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Analysis

Does urbanization lead to less energy use and lower CO_2 emissions? A cross-country analysis

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ABSTRACT

Despite the relationship between urbanization, energy use and CO_2 emissions has been extensively studied in recent years, little attention has been paid to differences in development stages or income levels. Most previous studies have implicitly assumed that the impact of urbanization is homogenous for all countries. This assumption can be questionable as there are many characteristic differences among countries of different levels of affluence. This paper investigates empirically the effects of urbanization on energy use and CO_2 emissions with consideration of the different development stages. Using the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model and a balanced panel dataset of 99 countries over the period 1975–2005, the findings suggest that the impact of urbanization on energy use and emissions varies across the stages of development. Surprisingly, urbanization decreases energy use in the low-income group, while it increases energy use in the middle- and high-income groups. The impact of urbanization on emissions is positive for all the income groups, but it is more pronounced in the middle-income group than in the other income groups. These novel findings not only help advance the existing literature, but also can be of special interest to policy makers and urban planners.

1. Introduction

Urbanization is a phenomenon of economic and social modernization. It is not only the process of transferring rural labor from an agricultural-based economy to urban areas where industrial and service sectors predominate, but also the process of the structural transformation of rural areas into urban areas. Through these processes, the world has undergone rapid urbanization in recent decades, with the world urban population increasing from 1.52 billion in 1975 to 3.29 billion in 2007 (UN, 2008). Further, the urban population is projected to double to about 6.4 billion by 2050. To support such unprecedented growth, additional urban infrastructure will inevitably be called for. This possibly causes more resource consumption, exerting additional pressure on the already fragile ecosystem. In 2006, cities consumed about two-thirds of global energy and produced over 70% of global carbon dioxide (CO_2) emissions (hereafter emissions), even though only around half the world's population lived there (IEA, 2008).

The relationship between urbanization and various environmental issues, including energy use and emissions, has been studied extensively in recent years. Some researchers show that urbanization increases energy demand, generating more emissions (Cole and Neumayer, 2004; Jones, 1991; Parikh and Shukla, 1995; York, 2007). Conversely, other scholars argue that urbanization and urban density improve the efficient use of public infrastructure (e.g., public transport and other utilities), lowering energy use and emissions (Chen et al., 2008; Liddle, 2004; Newman and Kenworthy, 1989).

Previous research has shown conflicting results, suggesting that the relationship between urbanization, energy use and emissions is complex. The disagreement in the extant literature can be attributed to differences in methodologies and data. In all likelihood, the failure to consider differences in the stage of development could also be one of these factors. Most previous studies have implicitly assumed that the impact of urbanization on energy use and/or emissions is homogeneous for all countries. Such an assumption can be questionable as there are many characteristic differences (e.g., energy structure and levels of urban public service provision) among countries of different levels of wealth. It also conflicts with the arguments of ecological modernization and urban environmental transition theories that urbanization pressure on the environment may vary across the different levels of development. For instance, Ehrhardt-Martinez et al. (2002) found a curvilinear relationship between urbanization and deforestation rates. The effects of population growth on energy use and emissions are greater in developing than developed countries (Mackellar et al., 1995; Shi, 2003). However, it remains unclear whether the impact of urbanization on energy use and CO_2 emissions varies across the different levels of development or income. Further study with careful consideration of the different development stages is imperative.

The objective of this study is to investigate the effects of urbanization on energy use and CO_2 emissions, while considering

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the differences in development. Using a balanced panel dataset of 99 countries over the period 1975–2005, the findings show that the impact of urbanization on energy use and emissions varies across the different levels of development. These novel empirical findings not only help advance the existing literature, but also deserve greater attention from policy makers.

The paper is organized as follows. Section 2 presents the theoretical background, literature review and hypotheses. Section 3 details the empirical model and methodology. Section 4 describes and discusses the results. Section 5 offers conclusions and policy implications.

2. Theoretical Background, Literature Review and Hypotheses

2.1. Theoretical Background

Although urbanization is often discussed in the context of economic modernization, it is a demographic indicator that increases urban density and transforms the organization of human behavior, thereby influencing household energy use patterns (Barnes et al., 2005). However, the extent to which urbanization affects national energy use and CO_2 emissions has not been fully and clearly explained in a single theory. Instead, some possible impacts of urbanization on the environment are partially and separately discussed in three relevant theories: ecological modernization, urban environmental transition and compact city theories. The first theory focuses on impacts at the national level, while the others discuss impacts at the city level.

Ecological modernization theory emphasizes not only economic modernization but also social and institutional transformations in explaining the effects of modernization on the environment. In this theory, urbanization is the process of social transformation regarded as one important indicator of modernization. It is argued that environmental problems may increase from low to intermediate stages of development. However, further modernization can minimize such problems, as societies come to realize the importance of environmental sustainability, seeking to decouple environmental impact from economic growth through technological innovation, urban agglomeration, and the shift toward knowledge and service based industries (Crenshaw and Jenkins, 1996; Gouldson and Murphy, 1997; Mol and Spaargaren, 2000).

