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Impacts of socioeconomic factors on monthly electricity consumption of China's sectors

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Abstract: In this paper, we report 4 sets of 8 multivariate regression equations, introducing the socioeconomic factors for the estimation models of monthly electricity consumption in the primary, secondary, tertiary industry, and the household sectors, to study the quantitative effects of socioeconomic factors (electricity real price, activity level, income, holiday, etc.). The results demonstrate that the price elasticity of electricity demand in the household and the secondary industry sectors is significant. When the electricity price increases by 1%, the demand in the household and secondary industry sectors reduces by 0.4-0.5% with a time lag.

Keyword: Socioeconomic factors; Monthly electricity consumption; Price elasticity

1 Introduction

Electricity plays a vital role in the energy supply and demand system in China, especially due to its fastest consumption growth compared to other energies. In China, the frequent appearance of "severe power shortage" events warns us that there is serious imbalance between power supply and demand, which has affected people's normal productivity and life and brings great threat to the security of electricity supply. In this context, it is necessary to explore how socioeconomic factors affect electricity consumption. Many previous studies have focused on the fields of electricity consumption forecasting, price elasticity of electricity demand, relationship between electricity consumption and economy growth (e.g. Huang 1993; Okajima and Okajima 2013; Labandeira et al. 2012).

In recent years, some studies have integrated socioeconomic factors as well as climatic factors into energy consumption modeling. For instance, Considine (2000) examined the price, the income, and the weather elasticity of US short-term energy demand through econometric analysis. However, most of these studies dealt with developed countries and the results are not directly applicable for developing countries.

In this study, the emphasis is on the influence of socioeconomic factors on electricity consumption in different sectors while the effect of the climate factors has been reported in Fan e t al. (2014).

2 Regression models and data source

2.1 Multivariable regression base model

We apply the multivariable regression model to study the impacts of various socioeconomic factors on electricity consumption in different sectors; in particular, monthly time-series data are used to capture the seasonality feature. Different from studies on the relationship between climate fluctuation and water resources (Schlenker and Roberts 2009), the mortality rate (Patz et al. 2005), crop yield (Piao et al. 2010) and power supply (Van Vliet et al. 2012), in addition to the effects of weather/climatic variables, the power demand is largely influenced by macroeconomic factors, such as the income and price. Therefore, independent variables of electricity consumption model include socioeconomic factors. In addition, since China's electricity prices have not yet been market-oriented, government pricing makes the price elasticity difficult to measure only relying on the little variant yearly data. By contrast, the regression model with monthly data can investigate the price elasticity of power demand according to the actual time when government pricing comes into force. Based on available literature and data, the basic regression model of electricity consumption in each sector is given by:

$$\ln(ec)_t = c + \sum_{s}^{h} \gamma_s Z_{st} + \sum_{p=1}^{k} \beta_p W_{pt} + \varepsilon_t \quad (1)$$

Where, the dependent variables (ea - primary industry, ei - secondary industry, es - tertiary industry, and

eh - households) are the logarithm of average daily electricity consumption in the t month. c is a constant term and Z_{st} is a hybrid vector of non-climatic factors consisting of various socioeconomic factors, such as real price that is different for each sector, the time trend factors, the time lag of the dependent variable, the dummy variable of holidays, industrial activities, and income for each sector.

Similarly, W_{pt} is a hybrid variable vector of climatic factors; β_p and γ_s are the regression coefficients; and ε_t is the error term of sample regression equation. Detailed descriptions and statistical characteristics of variables are given in Fan (2014).

2.2 Data sources and processing of socioeconomic factors

The dependent variable adopts the average daily electricity consumption in each month and takes the logarithm term in order to explore the elasticity and overcome the problem of the elasticity in regression estimation. According to the maximum availability of all variables, the time-series interval is from March 2006 to August 2013. Related variables excluding climatic factors are explained below.

(1) Real industry activities/income level

Due to its relatively more detailed data availability, we first introduce real industry activity level in secondary industry. The secondary industrial activities include the manufacturing industry and the building industry, of which the former has the dominant role. The industry value added represents industrial activity level and will inevitably affect the electricity consumption in the industry, so it is rational to be regarded as an independent variable. However, the monthly data of the National Bureau of Statistics (NBS) has some limitations: on one hand, the value added Industrial Enterprises above Designated Size does not fully cover the whole industrial activity level; on the other hand, since 2011, the standard point of core operation revenue has increased from 5 million yuan (about 0.81 million US$) to 20 million yuan (about 3.25 million US$). This means the coverage scope is inconsistent for the study period. Moreover, the statistics only includes the growth of relative quantity, that is, the year-on-year growth and cumulative year-on-year growth, not the monthly comparable price data of value added. Besides, data in January is not available or calculated and eliminating it will make the sample size smaller. In view of this, we use the monthly output of steel products as the proxy variable to represent the economic activity level of the secondary industry, in which data in January and February of 2013 is published together and we use the same proportion as total import and export volumes to distribute it. This will avoid the inconsistency of the concept of Industrial Enterprises above Designated Size, and also can obtain the comprehensive data of time series. Meanwhile, steel products are the necessary martial of building industry, so it can represent the activity level of the building industry to a certain extent.

