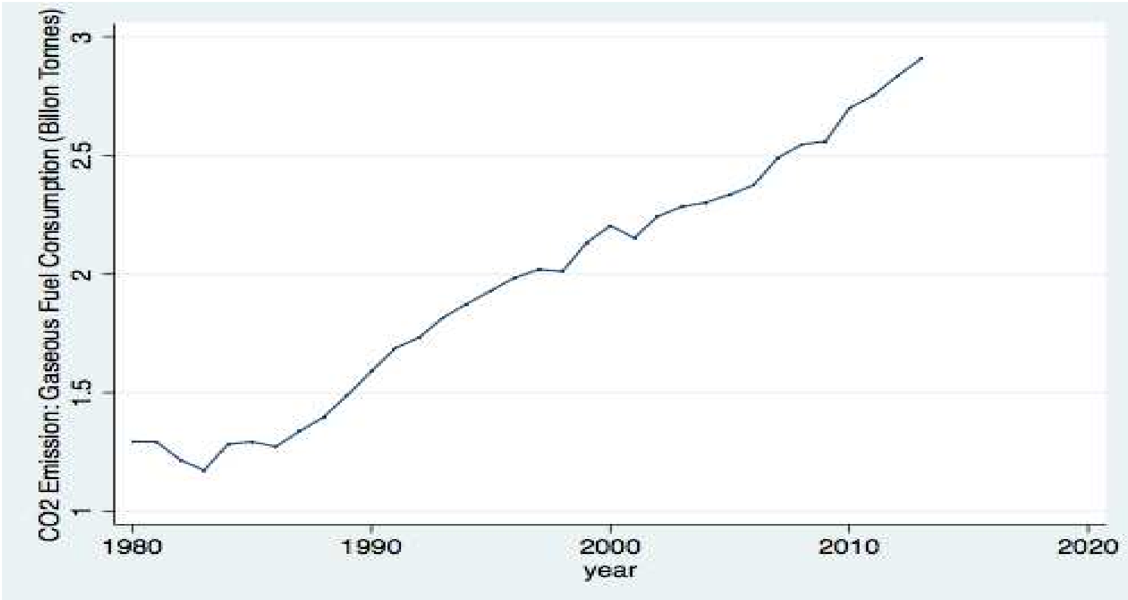

Figure 6: Total CO2 emissions From Gaseous Fuel Consumption Across Countries

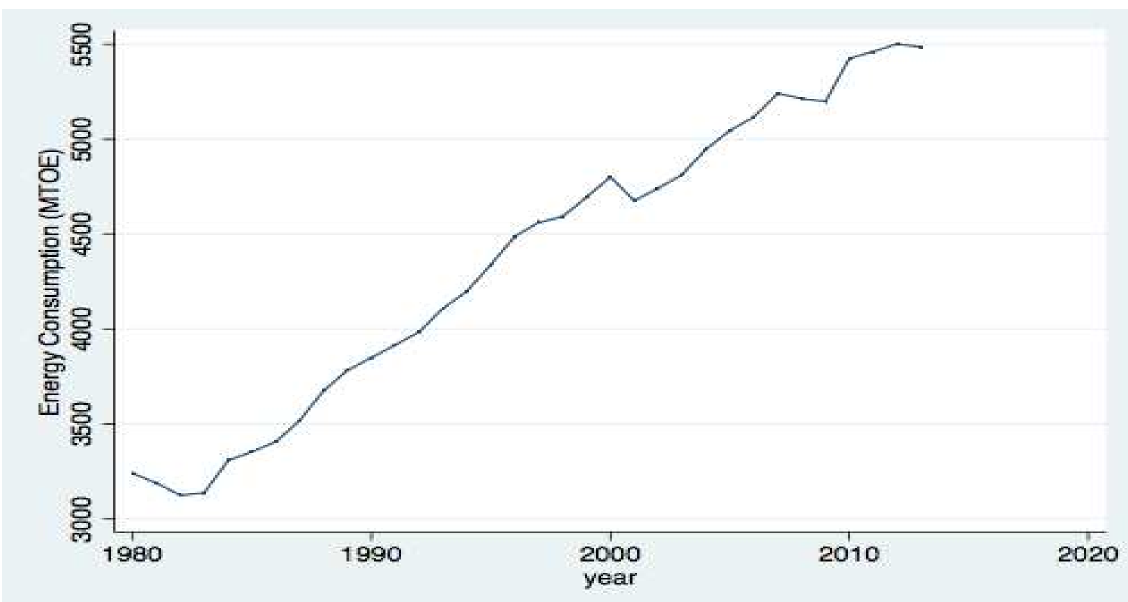

