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PEER REVIEWED ARTICLE

Measuring net environmental impact from population growth and alternative energy

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Abstract

Existing research on the relationship between economic growth and environmental impact has produced mixed results. Also, there has been a lack of attention on the effect of population, and per capita measures are used rather than total pollution. To address this gap, we analyze the role of population and alternative energy on the environment using total carbon dioxide emissions (CO_2) in the United States. We propose a new model integrating population demographics into the Environmental Kuznets Curve, and then apply this framework to an empirical analysis. The effect of population and immigration on total CO_2 is estimated, as well as the level of alternative energy use required to overcome increasing environmental pressure. Results suggest population and immigration growth may lead to an increase in total CO_2 growth, but alternative energy may lower total CO_2 growth after a threshold. Further, immigration and total CO_2 growth exhibit a nonlinear relationship.

JEL: Q56; Q53; O13

Keywords: environmental forecasting; environmental impact; green economics; population growth; renewable energy.

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1. Introduction

The impact of population on environmental degradation is a comparatively underexplored causal link in environmental economics. There is also an emphasis on per capita pollution rather than total pollution e.g., carbon dioxide emissions (CO_2). We have two main objectives in this note: (1) to propose a new model wherein the Demographic Transition Model (DTM)[2] and net migration, in conjunction with the I=PAT equation[3], are incorporated into the Environmental Kuznets Curve (EKC), and (2) to investigate the effect of population, immigration and technology on the environment through an empirical analysis of total CO_2 in the United States (US).

The link between population and environmental degradation has been discussed as far back as Malthus (1798).[4] More recently, Ehrlich and Holdren (1971) introduced the concept of the I=PAT equation to measure the environmental impact of economic activity in relation to population, affluence, and technology.[5] Ehrlich and Holdren (1971) argue that pressure from population growth has a disproportionate effect on environmental degradation. Because of the expected rise in population globally and the resulting pressure on resources via demand/supply factors (e.g., Baldwin, 1995), along with flows of migration becoming the main source of population growth in the near future (Vespa, Armstrong, and Medina, 2018), looking at population in the context of environmental degradation is relevant.

2 The Demographic Transition Model explains the shift in population structure during five phases: high death rates/high birth rates; falling death rates/high birth rates; low death rates/falling birth rates; low death rates/low birth rates; low death rates/stable birth rates near the replacement rate (Roser, 2017).

3 I=PAT stands for Environmental Impact = Population X Affluence X Technology.

4 Other early contributions include David Ricardo's theory on land rent, Arthur Pigou's work on tax policy to improve resource allocation, and Nicolas de Condorcet's proposal that air pollution was a negative externality from economic activity (Sandmo 2015).

5 Perhaps the most robust application of the I=PAT equation is the extended formulation by Dietz, Rosa, and York (2003) known as the STIRPAT project. The STIRPAT project assessed environmental impact with the I=PAT equation, using stochastic estimation through regression analysis, while converting the variables to natural logarithms and placing T as an error term (by arguing there is not an appropriately agreed-upon measurement for this variable) (Dietz, Rosa, and York, 2003). The study concluded that modernization leads to an overall negative impact on environmental degradation, with no evidence to support the widely held belief that economic growth eventually leads to declining environmental impact, such as predicted by the EKC (Dietz, Rosa, and York, 2003).

A second widely-used approach to capture the link between environmental degradation and economic activity is the EKC (Carson, 2010). The EKC was developed based on the theory concerning the relationship between increasing wealth in an economy and the corresponding environmental degradation of the ecosystem (Stern, 2003). There is a large body of empirical work regarding the EKC, yet no general consensus exists and few papers incorporate demographic factors into their analyses.[6] Given the lack of consensus and growing importance of population on environmental degradation, exploring the role of population and migration in the context of the EKC is pertinent for the formulation of policy.

