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Industrial electricity consumption, human capital investment and economic growth in Chinese cities[☆]

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ABSTRACT

We examine the cointegrating and Granger causal relationships between economic growth, industrial electricity consumption and human capital in China using a panel consisting of 210 prefecture cities across a period of 2003–2012. Applying continuously-updated fully modified panel estimation, we find that industrial electricity consumption has a significantly larger impact on economic prosperity than physical and human capital investment. Industrial electricity consumption plays a dominant role to boost growth in the center and the west, while human capital contributes most to the growth of the east. And notably, core cities are the largest beneficiaries from the growth of production inputs. Accounting for heterogeneity and cross-section dependence, results from the Granger non-causality tests suggest that the implementation of electricity-saving strategy is more feasible in inland China without hampering the economic growth and development of human capital. In the east, regulators must make efforts to increase investment in building electricity infrastructure to connect demand with supply to avoid shortage of power having an adverse effect on economic growth. Reducing the urban-rural gap in electricity tariffs and improving development of rural electricity network are rationalized to achieve sustainable economic development for the urban community in China.

1. Introduction

As a populous country, China's global influence due to the impressive economic growth and the associated impacts on climate change and environmental issues over the last four decades has thrusted her into the limelight. Nowadays, the public, government regulators and international organizations have increasingly paid attention to the accelerating energy consumption and green gas emissions in China, especially since the entry into WTO in December 2001. China's electricity sector is of particular concern as it generates almost 80% of the country's demand for coal (National Bureau of Statistics China, 2014), accounts for almost half of the greenhouse gas emissions (Steenhof and Fulton, 2007) and performs as a major emitter of SO_2, NO_x and fine particulate matter (Minchener, 2012). The significant use of coal as the primary power generation source causes severe air pollution problems such as smog and acid rain, especially in the urban areas of China, and adversely affects the health status of city residents (He et al., 2016; Xie et al., 2016). Chinese regulators have made addressing these problems as key priorities, but nearly 90% of cities fail to meet the pollution standards set for existing power plants (The Ministry of Environmental Protection, 2015), mostly constrained by her economic growth targets. Motivated by the context of fast and uneven urbanization, industrialization and concomitant environmental challenges characterizing cities in China, we aim to answer two main questions: (1) does industrial electricity consumption play a positive and equally important role in the economic growth of different cities[1] in China, and (2) what is the causal direction between industrial electricity consumption and economic growth of cities.

As a major player in the world electricity market, the growth rate of electricity consumption in China has been the highest in the world. During the period of 1990–2012, the average annual growth rate of electricity consumption in China reaches 10%, more than double the world average. Its total electricity consumption has surpassed the U.S. in 2011, and become the world's top consumer of electricity (Fig. 1).

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[1] We divide cities into four tiers in this article. The classification of city tiers is based on the following criteria: administrative power, economic size, population, and regional influence. The classification criterion of tier 1-4 cities is developed by the Institute of Finance and Trade Economics of the Chinese Academy of Social Sciences. Other institutions have their own classifications, but the definitions are conceptually similar. We define tier 1 and tier 2 cities as the core and the tier 3 and tier 4 cities as the periphery.

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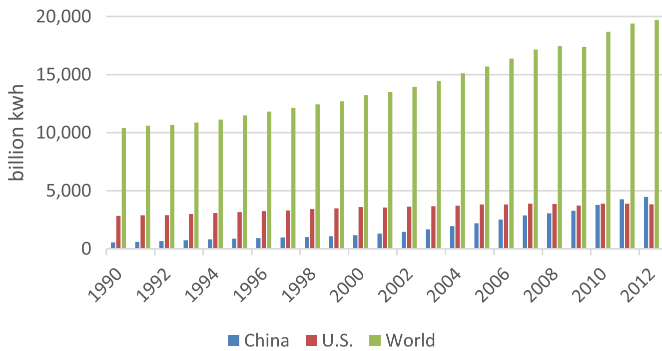

Fig. 1. Total electricity consumption in China, U.S. and the World (1990–2012).
Source: Energy Information Administration.

The drastic increase of power demand, especially since 2002 one year after China entering WTO, might be driven by an export-oriented industrial expansion and increasing demands for heating, cooking, lighting and electric appliances (International Energy Outlook, 2016). Decomposing the electricity consumption by sector, the annual average electricity consumption in the industrial sector accounts for 73% of total electricity consumption during 1994–2015, followed by 12% consumption in the residential sector, 3% in agriculture, 3% in the wholesale and retail service sector, 2% in transportation, 1% in construction and 6% in others (Fig. 2). This clearly indicates that power demand is particularly pertinent to industrial output activities.