Figure 7: Total Energy Consumption Across Countries

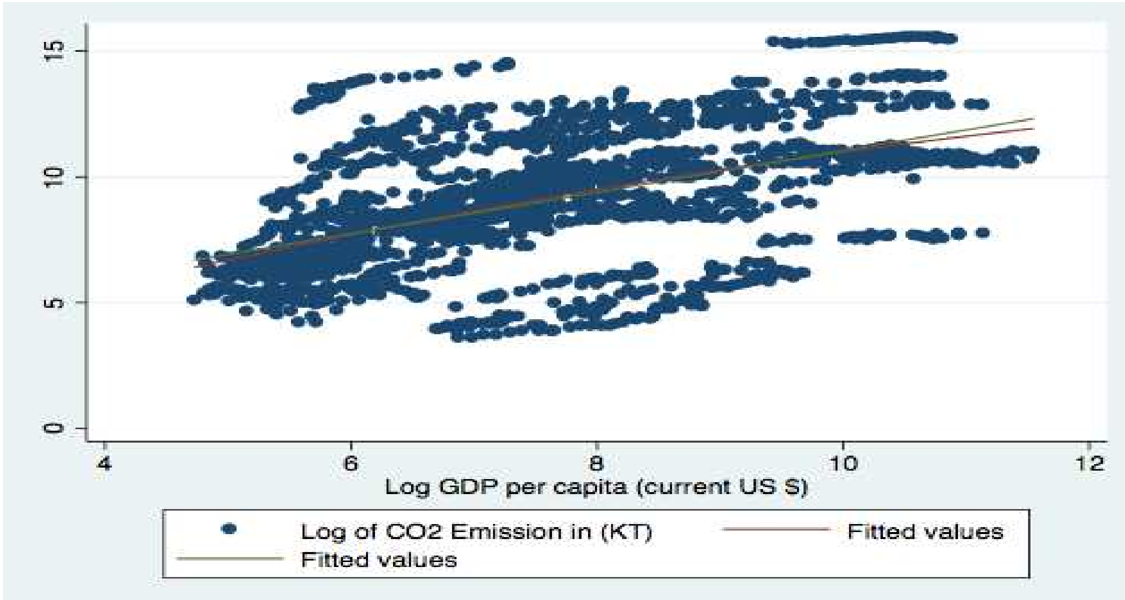

Figure 8: Total CO2 Emission: All Countries. Read line is quadratic fit and green line is linear fit

