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Effects of electricity-price policy on electricity demand and manufacturing output☆

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ABSTRACT

The rapid increase of global electricity consumption has led to electric power shortages and economic loss. Price controls for anticipated changes in electricity demand have been widely adopted as a short-term solution. This research analyzes the effects of electricity-price policy on electricity demand and manufacturing output. South Korea's electricity demand in the manufacturing sector is used as a case study. We fail to reject hypotheses that (1) an increase in electricity price decreases electricity demand, which adversely affects manufacturing output and (2) the effects of regionally-varying price changes versus regionally-uniform price changes on electricity demand and manufacturing output differ regionally. Our findings suggest that the South Korean government's plan to increase the electricity price should be implemented with caution. The plan would achieve the objective of mitigating electricity demand to avoid potential power shortages; however, the more rapid increase in electricity prices may trigger a slowdown in the manufacturing sector. Our findings also imply that South Korean experts' suggestion of regionally-varying electricity pricing needs further consideration. Although reflecting regional differences in costs of supplying electricity is important, regionally-varying pricing may prompt a slowdown in the Seoul metro area manufacturing sector where manufacturing is more concentrated than in other areas.

1. Introduction

1.1. Background

Electricity demand has increased faster than overall energy use in recent years [83]. Total worldwide electricity consumption grew by 40% during 2000–2010 while overall energy use grew by 26% during the same period [25]. The proportion of electricity consumption in total global energy use increased steadily from 16.3% to 17.7% between 2005 and 2010, while the share of oil consumption decreased by 2.2% during the same period [36,37]. The recent rise in electricity consumption can be credited to (*i*) a global prevalence of electronic devices such as televisions, personal computers, and mobile telephones and (*ii*) surging demand for electricity in emerging economies such as China, where electricity use increased by 66% during 2005–2010 [25,82].

The rapid increase of electricity consumption has led to electric power shortages and economic loss. Power shortages have occurred due to an increase in electricity demand caused by unusually extreme weather in recent years and unstable electricity supply caused by dramatic changes in fuel prices and power system malfunctions [66]. Blackouts caused major economic losses in western North America in the summer of 1996, Brazil in 1996, the northeastern United States and Europe in August and September 2003, and Greece in July 2004 [74]. For example, the blackout that occurred in August 2003 in the northeastern United States (i.e., Michigan, Indiana, Pennsylvania, New York, New Jersey, Connecticut, and Vermont) resulted in an estimated economic loss of $1 billion [56].

To avoid such power system failures in the future, the capacity and reliability of electricity supply can be improved and/or

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electricity demand can be mitigated. Improving electricity supply is considered a long-term solution because increasing reliable capacity requires significant resources. Alternatively, price controls by sector, region, and time for anticipated changes in electricity demand have been widely adopted as a short-term solution [67,70]. Although various price-control approaches can reduce electricity consumption in the short run, they may also affect the output of high energy-intensive industries (e.g., metals, mining, and steel), which consumed 43% of global electricity in 2011 [37] and concentrated in low-energy price regions [45]. In evaluating such relationships, the majority of research has focused on (i) the price elasticity of electricity demand and (ii) causality between electricity demand and manufacturing output. Despite the abundant literature dealing with those relationships, appropriate focus has not been given to assessing the effect of changes in electricity price on electricity demand and the resulting effect on manufacturing output. The scarcity of such research is surprising, given the possibility that (i) causality runs from both economic activity and electricity price to electricity consumption and (ii) causality runs from electricity price and electricity consumption to economic activity [8].

Likewise, proper attention has not been given to evaluating the impacts of regionally-varying prices on electricity demand and manufacturing output, or to their spatial dynamic processes. The lack of research in this regard is also unexpected given that (1) many countries have adopted (e.g., Australia, Canada, Japan, the United Kingdom, and the United States) or are considering adoption of regionally-varying prices based on regional differences in costs of generation, transmission, and distribution of electricity (e.g., South Korea) and (2) the findings that electricity demand and manufacturing output are spatially interrelated [11,18,22,23,45]. Our research attempts to fill theses gaps in knowledge by analyzing the relationships among electricity price, electricity demand, and manufacturing output in a spatial modeling framework to simulate the effects of regionally-varying prices and regionally-uniform prices on manufacturing's electricity demand and output.