Our contribution is at the intersection of two branches of the literature. First, demographic factors are often overlooked when analyzing possible environmental impacts (e.g., Curran and Sherbinin 2004). However, there has been some recent research incorporating demographic variables to better understand the relation between population and the environment (e.g., Galeotti et al., 2011; Franklin and Ruth, 2012; Roser, 2017). Our work is closest to Galeotti et al. (2011) where they consider the demographic transition in a sample of countries and find evidence for an "enriched" EKC.[7] We build on the work of Galeotti et al. (2011) in three ways. First, we examine the role of immigration in explaining total CO_2 by estimating changes in total population arising specifically from immigration and arguing that immigration may exert an upward pressure on CO_2 growth. Second, we complement Galeotti et al. by developing a model which incorporates the DTM into the EKC. Third, we show that the relationship between immigration and the rate of the growth of total CO_2 is nonlinear, an analysis not present in Galeotti et al (2011), but with important implications for policy formulation.

Our second contribution to the literature rests on what has been a lack of attention to total CO_2, an important area specifically absent from the EKC literature but with important policy implications (e.g., determination of carbon budgeting and

6 e.g., Atasoy, 2017; Carson et al., 1997; Franklin and Ruth, 2012; Grossman and Krueger 1995; Holt-et al., 1992; List and Gallet, 1999; Meadows et al. 1972; Mitchell 2012; Rupasingha et al., 2004; Shafik and Bandyopadhya 1992; York et al., 2003.

7 Baldwin (1995) points to the implications arising from demographic factors and argues that in order to reach environmental sustainability the majority of the world must move past the second phase of the demographic transition, while moving as quickly as possible through the ecological transition. Galeotti et al. (2011) builds on Baldwin (1995) using CO2 data for 17 Organisation for Economic Co-operation and Development (OECD) countries.

pricing policies). An issue with past analyses is the almost universal use of per capita emissions as the measure of pollution. Our main concern is the lack of attention to total CO_2, since an increasing population may produce higher total CO_2 even as CO_2 per capita declines.[8] However, this is not to dismiss using per capita measures altogether. For example, Jones and Warner (2016) used per capita measures to derive projections for future energy demands and CO_2 trajectories.

We also examine the role of alternative energy (defined as energy that does not produce carbon dioxide, including hydropower, geothermal, nuclear, wind, and solar power, among others) in the population-environmental degradation nexus and estimate a threshold level of alternative energy after which total CO_2 may fall. This is particularly important since alternative energy sources have increased in recent years (U.S. Energy Information Administration, 2019) and so identifying such a threshold can guide policy formulation.

Our contribution also extends to the role of the DTM in the EKC by extending demographic transition factors into the EKC and testing some of the results using US data. Even though the US does not necessarily face over-population issues vis-à-vis low-income countries, the US is considered as a case study because it has arguably experienced all the phases present in the DTM and at the same time the full range of income levels proposed in the EKC. An important consideration, absent from the DTM, is concern for levels of net migration. Any shift in lifestyle, related to ecological footprint, as migrants shift into high-income countries may be relevant. Our results suggest that immigration may play a role in explaining total CO_2 growth. Additionally, the literature suggests that the level of renewable energy usage and energy consumption patterns in the economy are responsible for any possible mitigation of pollution (e.g., Dogan and Ozturk, 2017; Soytas, Sari, and Ewing, 2007) and therefore we explore the role of alternative energy and migration on total CO_2 growth in the case of the US.

The literature on the demographic transition argues that such transition is driven by an increase in urbanization and industrialization, with potentially negative effects on the environment. These effects range from the population age structure and its implications on the demand for goods and services, to

8 A notable exception is Franklin and Ruth (2012), who argued that although CO2 per capita has leveled out in recent years, total CO2 continues to increase.

migration patterns (Franklin and Ruth, 2012; United Nations, 2015). O'Neil et al. (2012) consider demographic changes with regard to CO_2 by considering various household characteristics such as age, size, and urban/rural data. O'Neill et al. (2012) concluded aging populations have a lower overall environmental impact in comparison to younger populations as a result of labor productivity. Also, urbanization can lead to an increase in projected CO_2 (O'Neil et al., 2012; Weber and Sciubba, 2016). Conversely, Zhou and Liu (2016) argued urbanization led to decreased levels of CO_2 in China. Still, both Zhou and Liu (2016) and O'Neill et al. (2012) found urbanization to decrease overall energy use. Although results in the literature vary, all found population growth to have a significant impact on CO_2. And although our results are consistent with the literature, our contribution relies on the study of immigration and its impact on the environment.