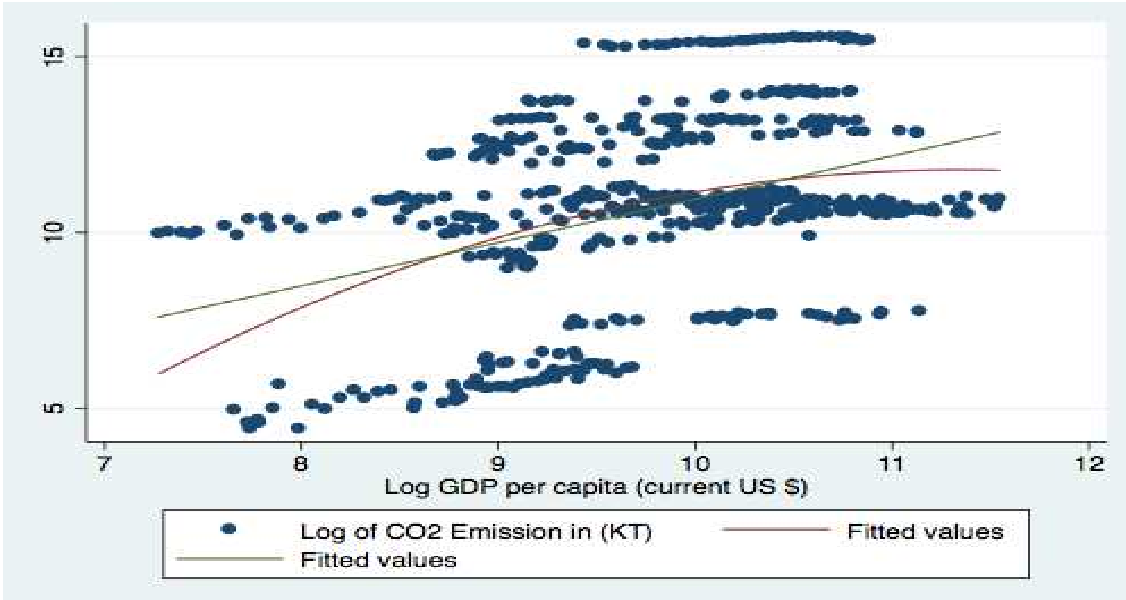

Figure 9: Total CO2 Emission: High Income Countries. Read line is quadratic fit and green line is linear fit

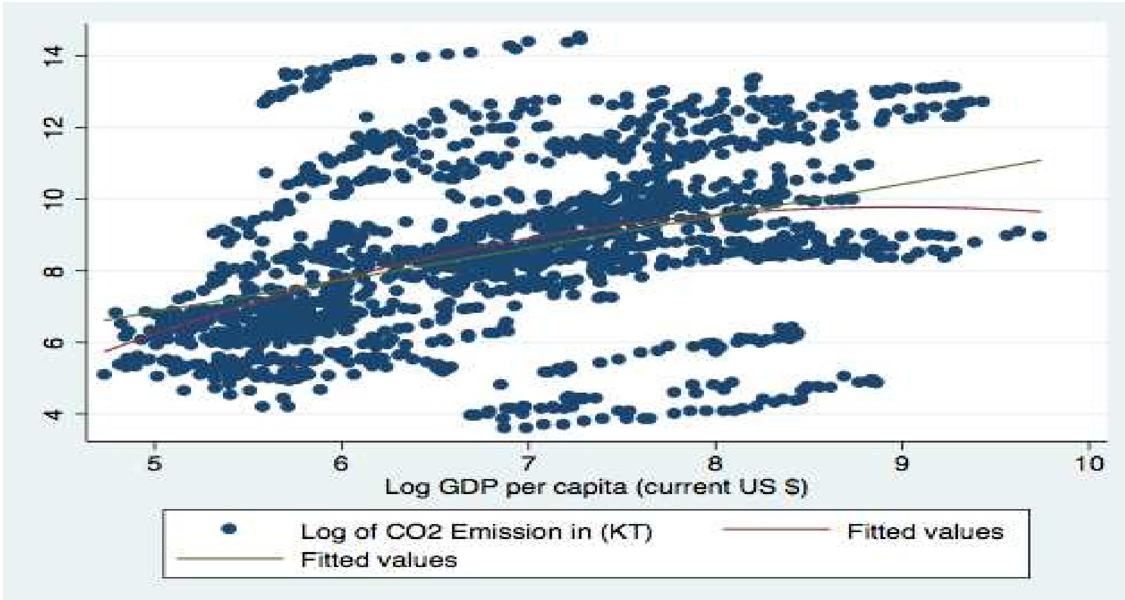

Figure 10: Total CO2 Emission: Non High Income Countries. Read line is quadratic fit and green line is linear fit