The monthly data of economic activity level of all sectors is difficult to acquire. Therefore, in the

regression equations for these sectors, the quarterly added value (referring to the GDP with 2006 price index and the year-on-year growth rate) with the constant price is used. In the regression equation of residential electricity consumption, the quarterly GDP with the constant price representing household income level (obtained by adjusting the rolling growth rate and cumulative year-on-year growth rate in 2011) is used.

(2) Real price level

According to the demand price theory in economics, the consumption of normal goods will reduce along with the price rise in the market economy. Taking the electricity price and the substitute price as independent variables one can display the price elasticity of power demand and cross price elasticity. Hence, the sale price level of electricity of various types of users (at current prices) is divided by the monthly consumer price index to obtain the monthly real price level of electricity. Since electricity price is fixed by the government in China, that is, the electricity price is not directly determined by power supply and demand, it is unnecessary to use other proxy variable.

Since 2003, the National Development and Reform Commission have made eight adjustments for the national sale price of electricity, as illustrated in Figure 1. The average sale price of electricity (the commercial electricity, the industrial electricity, the household electricity, electricity of agricultural production and non-general industrial electricity) in 2007 from the wind database, is chosen as the reference price. Among them, the average price of the industrial electricity and the non-general industrial electricity is used as the electricity price for the secondary industry, end-use electricity price of agriculture production, commercial and household are used as that of primary industry, tertiary industry and household sector in the models respectively (Figure 1). On the basis of the reference price, the monthly electricity price of each industry and household are obtained in accordance with the previous price adjustment, then they are adjusted to comparable price by the monthly CPI (Consumer Price Index) value which is obtained by year-to-year ratio and chain relative ratio. Thus, we take vaa, $steel$, vas and $income$ to represent sector activity for the primary industry, secondary industry, tertiary industry and household sector respectively.

Even though the electricity price is determined by the government, this study can identify the price elasticity of electricity consumption in each sector and provide the scientific basis for understanding consumer behavior in each sector and pricing mechanism reform.

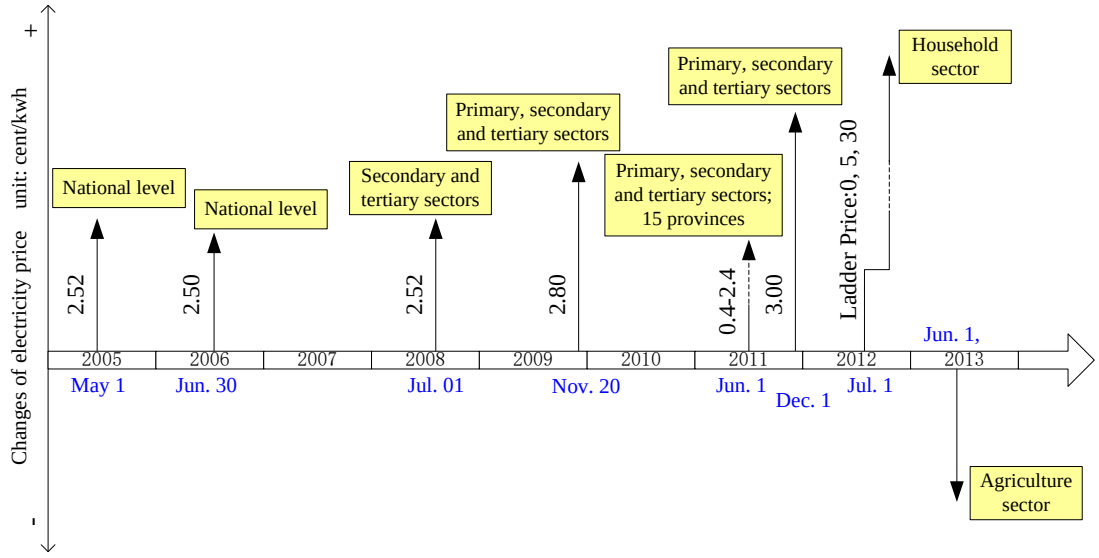

Fig. 1 China's eight main electricity price adjustments since 2003

(3) Other parameters and descriptive statistics

Holidays affect both the production activities and residents' life style, and hence their electricity consumption, so the holiday dummy variable is incorporated, making the months with holiday more than 3 days issued by the State Council 1 and others 0. For holidays that fall into two consecutive months, such as the Spring Festival and the International Labor Day, both months are set at 1. In addition, time trend is also treated as one explanatory variable to represent time-varying factors such as technological progress. Descriptive statistics of variables of key socioeconomic factors are shown in Table 1.

