POPULATION, AFFLUENCE, OR TECHNOLOGY? DETERMINANTS OF ANTHROPOGENIC EMISSIONS ACROSS INCOME GROUPS

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Overview

In the 1970s, Ehrlich and Holdren (1971) summarized the major driving forces of human activites (I) on the environment as a product of population (P), affluence (A), and technology (T). Accordingly, population and income growth as well as technological progress significanty impact the human-environment relationship simultaneously. During the 1990s, the IPAT identity was redefined by Kaya (1990) as an equation that relates to the driving forces of anthropogenic carbon dioxide emissions. Both concepts (IPAT and Kaya-identity) are used by the Intergovernmental Panel on Climate Change (IPCC) as an accounting identity to analyse energy-related carbon dioxide emissions. Dietz and Rosa (1994), translated the IPAT identity into the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model which is represented by the following equation:

$$I_i=\alpha P_i^b A_i^c T_i^d e_i$$

Converting all variables into logarithm results in an additive linear model, which can be tested empirically. The estimated coefficients represent the ecological elasticity of each impact factor and e_i is the error term (York et al., 2003). Against this background, the aim of this paper is to empirically identify the driving forces of anthropogenic carbon dioxide (CO_2) and greenhouse gas (GHG) emissions based on the STIRPAT model by comparing both the estimated short- and long-term dynamics. While most studies use carbon dioxide emissions stemming from the burning of fossil fuels and the manufacture of cement only, this paper uses both, CO_2 emissions as well as total greenhouse gas emissions as environmental impact. The latter measure includes the CO_2 total, other biomass burning (such as forest fires, post-burn decay, peat fires and decay of drained peatlands), and all anthropogenic CH_4 sources, NO_2 sources and F-gases (HFCs, PFCs and SF6). The analysis will be conducted at an aggregate level and includes as many countries as possible clustered into income based panels as well as a global panel for the longest period available. The empirical results help to understand the contribution of each anthropogenic impact factor on a measure for carbon dioxide and total greenhouse gas emissions in any income group. Thus, policy measures to reduce emissions can be aligned to different stages of economic development.

Methodology

This paper investigates the driving forces of anthropogenic greenhouse gas and carbon dioxide emissions by comparing both the estimated short- and long-term dynamics using data from the World Bank Development Indicators. The logarithmic baseline STIRPAT model to obtain the ecological elasticity of each impact factor is specified as follows:

$$\ln(\text{Environmental Impact}_{it})=\alpha_i+b_{it}\ln(\text{Population})+c_{it}\ln(\text{GDP/Population})+d_{it}\ln(\text{GDP/energy consumption})+e_{it}$$

We decompose population by incorporating the share of the population living in urban areas (Urban) and controls for the demographic structure by including the share of population aged 65 and above (Pop65) in total population. Technology is approximated by a measure of energy efficiency defined as GPD per unit of energy. By conducting the analysis at an aggregate level, the addition of the cross-section dimension to the time series dimension combines the method of dealing with nonstationary time series data with the increased data and power from the cross-section (Baltagi and Kao, 2000). To further improve the quality of the empirical results, this paper is using recently developed second-generation panel data methods which account for cross-sectional dependence. Thus, before estimating the STIRPAT model, testing for cross-section dependence (CD) (Pesaran, 2004) to test for the presence of cross-sectional dependence is necessary. Next, using the Pesaran (2007) CIPS second generation panel unit root test determines the order of integration of the variables. This paper uses a panel autoregressive distributed lag (ARDL) model developed by Pesaran et al. (1999) to compare the estimated short- and long-term relationships for both total greenhouse gas emissions and CO_2 emissions, population, affluence, and technology. With this approach it is possible to estimate the short- and long-term dynamics irrespective of the order of integration of the variables for population, affluence, and technology. Only the dependent variables are restricted to be integrated of order one. The pooled mean group (PMG) estimator by Pesaran et al. (1999) is used to obtain the coefficients.

Preliminary results

The table below reports the results of the pooled mean group (PMG) estimation:

		High-income		Middle-income		Lower-income	
		GHG	**CO_2**	**GHG**	**CO_2**	**GHG**	**CO_2**
Long-run coefficients	**P=Pop**	0.6779***	0.5018*	0.5873***	0.5153***	0.9600***	1.1972***
	Pop65	0.1404**	0.4155***	-0.1811	-0.0852	-0.4141***	-0.7398***
	Urban	-0.8316***	-0.9394**	0.5008**	0.4560**	-.4507**	-0.3129*
	A=GDP	0.8873***	-0.0057	0.6204***	1.1550***	0.6858***	0.9401***
	T=EE	-1.2770***	0.0820	-0.6047***	-1.2902***	-0.3668***	-0.4671***
	Error Corr.	-0.4383***	-0.1569***	-0.7097***	-0.6589***	-0.8138***	-0.5425***
Short-run coefficients	**ΔP=Population**	-1.4378	0.2231	-12.1601	-10.2422	-10.2606	-5.3289
	ΔPop65	0.0445	0.3240	5.5455	-0.3209	-2.9922	1.3373
	ΔUrban	47.8885	-6.7694	3.3303	3.4018	-53.6608	-27.5608
	ΔA=GDP	0.0659	0.9810***	0.2695	0.3030*	0.3208	1.1420***
	ΔT=EE	-0.0223	-1.0603***	-0.5946	-0.0861	-0.3852	-0.8986***
	Intercept	-1.1250***	0.9119***	-2.9089***	-4.5420***	-5.4816***	-7.8759***

Notes: *,**, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

The long-run results show that the influence of population on both GHG and CO_2 emissions is the highest for the lower-income panel. The effect of population differs only slightly between the high- and middle-income panels for both measures of environmental impacts. Increasing affluence is associated with higher GHG (CO_2) emissions for every income group but the most for the high (middle) income panel. The reduction in GHG as well as CO_2 emissions caused by improvements in energy efficiency is the lowest (highest) for the lower (high) income panel. Moreover, a higher degree of urbanization decreases both GHG and CO_2 emissions for the high,- and lower-income panel only. Interestingly, the higher the share of the population ages 65 and above in the total population, the higher are GHG and CO_2 emissions on average in high income economies only. The short-run resulst indicate, that only improvements in energy efficiency significantly reduce GHG and CO_2 emissions.

Preliminary conclusions

The current preliminary empirical results significantly indicate varying impacts of population, affluence, and technology on both GHG and CO_2 emissions at different income levels but also between the short- and long-run. As affluence significantly increases both measures of environmental impacts, policies supporting sustainable and green growth need to be implemented globally. Especially for low income countries, improvments in energy efficiency could help to stabilize GHG and CO_2 emissions in those countries. As the world population will continue growing in the near future and against the background of significantly increasing GHG and CO_2 emissions caused by population growth, the GHG and CO_2 emissions reduction potential for affluence and energy efficiency is of particular importance to tackle climate change. Moreover, improvements in energy efficiency are the most readily available means in order to reduce GHG and CO_2 emissions in any income group in the short-run.

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