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Key driving factor analysis on industrialization and CO_2 emission: based on data of madagascar, China and the united states

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ABSTRACT

This paper explores the key driving factors on the stages of industrialization and CO_2 emissions. With the STIRPAT model and Dynamic OLS technique to assess the driving forces leading to CO_2 emission in Madagascar, China and the United States within different stage of industrialization. Findings show that the key driving factor of CO_2 emission is different at different stage of industrialization. At early stage of industrialization where the economy is principally agriculture dominant, the GDP growth tend to be the key driving force of CO_2 emission, while at the middle stage where the economy is characterized by manufacturing and services, industry and energy intensity are both the key driving forces of CO_2 emission and at the highly stage where the economy is dominated by the service sector, Energy intensity is the key driving factor of CO_2 emission. To reduce CO_2 emissions in industrialization is to internalize advanced technologies into industrial transformation and energy intensity enhancement which form joint forces to make economic growth much cleaner.

KEYWORDS

Industrialization; CO_2 Emissions; Key driving factors; GDP per capita; Industry; Energy intensity.

INTRODUCTION

The greenhouse gases emitted in the atmosphere is no doubt responsible of the global warming that lead to climate change actually. 72% of the totally emitted greenhouse gases are carbon dioxide (CO_2), 18% Methane and 9% Nitrous oxide (NOx). CO_2 emissions therefore are the most important cause of global warming. This leads to the necessity of measuring the carbon dioxide in each country around the world and challenges humans to study what causes CO_2 emissions and what's relation with human activities.

Ehrlich and Holdren[1] have introduced the IPAT model in early 1970s by saying that the environmental impact is due to three endogenous factors: population, Affluence (per capita consumption or production) and Technology (impact per unit of consumption or production). The IPAT specifies that environmental impacts are the multiplicative product of three key driving forces: Population, affluence (per capita consumption or production) and technology, mathematically expressed as *(1)* (R. York et al., 2003[2]). Then the model has been transformed into ImPACT by Waggoner and Ausubel by adding C as consumption per unit of GDP. At the end Dietz and Rosa[3] in 2007 reformulated IPAT into a stochastic model as showed below which is called the STIRPAT:

$$I_i = aP_i^b A_i^c T_i^d e_i \qquad (1)$$

Since then, as showed in table 1, findings and discussions among researchers and scholars varies across variables used for each respective study and different approach of data analysis (time series data, panel data, cross-country…). Some results show a positive impact of the population size to the carbon emission in the atmosphere (York et al.2003[4], Cole and Neumayer 2004[5]). Hamilton and Turton [6](2002) conclude that income per capita and population growth are the main factors leading to CO_2 emissions in the OECD countries. Shi[7] (2003) in his research conclude that there is variation of the impact of population on CO_2 emission according to the level of affluence of the country and it is more pronounced in low income countries (Shi[7]. 2003). Similarly Fan et al[8]. (2006) says that there is a negative impact of population in high-income countries, and they call it "subjective awareness".

Table 1: Variables used in some previous researches

Authors	Variables
Anqing Shi 2001	CO_2 converted into carbon, Populations, real GDP per capita, Energy efficiency of economic activities is captured by a ratio of real GDP in 1995 US dollar to commercial energy use.
B.Liddle 2012	GDP, Energy consumption, Population/labor force , capital stock
Dietz and Rosa 2007	Population, Gross domestic product per capita, GDP not in service sector, urban population (%), population aged over 15 (%), land area, temperature…
Fan et al. 2006	CO_2 emissions, GDP per capita, Population, Technology (Energy use per constant 1995 ppp$ GDP)
Huanan Li et al. 2011	Urban population, population aged 15-64 GDP per Capita, industrial structure (the share of the secondary industry output value over the total GDP), Population, Urbanization rate, Technology level (the economic output of per unit energy consumption), Energy consumption (fossil fuel consumption), CO_2 emissions
Junsong Jia et al. 2009	Population (P), Affluences (GDP per Capita), Quadratic term of affluence (A2), Technology (denoted by the percent of the economy not in service sector or percent of the urban population, Ta1, Tb1), then Quadratic term of technology (Ta2, Tb2)
Richard York et al. 2003	CO_2, Energy footprint, Population, %population nondependent, GDP per capita, GDP per capita square, % GDP from industry, % urban, %urban squared, Tropical

