Estimating Energy and Water Demand Elasticities for Sustainable Consumption Policies: China Sample Evidence

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Abstract: China's water and energy price reform began in the late 1978 after running large-scale interventions in pricing system for long time then has a gradually deep influence on consumer's behaviors. The main objective of this paper is to empirically examine Chinese consumer reactions as a response to the introductions of pricing reform for water and energy resource. This study uses the full nonlinear Almost Ideal Demand System to estimate the income and price elasticities of household demand using expenditure survey data of urban household from1995 to 2006 across China. Expenditure elasticities for water, electricity and fuel are 0.44, 0.60 and 0.44 respectively and all of own price elasticities are negative and low which implies that an increase of relative prices for water, electricity and fuels leads to different effectiveness in their consumption, showing advantage and limitation of the price reform which intends to regulation of household consumption behavior in China. These can be used to evaluate recent and current correlative pricing and environmental policies directed at stimulating sustainable household consumption in China.

Key Words: AIDS, household demand, income, price, elasticity, sustainable consumption

INTRODUCTION

The main objective of this paper is to empirically examine consumer reactions as a response to the introductions of pricing reform for water and energy resource by estimating the income and price elasticities of household demand in China.

There are a number of motivations for this. Firstly water and energy are fundamental necessities for any household and also the specific goods and service with serious environmental impacts. China is a country with scarcity of water resources. The per capita water availability is one fourth of the world average. More than 400 cities are scanty of enough water supplements out of total 661 cities in China. Among them, 110 cities are facing serious water scarcity. At the same time, the polluting water has not been disposed completely and effectively which is one of the main Chinese environmental problems and it intensifies the water shortage. From 1990 to 2004, China's total energy consumption grew at 5.0% per annum from 18EJ (10^{18} J) to 58EJ (Sinton, 2004). In 2003 China had the highest SO_2 emission in the world and was the second largest contributor to global CO_2 emissions (Hang and Tu, 2007). Growth in chinese household consumption is a major cause of increased resourec consumption and environmental pressure.

Secondly, price and income elasticities of demand are important for the choice of domestic pricing and environmental policies which have a serious influence on household consumption behaviors. For a country like China, with a tradition of implicit and explicit government interventions that affect the prices of domestic water and energy, the environmental and social impact of such interventions on demand can be analyzed based on price elasticities of demand.

Finally understanding consumer response to the change in prices for resources is believed to be critical to design policies oriented towards sustainable consumption (Tarek, 2007).

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Sustainable consumption is the use of goods and services that respond to basic needs and bring a better quality of life, while minimising the use of natural resources, toxic materials and emissions of waste and pollutants over the life cycle, so as not to jeopardise the needs of future generations (Norwegian Ministry of Environment 1994). It has gained more and more popularity being looked as effective measures to achieve a more equitable consumption and reduce the overall environmental impact since it is shaped firstly in the United Nations Conference for environmental and Development in Rio de Janeiro in 1992. China's water and energy price reform began in the late 1978. After running large-scale interventions in pricing system for long time there has been a gradual deep influence on consumer's behaviors. Such behavioral response is considered to be a necessary precondition for the correct implementation of different instruments of any environmental policy. This kind of analysis could provide more realistic and accurate information to make suitable price instruments to stimulate sustainable consumption.

Given the importance of those elasticities towards consumer's behavioral response, policy formulation and sustainable consumption, it is surprising that not more formal analyses have been carried out for China to analyze income, price elasticities of demand especially in water and energy sectors. One of the reasons is scanty of published and reliable consumption and prices data for household water and energy for long time. In our study also we only can analyze the households in urban area and disaggregate energy into electricity and fuels. The other reason is resource consumption in household sector is ignored in national resource use due to water and energy supplies were treated as a kind of welfare for residents in China.

