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Is urbanization eco-friendly? An energy and land use cross-country analysis

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HIGHLIGHTS

- Ecological effects of urbanization are estimated.
- Ecological footprint is used to represent the integrated change related to energy and land use.
- Static and dynamic STIRPAT models are employed for regression.
- The reasons for the ecological protection effect of urbanization are analyzed.
- The heterogeneity of urban structure and function across income levels is discussed.

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ABSTRACT

Urbanization imposes complicated and heterogeneous impacts on ecosystems. With the purpose of reflecting the comprehensive influence of urbanization on the ecosystem, we choose the ecological footprint to represent the ecosystem's integrated change and distinguish low-income, middle-income and high-income countries to reflect the nonlinear impact. This paper uses both static and dynamic STIRPAT (Stochastic Impacts by Regression on Population, Affluence and Technology) models to analyze 72 countries at different income levels during the 1980–2008 period. The results show that the overall ecological elasticity of urbanization at the global level is negative. Specifically, results suggest urbanization, associated to increased income, to have eco-friendly potential in terms of decreased ecological footprint. To explain such results, this paper answers two questions: Why does urbanization show ecological protection effects? Why does a more pronounced protection effect seem associated to increased income levels? Improved market mechanism, increased resource use efficiency as well as increased environmental awareness in urban areas associated to increased income levels are likely to support an eco-friendly urbanization process. Burden-shift to low-income countries also needs to be taken into account, in order to avoid policies that increase wellbeing locally at the expenses of far-away areas.

1. Introduction

Currently, urbanization is proceeding worldwide, particularly in developing countries. In 2014, there were 3.9 billion people living in urban areas, representing 54% of the total population; this will increase to 66% in 2050 (UN, 2014). Large-scale urbanization has spurred global economic development. In 2011, 80% of global GDP originated from urban areas, and 600 urban cities contributed to 60% of the global GDP (Mckinsey Global Institute, 2011). However, resource consumption and environmental degradation were largely noted because population concentration would undoubtedly lead to a severe change in the ecosystem (Ji, 2015). In particular, energy scarcity, along with environmental problems, has seriously hindered global development (Ji and Long, 2016). Moreover, agricultural land was transforming to construction land in the process of urbanization. Angel et al. (2005) estimated that the average transformation rate from 1990 to 2000 was 3.2%, which was higher than that of the urban population (2.25% in the same period). Because of population swell and land expansion, interference caused by urbanization was unavoidable (Li et al., 2010). Cities accounted for two-thirds energy consumption and over 70% carbon dioxide emission in 2006 (IEA, 2008). Since

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urbanization will remain a central theme worldwide in future decades, particularly in developing countries, it is meaningful to analyze urbanization's impact on the ecosystem.

Urbanization's impact on the ecosystem is complicated and varied. In order to include energy and other natural resources as well as environmental services, this paper uses ecological footprint as an indicator that can integrate various resource consumption and environmental impacts. William Rees and Mathis Wackernagel proposed the measurement of human demands on ecosystems (Rees, 1992; Wackernagel, 1994); this is defined as the quantity of biologically productive land and sea area necessary to supply the resources a human population consumes and to assimilate the associated waste. Ecological footprint is composed of six types of land: cropland, grazing land, fishing ground, forest land, carbon uptake land and built-up land. Carbon uptake land, which is receiving more and more attention since global warming, is regarded as the land necessary to absorb the anthropic carbon emissions. Therefore, the ecological footprint provides us with an account to measure human's impact on the ecosystem. In addition, the ecological effect of urbanization was not identical across low-, middle- and high-income countries (Poumanyvong et al., 2012). Income level has a significant impact on resource utilization, technological level and resident lifestyle, thus making the ecological effect of urbanization heterogeneous across income levels.

Because of lack of suitable data and still insufficiently developed theory and methodology, existing studies suffer from simplification, homogeneity and localization. Firstly, most of them only focus on a single environmental indicator (e.g., carbon emissions) or a single natural resource (e.g., energy). A single environmental effect of urbanization only reflects a specific environmental impact caused by urbanization, whereas urbanization's influence on the ecosystem is diverse and complex. Secondly, “homogeneity”[1] is one of the most common hypotheses in existing studies, which prevents the identification of “heterogeneity” of urbanization across income levels. Third, regarding the research scope, most studies use a specific country or area as an investigated case; thus, results are not sufficiently discussed at global level. Therefore, this paper contributes to the existing knowledge in three different ways. The first novelty is to focus on comprehensive ecological impacts by means of ecological footprint as an evaluation method. The use of ecological footprint is justified by the relatively high comprehensiveness of this indicator, capable to capture at the same time the upstream and downstream demand for resources (land and energy, in particular), needed for production processes as well as for pollution abatement. In spite of still existing uncertainties, ecological footprint database is large enough to allow statistical treatment and partial uncertainty removal. The second novelty is to consider the “heterogeneity” of the ecological effect of urbanization across income levels using both the static and dynamic models. The third novelty is to evaluate the ecological effect of urbanization on a global scale.