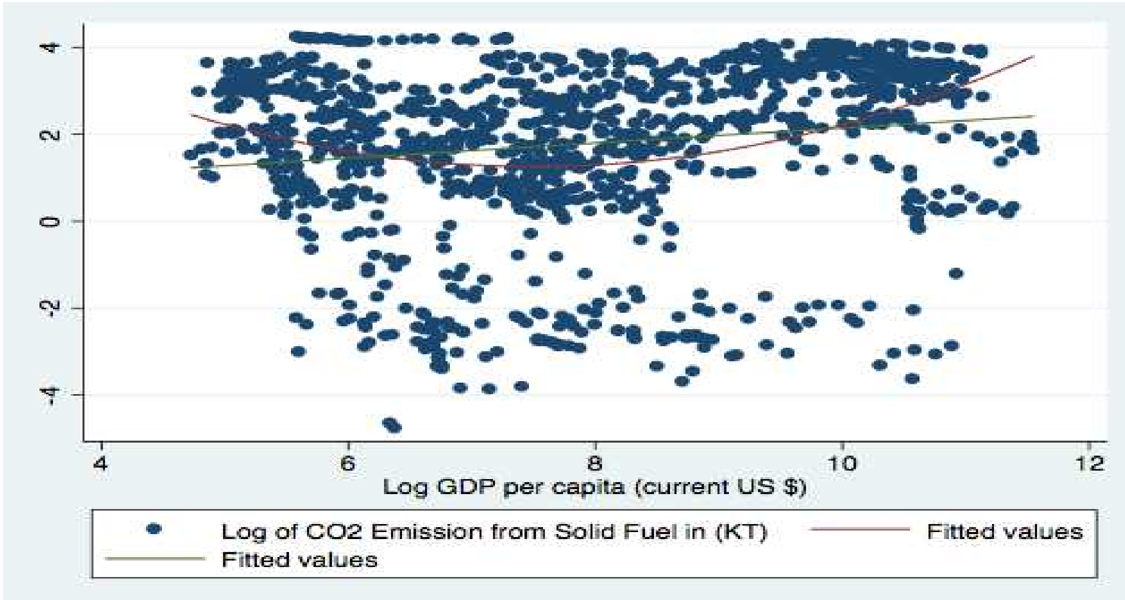

Figure 11: Total CO2 emissions From Solid Fuel Consumption: All Countries. Read line is quadratic fit and green line is linear fit

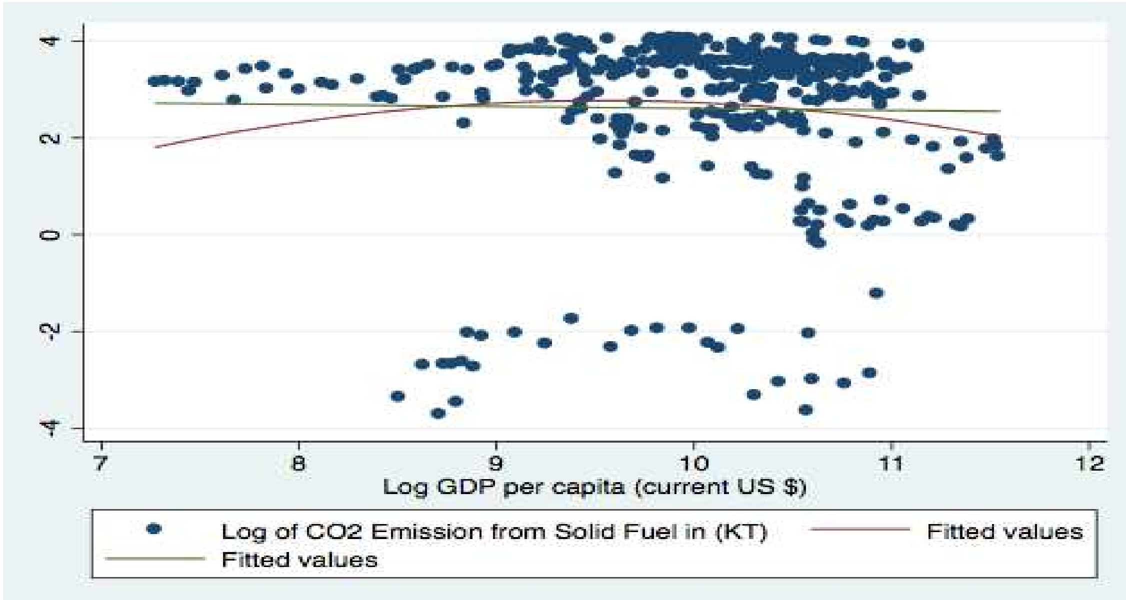

Figure 12: Total CO2 emissions From Solid Fuel Consumption: High Income Countries. Read line is quadratic fit and green line is linear fit

