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**MODELLING THE LINK BETWEEN AGGREGATE INCOME
AND CARBON DIOXIDE EMISSIONS IN DEVELOPING COUNTRIES:
THE CASE OF THE DOMINICAN REPUBLIC**

Abstract

The paper estimates the link between aggregate income and carbon dioxide emissions for the Dominican Republic. The econometric analysis finds evidence of an environmental Kuznets curve revealing that the level of annual real per capita income at which carbon dioxide emissions start to stabilise is around US\$1,600. The estimations support evidence in the literature revealing that the curve has been flattening and shifting to the left.

Keywords: CO2 emissions; Environmental Kuznets curve; Dominican Republic.

JEL classification numbers: Q56.

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1. Introduction

Nurturing the conditions to achieve economic growth and development is a primary goal for governments across the world. But in so doing attention has to be paid to the limits imposed on the pace of economic growth and development by various factors, including the potential adverse impact on the natural environment and the actions required to reverse the damages (e.g. Stern, 2015). Therefore understanding the link between aggregate income and the environment is a pressing task for academics and policymakers (e.g. Greenstone and Jack, 2015).

The paper contributes by investigating the Dominican Republic, an economy that has been fairly successful in implementing policies to preserve the natural environment vis-à-vis other developing countries. As an illustration, Diamond (2005) discusses concrete historical initiatives by the authorities in the Dominican Republic towards saving the natural environment starting from the second half of the last century. The policies, including successful schemes to educate people about agriculture's potentially damaging impact on the soil, reveal the preferences of domestic policy makers for encouraging a more balanced development. The precedent of implementing effective policies could also be the foundation to subsequently tackle other dimensions in the domain of environmental policy management, like reducing greenhouse gas emissions.

But there is no contribution assessing the level of pollution, as measured by carbon dioxide (CO₂) emissions, and its relation to aggregate income in the Dominican Republic, i.e. investigating the existence of an environmental Kuznets curve (EKC). Pursuing that line of research could generate results that serve as a yardstick for gauging the success or otherwise of environmental policies. The investigation seeks to answer the following questions: Is there an EKC for the Dominican Republic? If so, what is the level of income at which the curve

becomes negatively sloped, also known as the EKC's turning point? Is that period related to the implementation of specific policies for safeguarding the natural environment?

The literature contains theoretical and empirical contributions, starting with the seminal work of Grossman and Krueger (1995). Grossman and Krueger estimate that for a cross-section of countries the turning point for various pollutants happens when real per capita income reaches US\$8,000. But studies focusing on individual developing countries are more difficult to come by; Vincent (1997) tackles the matter and does not find evidence of an EKC for Malaysia. Therefore focusing on a country like the Dominican Republic could help in learning from specific experiences on the evolution of greenhouse gas emissions as developing economies grow.

The rest of the paper proceeds as follows. Section 2 motivates the specification to investigate the EKC and runs the econometric modelling. The exposition relates environmental policies in the Dominican Republic to the findings from the empirical analysis. Section 3 concludes.

2. Estimating an environmental Kuznets curve for the Dominican Republic

The environmental Kuznets curve arises from the empirical observation of a negative link between the level of output and pollution. The seminal work is Grossman and Krueger (1995) and there is a substantial literature deriving from that work. The EKC can be split into several possible original effects that vary through time, as discussed by Brock and Taylor (2005).

The impact of economic growth can lead to an increase in pollution if the underlying activities rise in proportion to overall growth. If, on the other hand, the underlying activities

either grow by less or more than overall growth pollution could decrease or increase in relation to economic performance. The empirical observation of a negative link between economic growth and pollution could imply that more advanced countries implement environment-friendly production techniques. And that is subsequently reflected in a lower level of pollution at higher income levels, generating the EKC. Ultimately, the nature of the link between income and pollution is an empirical question and what follows attempts to throw light on the matter by examining the case of the Dominican Republic.

