An Empirical Study on Economic Growth and Carbon Emissions of G20 Group

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Abstract—**The aim of the paper is to explore the relationship between economic growth and carbon dioxide emissions for a small sample of open and industrialized countries. We analyze panel data of the 19 nations of the G20 from 1995 to 2010. The research finds no compelling evidence for the existence of Environmental Kuznets Curve. Further research is needed.**

Keywords-economic growth; carbon emissions; Environmental Kuznets Curve; Pollution Haven

I. INTRODUCTION

The threat of climate change has attracted great attention in recent years. One of the most important issues is how to reduce carbon emissions, since CO2 is considered to be the main driving force behind global warming. However, CO2 emissions are still increasing despite common efforts to implement international binding agreements, such as the Kyoto Protocol. The objective of this paper is to examine the empirical relationship between carbon emissions and economic growth, investigate what are the main determinants of carbon emissions and how openness affects it.

The rest of the paper is organized as follows. Section 2 analyzes the theoretical links and empirical evidence between economic growth, carbon emissions and other factors. Section 3 introduces the model, data and estimation method. Section 4 presents the estimation results and Section 5 concludes.

II. ANALYSIS OF THE THEORETICAL LINKS

A. Economic Growth and CO_2 Emissions

Existing research on the relationship between environmental quality and economic growth mainly focuses on Environmental Kuznets Curve (EKC) approach. According to the EKC hypothesis, the relationship between per capita GDP and per capita pollutant emissions has an inverted-U shape. This implies that, past a certain point, economic growth may actually be beneficial to environmental quality.

Theoretical and empirical studies in general agree on the existence of the inverted-U form relationship between income level and some local pollution indicators such as wastewater discharge and suspended particles. However, the question of the existence of the EKC for the global pollution case of carbon dioxide has not yet been fully resolved (He and Richard, 2010). From a theoretical point of view, the original inverted-U relationship is less likely for CO_2 emissions since these emissions cause problems on a global scale, and the social costs of global warming accrue both across time and nations. Therefore the incentive for free-riding is much stronger and the positive correlation between income and CO_2 emissions tends to persist even for very high income levels (Arrow et al., 1995).

In line with this argument, the relationships between CO_2 emissions and economic growth can be divided into: (i) linear, a monotonically increasing relationship between CO_2 and income (ii) inverted U-shaped, implies that GDP is both the cause and cure of the environmental problem (Galeotti and Lanza, 2005). (iii) N-shaped, implies that any diminishing of pollution is only temporary, economic growth cannot be the solution to such environmental problems.

The evidence for environmental Kuznets curve hypothesis for CO_2 is "at best mixed" (Galeotti et al., 2006). One potential reason is carbon dioxide causes problem in global scale in terms of its wide spread and longevity in the atmosphere, whilst the other "more local" pollutants have more clear EKC. Also the use of control variables has great influence.

B. International Trade and CO2 Emissions

In open economies, besides that domestic economic growth may raise CO_2 emission levels, international trade may have a significant influence on carbon emissions. It may alter the composition of output because of the differences in the stringency of the pollution regulations in different countries (Pollution Haven Hypothesis) (Taylor, 2005). Theoretically, carbon emissions might rise in the lax regulation country and fall in the tight regulation country.

The pollution haven hypothesis (PHH) predicts that, under free trade, pollution-intensive production will move from developed countries to developing countries. Developing countries lower their environmental standard to

attract foreign investment, while multinational firms take advantage of the lax environmental regulation moving the heavy polluted factories from their own countries to avoid paying high level pollution abatement costs (developed countries have more stringent environmental standard). Over time, developing countries will develop a comparative advantage in pollution-intensive industries and become "havens" for the world's polluting industries (Temurshoev, 2006).

However, there is no consensus in the economic literature on whether or not there is a pollution haven effect. Both general and partial equilibrium approaches have shown that such an effect is possible, but the empirical research provides conflicting evidence regarding the effect of trade on environmental quality (Jayadevappa and Chhatre, 2000).

III. MODEL, DATA AND METHOD

A. Model

This study examines the relationship between GDP and CO_2 emissions. We start with the basic empirical specification and include some control variables in order to account for the different stages of economic development, regional disparity and other structural differences. Since the independent variables do not have an immediate influence on carbon emissions. The level of emissions depend on the existing technologies and the existing structure of industrial output, which can only slowly change, therefore we employ a one-year lag for all independent variables (same as Iwata et al, 2012). The lagged independent variables also help to control for the possible endogeneity of these variables if their current value was employed.