The literature also examines the rebound effect (e.g., Franklin and Ruth 2012; Sorrell, Gatersleben, and Druckman, 2020; Madlener and Alcott, 2009; Baldini and Jacobsen, 2016).[9] The rebound effect, in which energy consumption increases as technology improves efficiency, is estimated to be anywhere from 0% to 50% (Madlener and Alcott, 2009). However, Gilligan, Rapson, and Wagner (2016) make the case that even though rebound effects exist, the overall gains from implementing energy-efficient policy outweigh these effects. This result is consistent with our estimates, but our analysis focuses on total CO_2 rather than per capita.

The structure of this paper is as follows. Section two describes the US energy mix and population structure. Sections three and four, respectively, introduce a hypothesized model and describe the data. Sections five, six, and seven explain the benchmark model, present an empirical analysis, and describe the robustness check, respectively. Section eight concludes with a few remarks on policy implications, limitations of the analysis, and future lines of research.

2. The US energy mix and population structure

The energy mix in the US is an important consideration since CO_2 is directly tied to the type of energy consumed. Currently, the US uses a mixture of energy technologies including natural gas, crude oil, coal, nuclear, natural gas

9 Rebound effects were first hypothesized by Jevons (1866) regarding improvements in the efficiency of coal use in steam engines leading to their expansion.

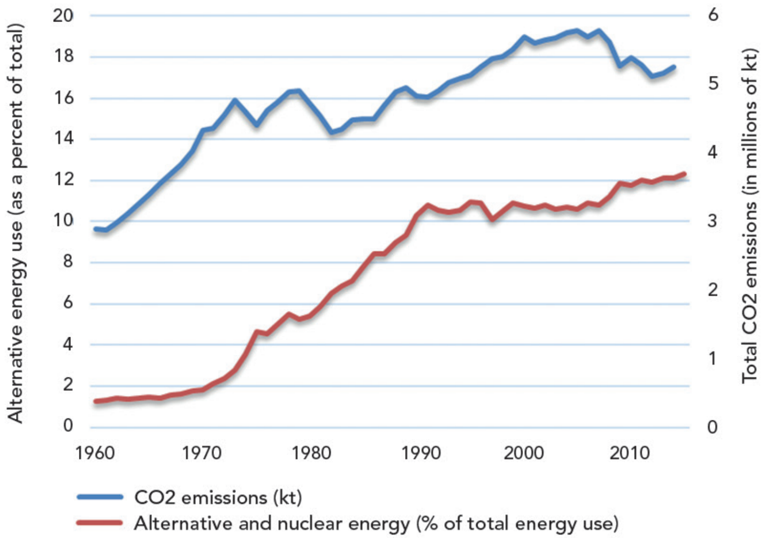
plant liquids, biomass, hydroelectric, solar, wind, and geothermal. Of these, petroleum comprises the largest share of total energy consumption, while natural gas makes up the largest share when considering energy for electricity generation (U.S. Energy Information Administration, 2019; BP Statistical Review, 2019). Renewables such as hydroelectric, solar, wind, and geothermal comprise the lowest four energy sources in terms of percentages, although their use has continued to increase in recent years (U.S. Energy Information Administration, 2019). Nuclear energy increased each year from 1960 to 1990 but has leveled off since 2000 (U.S. Energy Information Administration, 2019). The amount of coal used for energy production has been on a steady decline, while the use of natural gas and crude oil has been increasing (U.S. Energy Information Administration, 2019; BP Statistical Review, 2019).

Since our analysis focuses on alternative energy as a measure of technological advancement, we pay particular attention to its usage. It should be noted that alternative energy use can be broken into two distinct periods, 1960–1990 and 1990–2016, where different energy technologies played key roles in total CO_2. Specifically, the increase in nuclear energy use was prevalent for the 1960–1990 period, whereas increases in renewable energy (e.g., solar, wind, geothermal) were significant for the 1990–2016 period (see figure 1).[10]

In terms of policy, Jacobson et al. (2017) argue that 139 countries across the world can achieve 80% conversion to zero-emitting energy, defined as energy from wind, water, and sunlight (WWS), by 2030, and 100% zero-emitting energy by 2050. More specifically, Jacobson (2015) made the same case for each state in the US. Considering that the level of alternative energy use in the US was only approximately 12.3% as of 2015 (World Bank, 2018), Clark et al. (2017) warned policymakers to remain cautious over plans which call for the use of WWS exclusively and, instead, recommended a more balanced approach, which includes a range of energy technologies in the economy.