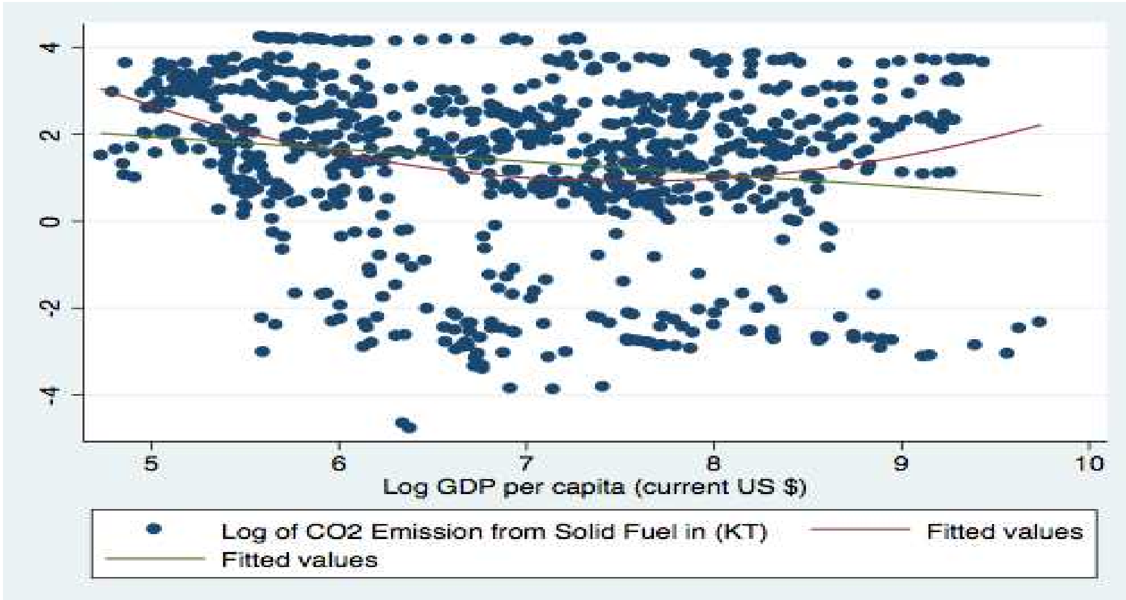

Figure 13: Total CO2 emissions From Solid Fuel Consumption: Non High Income Countries. Read line is quadratic fit and green line is linear fit

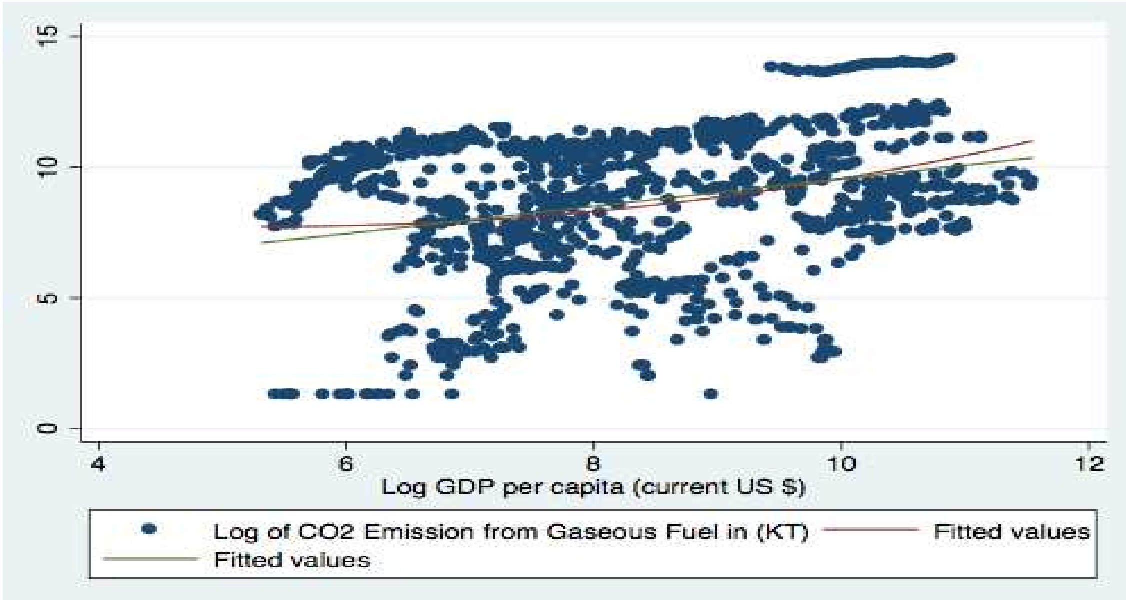

Figure 14: Total CO2 emissions From Gaseous Fuel Consumption: All Countries. Read line is quadratic fit and green line is linear fit