The time series for the empirical modelling are obtained from the World Bank World Development Indicators and range from 1960 to 2010. The data are CO2 emissions in metric tons per capita (EN.ATM.CO2E.PC), gross domestic product (GDP) per capita (NY.GDP.PCAP.KN), population density (EN.POP.DNST), and annual % population growth (SP.POP.GROW) -World Bank codes are inside parentheses.

The econometric analysis begins by estimating the following benchmark equation

$$\log CO2_t = \alpha + \beta_1 \log Y_t + \beta_2 \log Y_t^2 + \delta trend + \varepsilon_t. \quad (1)$$

In equation 1 all the variables are defined as above and log denotes the natural logarithm of a series; β_1, β_2 are coefficients to be estimated empirically. If a Kuznets curve exists $\beta_1 > 0$ and $\beta_2 < 0$, meaning that CO2 emissions increase with output but decline after reaching a threshold level. The equation also contains a time trend.

Running equation 1 using ordinary least squares (OLS) and annual data spanning from 1960 to 2010 produces

$$\log CO2_t = -\underbrace{89.16}_{11.90} + \underbrace{17.59}_{2.34} \log Y_t - \underbrace{0.86}_{0.11} \log Y_t^2 + \underbrace{0.01}_{0.01} trend. \quad (2)$$

$$AdjR^2 = 0.95 \quad SER = 0.1369$$

Equation 2 reports heteroscedasticity and autocorrelation consistent standard errors (HACSE) below each coefficient. The diagnostic statistics under the equation are the goodness of fit (adjusted R^2) and standard error of the regression (SER). All the coefficients in equation 2 are significant at the 1% level excepting the time trend which is significant at the 8% level. The coefficients affecting the level and the squared value of GDP are positive and negative, implying that there is an environmental Kuznets curve for the Dominican Republic during the period under investigation. The analysis also runs a RAMSEY test to detect the adequacy of the functional form. The F-test examines the hypothesis that the coefficients on the squared values of the fitted model (equation 2) are zero and the hypothesis cannot be rejected {0.325(0.570)}.

Even if the functional form is correct, there could be reasonable concerns about the lack of ancillary variables in equation 2 so the analysis proceeds to exploring a more general model. The investigation considers the following extended EKC specification

$$\begin{aligned} \log CO2_t = & \\ & \alpha + \beta_1 \log Y_t + \beta_2 \log Y_t^2 + \beta_3 (\log Y_t - \log Y_{t-1}) + \beta_4 Popden_t + \beta_5 Popgrowth_t + \\ & \delta trend + \varepsilon_t. \end{aligned} \quad (3)$$

The additional regressors in equation 3 are GDP growth ($\log Y_t - \log Y_{t-1}$), population density ($Popden$) and population growth ($Popgrowth$). Estimating equation 3 using OLS and annual data from 1961 to 2010 generates the following results

$$\begin{aligned} \log CO2_t = & \\ & - \underbrace{40.19}_{17.18} + \underbrace{8.49}_{2.93} \log Y_t - \underbrace{0.41}_{0.13} \log Y_t^2 + \underbrace{0.53}_{0.36} (\log Y_t - \log Y_{t-1}) + \underbrace{0.05}_{0.02} Popden_t - \\ & \underbrace{2.03}_{0.37} Popgrowth_t - \underbrace{0.21}_{0.08} trend + \varepsilon_t. \end{aligned} \tag{4}$$

$$AdjR^2 = 0.96 \quad SER = 0.1130$$

Equation 4 also reports HACSE below each coefficient. In equation 4 all the coefficients are significant at least at the 5% level, excepting the one affecting the rate of growth of GDP ($\log Y_t - \log Y_{t-1}$) which is not statistically significant at conventional levels. The key coefficients on the level of output and on squared output carry positive and negative coefficients, confirming the existence of an EKC for the Dominican Republic. Also, the coefficients on the two income measures are smaller than those reported in equation 2, lending support to focusing attention on a more general econometric model. Figure 1 shows the residuals from equation 4 and they reveal a stationary pattern.