Several studies have examined the elasticity of water in China, such as Shen et al. (1999) analyzed water demand function of urban residential in 1996, Shen et al. (2006) calculated the price and income elasticity of urban residential water demand in Shenzhen city base on sample survey data. Chen et al. (2007) applied ELES model to analyze on payment ability of urban household for water use in Beijing city. About energy elasticity, Qi et al. (2002) calculated electricity income and price elasticity of urban household in Jinan city and Fan and Ren (2007) studied the impact of demographic characteristics on the consumption structure in urban household including energy (here energy category included water, electricity and fuels for car and living). However, such studies are very few in number, and dearth of reliable and readily available estimates for electricity and fuels to make meaningful policy analyses.

It is more than 30 years for China's price reform and has a gradually deep influence on consumer's behaviors. This study examines consumer reactions as a response to introductions of pricing reform for water and energy resource in China. We also can learn the similar studies about the relationship among consumption, polices and environment from other countries, e.g. Haripriya and Gunnar (2008) for India, Runar et al. (2007) for Sweden, Ada and Jeroen (2004) and Linderhof (2001) for Netherlands and Jesus and Timothy (1992) for the U.S.A.

The estimations are made using the full nonlinear Almost Ideal Demand System(AIDS) (Deaton and Muellbauer, 1980) on urban household data from 1995 to 2006 in China. Instead of income we consider the total household expenditure as a proxy. The AIDS model has been widely used for analyzing demand for various commodities in the world. In this study we use a two-stage budgeting process to obtain the elasticities of water and energy. In the first stage it is assumed that the household decides how much to spend on seven consumption groups and in the second stage it is specialized to assume how the household allocate expenditure to water, electricity and fuel. Such method has been used to analyze demand for food (Brian and Hector, 2006 and Zhuang and Abbott, 2007) and animal product (Ma et al ,2004) for China. However no study has used such an approach to estimate water and energy elasticities. This study is thus an empirical contribution to the domestic water and energy literature in China.

This paper is organized as follows: Section 2 presents the two-stage budgeting model and data specification. Section 3 presents the empirical results and Section 4 concludes with the policy implications.

1. THE MODEL AND DATA

1.1 The price reform and data

The price of water and energy was fully state controlled in China until the beginning of economic reform in late 1978. Price reform systems try to change water and energy prices set by the central plan to market and lower resource price than their cost, improve use efficiency and levy their environmental impact cost. In 1992, energy price reform accelerated and large quantities of coal and oil were moved from plan to market allocation. By 1999, plan allocations of coal and oil had been largely eliminated. Since 1997, electricity prices have remained steady. Although electricity prices in China increasingly reflect market forces, they remain under tight governmental regulation, in comparison with coal and oil prices. Supplying water price kept rising from 1991 and began to levy water treatment fee in 1999.

The price reform for water and energy resource has a deep influence on household budget and consumption after 1995. As can be see in Fig.1 Per capita annual water use increased to peak about 86 ton in 1998 then begin to decreased to 50.69 ton in 2006, per capita annual electricity consumption raised sharply to 483.7kW.h in 2006, which is 3.5-times consumption comparing 1995's . On the other hand per capita annual fuels (exclude gasoline, diesel and heat) use declined from 4.6 GJ in 1995 to 2.8 GJ in 2006 due to Price rising and the fuels structure change, more and more urban household is transiting toward clean fuels (like nature gas, PLG and electricity) replacing coal (Geng et al., 2004 and Guan et al., 2006).

Fig.2 shows per capita annual the water, electricity and fuels share in total expenditure respectively. Only fuel expenditure share reduced slightly from 2.0% in 1995 to 1.9% in 2006, both of

