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The Impact of Economic Growth, Energy Consumption And Demographic Dynamics On Carbon Emissions: A Cross Country Analysis In 133 Nations

The Impact of Economic Growth, Energy Consumption And Demographic Dynamics On Carbon Emissions: A Cross Country Analysis In 133 Nations

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Abstract. The growth of economic has been a determinant factor increasing the volume of greenhouse gases, particularly CO^2 emissions. To provide appropriate measures to control CO^2 emission, it is necessary to address how such factors as population and economic growth impact the emission of carbon dioxide in any developing country. However, the answer to what are the key factors or whether these factors have jointly impacted on CO^2 emissions has been debated so far. This paper chooses five main factors, including economic growth, population growth, energy consumption, age structure and urbanization as independent variables for multiple regression model to analyse the relationship between these variables to CO^2 emission variable in 133 countries. The result shows that all these factors jointly impacted on CO^2 emissions energy use and demographic factors should be controlled due to the highest contribution to the level of CO^2. The research findings are expected to shed a light on those countries policy making in coping with climate change.

1. Literature review

The relationship between carbon emissions and economic growth has been debated for many decades [1]. Some of the empirical studies support the EKC hypothesis, which states that the level of carbon emission and economic growth follow an inverted U-shaped curve [2]. Some find that there is positive linear relationship between two variables [3]. After performing analysis a panel of 88 countries, [4] also conclude that a positive relationship exists between CO^2 emissions and economic growth. In general, there is many existing theories suggested that GDP growth and carbon dioxide emissions are strongly positive interrelated [5]. While many studies have primarily focused on the impacts of affluence on carbon dioxide emissions, other empirical studies suggested that population change also significantly increase the volume of greenhouse gas emissions for the last decades [6]. Yet, identifying the relationship between population growth and CO^2 emissions continue to be debated because most studies focus on the direct effect of population on the level of carbon dioxide emissions through only population size without considering the demographic dynamics [7]. Meanwhile, in fact, energy demand and greenhouse gases emissions can also be affected by a range of demographic dynamics, such as urbanisation rate, age structure and household size. Even the impact of distribution of population may be more important than population size and thus it needs to be considered, for instance the more population living in urban, the more energy are consumed, resulting in high level of CO^2 [8]. Age structure of the population should also be taken into account in explaining the effect of population change on CO^2 emissions because those people in working age have higher involvement of economic activities, resulting in more energy consumption than those in dependent group [9]. Many recent studies have employed the demographic factors as significantly additional explanatory variables for the increase of CO^2 [10]. According to [7], shrinking household size significantly influence the growth of carbon emissions in China. However, adverse environmental impacts are more a direct function of energy consumption than of indirect via the impact of population or economic growth. Thus, energy consumption should be employed to explain the relationship between CO^2 level and economic growth or population growth [11]. In general, all above empirical studies base on basic literature on environmental degradation from IPAT model in which three driving forces expected to influence the level CO^2 emissions includes economic growth or the affluence, population and technological change or specifically, the energy efficiency of economic activities [12]. They are interrelated in explaining the increase of CO^2 emissions in recent decades. The impacts of economic activity have become more severe when combined with demographic growth, as long as population increases lead to increases in energy consumption and consequently higher level of CO^2 emitted.

2. Data selection

The data of carbon dioxide emissions taken from Carbon Dioxide Information Analysis centre of World Bank are observations of total CO^2 emissions from all activities measured in kilo tonnes. It is also similar for data of total energy consumption variable, with all forms of commercial energy excluding firewood and other traditional fuels are converted into oil equivalents. The affluence or economic growth variable is captured by real GDP in U.S dollar. The population figures are based on the estimation of national censuses taken form World Bank. All data is cross-sectional data collected in 133 countries in 2010, with the aim of maximizing possible sample size. Regarding age structure variable, based on World Bank definition the structure of population of each country are divided into two age categories: dependent group (aged less than 15 or over 64) and another one is working group (aged 15-64). According to [9], those people in working age have higher participation in economic activities, resulting in more energy consumption than those in dependent group. Thus, it is expected that countries with higher percentage of working population (% total population) might produce more CO^2. However, the data related to age structure from World Bank only provide the data of the ratio of dependent group compare to working group, which is not relevant for my analysis. So, from the data of total population and the ratio of dependent group compare to working group in every country, the authors have built own data of percentage working population compared to the total population.

*% Working population= (population / (1+age dependency ratio/100))*100/population* (1)

This variable is named working population. Regarding urbanization, urban population (% of total population) data is used. Summary of all variables are presented in table 1.