Then the final functional form is below:

$$CO_{2it} = \alpha + \beta_1 GDP_{it-1} + \beta_2 GDP_{it-1}^2 + \beta_3 GDP_{it-1}^3 + \beta_4 IMP_{it-1} + \beta_5 EXP_{it-1} + \beta_6 IND_{it-1} + \beta_7 FDI_{it-1} + \beta_8 CPI_{it-1} + \eta_i + \gamma_t + \epsilon_{it}$$

The subscripts i and t denote countries and years respectively, the variables $CO2_{it}$ and GDP_{it} denote carbon emission and economic growth, IMP_{it} and EXP_{it} denote imports and exports as a share of GDP separately, IND_{it} denotes the share of industrial sector, FDI_{it} denotes net inflows of foreign direct investment as a share of GDP and CPI_{it} is short for Corruption Perceptions Index denotes the stringency of the environmental standard. The error term ε_{it} is composed of three elements, η_i stands for time-invariant regional effects, γ_t denotes the location-invariant time effects, and other deviation of the observed value from the true value (which is assumed to be randomly distributed with a mean of 0 and a constant variance).

B. Data Descriptions

Our sample comprises of 19 countries from G20 with a 16 years time length from 1995 to 2010. The G20 is a group of heads of government or state from 20 leading economies,

19 countries[1] plus the European Union. Collectively, G20 members represent 90% of the global GDP, 80% of the global-trade, over 2/3 of the world population, and 84% of the anthropogenic carbon emissions. The European Union is excluded from this analysis. Details of the data are in the table below.

In order to account for the different stages of economic development, position relative to the technological frontier and other structural differences, we classify the sample into two groups according to the World Bank's World Development Indicators[2].

- High-income economies ($12,616 or more) – eleven

  Australia, Canada, France, Germany, Italy, Japan, South Korea, Russia, Saudi Arabia, United Kingdom, United States

- Middle-income economies ($1,036 to $12,615) – eight

  Argentina, Brazil, China, India, Indonesia, Mexico, South Africa, Turkey

TABLE I.   DATA INFORMATION

Variables	Definition	Dimension	Source
CO_2	CO_2 emissions per capita	tonnes CO2 / capita	International Energy Agency
gdp	GDP per capita based on purchasing power parity and converted to international dollars	constant 2005 international $	World Bank
imp	Imports as a share of GDP	% of GDP	World Bank
exp	Exports as a share of GDP	% of GDP	World Bank
ind	Industry sector value added divided by GDP	% of GDP	World Bank
fdi	Foreign direct investment net inflows divided by GDP	% of GDP	World Bank
cpi	Corruption Perceptions Index	0 – 10 range	Transparency International

C. Methods

We start our empirical investigation using a panel model. It is commonly recognized that panel data sets possess several advantages over cross-sectional or time series data sets. It gives the researchers a larger number of data points. Moreover panel data models are able to capture the

individual heterogeneity (at the country level in this case) by introducing an individual specific effect term in the regression model, thus improving the estimation performance (Baltagi, 2008).

We prefer linear model to log-linear model in this study mainly because of its computational simplicity, the immediate interpretability of some of its coefficients and its temporal aggregability (Galeotti and Lanza, 2005). A linear model yields constant marginal effects and variable elasticities.

IV. ESTIMATION RESULTS

A. Full Sample Regressions Results

We estimate both two-way fixed effects and random effects models. We do choose the FE against the RE as our preferred model since the Hausman test suggests that the FE estimator remains consistent whereas the RE estimator does not and u_i is correlated with at least one of the explanatory variables. Moreover, we decide to use the FE model with robust cluster (by country) standard errors, since that the default FE estimation overestimates the significance of every explanatory variable. The results are given in Table II below.

TABLE II.   FULL SAMPLE REGRESSIONS RESULTS

Variables	FE (clustered robust)	
	Coefficients	*P-value*
l1gdp	0.0006476 (0.0002287)	0.011**
l1ind	0.0645518 (0.0215836)	0.008***
l1cpi	0.1959695 (0.0512104)	0.001***
y12 (year 2006)	-0.4296932 (0.2216308)	0.068*
y13 (year 2007)	-0.5204807 (0.2620952)	0.062*
y14 (year 2008)	-0.6757217 (0.263647)	0.020**
y15 (year 2009)	-1.148099 (0.2851251)	0.001***
y16 (year 2010)	-0.5939488 (0.2666056)	0.039**