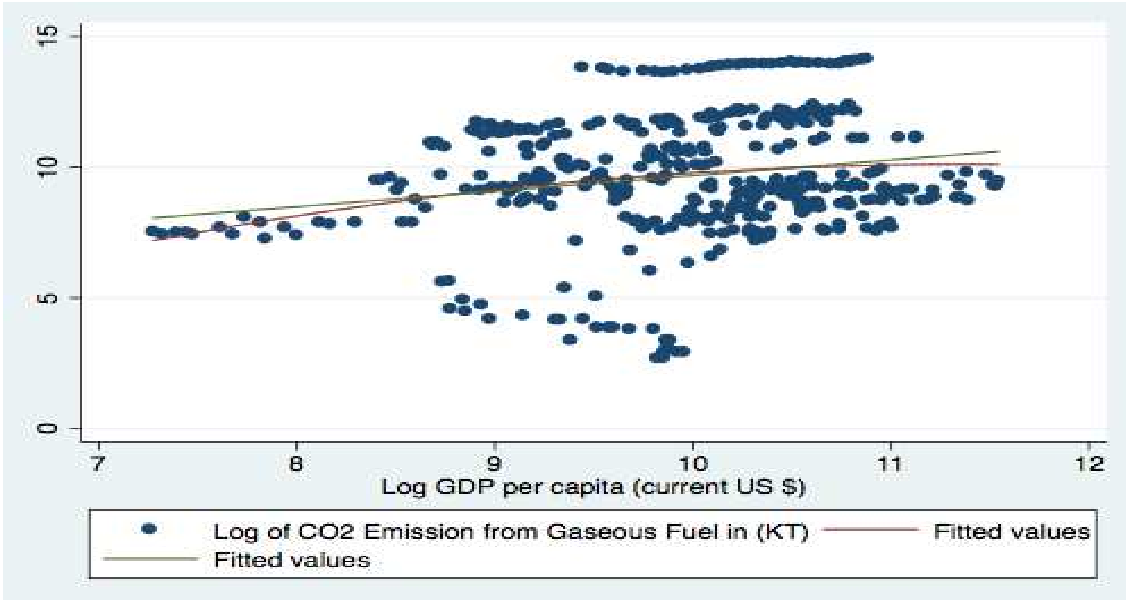

Figure 15: Total CO2 emissions From Gaseous Fuel Consumption: High Income Countries. Read line is quadratic fit and green line is linear fit