Table 1. A summary of variables

Variables	Obbs	Mean	Standard deviation	Min	Max
CO^2 (kt)	133	264454.3	913228.6	513.38	8286892
GDP(current US$)	133	5.83e+11	1.84e+12	2.12e+09	1.50e+13
population	133	5.39e+07	1.63e+08	318041	1.34e+09
Energy use (kt of oil equivalent)	133	105917.4	321660.7	744.529	2516731
Working Population (% total population)	133	64.99488	6.517571	49.77217	85.80555
Urban population (% total population)	133	62.47129	21.18596	13.444	100

3. Data analysis

3.1. The relationship between each independent variable and CO^2

Table 2. Correlation of each independent variable to CO^2

Variables (non-ln)	GDP	Population	Energy use	Working population	Urban population
Correlation coefficients	0.7545	0.8040	0.9842	0.1521	0.0423
Variable(ln)	LnGDP	LnP	LnE	LnA	LnU
Correlation coefficients	0.9231	0.6904	0.9459	0.4165	0.3165

All independent variables has positive linear relationship to CO^2 variable individual, shown in table 2, which is in the line with what theories suggest. Of which, GDP, population and energy consumption variable appear to strongly correlate to CO^2 variable, with coefficient of correlation 0.7545, 0.8040 and 0.9842 respectively. However, there is not enough information to conclude GDP, or population or energy use should be the main factor causing the high level of CO^2. Instead, a multiple regression needs to be conducted to demonstrate the true relationship between those variables because apart from direct effect, GDP also has indirect effects on CO^2 via other independent variables. Furthermore, visually the linear relationship between each independent variable to CO^2 is demonstrated clearer when all variable are taken logarithm.

3.2. Multiple regressions for five independent variables

The model used is a multiple regression formulation, shown in table 3:

$$CO^2 = B1+B2GDP+B3population+B4energyuse+B5workingpopulation+B6urbanpopulation+e \quad (2)$$

Where e is the error term

Table 3. Multiple regression summaries

Variables	Coefficient	t-ratio
GDP	-1.47e-07*	-16.01
population	-.0000637***	-0.74
energy use	3.531644*	48.67
working population	393.9955***	0.30
urban population	215.1645***	0.52
Number of obs	133	
F(5, 127)	3092.35	
Prob > F	0.0000	
R-squared	0.9919	
Adj R-squared	0.9915	
Root MSE	84035	

Note: *, **, *** significant at 1%, 5% and 10% respectively

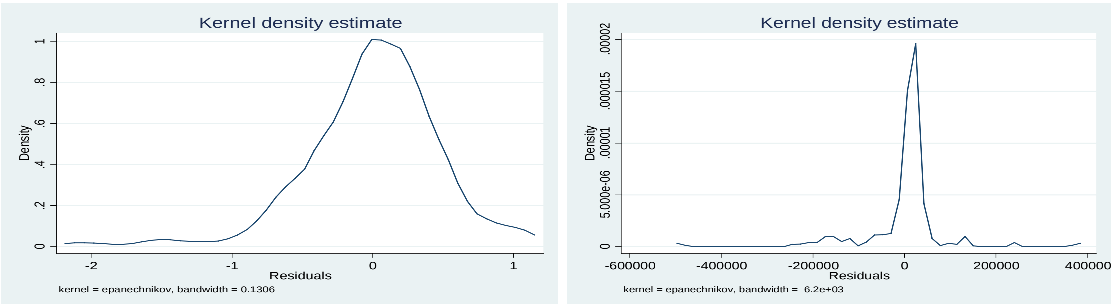
Although the high multiple coefficient of determinant is 0.9919, the signs of coefficients of GDP and population variable are not as expected. Only coefficients of GDP and energy use is individually significantly less than 1% significant level (P<0.01), while the estimated coefficient on population, working population and urban population are individually less significantly at (more than) 10% significant level and the overall F test for fit is also significant. Obviously, there is a problem of imperfect multicollinearity in which independent variables are highly linearly related. However, the paper cannot drop any of five variables because theory suggests that all of them should be included in the model. Instead, the research use logarithm model for the model specification.

3.3. Testing for heteroskedasticity

The Breusch-pagan/cook-Weisberg test has been used for homoscedasticity. The result of low p-value = 0.0000, <0.01 indicates that the heteroskedasticity is likely to be present. In this case, taking logarithm all variables might reduce the heteroscedasticity.

$$Ln\ CO^2 = B1+B2lnGDP+B3lnP+B4lnE + lnA+lnU + e \quad (3)$$

The high p-value = 0.0846, >0.05 indicates that the heteroskedasticity is not likely to be present, or the authors cannot reject the null hypothesis that errors are homoscedastic. Obviously, taking logarithm all variables is efficient to reduce problem. Furthermore, the assumption normality of residuals has been checked; the results show that the residual of linear model is quite skew compared to the normal distribution of residual of transformed model.



