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Dynamic demand for residential electricity in Taiwan under seasonality and increasing-block pricing

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ABSTRACT

This paper studies the dynamic demand for residential electricity in Taiwan employing a monthly panel data set, composed of 19 counties and spanning the period from 2007:01 to 2013:12. The partial adjustment model used addresses the endogeneity of the electricity price that results from the increasing-block pricing. The estimated results show that there is a significant seasonal difference in the demand for electricity between the summer and non-summer periods. Both the adjustment speed and own price elasticity during the summer months are found to be lower than those in the non-summer months due to the hot weather in summer. It is easier for consumers to adjust their electricity consumption in response to the changes in electricity pricing during the non-summer time. The estimated inelastic short-run and long-run income effects show that electricity is a necessity for consumers. Moreover, the controversial electricity-conservation policies are found to be ineffective measures for reducing electricity consumption in Taiwan.

1. Introduction

Energy-related resources are scarce in Taiwan. The indigenous energy supply accounts for only around 2% of the total and the remaining 98% must be imported (Bureau of Energy, Taiwan). Around half of the energy consumption in this island is in the form of electricity. Electricity consumption per capita was as high as 10,500 kWh in 2013, having grown by 100% over the previous two decades. To resolve the problems that result from the huge shortage of indigenous energy in the market, increasing and volatile international energy costs, CO_2 emissions, and the huge financial deficits recorded by the public electricity utilities among other things, the government has attempted to improve the demand-side management of electricity consumption by modifying electricity policies.

In terms of residential electricity demand, policies such as increasing the electricity tariff, providing a tariff discount based on energy conservation, launching the energy efficiency rating and labeling system, and subsidizing the purchase of energy-conservation appliances, have been advocated and implemented. These policies and proposals, in particular increasing the electricity tariff and the "Power Tariff Discount on Energy Conservation Incentive Measures," have, however, stirred up widespread controversy and led to conflicts among the government, the general population, industries, and the electric utility.

The electricity price is regulated in Taiwan. It has been adjusted upward several times in the past few years mainly to respond to the increasing and volatile production costs and is planned to be floating in the very near future. On the one hand, the rising electricity price has been criticized for aggravating the living burden faced by the general public and its effect in term of conserving electricity has been questioned. On the other hand, the "Power Tariff Discount on Energy Conservation Incentive Measures" have allowed those households whose average daily electricity consumption has fallen below that in the same period for the previous year to be entitled to certain tariff discounts. This policy has been aimed at promoting residential electricity conservation and at reducing the impact of and resistance to the enforcement of the rise in the electricity price. Nonetheless, the actual effect of this policy on electricity conservation is unclear. This is because it provides the conservation incentive only to existing (not new) electricity users and it might become harder and harder to further conserve electricity over time. In addition, because of the tariff discounts, this policy is associated with a revenue loss which worsens the already serious

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problem of the financial deficit generated by the utility. Exactly what the empirical effect of this policy might be deserves further research. Therefore, the unknown effects of the price and discount-incentive policies motivate us to estimate the empirical demand for electricity. The price and income elasticities of demand for electricity are essential measures describing the behavior of consumers and the empirical results can be used to examine the policy effects as well as provide us with useful policy implications.

There exist few studies that estimate the electricity demand function for the case of Taiwan. Holtedahl and Joutz (2004) used Taiwan annual time-series data for the period 1955–1995 to estimate the residential electricity demand. Su et al. (2011) used a household data set with monthly average variables for the period from January 2009 to August 2010. Hsueh (1988) pooled household data from 1982 and 1986 (summer and winter, respectively) to perform the estimation. This paper aims to improve the literature from the points of view of data collection, the treatment of seasonality, the endogeneity of the electricity price, and the specifications of the empirical model.

First, the samples that the above three papers applied are either based on time series or cross-sectional data sets. In this study, we instead collect a panel data set composed of monthly county-level aggregate data spanning the period from January 2007 to December 2013. This large and richer data set allows us to explore the electricity demand both over time and across regions. In particular in recent years, the economic and energy environments and relevant policies have varied dramatically in Taiwan and around the world. Our newer data set is able to offer more accurate information on consumer behavior and allow us to examine the effects of recently implemented electricity-conservation policies.

Second, by taking advantage of monthly data, we can study the seasonality of electricity consumption. Because the peak of electricity consumption in a year is concentrated in the summer months, the regulated rates in June, July, August, and September (called the summer rates hereafter) have been higher than those in the non-summer months (called the non-summer rates hereafter) since 1989. This pricing structure aims to reduce the possible waste of electricity consumption in the summer months in addition to reflecting the higher marginal production costs. Under different electricity prices and weather conditions, it is reasonable to expect that the residential electricity consumption patterns differ between the summer and non-summer months. It is thus crucial to distinguish the demand function in the summer months from that in the non-summer months, or biased estimates may result.

