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Carbon Dioxide Emissions and Economic Growth: An Assessment Based on Production and Consumption Emission Inventories ☆

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ABSTRACT

Working with a new dataset on comparable global CO_2 production and consumption inventories spanning the 1997–2011 period, we investigate the relationship between real gross domestic product (GDP) per capita and CO_2 emissions per capita associated with both production and consumption activities. By including linkages between production-based emissions in one country and final consumption in another (via cross-border value chains), we focus on the entire carbon chain. We estimate polynomial and threshold models, accounting for reverse causality and identification problems. We find that the income-elasticity for both inventories is regime-dependent and reflects small carbon efficiency gains from economic development. Carbon footprints show larger income-elasticities, while national policy instruments targeting production can clearly be circumvented by carbon embodied in intermediate trade. This implies problems of environmental sustainability that may require consumption-based policy instruments.

1. Introduction

The relationship between emissions and economic growth is at the centre of debate on the appropriate policies for targeting greenhouse gas emissions. The need for urgent action regarding climate change has been emphasised in the formulation of the UN's sustainable development goals (SDGs), while the Paris climate conference (COP21, December 2015) stressed the importance of broadening the geographic scope of action. The Paris Agreement was finally adopted by 195 developed and developing countries. In this regard, expanding production and consumption in emerging economies pose challenges not just to emissions targets themselves, but also to the cross-country fairness of effective policy instruments. The deepening of cross-border trade and production linkages weakens the links between national commitments on emissions and the actual incentives to control emissions globally and further complicates the policy challenge.[1]

Against this backdrop it is important to understand the connections between emissions and future economic growth. A substantial literature emphasises a linkage between national income levels and

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[1] See Baldwin and Lopez-Gonzalez (2015) and Koopman et al. (2014) on how national production networks have been supplanted by cross-border ones. This poses regulatory and political economy challenges well beyond managing carbon inventories.

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demand for greater environmental quality at local level—generally known as the environmental Kuznets curve (EKC) hypothesis. The EKC hypothesis postulates that pollution increases with economic growth in the early stages of development but decreases again after a certain level of development has been reached. The point beyond which economic growth is associated with reduced pollution depends on several factors such as greater willingness to pay for environmental quality at higher levels of income. However, the political economy factors driving a local EKC (such as voters demanding cleaner water and air) may not extend from local pollutants to global ones such as CO_2, since they show potential for externalisation due to global mixing of greenhouse gases and are regarded as a necessary cost of economic growth.[2] In addition, with outsourcing and global production networks, national targets, for example for industry based in Germany, fail to take account of CO_2 produced in one location, for example China, and consumed in Germany. Hence, while the treaty framework first developed to address emission levels, in particular the Kyoto Protocol, rests on commitments on emissions within national boundaries, the connection between local activity and global emissions has been weakened by the emergence of regional and global production networks (aka global value chains).

In this paper, we focus on the extent to which we can expect global patterns of production and consumption to become more (or less) environmentally sustainable as more low- and middle-income countries converge to the production and consumption patterns of higher income countries. Working with data that reflect cross border production linkages, we investigate the relationship between real gross domestic product (GDP) per capita and CO_2 emissions per capita from fossil fuel combustion associated with production and consumption emission inventories. In controlling for linkages between production-based emissions in one country and final consumption in another we are able to focus on the entire carbon chain. For this purpose, we work with a recent dataset developed by Fernández-Amador et al. (2016). These data comprise a panel of 78 geographic entities (66 countries and 12 composite regions, covering a total of 178 economies) over the years 1997, 2001, 2004, 2007, and 2011. The data provide comparable inventories of emissions based on production and final consumption for 14 years following the adoption of the Kyoto Protocol and the first six years since it came into effect in 2005. These data, by construction, trace emissions through stages of production (and so reflect CO_2 embodied in trade flows) to final consumption. This allows us to compare the income-elasticities of both inventories and to examine the sustainability of production and consumption patterns for countries in different states of development, allowing for cross-border sourcing of carbon in consumption.

