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Editorial

Sustainability and the Environmental Kuznets Curve Conjecture: An Introduction

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1. From Kuznets to the Environmental Kuznets Curve

In December 1954, Simon Kuznets delivered his Presidential Address at the American Economic Association about economic growth and income inequality. His talk was published a few months later by the American Economic Review [1], and that very paper laid the ground to what has been known as the Kuznets Curve.

In his seminal paper, Kuznets used data to see if inequality in the distribution of income increases or decreases with a country's economic growth. For being able to answer that question, he collected long-term data for the United States, the United Kingdom and Germany. Even though his research was meticulous and heavily documented, Kuznets was always careful to use words such as "conjecture", "hypothesis", "guess", etc. His conclusions were based on available data, available information, economic theory, statistical analysis and best guesses. With this precaution in mind, he stated that, for the countries studied, "One might thus assume a long swing in the inequality characterizing the secular income structure: widening in the early phases of economic growth when the transition from the pre-industrial to the industrial civilization was most rapid; becoming stabilized for a while; and then narrowing in the later phases" [1]. That is the essence of the Kuznets Curve: inequalities increase in earlier phases of development, then finally decrease until a certain income threshold has been reached, such that an inverted U-shaped relationship exists between inequalities and income.

This relationship cannot, however, be standardized across time and across nations. The timing of the turning point is indeed different for every country, and data showing a specific relation for one country does not ensure that all countries behave the same way. For the former point, Kuznets mentions the following: "No adequate empirical evidence is available for checking this conjecture of a long secular swing in income inequality; nor can the phases be dated precisely. However, to make it more specific, I would place the early phase in which income inequality might have been widening, from about 1780 to 1850 in England; from about 1840 to 1890, and particularly from 1870 on in the United States; and, from the 1840's to the 1890's in Germany. I would put the phase of narrowing income inequality somewhat later in the United States and Germany than in England-perhaps beginning with the first world war in the former and in the last quarter of the 19th century in the latter" [1]. For the latter issue, if the three developed countries under study were experiencing an inverted U-shaped relation between inequality and income at the time Kuznets wrote his paper, it remained to be seen if developing countries were following a similar path or were expected to follow such a path in the decades to come. Kuznets did not conclude with a strong affirmation but with a balanced opinion, mentioning that the widening inequality gaps in developing countries in the post-war period could be a sign that history repeats, but warning that swift conclusions may not always be advisable.

The inverted U-shaped relationship between inequality and income was rightfully treated as a conjecture, and not as "law", by Kuznets himself, as longer and more recent

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data showed that such a relation could not be generalized. For example, List and Gallet [2] collected data for many countries from the 1960s to the 1990s, and they found out that if lower-to-middle-developed countries do generally seem to follow an inverted U-shaped pattern, higher developed countries, however, see the relationship between income inequalities and per capita income become positive again. They explain this increasing trend, forming an N-shaped curve, as a shift from a manufacturing base towards a service base in advanced economies. This conclusion does not, of course, invalidate the interest of the Kuznets Curve but simply stresses that, as mentioned before, it is not a "law", nor is it a curve that is valid for all countries and at all periods of time.

A few decades after Kuznets' analysis, various researchers started studying the relation between environmental pollution (instead of inequalities) and economic growth. In 1991, Grossman and Krueger studied the impact of the NAFTA (North American Free Trade Agreement) on the environment, and for their analysis, they studied the relation between air quality and economic growth [3]. Two other important papers followed [4,5] before Grossman and Krueger again published their paper entitled 'Economic Growth and the Environment' in 1995 [6]. These researchers showed that an Environmental Kuznets Curve (EKC), that is, an inverted U-shaped relation between a measure of environmental damage and (per capita) income, could exist for various pollutants. At low levels of economic development, human behaviors are not imposing an excessive stress on natural capital. However, when the economy develops, natural resources are more and more impacted by human activities and environmental damages increase. Then, once a threshold is reached, after a certain level of development, environmental policies and individual preferences among others (e.g., agents give an additional value to a cleaner environment and are willing to invest part of their income in environmental conservation [7]), enabling them to reduce pollution.

Those studies were obviously limited to various pollutants and various countries. Grossman and Krueger [3] were the first to observe an inverted U-shape between urban air pollution (sulphur dioxide and dark matter) and income in the United States. Later on, a similar relationship was found between deforestation and national income [4] and between various air pollutants (sulfur dioxide, suspended particulate matter, nitrogen oxide and carbon monoxide) and per capita GDP [5]. In their seminal 1995 paper [6], Grossman and Krueger extended their analysis to several other countries and indicators related to air and water pollution and also found significant evidence of an EKC for most of their indicators.

