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Might electricity consumption cause urbanization instead? Evidence from heterogeneous panel long-run causality tests

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ABSTRACT

The share of a population living in urban areas, or urbanization, is both an important demographic, socio-economic phenomenon and a popular explanatory variable in macro-level models of energy and electricity consumption and their resulting carbon emissions. Indeed, there is a substantial, growing subset of the global modeling literature that seeks to link urbanization with energy and electricity consumption, as well as with carbon emissions. This paper aims to inform both modelers and model consumers about the appropriateness of establishing such a link by examining the nature of long-run causality between electricity consumption and urbanization using heterogeneous panel methods and data from 105 countries spanning 1971–2009. In addition, the analysis of the time series properties of urbanization has implications both for modelers and for understanding the urbanization phenomenon. We consider total, industrial, and residential aggregations of electricity consumption per capita, three income-based panels, and three geography-based panels for non-OECD countries. The panel unit root, cointegration, and causality tests used account for cross-sectional dependence, nonstationarity, and heterogeneity – all of which are present in the data set. We cannot reject pervasively Granger causality in the urbanization to electricity consumption direction. However, the causality finding that is both the strongest and most similar across the various panels is that of long-run Granger causality from electricity consumption to urbanization. In other words, the employment and quality of life opportunities that access to electricity afford likely encourage migration to cities, and thus, cause urbanization. Also, nearly all countries' urbanization series contained structural breaks, and the most recent post-break annual change rates suggested that nearly all countries' rates of urbanization change were slowing. Lastly, future modeling work on energy consumption or carbon emissions should consider subnational scales of analysis, and focus on measures of urban density or urban form rather than national urbanization levels.

1. Introduction

Increases in anthropogenic greenhouse gas emissions and concentrations – which predominately result from the combustion of fossil fuels – are believed to have caused most of the recent increases in global average temperatures, i.e., climate change. The increased interest in how energy consumption and its resulting carbon emissions impact climate, coupled with the availability of yearly, national-level data (from sources like the World Bank and International Energy Agency) covering various aggregations of energy consumption and socio-economic variables, has helped spur a substantial number of empirical analyses that estimate the socio-economic drivers of that consumption and emissions. Moreover, urbanization has become an important phenomenon – the level of world urbanization (the share of a population living in urban areas) crossed the 50% mark in 2009, and the United Nations expects that over the next 40 years urban areas will absorb all of the projected 2.3 billion global population growth while urban areas will continue to draw in some rural population; thus, the importance of that phenomenon has led several empirical analyses or models to include urbanization as a potentially key socio-economic driver. Indeed, 13 of the 21 papers listed in Table 1 were published from 2009 forward – Table 1 lists the studies that have examined the link between urbanization and energy or electricity consumption. A similar number of very recent papers have focused on the link between urbanization and energy consumption's resulting carbon emissions, e.g., Knight et al. (2013).

The first of these studies focused on developing countries and found a positive, significant relationship between urbanization and energy consumption (Jones, 1989; Burney, 1995; Parikh and

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Table 1
Summary of urbanization-energy/electricity consumption analyses.

Studies testing for an assumed urbanization causes energy or electricity consumption relationship

Study	Dependent variable	Method	Country/ies (period)	Urbanization results
Jones (1989)	Modern energy per capita	OLS	59 developing countries (1980)	+0.45
Burney (1995)[a]	Electricity consumption per capita	OLS	93 countries (1990)	+0.01
Parikh and Shukla (1995)	Energy consumption per capita	FE OLS	78 developed & developing countries (1965–1987)	+0.28
Holtedahl and Joutz (2004)	Residential electricity per capita	Cointegration, ECM	Taiwan (1955–1995)	+1.61
Liddle (2004)[a]	Road energy use per capita	FE OLS	23 OECD countries (1960–2000, 10-yr intervals)	−0.47
York (2007a)	Total energy consumption	Prais-Winsten regression	14 EU countries (1960–2000)	+0.53
York (2007b)	Total energy consumption	Prais-Winsten regression	14 Asian countries (1971–2002)	−0.22 (level); 0.37 (quadratic)
Jorgenson et al. (2010)	Total energy consumption	FD OLS	57 less developed countries (1990–2005)	+0.37
Liddle and Lung (2010)	Total residential electricity consumption	FD FE OLS	16 OECD countries (1960–2005, 5-yr intervals)	+1.92
Poumanyvong and Kaneko (2010)	Total energy consumption	FD FE OLS	99 countries (1975–2005)	+0.91 (HI); +0.51[b] (MI); −0.12[b] (LI)
Adom et al. (2012)	Total electricity consumption	ADRL, ECM	Ghana (1975–2005)	+0.62
Poumanyvong et al. (2012)	Total road transport energy use	FE OLS	92 countries (1975–2005)	+1.33(HI); +0.37(MI); +0.81(LI)
Fang et al. (2012)	Total primary energy use	FD system GMM	94 countries (1981–2007)	−0.01 (HI); NS (LI)

