Greenhouse Gas Emissions In European Regions: Spatial Spillovers Within The Environmental Kuznets Curve

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ABSTRACT

The increase in economic activities associated with global population growth over the years has generated various pressures on the environment, with significant regional disparities between countries and within national borders. Since the 1990s, with the wider dissemination of the concept of sustainable development, Grossman and Krueger (1995) have shown that there is a non-linear relationship between per capita income and pollutant emissions. This study presented an inverted U-shaped curve, indicating that for low levels of per capita income, pollution increased with economic growth and then declined for higher incomes. This theory gave rise to the Environmental Kuznets Curve (EKC) and has been tested and proven in several international studies. However, the traditional EKC model does not incorporate the spatial effects between countries and neighboring regions that influence the pattern of environmental contamination. Thus, recent panel data models with spatial effects have been adopted to understand the dynamics of environmental degradation in different regions and capture the externalities generated in neighboring regions, in addition to considering the impacts of socioeconomic and productive characteristics on the existing contamination pattern of a locality and its neighbors. Therefore, the use of spatial econometrics techniques attempts to capture the spillovers of environmental damage and the productive structure by including spatial dependencies and relaxing the assumption of CKA homogeneity. In this sense, the present study aims to understand the pollution pattern of European regions at a more disaggregated level (NUTS 2) and its spatial effects for a more recent period. Although there is already evidence of a CKA for several countries in the European bloc, aggregate data analysis at the country level may limit a deeper understanding of recent structural and environmental changes in Europe. Therefore, this study stands out for its analysis of greenhouse gas patterns in a more disaggregated manner, considering variables that go beyond GDP per capita and population in estimating CKA, including spatial effects. To this end, the research studies the patterns of GHGs emissions and their main determinants in 211 regions of the European Union (NUTS 2) for the years 2014, 2019, and 2023 using spatial panel data models. The period analyzed includes the year prior to the establishment of emission reduction targets in the Paris Agreement in 2015, namely 2014. One year before the COVID-19 pandemic, 2019, and one year after the pandemic, 2023, covering a total interval of 10 years. The database was

compiled from information available from EUROSTAT and ARDECO (Annual Regional Database of the European Commission). In the descriptive analysis of the data, a drop in the average level of emissions per NUTS 2 was observed in the period analyzed, which went from 15,624.89 Kton of CO2eq in 2014 to 13,102.47 Kton of CO2eq in 2023. It was also found that the European regions in the top 10% most polluting group had emission levels equivalent to 7.8 times that of the bottom 10% least polluting group in 2014 and 7 times in 2023. The econometric models estimated were, in addition to the traditional panel data model with fixed effects for NUTS 2 regions, the spatial panel models SAR (Spatial Autoregressive Model), SEM (Spatial Error Model), and SDM (Spatial Durbin Model). As usual, in the SAR model, spatial effects are captured in the dependent variable(in this study, they were the endogenous effects of the environmental pollution indicator measured in greenhouse gases (CO2 eq)). In the SEM model, the spatial effect is incorporated into the error. Finally, in the SDM model, spatial dependence is considered in the dependent variable and in the explanatory variables of the model. The neighborhood matrices adopted were the Queen and Rook matrices, the latter being used to test the robustness of the results. The explanatory variables used in all regressions include GDP per capita (to test the EKC hypothesis), population, share of energy intensity sectors, and share of the high-tech sector. The results confirm the existence of an inverted U-shaped Kuznets curve at the regional level in all regressions%. In spatial estimates, neighborhood effects were relevant for CO 2eq emissions at the NUTS 2 level, indicating that a polluting region tends to have neighbors with greater environmental degradation. The inflection point in the SDM model was an annual income equivalent to €41,882.20, which is a high value for many European regions. This shows that the turning point has not yet been surpassed.. In consequence, there is a significant group of regions with incomes below this value in the European bloc that may have a growing emission pattern as a result of GDP growth if no action is taken to stimulate the process of decarbonization and the use of renewable technologies. In the present study, the most polluting regions were found in the Czech Republic, Germany, Spain, France, Italy, the Netherlands, and Poland. The results also indicated a technological spillover in reducing emissions to localities and neighborhoods with greater involvement in the technology sector, which can benefit the ecological transition. In other words, it may be an indication that the ecological transition is stronger in regions with more advanced technologies and higher incomes, which also facilitates the decarbonization process in neighboring areas. Furthermore, technology could accelerate the decarbonization process in lower-income areas with positive spatial effects if, for example, it is encouraged through regional public policies for sustainable development. It is important to note that in the estimates obtained in the econometric models mentioned, population size was not relevant in the process of pollutant gas emissions. Regions with the highest weightings in the civil construction sector had a statistically significant pattern of high greenhouse

gas emissions, which was not observed for agriculture and manufacturing. In other words, construction in the European economies should be associated with a higher standard of energy efficiency in the ecological transition process. Although the results obtained provide important insights into the pattern and trajectory of air pollution in the European Union and can assist in the formulation of regional public policies aimed at sustainable development, there are still gaps that need to be filled in future studies. Therefore, this research aims to analyze various environmental indicators that include not only the emission of polluting gases, but also other variables such as pressure on water demand, use of chemicals, among others, with the objective of providing a more complete analysis of environmental impacts, including an analysis of structural changes in the productive sectors in recent decades. In addition, including political and energy variables, such as exposure to regional and national environmental regulations, renewable energy penetration, energy intensity, and regional energy mix, could help identify specific political factors of decarbonization, rather than relying solely on yield correlations. Another aspect that needs to be taken into account is the emission pattern for industrial, rural, and urban areas to test the CKA hypothesis, with each of these groups aiming to support the formulation of specific policies for these locations in promoting sustainable development. In order for these final stages of the research agenda to be carried out, the data containing this information must be made available to the European NUTS 2 regions. This point is very important for the environmental research agenda to move forward and be used as an important tool in the formulation of regional policies in the energy transition process in the coming years, considering the inequalities between the European regions.

Keywords: Environmental Kuznets Curve; European regions; spatial econometrics.

Jel codes: Q53, C21, C23.