For the past three decades, numerous papers have been published, whose studies concentrated on specific pollutants, on specific countries, on econometric estimates and on varying the ordinate (the type of environmental damage) and the abscissa (the measure of income) of the curve. The least than can be said is that the EKC is subject to much debate. If various local pollutants frequently exhibit an EKC, this is much more ambiguous for global pollutants, such as CO_2 emissions, for example. Results may also differ depending on the methodological approach used (time series, cross-country or panel data or more advanced methods, some of which are used in this Special Issue), on the country or group of countries used and on the time period. In one word, the EKC is not generalizable, and what Kuznets stressed for the relations between inequality and economic growth, that is, the need to use words of caution and to realize that the original inverted U-shaped relation between inequality and income is not a 'law' but a conjecture, is also valid here. Grossman and Krueger seem to be in line with this important cautionary note as they mention, for example, that "we find little evidence that environmental quality deteriorates steadily with economic growth" [6]. Hence, even though they find EKCs for most of the air and water pollutants studied, they do not claim that economic growth is the solution for tackling environmental issues. Rather, they suggest that economic growth might bring about pollution reduction for some pollutants (not all) after a threshold is reached.

2. CO_2, EKC and the Special Issue Articles

As climate change is the most pressing (long-term) environmental issue, what can we say about regional, national, international and global relations between CO_2 emissions and national income? As omitted variables and modeling formulations are significant drivers of the results obtained, what improvements can we propose for modeling techniques? Finally, what additional variables (on top of pollution and GDP) can we consider? Those and other questions are discussed in the articles of the Special Issue.

All papers of the Special Issue but one directly analyze the evolution of CO_2 emissions. The purpose here is not to undertake a literature review or go into the details of the debate about the EKC conjecture for CO_2 emissions, but it is interesting to pinpoint various issues and see how they are handled in this Special Issue.

A frequently cited shortcoming of the EKC is that it is generally not obtained for global pollutants such as CO_2. Some countries may show an inverted U-shaped relation while others follow an N-shaped pattern and others again seem to show a strictly positive correlation of emissions with growth. Hence, as the EKC is not generalized, its local existence may be (partly) due to stricter environmental regulations in some parts of the world that help reduce environmental damages. Concentrating their analysis on the G7 countries and using data spanning 150 years, Liu et al. [8] cannot confirm an EKC in most of these countries, even though the marginal propensity to emit CO_2 after a certain threshold is decreasing.

Over the years, many papers highlighted various econometrical flaws in the model formulations, arguing that issues such as, among others, cointegration or omitted variables render these models fragile. Concentrating on omitted variables and, more largely, additional variables, it is true that elements other than GDP (in)directly impact pollution. Bayar et al. [9] consider the impact of institutions and human capital on CO_2 emissions in 11 transition economies, and if they find mixed impacts for institutions, their results show a positive impact of human capital on CO_2 emission reductions in most countries in their sample. The importance of institutional quality is also highlighted by Razak et al. [10], as their models show that, in Malaysia, healthier governance (government stability, anti-corruption measures and law and order) allow for improvements in environmental quality, that is, a reduction in CO_2 emissions. Human capital is also considered as a crucial cornerstone in EKC modeling by Maranzano et al. [11]. Using data from 17 European countries and average years of schooling as a proxy for human capital, they were able to derive what they referred to as an 'Educational EKC' in various countries of their sample, controlling for income inequality, that is, an inverted U-shaped relationship between pollution and human capital.

Modeling techniques have also improved over time. Jena et al. [12] move away from linear regression models producing a single parameter estimate and propose a non-linear model with an adaptative process for estimating CO_2 emissions and possibly verifying the existence or inexistence of an EKC. They use a Radial Basis Function Neural Network applied to 19 countries representing 78% of global emissions with data spanning the last 60 years and found that renewable energy holds the key for future emission abatement. Liu et al. [8] also capture the non-linear characteristics without converting data into a quadratic (or cubic) form by using a kink (threshold effect) regression model. Razak et al. [10] employ various econometric techniques for Malaysia, among which is the non-linear autoregressive distributed lag model.

The final two papers aim at finding tools to reduce carbon emissions in specific countries and for specific sectors. Zhu and Lin [13] evaluate the impact of a carbon tax levied in China's mining industry to promote energy reforms and environmental improvements in traditional industries, while Borozan and Pekanov Starcevic [14] analyze the productivity gains in the European energy industry in light of the climate objectives.

Overall, the Special Issue provides useful insights on recent methodological developments, on the importance of additional variables to national income when estimating potential EKCs, on tools for promoting more sustainable policies and on applications to var-

ious parts of developed and the developing world for better understanding and grasping the complexity behind the Environmental Kuznets Curve.

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