10 The models presented in this paper were also formulated with nuclear and renewable energy as separate variables during these two time periods, each being statistically significant for each respective period.

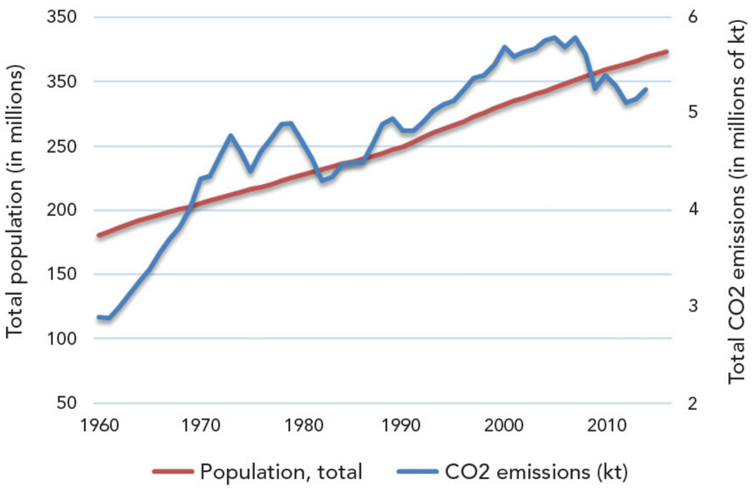
Figure 1 – United States Alternative Energy Use and Total CO2 Emissions



Although the US had a 11.5% increase in natural gas production in 2018, the use of non-hydro renewable energy grew by 9.8% and coal production fell by 1.9% (BP Statistical Review, 2019). Carbon emissions grew by 2.8%, while carbon intensity continued declining at a rate of 0.9% (BP Statistical Review, 2019). Further, energy consumption grew by 3.5% (BP Statistical Review, 2019). These figures suggest that the US is seeing improvements in the use of renewable energy, but as the demand for energy increases natural gas and coal remain as the primary sources of energy for electricity generation.

Galeotti et al. (2011) argue that for long-term environmental sustainability, both economic growth and policy for lowering population are needed. The increased global total CO_2 resulting from cross-country migration is a major concern (Cafaro and Staples, 2009). At the same time Cafaro and Götmark (2019) show, in the case of the European Union, that minor changes in annual net migration can lead to large changes in future population. And in the case of the US, immigration has become the main driver of population growth (Cafaro and Staples, 2009). Although fertility rates in the US are below the replacement rate of 2.1 births per woman, the increase from positive net migration has a larger impact on population than this decline in fertility (figure 2) (World Bank, 2018). Therefore, the US population is projected to increase for the foreseeable future. The implication is that even if CO_2 per capita is declining a net increase in total CO_2 may be expected as each additional person contributes to the sum.

Figure 2 – United States Population and Total CO2 Emissions



3. A Model

Figure 3 illustrates an overview of the relationship between the demographic transition and the I=PAT equation from the standard theory, factoring in net migration levels (positive for the US). The arrows in front of the variable signal the effect on environmental impact, I, not the rate of increase in the variable itself. For example, an increase in technology, T, has an upward pressure on environmental impact, I, during phase one of the demographic transition, but an increase in technology, T, has downward pressure on environmental impact, I, during phase three of the transition process.

