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Estimation of demand response to energy price signals in energy consumption behaviour in Beijing, China

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ABSTRACT

The energy price system in Beijing has not fully exploited customers' price elasticity, and has a negative impact on achieving the goals of energy saving. This paper analyses the response behaviours of different customers to typical energy prices. As for electricity self-elasticity, the range of the primary, secondary, tertiary industry and residents are −0.026 to −0.033, −0.045 to −0.059, −0.035 to −0.047 and −0.024 to −0.032, respectively. As regards self-elasticity on coal, the range of the primary, secondary, tertiary industry and residents are −0.030 to −0.037, −0.066 to −0.093, −0.055 to −0.072 and −0.034 to −0.051, respectively. The self-elasticities on oil and natural gas are very weak. As for cross-elasticity, when consuming electricity and oil, customers mainly focus on the prices of natural gas, which are 0.185 and 0.112. When consuming coal and natural gas, customers are concerned about the electricity prices, and their cross-elasticities are 0.03 and 0.36, respectively. The estimation of demand response to energy price signals in energy consumption behaviours can provide a decision support for formulating rational energy price policies.

1. Introduction

Resources in Beijing are scarce. Along with rapid economic development, growing energy consumption and the ceaselessly deteriorating environment, the problems of energy resources have had some effect on economic and social sustainable development. In recent years, although energy price reforms in Beijing have achieved some positive results, the reform process has been slow and there are still many obstacles. Beijing proposes a binding target of decreasing carbon emission intensity by 18% during the '12th Five-Year Plan' (2011–2015), while the reasonable selection and regulation of energy prices is one of the key factors in achieving this goal.

Energy price elasticity reflects the impact of energy price fluctuations on energy consumption. In order to provide effective reference to the energy pricing mechanism, fully quantifying the influence of energy prices on energy consumption involves acquiring the response characteristics of all kinds of customers to energy prices, which is based on energy price elasticity. According to the estimation of demand response to energy price signals in energy consumption behaviours, the Government in Beijing can adjust the energy consumption structure of customers through energy price policies, which can also achieve energy savings and emission reduction.

Analyses of energy price, energy demand and energy price elasticity have been carried out by many scholars and several methods have been proposed. The methods commonly used in electricity price forecasting are least square support vector machine [1], neural networks [2,3], multivariate adaptive regression splines and wavelet neural network [4], seasonal autoregressive integrated moving average model [5], and others. There are some methods to forecast energy demand, including genetic programming and simulated annealing [6], mix-encoding particle swarm optimisation and radial basis function [7], neural network [8], particle swarm optimisation and ant colony optimisation [9] and so on. Energy price elasticity is formed based on energy price and energy demand, which can be calculated using various methods. Amarawickrama and Hunt [10] used six econometric models to study Sri Lanka's electricity price self-elasticity and income elasticity, and concluded that the long-term income elasticity was 1–2 and the long-term electricity price self-elasticity was 0–0.6. Athukorala et al. [11] used the unit root test and the error correction model to analyse residential electricity demands in Sri Lanka for the period 1960–2007, and concluded that the long-term income elasticity, electricity price self-elasticity and cross-elasticity between kerosene and electricity were 0.78, −0.62 and 0.14, respectively,

