Urbanization, energy consumption and climate change

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Abstract

Existing projections of energy consumption and climate changes typically do not explicitly consider the impact of urbanization which is one of the most prominent global demographic trends in the coming decades. How serious a shortcoming this may be remains an open question given the scarcity of research on the links between urbanization and energy use. A few researches of the impact of urbanization on energy use suffer a number of problems including do not consider the different patterns of urbanization and the effect of collinearity involving other variables, such as economic growth, industrialization. Based on data of 183 countries/regions of the world for the period of 1950-2005, this research statistically identifies three major types of urbanizations, according to its relationships with industrialization and economic growth. The research explores the net effect of urban population growth under various urbanization processes, provides useful information for developing scenarios of future climate change.

Extended abstract

Most outlooks for future energy use and associate emissions do not account explicitly for urbanization (O'Neill et al., 2001). This may seem surprising given the substantial attention in the energy studies literature devoted to attempt to understand the determinants and consequences of urban and rural energy use. A key obstacle to bridging these two areas of research has been a difference in scale: while energy projections are often made at the national or global level and attempt to account comprehensively for economy-wide energy demand, the energy studies literature has focused largely on specific household and market activities and/or specific energy types, usually at a relatively small geographic scale (e.g., Meier, Berman et al. 1978; Sathaye and Meyers 1985; Sathaye and Tyler 1991; Sheinbaum, Matinez et al. 1996; Karekezi and Majoro 1999; Adeoti, Idowu et al. 2001). Only a few studies have attempted to assess the aggregate effects of urbanization on energy consumption and greenhouse gas emissions. Jones (1989, 1991) used data from 59 developing countries in 1980 to identify mechanisms through which urbanization affects energy consumption. Parikh and Shukla (1995) regressed per capita energy consumption on urbanization and some economic indicators for a sample of developed and developing countries over the period 1965-87. Both studies suggest a weak positive contribution of urbanization to energy use: holding income and industrialization level constant, the urbanization elasticity of per capita commercial energy consumption is close to 0.5 (i.e., a 1% increase in the proportion urban leads to a 0.5% increase in average per capita commercial energy consumption). When total energy (both commercial and biomass) consumption is considered, the elasticity is reduced to 0.35 (Jones 1991); when fixed effects of countries and time periods are accounted for, the elasticity fall to 0.28 (Parikh and Shukla 1995).

The two studies provide a useful framework for analyzing the relationships between urbanization and energy consumption at the aggregate level, but have two shortcomings relative to the goal of estimating the effect of urbanization *per se* on energy use. First, some effects of industrialization and income growth were attributed to urbanization, blurring distinctions among these processes. For instance, increases in energy-use in agriculture due to increased mechanization and commercial fertilizer use, and changes in industrial structure – both essential components of industrialization – were attributed to urbanization. Similarly, income-induced increases in demand for modern appliances and more efficient and convenient fuels by households were also attributed to urban growth (Jones 1989).

It is particularly important to be clear about terminology because the terms "urbanization" and "industrialization" are not always defined consistently and are often used inter-changeably in the field of development. For example, Schnore (1964) summarized three types of approaches in the study of urbanization: (1) a process of population concentration; (2) a reorganization of economic activities; (3) a change in the social values and behavior of people. The second definition clearly overlaps with "industrialization" (as define, e.g., in Hewitt, Johnson et al. 1992). Economists and demographers typically use a strictly demographic conception of urbanization in order to permit examination of its interrelations with other aspects of economic and social development. In this analysis, we adopt the definition of urbanization which is commonly used in the field of population studies, measured by the proportion of population residing in urban areas (Goldstein and Sly 1975).

Second, regression analyses in these studies did not take sufficient account of multi-collinearity. The multiple regression models they employed used urbanization, industrialization and per capita GDP along with other variables to predict changes in per capita energy consumption. The high correlations among these three variables leads to the problem of multi-collinearity, in which a model may explain a high proportion of the variance in the dependent variable, but the coefficient of any given independent variable cannot be reliably interpreted. Thus conclusions on the net effect of single variables (such as urbanization) cannot be drawn confidently.

In addition, both studies use multi-country, macro-level data sets, in which the results are sensitive to the number and types of countries included in the analysis as well as to model specification. Moreover, China was excluded from those two studies, possibly due to data shortage. However, as the largest developing country and the second largest green house gas emitter, China's energy consumption has important implication for global climate change. A recent study, using time series aggregate data and micro-level data from the 1999 China rural and urban socio-economic household survey, reveal that industrialization was the major driving force behind increasing energy use in China since 1950, while urbanization *per se* and income growth did not exert significant net effects until the end of 1990s (Jiang and O'Neill, 2007).

In this paper, historical data is collected and organized from World Bank World Tables of Economic and Social Indicators 1950-1992 and later years, IEA Energy Balances for

OECD countries 1960-2005 and for Non-OECD countries 1970-2004, EIA International Energy Annual. This dataset includes variables of proportion of urban population, proportion of agricultural labor, GDP per capita, GDP contributed from industrial sectors, per capita overall energy consumption and energy consumption by sectors, and per capita carbon dioxide emission and emission by sectors, for 183 countries/regions, and for the period of 1950-2005 (some years not available for certain variables).

Using this set of data, urbanization is divided into three categories according to its relationships with economic growth and industrialization: (1) urbanization accompanied by industrialization and economic growth, (e.g., it occurred in the history of many industrialized countries), (2) urbanization without industrialization (e.g., in many Latin American, African and Middle Eastern countries in the 1960s and 1970s) (Hoselitz and Moore 1966; United Nations 1969; Hance 1970), and (3) industrialization without urbanization (as experienced in many former socialist countries in eastern Europe and China in the 1960s to 1980s). Adopted autoregressive analysis method, this research explores the causal relations between urbanization, income growth, industrialization and energy consumption, carbon emissions among all the countries of various historical patterns of urbanization. It aims to improve our understandings on the impacts of urbanization on energy consumption and climate change, and gain insights for future urbanization planning, and contribute to the development of assumptions/scenarios for climate changes modeling in which population dynamics (including urbanization) is adequately taken into account.

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