Figure 3 – PAT Equation & DTM Integration

$$I = \text{PAT Equation \& DTM Integration}$$

with positive net migration in phase 3-5

$$\text{Phase 1:} \quad \uparrow I = P \uparrow AT$$

$$\text{Phase 2:} \quad \uparrow I = \uparrow P \uparrow AT$$

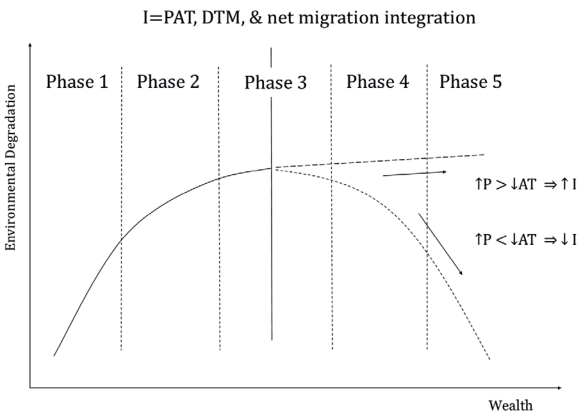
$$\text{Phase 3-5:} \quad I = PAT$$

$$\text{if } \uparrow P > \downarrow AT \Rightarrow \uparrow I$$

$$\text{if } \uparrow P < \downarrow AT \Rightarrow \downarrow I$$

Figure 4 presents a preliminary integration of the I=PAT equation and DTM into the EKC, including net migration. This model illustrates environmental impact from population, affluence, and technology through the five stages of the demographic transition. A key point to this proposed model is the consideration of positive net migration as advanced economies have significantly larger levels of energy/goods consumption. Although the demographic transition will drive down population growth as an economy develops, and thus environmental impact, immigration may offset this decline as overall population in developed countries continues to grow. An empirical analysis of this hypothesis follows.

Figure 4 – Hypothesized EKC for Total Pollution



4. Data

Annual data for the US from years 1960-2016 was obtained from the World Bank. We use total CO_2 (total emissions in kt) as the measure of environmental impact, total population, and real GDP as a control to capture changes in economic activity. Time dummies were constructed to capture period-specific effects such as recessionary periods and global oil shocks. Alternative energy, as a percent of total energy use, is used as a measure for technological advancement to capture increasing technology in an economy while avoiding high correlation with population. As noted earlier, this will incorporate the effects of all near-zero-emissions energy use from 1960-2016.

In addition to population we look at the role of immigration. Even though there is total immigration data available for the US, we focus on cumulative immigration instead. The reason for this is threefold. First, total immigration is measured on an annual basis and thus represents a relatively small share of total population: the US population is over 326 million and approximately 41 million have immigrated since 1960, while total immigration has averaged 722 thousand annually (World Bank, 2018). As a result, any changes in CO_2 explained by immigration are likely to be offset by the variability explained by total population. Second, cumulative immigration is defined as immigration at time t, plus all previous immigration from 1960. Thus, cumulative immigration arguably captures the potential cumulative effects of immigration on CO_2 while accounting for changes in consumption behavior once migrants settle in the US. Third, net migration growth (net migration defined as either total population minus total immigration or total population minus total cumulative immigration) mirrors total population growth over time and exhibits a Pearson correlation coefficient of just over 0.92.

To test for stationarity we rely on Dickey-Fuller and Phillips-Perron tests, where total CO_2, total population, alternative energy and real GDP are I(1), whereas cumulative immigration is I(0).

5. Benchmark Model Specification

We estimate the following benchmark model in first differences using Ordinary Least Squares (OLS):

$$d(lnCO_2total_t) = \alpha + \beta_1 d(lnPOP_t) + \beta_2 d(lnALN_t) + \beta_3 Z + \epsilon_t \qquad (1)$$

where $d(\ln CO_2total_t)$ denotes the first-differenced natural log of total CO_2 (in kt) at time t, $d(\ln POP_t)$ first-differenced natural log of total population at time t, $d(\ln ALN_t)$ first-differenced natural log of alternative energy use at time t, and ε_t the residuals. We model residuals following an autoregressive-moving-average (ARMA) structure when applicable.[11] The term Z in (1) denotes a set of controls such as the one-period lagged first-differenced natural log of real *GDP* (constant 2010 USD), a linear time trend and time-specific dummies to capture, for example, recessionary periods in the US.

It is noteworthy that real GDP is arguably correlated with population and CO_2. As a result, alternative energy is used to avoid issues of correlation with population, but also the one-period lag for real GDP was used to avoid issues of endogeneity. In any case, Pearson correlation coefficients do not suggest a high degree of correlation between real GDP, alternative energy, total population and cumulative immigration.

