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Do countries influence neighbouring pollution? A spatial analysis of the EKC for CO_2 emissions

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ABSTRACT

By considering spatial relationships, this study aims to analyse to what extent per capita CO_2 emissions are determined by renewable energy consumption, the share of the services sector in GDP, energy intensity and real per capita income. A panel data set composed of 173 countries over the 1990–2014 period is used to estimate an environmental Kuznets curve (EKC) augmented by neighbouring per capita income and energy intensity. Both standard and spatial forms are estimated for seven different sets of countries to assess the robustness of the results. Finally, several forecasts are performed to verify global sustainability and to provide some policy suggestions for the period 2015–2100. The empirical results indicate that (i) most areas support the standard EKC, (ii) there seems to be an inverted U-shaped relationship between neighbouring per capita income and national per capita emissions in Europe, Asia and the World as a whole, (iii) neighbouring energy intensity increases national per capita emissions, and (iv) forecasts show that economic growth will accelerate climate change. However, a steady annual growth in renewable energy consumption and a steady decrease in energy intensity, both close to 2.5%, may guarantee environmental sustainability prior to 2100.

1. Introduction

According to the IPCC Fifth Assessment Report (2014), anthropogenic greenhouse gas (GHG) emissions have increased since 1750, leading to a situation where atmospheric concentrations of CO_2, CH_4 and N_2O have reached unprecedented levels over the past 800,000 years. The major contributor to GHG emissions, as well as the gas that remains longest in the atmosphere, is carbon dioxide -CO_2-. More precisely, 78% of total GHG emissions have been caused by CO_2 emissions for the 1970–2010 period, at the same time CO_2 concentrations have been increasing at their fastest observed decadal rate of change (2.0 ± 0.1 ppm/yr) for 2002–2011. Therefore, the threat of climate change is more intense than ever due to uncontrolled carbon dioxide emissions.

Carbon dioxide pollution is highly correlated to the usage of energy derived from exogenous sources to manpower; more specifically, to fossil fuel consumption. Since the Industrial Revolution, the increasing production scale and needs of trade of Western countries required new forms of automated production and faster transport. This would probably not have been possible without the development of better techniques that seized the energy potential of fossil fuels, such as coal in the first stages, or petroleum and natural gas in the mid-late nineteenth century. In this regard, recent economic literature has pointed out the importance of growing and non-decreasing trade relationships around the world. More precisely, Jones and Romer (2010) state that “Increased flows of goods, ideas, finance, and people—via globalisation, as well as urbanisation—have increased the extent of the market for all workers and consumers. (…) World trade as a share of GDP has nearly doubled since 1960”. Previous EKC studies have also noted that international trade may be a key factor for explaining changes in CO_2 emissions (e.g. Roberts and Grimes, 1997; Friedl and Getzner, 2003; Halicioglu, 2009; Ertugrul et al., 2016). Therefore, it seems reasonable to study to what extent the increasing globalisation has impacted in economic growth, energy consumption, CO_2 emissions and, eventually, in world's environmental sustainability.

The aim of this paper is to analyse the relationship between economic growth and carbon dioxide emissions in 173 countries during the 1990–2014 period yet paying special attention to the influence of globalisation on it. To do so, we test the existence of spatial spillovers in the traditional CO_2 EKC framework which, as far as we are concerned, have been largely overlooked and not sufficiently studied. Moreover, their inclusion may be crucial to overcome the misspecification issue, which has been previously highlighted as one of the major causes of disparity in final estimations (Stern, 2004, 2010). In addition to this, the omission of spatially lagged variables when they are relevant for the data generating process will lead to biased estimates (LeSage and Pace,

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2009), which may explain why many studies on CO_2 emissions have found extremely high and out of sample turning points (e.g., Holtz-Eakin and Selden, 1995; Galeotti and Lanza, 1999).

According to the foregoing, the question is how spatial models may contribute to estimate the impact of globalisation on the EKC. In this sense, trade profits are heavily influenced by distance costs (e.g., Hummels, 1999; Nitsch, 2000; Head and Mayer, 2002; Berthelon and Freund, 2008), thus one might suggest that international relationships are prone to be clustered around certain areas as long as trade and communication costs are sensitive to distance. In this regard, Beckerman (1956) states that developing countries are highly dependent on means of transport. Thus, as they close the distance between themselves and more-developed and important economies, their potential growth increases. Moreover, less-developed countries tend to generate a higher trade concentration than developed ones.

Given that distance is important for trade, the inclusion of spatial relationships allows us to test the pollution haven hypothesis (PHH) using new methodologies, as well as the existence of technological spillovers increasing energy efficiency. The PHH proposes that richer countries might present decreasing growth rates of pollution due to their export of environmentally harmful productive processes to poorer economies, leading to a situation where global net emissions do not decrease (Cole, 2004). Previous studies have tested the PHH for CO_2 emissions relying only on the statistical significance of explanatory variables reflecting trade (trade openness, imports from developing countries, exports to developing countries), which did not account for pollution transfers among countries in the same state of development (Cole, 2004; Kearsley and Riddel, 2010). In this sense, we propose to overcome this shortcoming by considering spatial econometric models.