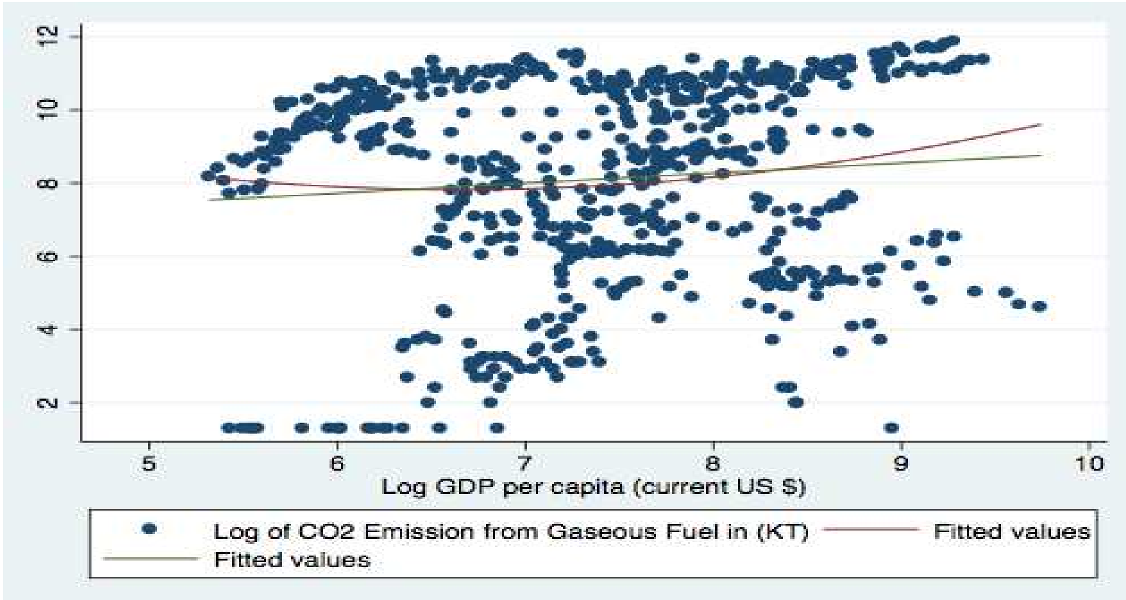

Figure 16: Total CO2 emissions From Gaseous Fuel Consumption: Non High Income Countries. Read line is quadratic fit and green line is linear fit

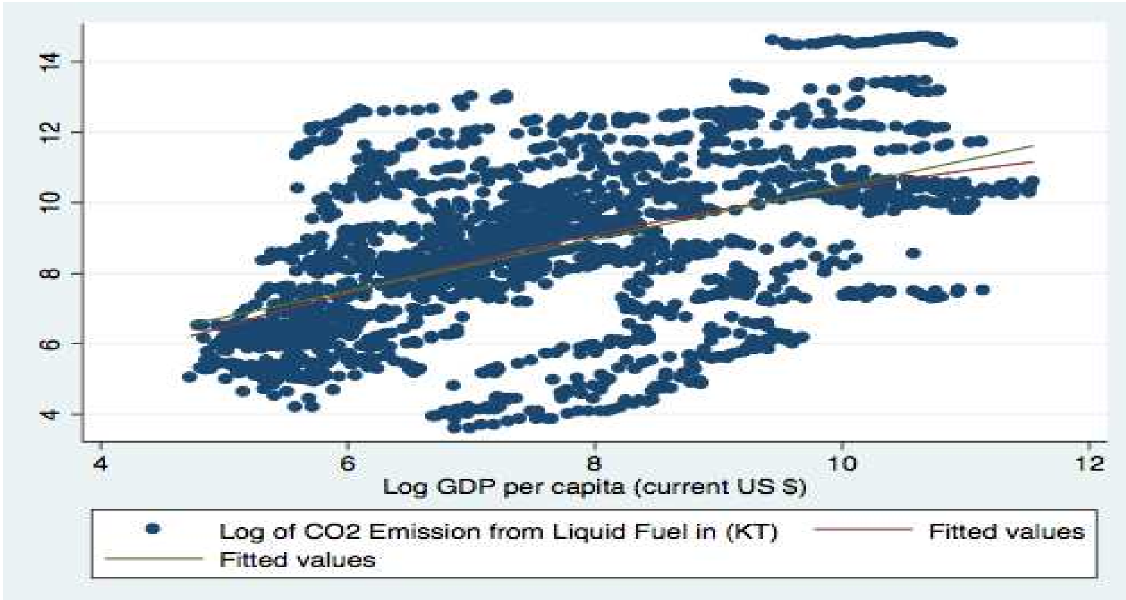

Figure 17: Total CO2 emissions From Liquid Fuel Consumption: All Countries. Read line is quadratic fit and green line is linear fit