6. Results

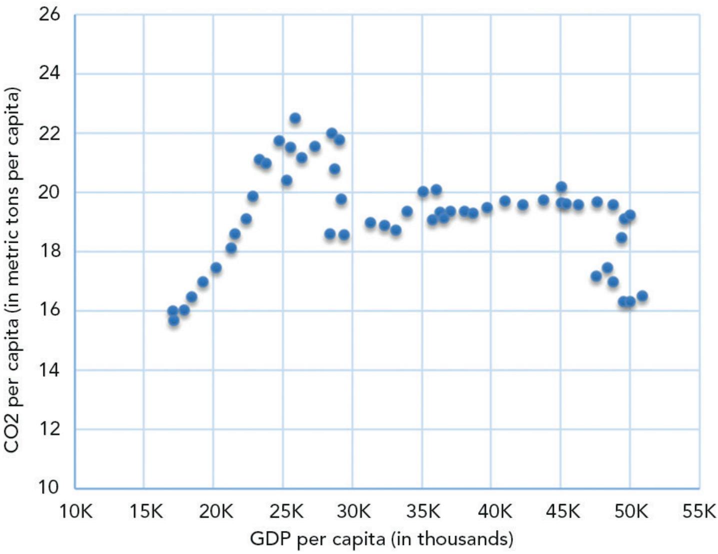
Estimation of (1) suggests that higher growth rates of population imply higher growth rates of total CO_2. The estimated coefficient, β_1, is positive and statistically significant, implying a 1 percentage point increase in the growth rate of population results in an approximately 1.92 percentage point increase in total CO_2 growth (see summary table in the appendix). The alternative energy coefficient, β_2, is negative and statistically significant, which implies that increasing the rate of growth of alternative energy use by 1 percentage point results in an approximately 0.15 percentage point decrease in total CO_2 growth. Estimates also suggest that the inclusion of alternative energy into the model may reduce the upward pressure population has on CO_2, thereby pointing to the key role of alternative energy in explaining variations in CO_2.

To explore the potential interaction between population and alternative energy, a second model specification is considered:

$$d(lnCO_2total_t) = \alpha + \beta_1 d(lnPOP_t) + \beta_2 d(lnALN_t) + \gamma_2 d(lnPOP_t) * d(lnALN_t) + \beta_3 Z + \epsilon_t \qquad (2)$$

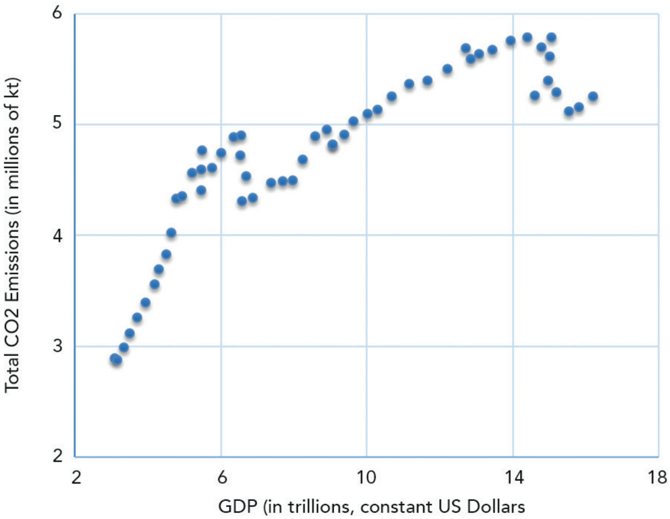
Estimation of (2) points to two important results. First, population may have a larger increasing effect (i.e. increase in the growth rate of CO_2) vis-à-vis the decreasing effect (i.e., decrease in the growth rate of CO_2) of alternative energy use on the growth rate of total CO_2. This indicates that although CO_2 per capita is in decline (figure 5), the effect of population can be larger so there is a net increase in total CO_2 (figure 6). This increase is consistent with our hypothesized EKC (figure 4). Second, the model suggests that the growth rate in the share of alternative energy required to achieve the turning point predicted in the EKC is approximately 23%.[12] As of 2015, the level of alternative energy use in the US was 12.3% (World Bank, 2018). This indicates that total CO_2 growth may continue rising until alternative energy use is expanded. It is noteworthy that we were also able to identify such a result for the 1990–2016 period, where the population growth rate in the US shows a clear downward trend, but also a fairly stable use of alternative energy, particularly in renewables.