Motivated by the concept of the carbon footprint, we extend the work by Peters and Hertwich (2008) and Steinberger et al. (2013) by testing for an EKC-type relationship between income and CO_2 emissions derived from production and consumption inventories in a panel framework.[3] In addition, we simultaneously address potential sources of endogeneity postulated by theory.[4] Finally, besides estimating polynomial functions as is commonly done in the EKC literature, we estimate instrumental-variable fixed-effects threshold panel models in the spirit of Caner and Hansen (2004), treating the threshold as unknown and estimating it endogenously together with the slope parameters of the regressors, while accounting for potential reverse causality and endogeneity issues. In sum, with the aim of obtaining reliable estimates to compare the income elasticities across carbon emission inventories, the contribution of this paper is the combination of the focus on production and consumption inventories, the treatment of endogeneity of control variables, and the threshold estimation in a panel data framework, which allows to account for fixed effects and to address endogeneity and omitted variable bias.[5]

Our results indicate that income-driven shifts in consumption are more carbon intensive than those associated with production, with the difference being of economic significance. Still, both income-elasticities are smaller than one, showing relative decoupling between carbon emissions and economic growth. Income elasticities associated with both inventories tend to slightly decrease after a certain level of development has been reached, showing small carbon efficiency gains from development. On net, while emissions intensity per unit of output may decline with per capita income, the volume effects of greater production/consumption far outweigh any tendency to falling CO_2 intensity per additional dollar of income. Globally, with rising incomes, we can expect rising CO_2 levels embodied in both production and consumption. Our findings highlight the need for a more comprehensive framework of policy instruments that target emissions embodied in final consumption and not just the geography of production so that carbon efficiency gains can spread across supply chains and levels of development.

Our paper is structured as follows. In Section 2, we briefly review the theoretical and empirical literature. Our econometric framework is explained in Section 3. We describe our data in Section 4. We present results in Section 5. In Section 6, we offer conclusions.

2. Literature Review

The theoretical literature has been able to generate an income-elasticity of CO_2 emissions of the type postulated by the EKC in the framework of neoclassical (endogenous) growth and overlapping generations models. The factors that modulate the form of the (EKC-type) income-elasticity of pollution include consumption preferences incorporating disutilities from pollution, constant or increasing returns to scale of abatement investment, propensity to spend in abatement endogenously determined by utility maximisation, and the existence of intergenerational externalities.[6]

Most of these theoretical mechanisms provide an explanation for the emergence of an EKC for local pollutants. These pollutants directly and immediately affect the utility of the local population, such that there is a clear incentive to mitigate their effects. Their abatement is relatively cheap given available technologies and can be effectively implemented by local institutions. For global pollutants, like CO_2, by contrast, theoretical models usually predict a very flat or monotonic relationship between pollution and income. There are two main theoretical arguments to explain this. One of the main theoretical mechanisms for a break in monotonicity and

[2] The empirical evidence for the existence of an inverted-U relationship between CO_2 emissions and economic development is rather weak and restricted to developed economies. Indeed, it suggests that CO_2 emissions per capita may increase as income per capita rises (see, e.g., Dasgupta et al., 2002 and Stern, 2004 and 2015).

[3] Although Aichele and Felbermayr (2012) estimate the impact of the ratification of the Kyoto Protocol on CO_2 production and consumption inventories, they do not empirically test the Kuznets curve hypothesis.

[4] We follow Frankel and Rose (2005) and Aichele and Felbermayr (2012) in addressing endogeneity of carbon emissions with income and with the ratification of the Kyoto Protocol.

[5] To the best of our knowledge, this is the first study that uses the threshold regression framework developed by Caner and Hansen (2004) for a panel setup in order to assess the existence of environmental gains from development in the form of a decrease in the income-elasticity of carbon emissions.

[6] For theoretical work where an EKC-type income elasticity was modulated using the disultility from pollution, see e.g. Andreoni and Levinson (2001), Selden and Song (1995) and Stockey (1998); for constant or increasing returns to scale of abatement investment, see for example Andreoni and Levinson (2001) and Egli and Steger (2007), while Ordás-Criado et al. (2011) defined the mechanism through the propensity to spend in abatement endogenously determined by utility maximisation. For intergenerational externalities, see for example John and Pecchenino (1994), John et al. (1995), and Lieb (2004). See Dinda (2004), Pasten and Figueroa (2012), or Stern (2015), for more comprehensive reviews covering both theoretical and empirical literature.