In general, STIRPAT variables are stock variable or stock-related variables and thus are likely non-stationary (B. liddle[9] 2012) and the model suffer from autocorrelation. To remedy this problem some researchers tried adopt some technic like partial least square, Ridge regression, first differentiation and co-integration test, panel fully modified OLS (B. liddle[9] 2012) etc.

In this study we assess the driving factors of CO_2 emissions in 3 different typical countries: China, The United states and Madagascar, which are in different stages of industrialization in order to know if the key driving factors that lead to CO_2 emission have the same influence across the different stage of industrialization. Here is supposed that at the early stage of industrialization the economy of a typical country is contributed mainly by agriculture industry. At the middle stage, the country's economy is typically based on manufacturing industries domination while at the highly stage of industrialization the country's economy is largely dominated by services. We use the same variables used in STIRPAT model: CO_2 emission per capita as impact, Populations (in million), Affluence represented by the GDP per capita using purchasing power parity, Energy intensity per unit of the GDP and industry value added to the GDP are representing the Technology factor. And we use the Dynamic OLS (DOLS) technique to assess the coefficient of elasticity, which is new in the domain of the STIRPAT.

METHODOLOGY

We follow the modifications done by Fan et al[8]. (2006) by modifying the stochastic functions [Equation (1)] into a log-log linear equation:

$$\log(I) = a + b\log(P) + c\log(A) + d\log(T) + e \qquad (2)$$

Where I represent per capita CO_2 emissions from the Consumption of Energy (Metric Tons of CO_2 per Person), P the populations size in million, A affluences represented here by the per capita Gross domestic product based on purchasing-power-parity (PPP) and T as Technology. Concerning the coefficients *a* is a constant that scales the model, *b*, *c* and *d* are respectively the elasticity coefficient of P, A and T.

Dietz and Rosa[10] (1994) have disaggregated T by introducing additional factors in the STIRPAT model that are theorized to influence the impact per unit of production (York and Rosa[4] 2003). In this study we have disaggregate T into two variables: Industry value added to the GDP in percentage (It comprises value added in mining, manufacturing, construction, electricity, water, and gas) and energy intensity measured in Total Primary Energy Consumption per Dollar of GDP (Btu per Year 2005 U.S. Dollars). Here these two variables (industry and energy intensity) are chosen in order to know which one affect more the emission of CO_2, and they are not highly auto correlated in the long run but should be correlated with the GDP. In other hand, the relationship allows us to evaluate the energy efficiency in the concerned country. If the contribution of the industry to the GDP is high but the energy intensity is low, we conclude that there is high energy efficiency. Those precedent arguments led us to form the following equation:

$$\log(I) = a + b\log(P) + c\log(A) + d\log(Ind) + f\log(EI) + e \qquad (3)$$

Where *Ind* and *EI* are representing the Industry contribution to the GDP and the Energy intensity respectively and d and f are their respective coefficient.

ECONOMETRIC ESTIMATIONS

The objective in this study is to estimate the effect of those anthropogenic forces (population, GDP, and technology) on emission of CO_2. As stochastic model, the STIRPAT can be used for two purposes: predicting environmental impacts based on key driving forces and estimating causal effects represented by coefficients in the STIRPAT model (T.Wei[11]. 2011). In that case, depending on papers' objectives those who aim to predict the variations of the impacts can adopt econometric method of Partial Least Square (PLS) regression or ridge regression (Hoerl and Kennard, 1970). (T.Wei[11].2011). As the stochastic form of the STIRPAT is transformed into natural logarithm to evaluate the equation, coefficients of the driving factors represent elasticity. To estimate the model, one can adopt panel unit root test in case of panel data, cross-section in a single year (R.York et al[2]. 2003), and method of first differentiation and lately B.Liddle[9] adopted the model of Fully Modified OLS (FMOLS).