Figure 5 – United States GDP per capita and CO2 per capita



12 The approximation for the level of alternative energy use required, as a percent of total, is obtained from $\beta1 + \gamma2ALNt$ in summary table, column 6.

Figure 6 – United States GDP and Total CO2 Emissions



A third model is estimated to analyze the effect of cumulative immigration on total CO_2:

$$d(lnCO_2total_t) = \alpha + \delta_1 lnCIMM_t + \delta_2 lnCIMM_t^2 + \beta_2 d(lnALN_t) + \beta_3 Z_t + \epsilon_t \qquad (3)$$

where $lnCIMM_t$ denotes the natural log of cumulative migration at time *t*. Results indicate (i) a nonlinear inverted-U relationship between cumulative immigration and the growth rate of total CO_2, and (ii) alternative energy, consistent with (1), puts a downward pressure on the growth rate of total CO_2. These results are important because immigration will become the main source of population growth by the year 2030 as the natural rise from population momentum begins to slow (Vespa et al., 2018).

The non-linear relationship between cumulative immigration and growth in total CO_2 growth indicates that the growth in cumulative migration can have an upward pressure on CO_2 if cumulative migration remains on average just under 1.5 million a year. Since this threshold has been exceeded, the analysis suggests that the growth rate of total CO_2 may likely slowdown via immigration.

7. Robustness Check

We employ a two-stage least squares estimation technique with the dual purpose of addressing potential issues of endogeneity between population and CO_2, but also account for variations in population arising specifically from immigration. Results from previous sections hold indicating that (i) population growth explained by growth in immigration may exert an upward pressure on total CO_2 growth, and (ii) there is an alternative energy use threshold level after which total CO_2 growth falls. The result in (i) suggests that variations in immigration play a role in explaining total CO_2 growth and thus should be kept in mind when formulating policy, albeit the effects on the level of total CO_2 are likely relatively small given the small share of immigration with respect to total population in the US.

The two-stage least squares estimation consists of first estimating population growth as follows:

$$d(lnPOP_t) = \alpha + \gamma_1 d(lnCIMM_{t-1}) + \gamma_2 d(lnIMM_{t-1}) + \gamma_3 \Delta + u_t \qquad (4)$$

where *d(lnIMM)* denotes the growth rate of immigration, and Δ a set time dummies and linear and non-linear time trends. The specification in (4) considers one-period time lags to avoid issues of endogeneity since total population incorporates immigration in its measurement. On the second stage, the estimated growth in total population obtained from (4), $d(\widehat{lnPOP_t})$, is used to re-estimate (1) and (2). Results are shown in the Appendix.

8. Conclusion and Policy Implications

After controlling for economy-wide and time-specific effects, estimates suggest evidence against an inverted-U EKC for total CO_2 growth in the US. Population growth increases total CO_2 growth, which may surpass the downward pressure from increased technology measured through alternative energy. This result indicates that although CO_2 per capita is in decline, the effect of population is greater, thus leading to a net increase in total CO_2. Results also point to a threshold level of alternative energy growth after which growth in total CO_2 may fall.

While we provide some evidence that total CO_2 is increasing as a result of population growth, there are areas which need further consideration. First, expanding the analysis to include the effect of population on pollution apart from CO_2 (e.g., NOx) would be an improvement, particularly if connections to the energy sector are sought. Second, broadening the analysis to include a range of countries in various stages of the demographic transition, while increasing the number of observations, would help in understanding the effect of population as an economy develops. Third, the analysis considers total CO_2, not total consumption-based CO_2. Thus, checking whether results hold using total consumption-based CO_2 would give a better sense as to whether immigration is having a significant effect on total CO_2. In this sense our results should be taken with caution.