Given the importance of the results in equation 4, the investigation computes an F-statistic to test the hypothesis that both coefficients on real output per head are zero $\{\beta_1 = \beta_2 = 0\}$. The hypothesis is rejected at the 1% $\{5.29(0.00)\}$. The 1% confidence ellipse

shown in Figure 2 provides a visual impression of the range of values for β_1 and β_2 derived from equation 4. Figure 3 shows a cross-plot of the fitted values from equation 4 and the log of real income per head: the graph clearly reveals the EKC pattern implying the existence of a turning point in the income-pollution relationship for the Dominican Republic.

The turning point for the EKC, meaning the level of income at which pollution starts to decline, can be calculated using the following formula

$$Y_t = -\beta_1 / 2\beta_2. \quad (5)$$

Using the coefficients from equation (4) yields

$$Y_t = -8.499068 / 2(-0.419991) = 10.11 . \quad (6)$$

The calculation implies that for the Dominican Republic the turning point occurs in 1999.

The estimated turning point is around the time when the Dominican Republic took concrete steps to boost the government's capacity to regulate the natural environment. This relates to discussions in Dasgupta et al (2002) and references therein, citing empirical evidence showing that the main factor driving reductions in pollution in countries reaching middle-income status seems to be changes in the pertinent regulatory framework (see also the discussions in Carson, 2010).

In the Dominican Republic the General Law on the Environment and Natural Resources (Law 60 of 2000) provides the legal basis for the Ministry of the Environment and Natural Resources (see Lizardo and Guzmán, 2005). The Ministry's mandate is to foster policies aimed at preserving and improving the environment and natural resources, with the ultimate goal of securing its sustainability. It is worth noting that so far the Dominican Republic's Ministry of the Environment and Natural Resources has been fairly effective and commands considerable credibility in the country.

Going back to the results from the empirical modelling, the turning point in the EKC occurs around an annual real GDP per capita of US\$1,600 -calculated at market exchange rates. Considering PPP-based GDP numbers, converted with current dollars, the turning point would amount to an annual real per capita income of US\$5,300 according to data produced by the World Bank. The number is lower than the corresponding figure for the conventional EKC and could help to support evidence suggesting that the EKC has been flattening and shifting to the left -Dasgupta et al (2002) label this a 'revised EKC'. The EKC's changing pattern could be the result of catch-up growth involving the adoption of environment-friendly technologies in developing countries. But, more likely, it is the outcome of specific policies aimed at preserving the environment.

In that regard, going back to the institutional context, subsequent to creating the Ministry of the Environment the Dominican Republic has taken concrete steps towards reducing greenhouse gas emissions. Concretely, the National Committee on Climate Change and Clean Development Mechanism was created in 2008. The Committee's mandate includes designing and implementing policies to mitigate and prevent greenhouse gas emissions in the Dominican Republic. The institution also keeps track of the compliance with commitments agreed with the United Nations concerning climate change, notably those derived from the Kyoto protocol. The Dominican Republic is also implementing an Economic Development

Plan Compatible with Climate Change in order to keep greenhouse emissions under control, and recently passed new legislation to tax motor vehicles according to their CO₂ emissions, a policy that has been difficult to implement in other Latin American countries¹. Another example of related efforts is the Dominican Republic's success in reducing ozone depleting emissions of hydrochlorofluorocarbons by 10% during the three years preceding 2015 – according to the United Nations Development Program's office in the country. World-wide efforts in that direction are partly supported by funding from advanced countries pledged via the Montreal Protocol -a treaty focusing on reducing substances that deplete the ozone layer.

3. Conclusion

The paper investigates the link between aggregate income and CO₂ emissions for the Dominican Republic. The econometric analysis shows evidence of an environmental Kuznets curve revealing that the level of annual real per capita income at which CO₂ emissions start to stabilise is around US\$5,300 measured in PPP terms. The level computed for the Dominican Republic is lower than for conventional EKC estimates reported in the literature but in line with the revised Kuznets curve discussed in Dasgupta et al (2002). The findings may contribute to substantiate the hypothesis that the curve has been flattening and shifting to the left, possibly due to catch-up growth involving the adoption of environment-friendly technologies and specific policies to preserve the natural environment.