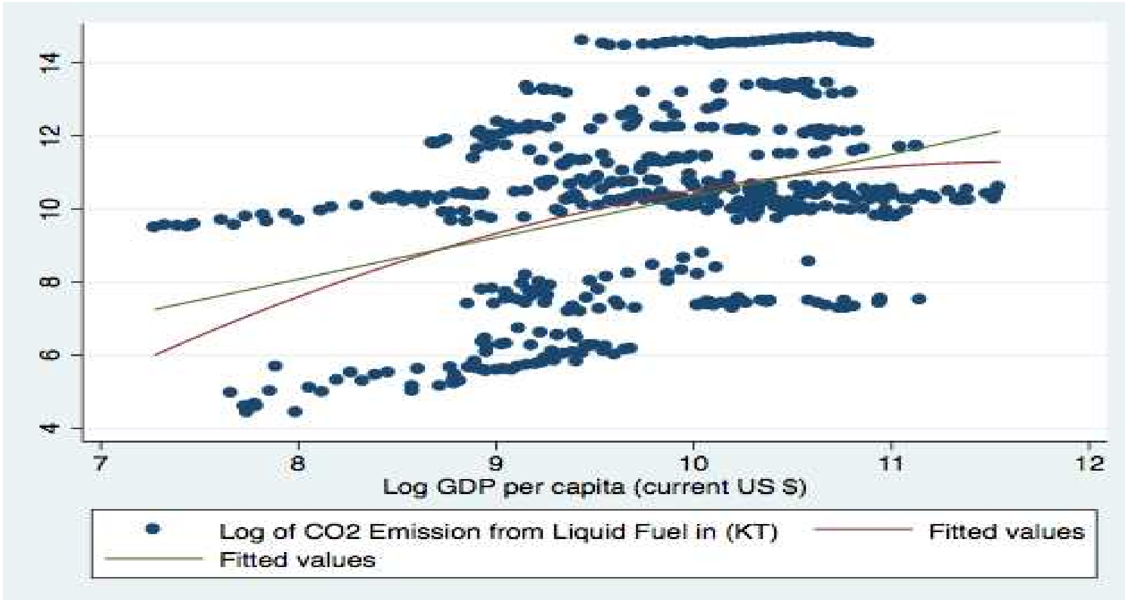

Figure 18: Total CO2 emissions From Liquid Fuel Consumption: High Income Countries. Read line is quadratic fit and green line is linear fit

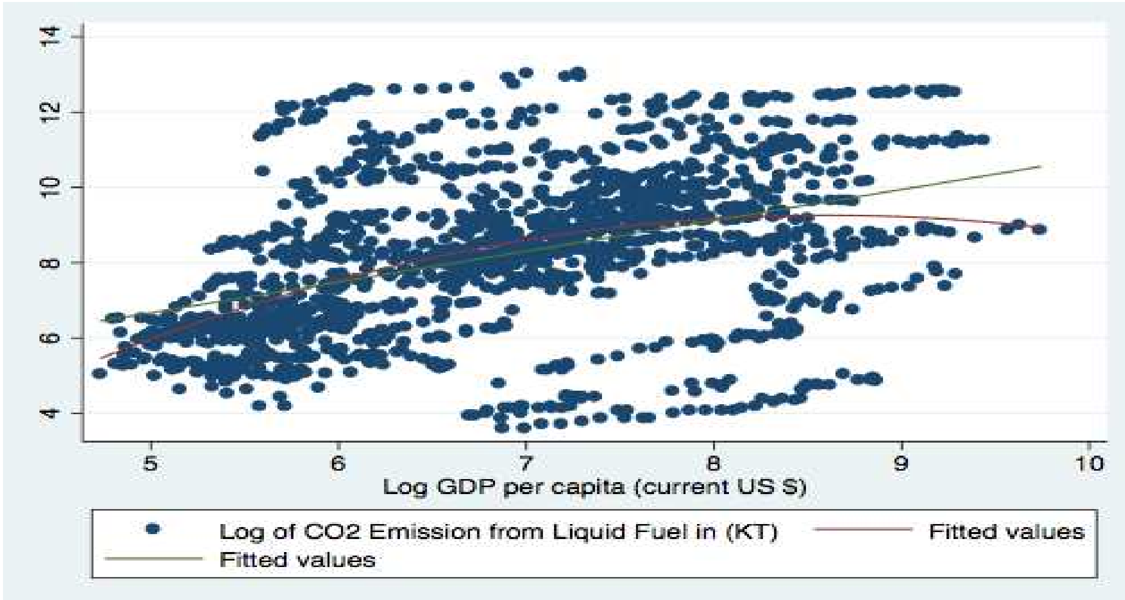

Figure 19: Total CO2 emissions From Liquid Fuel Consumption: Non High Income Countries. Read line is quadratic fit and green line is linear fit