Table 1: Descriptive statistics of variables

Items	Units	Abbreviation	Mean value	Standard deviation
Electricity consumption of household sector	10^8kwh/day	*eh*	13.274	3.544
Electricity consumption of tertiary sector	10^8kwh/day	*es*	11.825	3.304
Electricity consumption of secondary sector	10^8kwh/day	*ei*	82.084	16.856
Electricity consumption of primary sector	10^8kwh/day	*ea*	2.590	0.587
Real price of household sector	Yuan/10^3kwh[a]	*realpriceh*	418.593	27.147
Real price of tertiary sector	Yuan/10^3kwh[a]	*realprices*	792.739	26.579
Real price of secondary sector	Yuan/10^3kwh[a]	*realpricei*	572.115	14.369
Real price of primary sector	Yuan/10^3kwh[a]	*realpricea*	378.008	12.120
Activity of primary sector	10^8Yuan[a]	*vaa*	5229.105	2027.104
Activity of secondary sector	10^4Tons[b]	*steel*	6181.926	1597.967
Activity of tertiary sector	10^8Yuan[a]	*vas*	43503.18	18546.860
Income of household sector	10^8Yuan[a]	*income*	87824.96	17378.920

Note: a. The exchang rate of Chinese Yuan to US dollars (USD) is 6.1658 Yuan/USD according to the report from the People's Bank of China.

b. One ton is equal to 1000 Kg.

3 Discussion of results

Following Fan et al. (2014) we first describe the results of household sector and take those of other three industrial sectors for comparison. Table 2 reports the key results of four out of eight sets of multivariable regression models, the models use the least squares estimation and only refined models that omit the explanatory variables with having coefficients of insignificance at 20% level are reported. The abbreviations *hol, dep-1* and *activ* in the second row are represented for the dummy variable holiday, the logarithm of one period lagged dependent variable and sectoral activities level, respectively. As explanatory variable the price used for secondary industry modeling is in terms of one period lagged, others are in terms of current periods, while both are in logarithm form. The results are shown in table 2 in two groups, i.e. models include climatic factors and exclude climatic factors, in order to compare the role of climatic factor in estimation.

Table 2 Regression results of impacts of socioeconomic factors on sectorial electricity consumption in China

	Climatic factor included					Climatic factor excluded				
Sectors	*price*	*hol*	*dep-1*	*activ*	*trend*	*price*	*hol*	*dep-1*	*activ*	*trend*
Household sector	-0.456 *	-0.054 ***	0.864 ***			-1.356 ***	-0.095 ***	0.627 ***		
Primary industry	-0.286	-0.013	0.043		0.003 ***			0.788 ***	-0.111 *	0.001
Secondary industry	-0.452 *	-0.027 **		0.726 ***		-0.375	-0.040 ***		0.733 ***	
Tertiary industry	-0.091	-0.005	0.500 ***	0.026	0.005 ***	0.331	-0.036 *	0.416 ***	0.043	0.006 ***

Note: The results of impacts of climatic factors which are also included in models are not reported here, but they can be found in Fan et al (2014).

*** Significant at 1% level.

** Significant at 5% level.

* Significant at 10% level.

3.1 Socioeconomic impacts on household sector

The coefficient of the real electricity price is negative and significant in the model when climate factors are included, which means that the residential electricity consumption behavior is impacted by the price. Hence, if the price rises by 1%, the electricity consumption will decrease by 0.46%, so the implementation of step tariff can make a contribution to saving electricity. However, the overall price elasticity of household electricity demand is less than 1%, which reflects that residents have a rigid demand for electricity. In addition, the price elasticity of the model excluding climatic factor is greater than 1 (-1.36), meaning that if effects of climatic factors are ignored, the price elasticity of electricity demand will

be overvalued, which is associated with that electricity price adjustments are mostly in July, the peak demand of electricity.

The coefficient of the 1 lagged dependent variable in both models are all above 0.8 and statistically significant, suggesting that the electricity consumption behavior of residents has high consistency and is difficult to change. The dummy variable coefficient of holidays is negative and statistically significant in the climate included model and the residential electricity consumptions in months with more than 3 holidays are 5.4% lower than these in months without holidays, suggesting that people's life style changes during the holidays. For example, to travel or to go out for dinner during the holidays reduces the household electricity consumption. Meanwhile, the variable of time trend on behalf of technical level is not significant (not reporte here), indicating that the electricity consumption mode in the household sector does not change technologically; The variable of seasonal income is also not significant and it is difficult to prove that the residential electricity consumption has income elasticity statistically, which is related to the seasonal income level and time series we used here rather than the monthly income level and sectional data.