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whereas the short-term elasticities were 0.32, 0.16 and 0.10. Narayan et al. [12] estimated the elasticity of the G7 residential electricity demands using a panel co-integration method, and the results showed that the long-term electricity price self-elasticity was −1.450 – −1.563, while long-term electricity income elasticity was 0.2–0.4. Hosoe et al. [13] supplied the least square method to analyse electricity self-elasticity of nine areas in Japan, and concluded that the range of short-term electricity price self-elasticity was 0.09–0.30, while in the long-term it was 0.12–0.56. They also concluded that the electricity self-elasticity of the rural areas was higher than that of the town. Based on the demand model, Fan and Hyndman [14] analysed electricity prices and demand in different periods and in different seasons in South Australia, and noticed that the electricity price self-elasticity was −0.363 – −0.428. Furthermore, Türkekul et al. [15], based on annual data of diesel and electricity consumption from 1970 to 2008 in Turkey, adopted an integrated and error analysis method to study the long-term income elasticity and diesel price self-elasticity, which were 1.47 and −0.38, while the long-term income elasticity and electricity price self-elasticity were 0.19 and −0.72. Based on the econometric model, Arthura et al. [16] studied the price and income elasticity of four domestic energies (wood, charcoal, oil, electricity) in Mozambique, which were −0.41, −0.28, −0.79, −0.60 and 0.45, 0.32, 0.84, 0.69, respectively. According to the oil data from 1977 to 2006 in Nigeria, Iwayemi et al. [17] used the multivariate cointegration method to show that gasoline, diesel and kerosene price self-elasticities were −0.055, 0.108 and −0.115, while their income elasticities were 0.747, 0.625 and −0.100. Faris [18] used the dynamic cointegration model to conclude that Oman's long-term electricity price self-elasticity was −0.82. Based on nine areas in India, Bose et al. [19] adopted the econometric model to show that the commercial and industrial electricity income elasticity were more than 1, while the income elasticity of residents in agriculture and small and medium-sized industry was less than 1. The short-term electricity price self-elasticities for agriculture, residents, large industries and commerce were −1.35, −0.65, −0.45 and −0.26, respectively, while small and medium-sized industry did not have self-elasticities. Zachariadis et al. [20] used co-integration and the error correction model to analyse electricity consumption in Cyprus, and revealed that the short-term electricity price self-elasticity had a lack of flexibility mainly because of fluctuations in the weather, while the long-term electricity price self-elasticity was −0.3 – −0.4. A summary of the literature on energy price elasticity is shown in Table 1. In addition, Salazar et al. [21] noted the capability of large customers to take part in short-term electricity markets based on their daily and monthly energy consumptions, and concluded that their electricity would reduce when electricity price is high. Some methods were also used to analyse demand response. Manuel et al. [22] established a two-step methodology to validate the flexibility of a wide range of commercial and industrial sectors, which can help the customers to understand how to use this flexibility in a profitable way in the electricity operation markets. Bel et al. [23] analysed the impacts of the electricity service provided over different time periods (hour, week, year) on the economic parameters (costs and benefits) based on a two-step method, which can allow customers to take part in electricity markets and improve the electric energy systems' behaviours.

The above studies use different models to analyse energy price, energy demand and energy price elasticity in different countries and regions. However, the energy price elasticities in different countries and regions are different because of different development levels, pricing mechanisms, climates and so on. Even in different periods in the same area, the energy price elasticity can vary. Based on the CGE model, this paper simulates energy price self-elasticity and cross-elasticity of different kinds of customers in Beijing, and verifies the results through a multiple linear regression model, in order to provide certain instructions for regulating reasonable energy policies and promoting energy savings and emission reduction.

The paper is organised as follows. Section 2 discusses the theories of energy price response, including CGE model, multiple linear regression model and the theory of price elasticity. Section 3 presents the empirical analysis and the energy self-elasticity and cross-elasticity of different kinds of customers in Beijing. Section 4 concludes and offers recommendations for the policy makers.

2. Theories of demand response to energy price signals

2.1. CGE model

The CGE model of general equilibrium framework has a solid foundation in microcosmic economy theory, and clearly expresses the intrinsic relationship between macroscopic and microscopic variables. At the same time, in this model all descriptions of the behaviours of the economic subject are placed in a systematic framework, and are estimated in terms of their direct and indirect effects and their overall economic impact, resulting from specific

Table 1
A summary of the literature on energy price elasticity.

Author (Year)	Country	Customers	Method	Year of data	Energy price elasticity	
Bose and Shukla (1999)	India	Agriculture Residents Large Industry Commerce	OLS, demand function with hysteresis effect, demand function without hysteresis effect	1985–1993	Electricity	−1.35 (SR) −0.65 (SR) −0.45 (SR) −0.26 (SR)
Narayan et al. (2007)	G7	Residents	Panel unit root and cointegration techniques	1978–2003	Electricity	−1.450∼−1.563 (LR)
Amarawickrama and Hunt (2008)	Sri Lanka	Residents	Unit root test, time series, dynamic Engle-Granger method, OLS	1970–2003	Electricity	0–0.6 (LR)
Athukorala et al. (2009)	Sri Lanka	Residents	Unit root, cointegration regression and error correction model	1960–2007	Electricity	−0.16 (SR) −0.62 (LR)
Hosoe and Akiyama (2009)	Japan	Residents	The logarithm cost function	1976–2006	Electricity	0.09–0.3 (SR) 0.12–0.56 (LR)
Iwayemi et al. (2010)	Nigeria	Residents	Multivariate cointegration method	1977–2006	Oil	−0.115∼0.108
Fan and Hyndman (2011)	South Australia	Residents	Demand model	1997–2008	Electricity	−0.363∼−0.428 (SR)
Türkekul et al. (2011)	Turkey	Agriculture	The integration and error correction method	1970–2008	Diesel Electricity	−0.38 (LR) −0.72 (LR)
Arthura et al. (2012)	Mozambique	Residents	Econometrics model	IAF 2002/3	Oil	−0.28∼−0.79