Standard errors are in parenthesis
*** P<0.01, ** P<0.05, * P<0.10

According to results of the FE model with cluster robust standard error, the variables l1gdp which is one-year lag of GDP per capita is significant, while GDP^2 and GDP^3 (l1gdp_2 and l1gdp_3) are not. This implies that the relationship between carbon dioxide emissions and income is monotonic, a \$1 (U.S. dollar based on PPP in 2005) increase in the GDP per capita leads to a 0.00065 tonnes CO_2 per capita increase. The share of industrial value added in GDP (l1ind) is significant, a rise of 1 percentage point leads to 0.065 tonnes CO_2 per capita increase. Thus there is evidence that industry sectors do have negative impact on the environment. The Corruption Perceptions Index (l1cpi) is

also significant and has a positive impact with carbon emissions, if the value of the index rises by 0.1 which means less corruption within the country, the per capita CO_2 emissions increase 0.02 tonnes. This is the opposite from our expectation, may be misleading. Since 2006, the time dummy variables are significant, and have negative signs. This may be because of steep increase of oil price since 2004, leading to countries switching to less energy consuming and less polluting activities, thus carbon emissions reduction occurred. However the trade variables are insignificant and not of the expected sign.

B. Group Regressions Result

Since developed and developing countries are in different stages of economic development and technological positions, We carry out our empirical investigation separately for the sample of high-income and middle-income countries, the results are given in Table III below.

TABLE III.   GROUP REGRESSIONS RESULTS

Variables	Group 1-high income		Group 2- middle income	
	Coefficients	*P-value*	*Coefficients*	*P-value*
l1gdp	0.0003476 (0.0001355)	0.028**	0.0010287 (0.0003008)	0.011**
l1gdp_2	3.82e-09 (6.64e-09)	0.578	-3.43e-08 (5.20e-08)	0.531
l1gdp_3	-1.57e-13 (8.61e-14)	0.098*	2.79e-13 (2.37e-12)	0.910
l1imp	0.0590227 (0.0466673)	0.235	-0.0299136 (0.0153931)	0.093*
l1exp	-0.0257898 (0.0283152)	0.384	0.0389148 (0.010277)	0.007***
l1ind	0.0923459 (0.0431548)	0.058*	0.0081588 (0.0107452)	0.472
y5 (year 1999)	-0.0587317 (0.1648566)	0.729	-0.3251347 (0.1287544)	0.040**
y7 (year 2001)	-0.1222004 (0.2110982)	0.575	-0.4800874 (0.1601721)	0.020**
y8 (year 2002)	-0.1876857 (0.2582874)	0.484	-0.447215 (0.1520608)	0.022**
y9 (year 2003)	-0.0285478 (0.2813519)	0.921	-0.3567663 (0.1319977)	0.031**
y10 (year 2004)	-0.0965224 (0.2875713)	0.744	-0.2795446 (0.1122587)	0.042**
y11 (year 2005)	-0.3155204 (0.3531528)	0.393	-0.395826 (0.1133775)	0.010***
y12 (year 2006)	-0.5302247 (0.3468589)	0.157	-0.4626621 (0.1353334)	0.011**
y13 (year 2007)	-0.6697851 (0.4007711)	0.126	-0.4808182 (0.1631274)	0.021**
y14 (year 2008)	-0.9172316 (0.3707964)	0.033**	-0.5249261 (0.1860199)	0.026**
y15 (year 2009)	-1.527717 (0.4064855)	0.004***	-0.6869271 (0.1961901)	0.010***
y16 (year 2010)	-0.7724349 (0.4266004)	0.100*	-0.5879647 (0.2097346	0.026**
constant	-1.71026 (2.373365)	0.488	-2.411785 (0.6053359	0.005***

Standard errors are in parenthesis
*** P<0.01, ** P<0.05, * P<0.10

Compare to the full sample estimation, the results of group estimations are quite different, both in terms of magnitude and of statistical significance.

For the high-income countries, GDP, GDP^2 and GDP^3 are jointly significant. However the signs are not as expected for N-shaped (($\beta_1>0$, $\beta_2<0$, $\beta_3>0$), instead they are $\beta_1>0$, $\beta_2>0$, $\beta_3 <0$. This suggests there is an inverted-U shape environmental Kuznets curve with one turning point in the real sector at \$36461(see Figure Ⅰ). Only United States has already passed the turning point, implies that as it further develops the carbon emissions decrease and environmental quality improves, by importing more pollution intensive good at the expense of environmental quality in other countries, or by switching away from coal and oil to cleaner fossil fuels and nuclear and hydroelectric power because the increasing demand for cleaner environment from residents. For the share of industrial value added in GDP, a rise of 1 percentage point leads to 0.092 tonnes CO2 per capitaincrease, but this is only significant at the 10% level. The period dummy variables are significant since year 2008, maybe because the high-income countries are less sensitive to the increasing of energy prices.
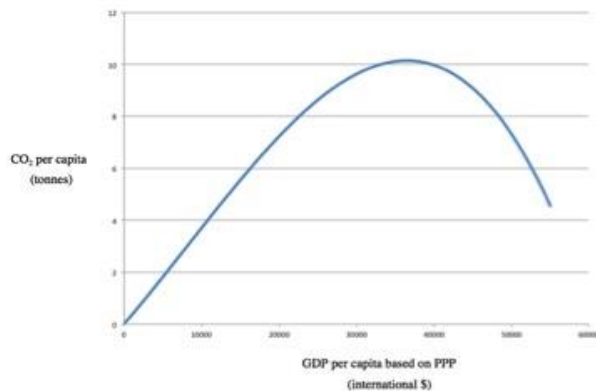