In contrast to previous spatial studies, which have mainly focused on the policy mimicry of environmental standards using spatial lags on the dependent variable, we study how neighbouring per capita income and other explanatory variables, such as energy intensity, can impact national per capita CO_2 emissions. To this end, we estimate two types of EKC: a standard type, augmented by the share of renewable energy consumption over total energy consumption, the value added of the services sector over GDP and the energy intensity; and a "spatial EKC" (SEKC), which extends the previous one by using both spatially lagged per capita income and energy intensity.

The remainder of the paper is organised as follows. Section 2 contains a brief literature review for the EKC and its spatial approach. Section 3 describes both augmented and spatial EKC that will be estimated. Section 4 describes the data used in the empirical part of the paper. Section 5 presents the estimated models and discusses their results. Section 6 shows several forecasts for the EKC and SEKC. Section 7 presents conclusions and policy implications.

2. Literature review

The origins of the "Kuznets-like" analysis for environmental quality can be traced back to the study of NAFTA's effects on certain pollutant concentrations (Grossman and Krueger, 1991) and the World Bank report about the effects of economic development on the environment (IBRD, 1992). The pioneering works of Grossman and Krueger (1991, 1994) considered the idea that expanding economies might not always lead to greater environmental harm. The central thrust is that increasing trade may create new opportunities for environmentally friendly sectors (*composition effect*), as well as boost greener technical progress and productive efficiency (*technique effect*). Both effects should compensate, or even overcome, the impact of economic growth on pollution (*scale effect*). Nevertheless, it must be also highlighted that trade based on differences in production costs can account for migration of pollution from developed to developing countries, provided that in these latter there is a less stringent environmental regulation. Therefore, some sort of pollution displacement might occur between these types of countries (the pollution haven hypothesis), leading to a situation where global net pollution does not decrease. Despite this event might be crucial for understanding the evolution of global CO_2 emissions, we have found few studies that have directly considered it. Additionally, none of them have taken into account how geographical space, and therefore spatial processes, may play a major role in pollution transfers. In this sense, we follow the hypothesis expressed by Wang et al. (2013) that not only "all the subjects that are related to environmental issues are inherently spatial" but there also exist spatial interactions between countries due to trade or technological diffusion.

The first category of empirical studies of EKC for CO_2 was principally focused on the per capita income impact on per capita emissions, without taking into account other explanatory variables rather than national traits or time trends. Therefore, the 1990–2000's framework revolved around panel data estimations considering fixed effects for large sets of countries. Almost all these studies agree on the non-existence of an inverted U-shaped curve due to the excessive size of the estimated turning points (Shafik, 1994; Holtz-Eakin and Selden, 1995; Roberts and Grimes, 1997; Galeotti and Lanza, 1999), the finding of a monotonically increasing relationship (De Bruyn et al., 1998), the consideration of nonlinear dynamics as the major driver of polluting behaviours (Moomaw and Unruh, 1997) or the existence of heterogeneity in the estimated coefficients among countries (Dijkgraaf, Vollebergh, 1998). Some of them argued that the most developed countries were coming closer to a less steep trend of per capita emissions beyond a certain level of wealth rather than an inverted U-shape curve.

In essence, these preliminary works presented an important absence of explanatory capacity due to their focus on per capita income levels. As Moomaw and Unruh (1997) asserted, these initial results seemed to be more a by-product of the specification than a reflection of reality. These authors stressed the importance of market shocks in the long-term reduction of CO_2 emissions, pointing out that the EKC in its initial reduced form is not a fair representation of structural changes. In this sense, Schmalensee et al. (1998) argued that there might be a misspecification problem. More precisely, the inclusion of explanatory variables reflecting shifts in the industrial composition or changes in environmental policy would better explain differences in pollution among industrialised and developing countries. In addition, De Bruyn et al. (1998) also pointed out the weakness of reduced forms for policy implications.

In order to overcome this misspecification problem, the second category of carbon-dioxide-EKC studies started to consider new explanatory variables on the basis of a deeper theoretical background and the reassessment of previously posed hypotheses. Nevertheless, the misleading results derived from the juxtaposition of countries in different development stages and the existence of heterogeneity among the estimated coefficients for every country (Dijkgraaf, Vollebergh, 1998), led to the study of time series instead of cross section or panel data. In this regard, the use of Error Correction models and autoregressive models became more popular in the carbon-dioxide-EKC framework for the late 1990's to the mid-2000's (Lim, 1997; Panayotou et al., 2000; Egli, 2002; Pauli, 2003; Friedl and Getzner, 2003; Cole, 2004).

A large part of these second-group studies tested the existence of the PHH by including some sort of trade-reflection variable (Panayotou et al., 2000; Egli, 2002; Friedl and Getzner, 2003; Cole, 2004). There was no consensus about the final results. However, most of them pointed towards the non-existence of this phenomenon, or at least, that it was not required to achieve a bell-shaped relationship. We stand out the comprehensive analysis carried out by Cole (2004) about the PHH. This study employed trade-paired data for the US, the UK and Japan in relation to their main undeveloped foreign markets and its results did not support the PHH for CO_2 emissions. Nevertheless, the lack of a more representative sample for the industrialised world should be taken into account when interpreting its final results.

The other major focus of this second group was to test how