The method of Dynamic OLS (DOLS) is a technique similar to FMOLS. DOLS and FMOLS are designed to tests time-series data and also have been expanded to cover panel data sets. DOLS technique is used for the original purpose of assessing time series data, for the following reasons: First, the simplicity of the method; second, it takes accounts all problems of residuals, and long run serial correlation among variables. Then, DOLS method is preferred and more accurate than OLS and FMOLS. Chihwa Kao and Min-Hsien Chang[12] (2000) in their research conclude that the Monte Carlo experiment results illustrate the sampling behavior of the proposed estimators and show that (1) the OLS estimator has a non-negligible bias in finite samples, (2) the FMOLS estimator does not improve the OLS estimator in general and (3) the DOLS outperforms both the OLS and FMOLS estimators. And so the method of DOLS is used in this study to estimate the coefficient.

Hypothesis

Based on the equation (3), all the focus depends on the sign of *b*, *c*, *d* and *f* which are the coefficient of elasticity of the Population, affluence (GDP per capita), Industry and Energy intensity. Table 2 below summarizes the entire alternative hypothesis:

Table 2: Coefficients sign and alternative hypothesis

Coefficient	Hypothesis
Coef.=1	The explanatory variable is unit elastic to the impact, holding other things constant
Coef>1	Suggest an elastic relationship, i.e. a change in one unit of the variable, holding everything else constant, will lead to an increase more than one percent into the explained variable.
0<Coef<1	Indicates that the relationship between the explanatory variable and the explained variable is inelastic.
Coef.= -1	Indicates a unit negative elasticity between the impact and the driving force.
Coef.<-1	Indicates a negative elasticity
Coef.>-1	Indicates a negative inelasticity between the impact and the driving force or explanatory variable.

EMPIRICAL TEST

Madagascar, China and the United States are selected as sample countries in this study which are at the different stage of industrialization. Madagascar, classified as developing country by the World Bank, is a typical country in early stage of industrialization, within a population at 80% living in farming and agriculture. China is the perfect typical country to representing a middle stage of industrialization in general. Sifting actually into services domination (46.1% of the GDP in 2013 versus 43% for industry) Chinese economy is characterized by heavy manufacturing and industry over the past 3 decades. Still classified as developing country since China's industries take an important place to the contribution to the GDP and over the past three decades the contribution to the GDP was above 40% (World Bank data. 2013). Concerning the US is the highly industrialized country with an economy largely dominated by service sector where the contribution to the GDP is 79.3% in 2013 (World Bank data 2013 est.). From these three typical countries we think it necessary to assess which is the key driving factor contributing to the CO_2 emissions and how they varies across the different stage of industrialization.

All the data for a period of 30 years, from 1980 to 2010, used below in this study, were sourced from: INSTAT Madagascar, US Energy Information Administration, and International Monetary Fund-2011 World Economic Outlook, and the World Bank data website.

The Dynamic OLS estimation for variables of equation (3) is represented in table 3 bellow and is freed from residual problems.

Table 3: Dynamic OLS regression result (1980-2010)

Variables	**Madagascar**		**China**		**US**	
	Coefficient	**Std. Error**	**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**
LOGP	**-2.468970**	**0.743632**	**-4.285538**	**1.996497**	**-0.824044**	**0.348266**
LOGA	**3.817954**	**1.251423**	**1.157676**	**0.107344**	**1.280338**	**0.049561**
LOGIND	**-0.615926**	**0.348782**	**1.325155**	**0.520987**	**-0.565896**	**0.050652**
LOGEI	**1.625488**	**0.251852**	**1.328286**	**0.267628**	**2.909621**	**0.187725**
C	**-31.48891**	**6.910829**	**5.755526**	**16.21180**	**-30.09754**	**3.539657**
R-squared	**0.952530**		**0.998670**		**0.996578**	
Adjusted R-squared	**0.794295**		**0.994235**		**0.985172**	
S.E. of regression	**0.093377**		**0.028472**		**0.004028**	

First, the R^2 are both very significant for the countries 95% for Madagascar and 99% for China and the US. These assure that the CO_2 emissions in both countries are explained by the used variables. Concerning variables' significance, the t-test result (ref. to appendix) shows that the following factors are not significant, in consequence it is relied on because the interpretation is not be reliable: Variable industry for Madagascar (t-test p value = 12.78% > 5%), Population for both US and China which have respectively a p value of 5.58% and 7.55%.