There are a few cross-country studies with a coverage of China that confirm the co-integration of GDP and electricity consumption (Cowan et al., 2014; Karanfil and Li, 2015), time-series analyses with mixed findings in the direction of causal relationship (Shiu and Lam, 2004; Yuan et al., 2007) and one panel study of the nexus of provincial economic growth and electricity (Herrerias et al., 2013). However, there has been no empirical work focusing on the electricity-growth nexus for the urban community in China. In addition, though the innovation in new economic geography theory (Krugman 1992, 1993; Krugman and Venables, 1995) clearly points out that the growth of core with increasing share of industrial activities might be at the expense of the periphery area. None of these energy-growth studies consider the core-periphery framework or account for the large heterogeneity in electricity consumption and economic development across different types of cities grouped by such criteria as administrative power, economic size, population, and regional influence. In this study, we divide cities into four tiers and group tier-1 and tier-2 cities into the core and tier-3 and tier-4 cities into the periphery. The core comprises of five tier-1 prefecture-level cities which are either political or economic centers of the nation such as Beijing, Shanghai, Tianjin, Guangzhou and Shenzhen, and thirty-three tier-two cities which are provincial capitals and or regional economic hubs. The periphery comprises the rest of cities. Based on this tier classification, we plot in Fig. 3 the annual growth of output against the annual growth of industrial electricity consumption in per unit-labor term by city tier and show that contribution of electricity consumption to economic growth is strikingly different across tiers. It is thus interesting to explore whether and to what extent the industrial electricity consumption contributes to city economic prosperity within the core-periphery framework.

We contribute to the electricity-growth nexus studies in three distinct aspects. First, we focus on the growth-electricity nexus exclusively in China, accounting for commonly observed cross-sectional dependence and potential heterogeneity of causal relations using the city-level panel data. Recent electricity-growth nexus studies have increasingly used panel data and panel causality tests that allow for both the heterogeneity and cross-sectional dependence, to provide updated and more convincing conclusions (Wolde-Rufael, 2014). This new advancement in the Chinese electricity-growth nexus literature, however, seems to be lagging behind. Herrerias et al. (2013) is one of the pioneering works that have used Chinese provincial data for a period of 1995–2009 to investigate the relationship between energy consumption and economic growth; nonetheless, results from their bivariate framework analysis are subject to omitted variable biasness. Therefore, more panel studies in the Chinese context are justified. The city panel used in this paper has never been seen in the existing literature and enables more in-depth discussions.

Second, a multivariate framework that accounts for both physical and human capital investment is applied. While the energy-augmented neoclassical production function is often used as a framework, Stern (1993) points out the issue of missing variable biasness in the bivariate setup. Human capital, a vital contributor to economic growth, has only recently been incorporated to the analysis (Pablo-Romero and Sánchez-Braza, 2015; Fang and Chang, 2016; Salim et al., 2017). This is largely due to lack of reliable human capital data across countries and regions, which is more of an issue when we use city-level data in China. In the human capital literature, Madariaga and Poncet (2007), Ouyang and Fu (2012) and Su and Liu (2016) use the share of city population enrolled in higher education as a measure of human capital; Jones et al. (2003) use the high school enrollment without considering the quantity of skilled labor; and average years of schooling is adopted by Bengoa et al. (2017) and Zhu et al. (2014). Each of these measures comes with its own justifications and limitations. In our sample, average years of schooling are not available, and there is a serious problem with the enrollment measure which has many zero values for cities without universities or colleges. Thus, we use the city-level public expenditure on education as a measure of

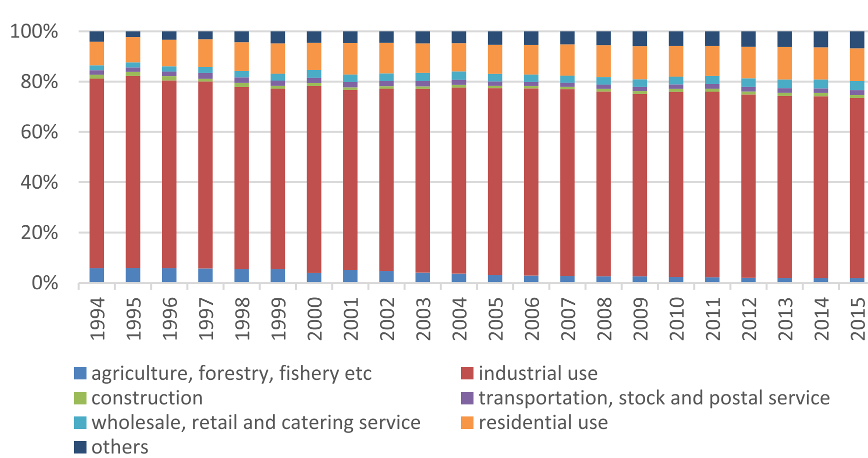

Fig. 2. The composition of electricity consumption by sector (1994–2015).
Source: National Bureau of Statistics China (1995–2016); authors' self-calculation.