¹ Oliva (2015) studies Mexico's experience in trying to regulate automobile emissions in Mexico City.

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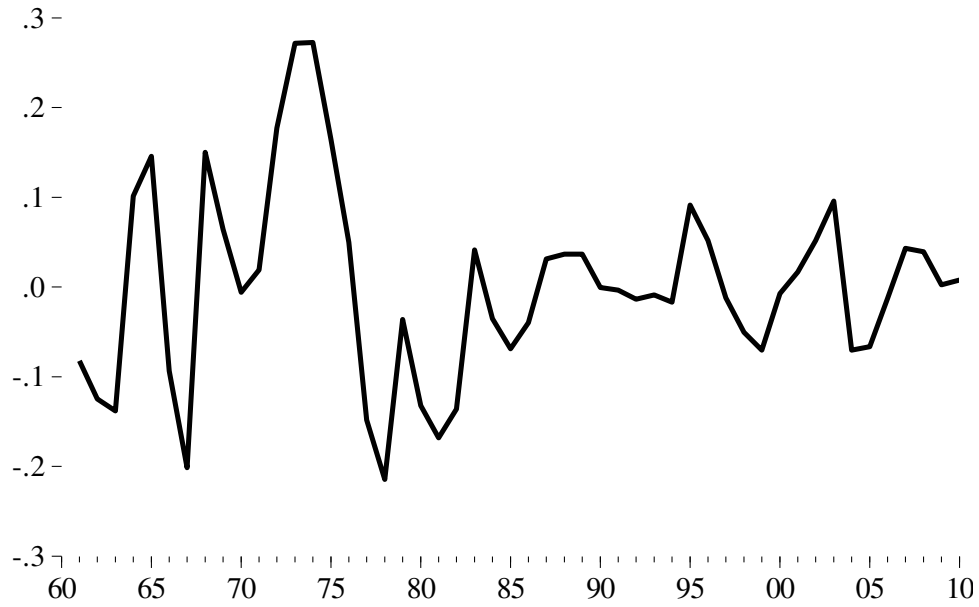
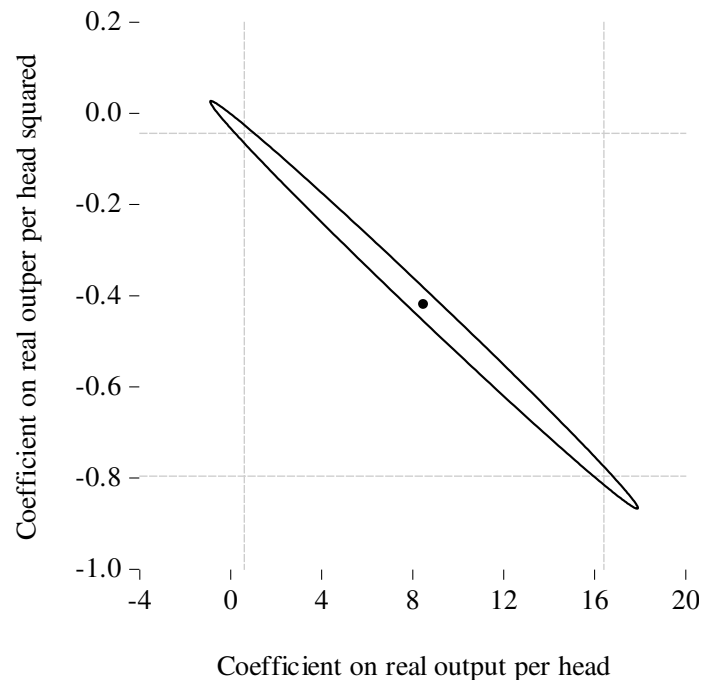
Figure 1**Residuals from the extended EKC model, equation (4)****Figure 2**1% confidence ellipse for β_1 and β_2 coefficients, equation 4

Figure 3

Environmental Kuznets curve for the Dominican Republic
Cross-plot of the fitted values from equation 4 and the log of real income per head
1961-2010