1.2. Objectives and significance

The objective of our research is to analyze the effects of electricity-price policy on electricity demand and manufacturing output, focusing particularly on whether and how these relationships vary over space. By assessing these relationships in a spatial econometric modeling framework, we hypothesize that (1) an increase in electricity price decreases the quantity of electricity demanded, which adversely affects manufacturing output. The spatial econometric estimates are then used in a simulation analysis to test the hypothesis that (2) changing from a regionally-uniform pricing policy to a regionally-varying pricing policy has different regional effects on electricity demand and manufacturing output.

Related to hypothesis (1), the literature shows different price elasticities of electricity demand across different economic sectors (e.g., [2,11,12,31,35,53,70], causal relationships between electricity consumption and economic activity [6,13,49,52,73], and causality among electricity price, electricity consumption, and economic activity [3,8,58].

Regarding hypothesis (2), the literature shows regional variation in price elasticities of electricity demand (e.g., [7,70,76], differences in price elasticities of electricity demand depending on the electricity-intensities of industries [9], better cost efficiency of regionally-varying pricing relative to regionally-uniform pricing [47,57], and spatial neighborhood effects of electricity demand and manufacturing output [11,18,22,23].

Our research contributes to the literature in three ways. First, we simulate the effect of changes in electricity price on electricity demand and how those changes in electricity demand subsequently affect manufacturing output in a single modeling framework. Within the literature dealing with the relationship between electricity price and electricity demand, the impact on manufacturing output has been ignored (e.g., [12,31,35,53]. In contrast, the literature dealing with causality between electricity demand and manufacturing output has ignored the electricity price and demand relationship (e.g., [13,73]. The development of two separate threads of relevant literature is surprising knowing that the two relationships (i.e., electricity price/electricity demand and electricity demand/manufacturing output) are interrelated. By analyzing these relationships in one modeling framework, we anticipate the potential consequences of electricity-price policies on both electricity demand and manufacturing output simultaneously.

Second, we simulate electricity demand and manufacturing output under the *status quo* (baseline) and two hypothetical electricity price plans. Among the relevant literature, the causality among electricity price, electricity consumption, and economic activity in the manufacturing sector was explored [8]. Despite their contribution in determining causal relationships, price simulations of electricity demand and economic output were not performed to evaluate electricity-pricing policy. The need for *ex-ante* price simulations arises because *ex-ante* simulations can help policy makers evaluate the potential consequences on electricity demand and manufacturing output before a price policy is actually implemented.

Third, we apply a general spatial model that accommodates spatial correlations in the relationships among electricity price, electricity demand, and manufacturing output. The earlier literature mostly focused on estimating electricity demand functions for residential and other sectors without considering spatial issues associated with the relationship (e.g., [12,31,35,53]. More recently researchers have begun dealing with the spatial issues inherent in electricity prices and demand (e.g., [2,11,18,70]. Similarly, recent literature has begun dealing with the spatial issues related to manufacturing output (e.g., [22,23]. Nevertheless, few, if any, studies have dealt with the spatial aspects that characterize the relationships among electricity price, electricity demand, and manufacturing output in a single modeling framework.

In the remainder of this paper, we present a conceptual framework for the joint analysis of electricity demand and its effects on manufacturing output in the context of input demand and production output. Then, we specify an empirical model for use in simulating electricity-pricing policy. Next, we discuss the results of the empirical estimates and simulations, followed by conclusions.

2. Methods

2.1. Theoretical framework

Consider a manufacturing firm that produces output quantity Q using electricity E, labor L, and capital K inputs at minimum total cost. Assuming a Cobb–Douglas production function with constant returns to scale and constant total factor productivity that is not explained by electricity, labor, and capital (e.g., technology) (A), the firm's cost-minimizing input choice is determined by solving:

$$\min_{E,L,K} eE + wL + vK, \tag{1}$$