While our research focuses on alternative energy sources, recent trends are moving away from nuclear energy and towards renewable energy sources. We should note that renewable energy use has increased, reaching record highs in 2019 (U.S. Energy Information Administration, 2019). Also, alternative energy was chosen for the measure of technology to avoid high correlation with population, but the relation to CO_2 should be noted. There is the concern that CO_2 affects the level of alternative energy in a country, which would need further investigation to rule out issues of endogeneity (i.e., is increasing renewable energy use driving down CO_2, or is increasing CO_2 causing faster implementation of renewable energy?). Exploring other measures of technology and comparing results would be worthwhile as robustness checks.

Improving our understanding of the impact of human population and economic growth on the environment is invaluable for policymakers. This is equally important for both economically advanced and developing regions. The ability to collectively lower our environmental impact in both advanced and developing economies is vital to the future of the planet. Implementing effective environmental and economic policies which can be strategically enacted for specific stages of development, to reduce overall environmental degradation while maintaining an acceptable standard of living, is crucial to this task.

Appendix – Regressions: Summary Table

Appendix – Regressions: Summary Table. Dependent variable d(lnCO_2total).

									TWO-STAGE LEAST SQUARES				
	1	2	3	4	5	6	7	8	9	10	11	12	13
constant	.03	.06	.08	.05	.06	.01	-3.70	7.20	.02	.06	.07	.05	-.003
	(2.33)*	(4.20)*	(6.7)*	(3.71)*	(8.52)*	(.50)	(-2.43)*	(1.56)	(1.76)	(3.59)*	(4.13)*	(3.01)*	(-.17)
dlnPOPt	1.92	.34	-.95	.80		3.22							
	(2.27)*	(.36)	(-1.14)	(.82)		(2.97)*							
dlnALNt		-.14	-.61		-.49					-.16	-.83		
		(-2.93)*	(-2.93)*		(-2.35)					(-2.99)*	(-3.01)*		
dlnPOPt* dlnALNt			39.53	-12.38	34.21								
			(1.92)**	(-2.76)*	(1.68)**								
dlnPOPt* ALNt						-.14							
						(-2.52)*							
dlnGDP(t-1)	.09	.003	-.04	-.001	-.04	-.004	.03	.15	.11	.03	.03	.03	.12
	(.48)	(.03)	(.62)	(-.001)	(-.35)	(-.04)	(.26)	(2.81)	(.84)	(.22)	(.26)	(.27)	(1.08)
lnCIMMt							.54	-.83					
							(2.48)*	(-1.52)					
lnCIMM²t							-.02	.02					
							(-2.47)*	(1.47)					
lnCIMMt* dlnALNt								-.23					
								(-5.21)*					
D79_82;D09;D12;D73;D01;D08;D70							YES						
D79_82;D90_91;D09;D97;D88;D12								YES					
D73;D70;D01													
$dln\widetilde{POP}t$									2.27	.46	-.84	.95	4.61
									(2.29)*	(.67)	(-.72)	(.82)	(2.77)*
$dln\widetilde{POP}t$* dlnALNt											63.47	-13.01	
											(2.44)*	(-2.53)*	
$dln\widetilde{POP}t$* ALNt													-.18
													(-1.84)**
D73_75; D79_82; D90_91; D09_11; D09	YES	YES							YES	YES			
D_79_82; D_90_91; D_09			YES										
D73_75; D79_82; D90_91; D09_11; D09; D12				YES							YES	YES	
D73_75; D79_82; D90_91; D09; D12					YES								YES
D73_75; D79_82; D90_91; D09; D08						YES							
Linear time trend	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
AR ; MA terms -residuals	1;2	1;2	1;2	1;2	1;2	1;2	NO	3;7	1;2	1;2	1;2	1;2	1;2
R^2	0.83	0.86	0.86	0.85	0.86	0.88	0.85	0.94	0.82	0.86	0.88	0.85	0.83
Durbin Watson	2.01	2.06	2.02	2.01	2.04	2.03	2.01	2.05	2.04	1.99	1.98	1.99	2.09
N	52	52	52	52	52	52	53	50	50	50	50	50	50

*5% significance level; **10% significance level

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