FIGURE I.   EXAMPLE OF A ONE-COLUMN FIGURE CAPTION

For the middle-income countries, the relationship between economic growth and carbon emissions are monotonic as the full sample analysis, maybe because these developing countries are in the earlier stage that stilldeveloping economy at the expense of environment. Carbon emissions are increasing as the economies are growing. Different from the full sample and high-income countries cases, imports and exports are both significant. It provides evidence for the pollution haven hypothesis, CO_2 emissions go up 0.039 tonnes as exports share of GDP grows up 1%, and go down 0.030 tonnes as imports share of GDP increases 1%. The time dummy variables are significant since 1999, except for 2000, maybe because of Kyoto Protocol (1997) has greater influence in developing countries than developed countries.

V.   CONCLUSIONS

This study estimates the environmental Kuznets curve for the 19 countries from G20 group, and tries to examine the key determinants of carbon emissions. Due to the fact that other factors such as trade, industry sector value added and corruption perceptions index may also have impact on CO_2emissions, we expand our estimation models by including these factors into the models as control variables.

The result shows that the Environmental Kuznets Curve may exist, however the turning point is really high, this goal is still many decades away. For the full sample and middle-income group, CO_2 is monotonically increasing with economic growth, while for the high-income group, carbon emissions begin to decrease at a high turning point. For the middle-income countries, imports and exports are significant, provide some evidence for the Pollution Haven Hypothesis, CO_2 emissions go up as exports grow and go down as imports increase. The industry sector does have a negative impact on the environment for both the full sample and the high-income group. As mass production and consumption grow, carbon emissions increase.

Therefore, the policy based on a "wait and grow" assumption is not adequate. Governments need to undertake policies as soon as possible to reduce levels of CO_2 emissions. For individual countries, options for economic growth with a less increase in pollution include: (i) increasing the service industry share; (ii) importing pollution intensive goods; (iii) strengthen controls on air pollutions; and (iv) increasing technology innovations on energy efficiency. However, the first two solutions reduce carbon emissions domestically on the expense of other countries' environment. Only the last one is the real solution for controlling CO_2 emissions worldwide. Future policies for climate change and pollution should explicitly focus on technological innovations.

REFERENCES

[1]   Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C. S., Jansson, B., Levin, S., Maler, K., Perrings, C., Pimentel, D. (1995). Economic Growth, Carrying Capacity, and the Environment. *Ecological Economics.* 15, 91-95.

[2]   Baltagi,B.H (2008) *Econometric analysis of panel data*, 4th Edition, Hoboken, NJ: John Wiley & Sons, Inc.

[3]   Galeotti, M., Lanza, A. (2005). Desperately seeking environmental Kuznets. *Environmental Modelling & Software.* 20, 1379-1388.

[4]   Galeotti, M., Lanza, A., Pauli, F. (2006). Reassessing the environmental Kuznets curve for CO_2 emissions: A robustness exercise. *Ecological Economics.* 57, 152-163.

[5]   He, J., Richard, P. (2010). Environmental Kuznets curve for CO_2 in Canada. *Ecological Economics.* 69, 1083-1093.

[6]   Iwata, H., Okada, K., Samreth, S. (2012). Empirical study on the determinants of CO_2 emissions: evidence from OECD countries. *Applied Economics.* 44 (27), 3513-3519.

[7]   Jayadevappa, R., Chhatre, S. (2000). International trade and environmental quality: a survey. *Ecological Economics.* 32 (2), 175–194.

[8]   Taylor, M. S. (2005). Unbundling the Pollution Haven Hypothesis. *The B.E. Journal of Economic Analysis & Policy.* 2, 1-28

[9]   Temurshoev, U. (2006). Pollution Haven Hypothesis or Factor Endowment Hypothesis: Theory and Empirical Examination for the US and China. *CERGE-EI Working Papers wp292.* The Center for Economic Research and Graduate Education - Economic Institute, Prague.