The urban environmental transition theory mainly discusses the types of urban environmental issues and their evolution. It suggests that urban environmental problems vary with respect to stages of economic development (McGranahan et al., 2001). Because of limited resources, low stages of development often face poverty-related environmental problems (lack of safe water supply and inadequate sanitation). However, as income levels rise, these problems gradually subside. The increasing wealth of cities is often accompanied by an increase in manufacturing activities, causing substantial industrial pollution-related issues (water and air pollution). Nonetheless, such problems decrease in wealthy cities as the result of improved environmental regulations, technological progress and structural change in the economy.

However, wealthy cities are often associated with consumption-related environmental issues. Consumption patterns and lifestyles of the wealthy cities tend to be more resource intensive than those of lower-income cities. As cities become affluent, demands for urban infrastructure, transportation and individual resource consumption rise. Consequently, consumption-related issues such as energy consumption and CO_2 emissions become more prominent. The three types of urban environmental issues could occur simultaneously at the same development stage (Bai and Imura, 2000; Marcotullio et al., 2003). However, the dominant issues of each stage described by this theory seem plausible.

The compact city theory mainly discusses the environmental benefits of urban compaction. The theory argues that high urban density allows cities to exploit economies of scale for urban public infrastructure (e.g., public transport, schools and water supply), and reduces car dependency, travel distance, the transmission and distribution losses of electricity supply, decreasing energy consumption and CO_2 emissions (Burton, 2000; Capello and Camagni, 2000; Jenks et al., 1996; Newman and Kenworthy, 1989). However, some critics argue that increasing urban density is likely to cause traffic congestion, overcrowding and greater air pollution, which will outweigh the claimed benefits of compact cities (Breheny, 2001; Rudlin and Falk, 1999). In turn, this may increase energy use and emissions. Without adequate urban infrastructure support, greater urban density can cause substantial urban environmental issues (Burgess, 2000).

2.2. Literature Review

The relationship between urbanization and various forms of environmental pressure, including energy consumption and CO_2 emissions, has been extensively investigated in recent decades using various types of data and models at the national, city and household level. To start with, using a national level analysis with cross-sectional data, Jones (1991) derived a positive correlation between urbanization and energy use per capita, noting that while urbanization enabled cities to benefit from economies of scale in production, it increased transport energy use and energy use per unit of output. Using a STIRPAT model, York et al. (2003a,b) also found that urbanization positively affects national energy footprints and emissions. Ehrhardt-Martinez et al. (2002) examined the relationship between urbanization and deforestation rates in developing nations using the environmental Kuznets curve (EKC) model. The results suggested that deforestation rates increase at the early stage of urbanization, but decline as urbanization advances. This curvilinear relationship was attributed to the effects of urban agglomeration and growing service sector dominance in urban areas.

In a time-series data context, Alam et al. (2007) investigated the impact of urbanization on CO_2 emissions in Pakistan with a model similar to the STIRPAT, and found a positive link between urbanization and emissions. Liu (2009) also found that urbanization positively influences energy use, but that the magnitude of the influence is declining. Liu (2009) attributed this decreasing influence to improvements in industrial and technological structure and more efficient utilization of resources. Similarly, Holtedahl and Joutz (2004) suggested that urbanization increases residential energy consumption for two reasons. First, moving to urban areas increases household accessibility to electricity. Second, households that had access to electricity in rural areas may increase their energy consumption after moving to urban areas by using existing electric appliances and after the purchase of new items.

In a panel data context, Parikh and Shukla (1995) showed that urbanization increases per capita energy consumption, noting that urbanization affects energy use in three ways: first, by shifting energy use from traditional fuels to modern fuels, second, by increasing embodied energy consumption through goods and service demands, and third, via direct household and transport consumption. Using the STIRPAT model, similar evidence was obtained by York (2007), who further argued that even in the most modernized nations, urbanization contributes to the growth of energy use. Following a similar model, Cole and Neumayer (2004) found that urbanization increases CO_2 emissions. On the other hand, Mishra et al. (2009) reported that the relationship between urbanization and per capita energy was negative in New Caledonia, but positive in Fiji, French Polynesia, Samoa and Tonga. Using the EKC model and OECD data, Liddle (2004) found that urbanization and population density negatively affect per capita road transport energy use, implying that populous and highly urbanized societies have less demand for personal transport.

In terms of analysis at the city level, Newman and Kenworthy (1989) examined the relationship between urban density and transport energy use using data on 32 cities in high-income countries, and found that high urban density is associated with less per capita transport energy use. Likewise, Chen et al. (2008) investigated the impact of urban compaction on household energy use using Chinese city data, concluding a negative link between urban density and per