Studies testing for possible bi-directional causality between energy or electricity consumption and urbanization

Study	Dependent variable	Method(s)	Country/ies (period)	Causality	Urbanization elasticity
Halicioglu (2007)	Residential electricity consumption per capita	ADRL, ECM	Turkey (1968–2005)	No causality	0.04[b]
Liu (2009)	Total energy consumption	ADRL, ECM	China (1978–2005)	Urbanization→ energy (+)	NS
Mishra et al. (2009)	Energy consumption per capita	Panel cointegration & Granger causality	9 PIC (1980–2005)	Urbanization→ energy (+)	2.41
Gam and Ben Rejeb (2012)	Electricity consumption	Cointegration, error correction, & Granger causality	Tunisia (1976–2006)	Urbanization ←→ electricity (+)	NS
Michieka and Fletcher (2012)	Coal consumption; Electricity production from coal sources	Toda & Yamamoto version of Granger causality	China (1971–2009)	No causality Urbanization → electricity (+)	NA
Shahbaz and Lean (2012)	Energy consumption per capita	ADRL, Granger causality	Tunisia (1971–2008)	Energy → urbanization (+)	0.87
Al-mulali et al. (2013)	Energy consumption per capita	Granger causality, DOLS	20 MENA countries (1980–2009)	Energy ←→ urbanization	0.57
Solarin and Shahbaz (2013)	Electricity consumption per capita	ADRL, Granger causality	Angola (1971–2009)	Urbanization ←→ electricity	NA

Notes: ARDL: Autogressive distributed lag; OLS: ordinary least squares; FE: fixed effects; ECM: error correction model; FD: first differences; GMM: generalized method of moments; DOLS: dynamic ordinary least squares; HI: high income; MI: middle income; LI: low income. PIC: Pacific Island countries; NIC: Newly industrialized countries; MENA: Middle East North Africa; NS: not significant; NA: not estimated.

[a] Used a semi-log model; all other studies took natural logs of all variables; and thus, their coefficients can be interpreted as elasticities.

[b] Statistically significant at $p < 0.10$; all other reported urbanization coefficients were statistically significant at $p < 0.05$ or higher.

Shukla, 1995). More recent, similar studies have considered developed countries as well, disaggregated energy consumption, and provided additional explanatory variables; and those studies have typically confirmed the positive relationship between urbanization and energy consumption (see the listing in the top panel of Table 1).

The papers shown in the top panel of Table 1 all assumed a one-way causal direction, i.e., urbanization causes energy or electricity consumption; yet, it is possible energy or electricity consumption causes urbanization by motivating rural–urban migration. Studies that test for the possibility of a mutual causal relationship between urbanization and energy or electricity (shown in the bottom panel of Table 1) have focused on single countries or panels consisting of a relatively small sample of countries. In this paper we examine the potentially bi-directional causal nature of the urbanization and electricity consumption relationship considering several different aggregations of electricity consumption, panels of a large number of developed and developing countries, and the long-run panel version of Granger causality recommended by Canning and Pedroni (2008). Our analysis of a large number of countries' urbanization series and our finding of a bi-directional causal relationship between electricity consumption and urbanization (i) have several important implications for modelers; and (ii) suggest that the policy proscriptions derived from models that do not allow for this bi-directional causal possibility may not be so straightforward.

2. Urbanization and energy or electricity consumption links

A key reason urbanization tends to accompany economic development is the industrialization process through which the typically rural agricultural labor force migrates to the typically urban manufacturing factories. The co-evolving movement of people from rural to urban areas and from agricultural to industrial employment causes energy consumption to increase in at least three ways: (1) agricultural operations must mechanize as they become less labor intensive; (2) urbanization spatially separates food consumers from food producers, thus necessitating a