RESULT AND DISCUSSION

Madagascar

There is a negative inelasticity between population and CO_2 emission in Madagascar (b = -2.46> -1). The main driving force of CO_2 emission there is GDP per capita within a coefficient c = 3.8 which is alarming because an increase of 1 unit of the GDP will lead to 3.8% unit of the CO_2 emission. This could be due to the fact that increase in the GDP could be a response of increase in the industry sector. Also a rise in the GDP per capita implies that households' consumption in energy will increase principally the demand of firewood, which is principal source of energy in Madagascar covering 92% of the demand in energy (WWF report September 2012)[13]. In addition to that the energy intensity coefficient is also positive $f = 1.6$ meaning that holding other variable constant an increase of 1 unit of the Energy intensity leads to an increase of 1.6% of CO_2 emission. From these we can assume the necessity of finding an alternative source of energy than firewood.

China

As we mentioned above the factor of population is not significant after t-test so we cannot draw conclusion from it. But the result for other variables shows that industry and energy intensity coefficients of elasticity are the same, $d = f = 1.32$. This means that CO_2 emissions response to industry and energy intensity is the same in China. In other words, an increase of 1 unit of the energy consumption leads to an increase of 1.32% in CO_2 emission, which is the same for industry. There is also a positive elasticity relationship between GDP and CO_2 emission. Coefficient c = 1.15 indicates a variation of 1.15% of CO_2 emission in response of 1 unit increase in GDP.

The United States

For the US the most driving factor of CO_2 emissions is the energy intensity, within a value of 2.9. CO_2 emission's response to one unit increase in energy intensity is quite high. The dependency of the fossil fuel could be one of the reasons explaining it. Also as mentioned by Shi (2001) in previous research that country located geographically in the north hemisphere need more heating and consume more energy for that. In another hand result indicate a negative elasticity relationship between industry and CO_2 emission. With $d = -0.56$ means that CO_2 emissions decrease in greater proportion to an increase in the industry. This demonstrates higher energy efficiency in the US and the result of CO_2 emissions policy implemented by the government to firms and companies. In other words, their industry is able to produce more with a controlled amount of energy. But we have to take account that most of US firms possess some branches outside the country that make some semi-final product and make the final product in the US. At the end there is a positive elasticity relationship between the GDP and CO_2 emission. A positive variation of one unit of the GDP leads to 1.28% of emission.

CONCLUSION

With the STIRPAT model and Dynamic OLS technique to assess the driving forces leading to CO_2 emission in Madagascar, China and the United States, three typical countries within different stage of industrialization. Findings show that the key driving factor of CO_2 emission is different at different stage of industrialization with differential evolution from early stage to middle stage to highly stage of industrialization. For a country at early stage of industrialization where the economy is principally agriculture dominant, economic growth tend to be the key driving force of CO_2 emission. For a country at the middle stage of industrialization where the economy is characterized by manufacturing and services, industry and energy intensity are both the key driving forces of CO_2 emission. For a developed country in the highly stage of industrialization where the economy is dominated by the service sector, Energy intensity is the key driving factor of CO_2 emission. It is highly relevant between the stages evolution of industrialization and CO_2 emission based on the driving force of technology which is called the key endogenous variable affecting economic growth and social progress. With the development of technology advance and use in production, the advanced technology is decomposed into industry developing and energy efficiency enhancement to promote the economic growth in the evolution stage by stage of industrialization. The key driving forces to reduce CO_2 emissions is to internalize advanced technologies into industrial transformation and new energy exploitation and development which form joint forces to make economic growth much cleaner.

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