Third, the rate structure in Taiwan is increasing-block pricing (see Table 1 for the rate structures promulgated within the time span of our data set). The co-determination of the price and consumption of electricity will yield biased and inconsistent estimates when ordinary least squares (OLS) is used. In this paper, an instrumental variable approach proposed by Billings (1982) is employed to deal with the simultaneity bias.[1] This IV method creates a set of constant IVs for each legal rate structure that corresponds to the Taylor–Nordin specification of the marginal price and difference parameters (see Nordin (1976) and Taylor (1975)). It assumes that consumers, instead of taking the effort to learn how a rate structure works and which block they are applying at each moment in time, will roughly estimate the whole rate structure from a linear regression of the theoretical electricity bills to obtain the price information and consume electricity accordingly. Because the IVs are predetermined and vary over the rate structures (and not over the quantities consumed), no feedback regarding the effect of quantity on price can be obtained. This IV method appears to be appropriate for the case of Taiwan. The reason is that because the rate structure enforced on the island is very complicated, it is impossible for households to fully understand what is the exact marginal price they are charged. In addition, the IVs can reflect the differences in rate structures among seasons and years and avoid the problem of simultaneity bias.[2]

Finally, we specify a dynamic panel data model to estimate the balanced panel data set that covers the county-level, monthly data for 19 counties in Taiwan. It is recognized that household consumption may be governed by habits. A partial adjustment model of household electricity consumption appears to be more suitable and this model allows for serial correlation in the error term.

In sum, in this paper we wish to estimate the price and income elasticities of the demand for electricity in Taiwan and to examine the empirical effects of electricity-conservation policies which are now unclear and controversial. We use a newer and larger panel data set, consider the seasonality and the endogeneity of the electricity price, and specify a dynamic panel data model in our estimation.

The remainder of this paper is organized as follows. In Section 2, we offer a brief review of the literature. Section 3 discusses our model specification and related econometric issues. Section 4 describes the data. The empirical estimation results are discussed in Section 5. Section 6 concludes.

Table 1
Legal rate structures in 2007–2013.

Time span	Electricity blocks (kWh per month)	Summer rate (NT$/kWh)	Non-summer rate (NT$/kWh)
2007.01–2008.06	1–110	2.10	2.10
	111–330	2.73	2.415
	331–500	3.64	2.90
	501 and above	3.74	
2008.07–2008.09	1–110	2.10	2.10
	111–330	2.87	2.54
	331–500	3.85	3.09
	501–700	4.11	3.24
	701 and above	4.47	3.48
2008.10–2012.05	1–110	2.10	2.10
	111–330	3.02	2.68
	331–500	4.05	3.27
	501–700	4.51	3.55
	701 and above	5.10	3.97
2012.06–2013.09	1–120	2.10	2.10
	121–330	3.02	2.68
	331–500	4.39	3.61
	501–700	4.97	4.01
	701 and above	5.63	4.50
2013.10–2013.12	1–120	2.10	2.10
	121–330	3.02	2.68
	331–500	4.39	3.61
	501–700	5.44	4.48
	701–1000	6.16	5.03
	1001 and above	6.71	5.28

Notes: 1. Summer denotes the time period from Jun. 1 to Sep. 30; Non-summer denotes all other days of the year.
2. In 2013, NT$ 29.77 = US$ 1 (Central Bank, Taiwan).

[1] See Section 4 for the details. This IV method is also applied by some recent papers to estimate the residential water demand with increasing block pricing (see Agthe and Billings (1996), Dharmaratna and Harris (2012), Martínez-Espiñeira (2003), and Martínez-Espiñeira and Nauges (2004)).

[2] The price variable used by Holtedahl and Joutz (2004) was the annual average real price of electricity per kilowatt hour for all sectors, which was not specific to the residential sector. The price variable employed by Su et al. (2011) was the ex post average electricity price that was obtained with the electricity expenditure divided by electricity consumption. The price variable so derived tends to distort the actual rate structures. Because the electricity consumption and expenditure are influenced by various factors, e.g., weather conditions, in addition to the electricity price, this gives rise to an uncertainty that the average price in the summer months might not be higher than that in the non-summer months, as implied by the actual rate structures. Hsueh (1988) applied the IV procedure used by Henson (1984) to deal with the simultaneity bias arising from the use of the marginal price. However, the rate structures in the summer and non-summer months were the same during the sample period. The only variation in price between seasons came from the CPI deflator.