Linear model *Transformed model*

Figure 1. Distribution of residuals

As a result of these above result, a log-log model is better suitable than linear model in this case. The model used is a multiple regression formulation, shown in table 4:

$$Ln\ CO^2 = B1+B2lnGDP+B3lnpop+B4lnEnergy+lnAge+lnUrban+e \quad (4)$$

Table 4. Multiple regression summaries of transformed model

Variable (ln)	Coefficient	Standard error	t	P>t
LnGDP	.1560336	.0732798	2.13	0.035
LnP	.1507816	.0651587	2.31	0.022
LnE	.7235889	.090821	7.97	0.000
LnA	3.750907	.559135	6.71	0.000
LnU	.287917	.1474757	1.95	0.053

The t-statistic tests show that the low p-value (< 0.05) for the coefficient of GDP, population, energy use and working population implies: the effect of the (logarithm of) all four variables on the CO^2 emissions is individual significant at 5% level of significance. However, the p-value for the coefficient of the logarithm of urban population is less individual significant, 0.053. This means that

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we should exclude this variable due to no relationship between the level of CO^2 and the urban population in studied countries. However, the estimated result will be bias due to omitted variable because the theories have recommended that urban population should be considered as main demographic factor influencing CO^2 in recent years. Additionally, population size might not only represent its direct effect on CO^2, but also its indirect effect via urban population. Therefore, based on the F-statistic tests, with the low p value < 0.01 to reject the null hypothesis that all coefficients for the explanatory variables are simultaneously equal to zero. Obviously, urban population variable is jointly significant with other independent variables to explain the increase of CO^2 in 133 countries. Therefore, urban population should be included in the final model.

3.4. Testing for omitted variables

A Ramsay reset test has been conducted to test omitted variables with transformed model.

$$Ln\ CO^2 = B1 + B2lnGDP + B3lnpop + B4lnEnergy + B5lnA + B6lnU + e \qquad (5)$$

The authors fail to reject the null hypotheses that the model has no omitted variables because the high p-value= 0.9958>0.1. So, statistically, this double log model is correctly specified, with no omitted variables. However, the F test is not always true with 100% as there are many other factors which are important in contributing to the levels of CO^2 as well such as industry composition and household size**.** Due to the limit of a small essay combined with the limit data, the research have just included five relevant variables. After analysing combined with theory, a log-log model has been considered as a final useful model.

$$Ln\ CO^2 = B0 + B1lnGDP + B2LnP + B3lnE + B4lnA + B5lnU + e\ (Model\ specification) \qquad (6)$$

Table 5. Estimated results

Variable	Coefficient	t-ratio
LnGDP	0.1560336**	2.13
LnP	0.1507816**	2.31
LnE	0.7235889*	7.97
LnA	3.750907*	6.71
LnU	0.287917***	1.95
Number of obs	133	
F(5, 127)	393.91	
Prob > F	0.0000	
R-squared	0.9394	
Adj R-squared	0.9370	
Root MSE	.47955	

Note: *, **, *** significant at 1%, 5% and 10% respectively

The model has produced a high adjusted multiple coefficient of determinant of 0.93, implying that 93 % of variation in CO^2 emissions can be explained by the model, shown in table 5. The sign of all coefficients is in the line with the suggestion from the basic theory. Since both CO^2 and all explanatory variables are in logs, all slope coefficients are estimated global elasticity of CO^2 with respect to a relevant determinant, while keeping other independent variables constant. For example, the interpretation of B1 = 0.1560336 suggests that if GDP increases by 1%, the emission of CO^2 will increase proportionally by approximately 0.15% while keeping other independent variables constant. Similar interpretation is applied to the other explanatory variables. It can be seen that working population and energy use appear to have greater predictive power than the other variables, with coefficients of 3.750907 and 0.7235889 respectively.

4. Conclusion

The estimated result of the model shows that all these factors jointly impacted on CO^2 emissions. There is little association between economic growth and CO^2 emissions while energy use and demographic factors should be controlled due to the highest contribution to CO^2 level. Of demographic variables, age structure is a more reasonable explanation for the impact on carbon emissions than urbanization while keeping other independent variables constant. This finding is likely to be accepted because urbanization from rich countries can improve energy use efficiency and pollution treatment, mitigating the damage to the environment. By contrast, no matter what efficient level of energy use has been controlled, higher percentage of working age population will lead to the increase of CO^2, especially in those developed countries. The essay also suggested that using household size in explaining the impact on carbon emissions should be more effective approach for further research on this issue.

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