3.2 Socioeconomic impacts on the primary industry

Different from the household sector, the effect of holidays on the primary industrial electricity use is not significant, related to the continuity of the agricultural production, the planting and breeding and so on. Both coefficients of the current and lagged agricultural electricity prices are not significant, which indicates that the agricultural use of electricity is a firm demand to a certain extent. The coefficient of the lagged dependent variable is rather small and not significant, meaning that the agricultural use of electricity has no monthly variable characteristic. However, the coefficient of the trend variable is highly significant, that is, the agricultural electricity consumption increases obviously along with the time, at the terminal growth rate of 2%-3% on the average. This shows that with more advanced technology and agricultural modernization has contributed to the growth of the primary industrial electricity use. However, the regression results vary greatly when we omit the climatic factor in the models, suggesting that electricity consumption of primary industry is more sensitive to cold and hot events.

3.3 Socioeconomic impacts on the secondary industry

Electricity consumption of months with holidays is less than those without holidays (2.7%), which suggests that the production activities of the secondary industry are also affected by the holidays (the duration of the Spring Festival explains the results). It is worthwhile to note that the effect of current electricity price on the secondary industry is negative (-0.25, not report here) but not significant, but the absolute coefficient of the lagged-period electricity price is larger (-0.45), with improved significance. It indicates that the price elasticity of the secondary industrial electricity demand, whose absolute value is

between 0.4 and 0.5 or so, has the hysteresis quality and the price has significant inhibitory effect on the following period's electricity consumption, which may be related to the hysteretic report of the cost accounting of industrial enterprises. Consistent with our expectations, the effect of steel products output charactering the industrial activity level on the secondary industrial electricity consumption is positive and extremely significant. If the activity level increases by 1%, the electricity consumption will increase by more than 0.7% on the average, reflecting the scale effect of the secondary industrial electricity use to a certain extent. In addition, the results with climate factors included vary slightly, which shows that climatic factor and non-climatic factors affect the electricity consumption of secondary industry in different but relatively individual ways.

3.4 Socioeconomic impacts on the tertiary industry

Unlike the effects of climatic factors (Fan et al. 2014), the impacts of socioeconomic factors on the tertiary industry are different from those on the household sector. The regression coefficient of the holidays and the real price of electricity are negative, which means an increase in electricity price and months with holidays decreases the tertiary industrial electricity consumption. However, the absolute values are very small compared to those of the household sector, and are not statistically significant. Therefore, the electricity consumption behavior in the tertiary industry does not have a statistically significant effect of the holidays. The equation without heating and cooling degree days also has the holiday effect and the price elasticity, but is still not very significant. The coefficient of lagged dependent variable is between 0.4 and 0.5 and is very significant, indicating that the tertiary industrial electricity consumption behavior also has certain viscosity (inertia): the electricity use behavior at the previous stage influences the behavior at the next stage; but from the viewpoint of numerical values, the degree of impact is lower than that of the household sector.

In addition, the coefficient of the tertiary industrial value added is positive (not at the 10% significant level) but in line with expectation, and each additional 1% of the value added makes electricity consumption increase by 0.03%, to a slight extent. But ignoring part of the quarterly variation may influence the estimation accuracy due to the use of quarterly data. The time trend is positive and significant and when other conditions remain unchanged, the unpredicted trend can strengthen the tertiary industrial electricity use (average growth rate of about 0.5% per month).

4 Concluding remarks

The current electricity price elasticity of the household sector is significant. Additionally, if the electricity price rises by 1%, the electricity consumption will reduce by 0.46%. Non-inclusion of climatic effects may overestimate the price elasticity. The lagged electricity price elasticity of the secondary industry

is significant and if the price rises by 1%, the following period electricity consumption will decrease by 0.45%; the electricity consumption behavior of the primary and tertiary industry are not affected significantly.

The effect of holidays on the electricity consumption in the household sector and the secondary industry is negative and statistically significant and the household electricity consumption in months with holidays is 5.4% less than that without holidays while the value in the secondary industry is about 2.7%. The effect on the primary industry and the tertiary industry is not statistically significant and it still needs further study.

The electricity consumption of the primary industry and the tertiary industry have obvious trends and the average growth rates of the former and the latter are 0.25% and 0.45%, respectively. The electricity use in the household sector and the tertiary sector has impact characteristics and the dependences on the previous stage are 86% and 50% respectively. The effect of the secondary industrial activity levels on the electricity use is very significant and the elastic level is around 0.73.

5 Suggestions for the future research

This paper only makes the elementary exploration on the effects of socioeconomic factors on the electricity consumption of various sectors. Although this is an important basis for other research work, it still has some deficiencies and needs further research. For example, China is a vast territory, regional electricity/energy use behavior are affected differently. More detailed studies focusing on income elasticity and price elasticity of electricity consumption in particular sectors, such as residential sector are also needed. Household survey technique may be useful to obtain information.

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