In this paper, we define the ecological effect of urbanization as the comprehensive impact of urbanization on the ecosystem, which can be categorized into the ecological protection effect and the ecological degradation effect. The ecological effect of urbanization is a synthesized result of these two aspects. We distinguish the income level to evaluate the ecological effect of urbanization based on panel data using data from 72 countries from 1980 to 2008, to explore the influence mechanism of urbanization under different structures and functions.

The next sections are organized as follows: Section 2 summarizes theoretical background and relevant literature. Section 3 presents the methodology, data and regression procedure; Section 4 shows the regression results; Section 5 discusses the implications of regression results; and Section 6 draws conclusions and proposes suggestions on urbanization for policy makers.

2. Literature review

2.1. Existing studies on single environmental effects of urbanization

Existing studies mainly focus on urbanization's impact on a single environmental indicator or a single natural resource, defined as a single environmental effect of urbanization in this paper. Among these studies, the impact on the energy consumption and carbon emissions is the main research field (Jones, 1991; Parikh and Shukla, 1995; Cole and Neumayer, 2004; Wei et al., 2006; Wei et al., 2007; York, 2007). Most studies showed that urbanization would accelerate the energy demand and greenhouse gas emissions. For example, Jones (1991) proposed that urbanization increased the energy demand on transportation and agriculture; Parikh and Shukla (1995) analyzed the relation between urbanization, energy consumption and the greenhouse effect in developing countries and concluded that when the urbanization rate increased by 10%, the energy consumption per capita would increase by 4.7%, and the carbon dioxide emission per capita would increase by 0.3%. Cole and Neumayer (2004) verified the positive relation between carbon dioxide emissions and urbanization using data in 86 countries from 1975 to 1998 and similarly concluded that when the urbanization rate increased by 10%, carbon dioxide emissions would increase by 7%. In contrast, some researchers believed that urbanization had a scale effect because it could increase public infrastructure's usage efficiency, adjust the economic structure and reduce the commuting distance, thus decreasing energy consumption (Liddle, 2004; Chen et al., 2008). Furthermore, some studies focused on the “heterogeneity” of urbanization's energy effect. For example, Fan et al. (2006) used the STIRPAT model to recognize CO_2 emission factors at different income levels over the 1975–2000 period and observed an inverse U-shape for the urbanization impact. Poumanyvong and Kaneko (2010) realized most studies' tacit approval of the homogeneity of urbanization across income levels, and they found that urbanization in low-income countries would reduce energy consumption, whereas urbanization in middle-income and high-income countries would promote energy consumption. Ji and Chen (2015) concluded that the energy-saving effect of urbanization follows a U-shaped path across different stages of urbanization in China. Martinez-Zarzoso and Maruotti (2011) focused on the “heterogeneity” of urbanization's impact on CO_2 emissions as well, using the Bayesian Information Criterion (BIC) and the Integrated Completed Likelihood (ICL) to distinguish.

In addition, researchers have studied the impact of urbanization on land resources, forest resources, water resources and biodiversity. First, Carlson and Arthur (2000), Leitão and Ahern (2002) and Deng et al. (2009) explored the changes in land area and land use patterns in the process of urbanization. Wei and Zhang (2006) illustrated a negative relation between the urbanization rate and cultivated land area, which helped to prove that the shrinkage of the agricultural area was one feature of urbanization. Second, studies showed that urbanization would impose pressure on forest resources because forest areas were becoming tourist attractions (Ode and Fry, 2006; Atmiş et al., 2007). Third, urbanization has an influence on water volume and water quality. Hubacek et al. (2009) explained the relation between urbanization and water footprint and discussed how urbanization affected

[1] The “Homogeneity” hypothesis indicates an identical impact of urbanization on the ecosystem regardless of income level, which means evaluating the relation between urbanization and the ecological variable without distinguishing income level in the regression model; in addition, the regression result of the coefficient of urbanization is regarded as a result for all income level countries.

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