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Impacts of urbanization and industrialization on energy consumption/CO_2 emissions: Does the level of development matter?

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ABSTRACT

Urbanization and industrialization have significant impacts on energy consumption and CO_2 emissions, but their relationship varies at different stages of economic development. Taking cognizance of heterogeneity and the "ratchet effect," this paper adopts the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) framework as a starting point and re-estimates the relationship using different panel date models. The main results are obtained by dynamic panel threshold regression models, which divide a balanced panel dataset of 73 countries over the period of 1971–2010 into four groups according to their annual income levels. The key results are: (1) in the low-income group, urbanization decreases energy consumption but increases CO_2 emissions; (2) in the middle-/low-income and high-income groups, industrialization decreases energy consumption but increases CO_2 emissions, while urbanization significantly increases both energy consumption and CO_2 emissions; (3) for the middle-/high-income group, urbanization does not significantly affect energy consumption, but does hinder the growth of emissions; while industrialization was found to have an insignificant impact on energy consumption and CO_2 emissions; (4) from the population perspective, it produces positive effects on energy consumption, and also increases emissions except for the high-income group. These novel methodology and findings reveal that different development strategies of urbanization and industrialization should be pursued depending on the levels of income in a bid to conserve energy and reduce emissions.

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1. Introduction

The industrial revolution propelled urbanization and industrialization as the predominant paths to economic and social modernization. However, these paths promote the rapid growth of fossil fuel consumption and produces significant amounts of carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions [1]. Since the 1970s, developing countries have undergone fast-paced urbanization and industrialization, triggered by rapid economic growth. These processes are also accompanied by rapid increases in fossil energy demand and CO_2 emissions (hereafter emissions). As shown by IPCC [1], emissions have grown from 21 to 38 gigatons (Gt) between 1970 and 2004, indicating an increase of about 80%, and comprise 77% of total anthropogenic GHG emissions in 2004. Increasing and robust evidence points to the fact that sizeable accumulation of emissions from fossil energy use by human activities are the main drivers of global warming, which could trigger a global climate catastrophe. Developed countries have produced most emissions in the past and currently have high per capita emissions, but the pursuit of economic growth means that most of the world's future emissions will be generated by developing countries [2,3]. However, economic growth does not carry an inherent requirement to emit greater amounts of GHG, even if these processes have gone hand in hand in the past. Excluding oil producers, per capita emissions in high-income countries vary by a factor of four, from 7 t of carbon dioxide equivalent (CO2e) per capita in Switzerland to 27 t in Australia and Luxembourg [2]. This phenomenon indicates that the relationship between economic growth, energy consumption patterns, and emissions are not unique—or mandatory.

The history of developed countries shows that economic growth is a process of urbanization and industrialization—the co-evolving movement of people from rural to urban areas and from agricultural to industrial employment. Most studies confirm that urbanization and industrialization increase energy consumption and carbon emissions [4–6], while some empirical researches find the relationship is negative [7,8]. Recent studies argue that economic growth has varied impacts on energy consumption and emissions at different development stages, such as under different per capita income levels or different urbanization rates [9–13].

Previous research has shown inconsistent results, partly due to differences in methods and sample data, but also reflecting different influences of urbanization and industrialization on energy consumption/emissions at different development stages. Industrialization is closely associated with urbanization but the two are not identical and an attempt is made to separate their respective influences on energy consumption/emissions. Generally, starting from a low stage of development, progress in urbanization and industrialization leads to industrial transformations and changes in energy consumption models, which in turn increase energy use/emissions. Rising levels of urbanization and industrialization leads, on the one hand, to improved and more effective use of urban infrastructure and industrial agglomeration, which produces negative effects on energy consumption/emissions.

This study aims to investigate the effects of urbanization and industrialization on energy consumption/emissions while considering the different levels of development. We use dynamic panel threshold regression models to regroup a balanced panel dataset of 73 countries, and our conclusion shows that the impacts of urbanization and industrialization on energy consumption/emissions vary across the levels of GDP per capita. This means that one country may exhibit a range of impacts over time due to varied levels of GDP per capita in different years. We believe these novel methods and empirical findings not only enrich the existing literature, but also merit greater attention from developing countries. The important implication of the findings is that countries should follow different strategies to promote urbanization and industrialization at different stages of development in order to conserve energy and reduce emissions.

The paper is organized as follows. Section 2 presents the literature review in detail. Section 3 details the empirical model, data and methodology. Sections 4 and 5 describe and discuss the results, respectively. Section 6 offers the conclusions and policy implications.

2. Literature review

2.1. The impact of urbanization and industrialization on energy consumption

The impact of urbanization and industrialization on energy consumption is a substantially interesting issue, and an increasing number of studies investigate it (see Table 1). Typically, a positive relationship between urbanization/industrialization and energy consumption is widely found in empirical literatures.

In a cross-country database context, the earlier literatures use a cross-section of countries to confirm a positive correlation between urbanization/industrialization and energy use [14–18]. More studies adopt cross-country panel data analysis. A typical one is York et al. [15], who found urbanization and industrialization (the percentage of the economy in the industrial sector) monotonically increase energy use and CO_2 emissions. Another typical one is Poumanyvong and Kaneko [11]. Using the STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) model, they investigated the effects of urbanization on energy in a balanced panel dataset of 99 countries over the period 1975–2005. Their results show that the relationship is positive but insignificant, while industrialization (the share of the industrial sector in the economy) positively affects energy use. York [19]found a positive relationship between urbanization and energy use for 14 EU countries using the STIRPAT model. A similar result is also found in OECD countries [20]. Jorgenson et al. [21] studied total energy consumption in 57 less developed countries and found that urbanization had a significant positive influence, but the share of the population living in urban slum conditions had a significant negative influence on energy consumption. In their analysis, manufacturing as percentage of total GDP is a control variable, and its effects on energy consumption is different according to models.

Also, some papers investigated the relationship for specific countries. For example, Lenzen et al. [22]compared the effects among the countries including Australia, Brazil, Denmark, India and Japan, and found the impacts of urbanization on energy