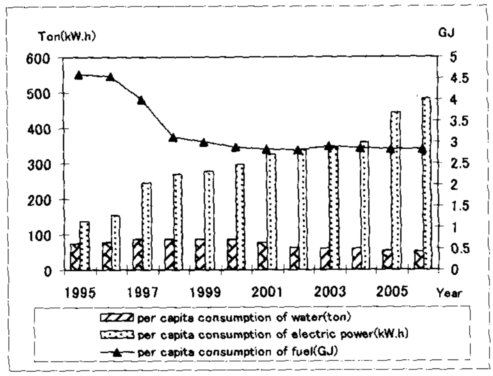

Fig.1. Per capital annual consumption for water, electricity and fuels

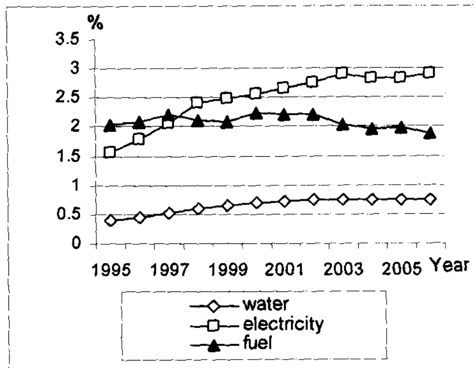

Fig.2. Per capita annual expenditure share for water, electricity and fuels

electricity and water expenditure share rose. The main reason for electricity expenditure share rising is the rapidly increase of electricity consumption, for water expenditure share it is attributed to the rising rate of water supplying price surpass the dropping rate of water use.

The data on living expenditure of urban household and price index are time series data from 1995 to 2006 that taken from a yearly survey carried out by the National Bureau of Statistics of China (1996-2007) including 31 provinces in China. And data on water and electricity consumption of urban household is from China City Statistical Yearbook (1996-2007) and on fuel consumption is from China Energy Statistical Yearbook (1995, 1997-1999, 2000-2002, 2004, 2005, 2006 and 2007).

1.2 The econometric model

In our model we assume a two-stage budgeting process. In the first stage total expenditures are allocated in seven consumption groups: (i) food; (ii) clothing; (iii) household appliances; (iv) health care; (v) transport; (vi) education; (vii) housing. The second stage comprises the allocation of housing expenditure on individual goods within the group, in this case household allocates house, housing service, water, electricity and fuel within housing group.

In the specification of the demand system, we apply Almost Ideal Demand model (AID model), first derived by Deaton and Muellbauer (1980). The advantages of this system are well known. It gives an arbitrary first order approximation to any demand system, satisfies the axioms of choice exactly, and is simple to estimate.

The AIDS assumes that consumer preferences fall within the price-independent generalized logarithmic (PIGLOG) class so that exact aggregation over consumers is possible. In the AIDS model the budget share on a specific commodity, or group of commodities, in relation to full expenditure, can be written as

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i \ln(X/p) \qquad (1)$$

where w_i is the budget share for good i, p_j is the price for good j, X is total expenditure, P is the consumer price index, and the parameters to be estimated are α, γ, and β. The consumer price index, P, which is approximated using

$$\ln(P) = a_0 + \sum_{i=1}^{n} a_i \ln(p_i) + 1/2 \sum_i \sum_j \gamma_{ij} \ln(p_i) \ln(p_j) \qquad (2)$$

In the estimation adding up, homogeneity and symmetry restrictions are imposed for demand system. The basic demand restrictions are expressed in terms of the model's coefficients

Adding up: $\sum_i \alpha_i = 1, \sum_i \beta_i = 0, \sum_i \gamma_{ij} = 0$

Homogeneity: $\sum_j \gamma_{ij} = 0$

Symmetry: $\gamma_{ij} = \gamma_{ji}, \forall i (i \neq j)$

Given the two-stage structure, incorporating time and regional dummy variables for improving the precision of model, the nonlinear AIDS model can be written in stochastic form as (Tarek, 2007)

$$W_{(r)} = \alpha_{(r)} + \beta_{(r)} \ln(X/P) + \sum_{s=1}^{7} \gamma_{(r)(s)} \ln(p_{(s)}) + \sum_k dt_{(r)k} T_{(r)k} + \sum_\lambda dz_{(r)\lambda} Z_{(r)\lambda} + \varepsilon_{(r)} \qquad (3)$$

$$W_{(r)i} = \alpha_{(r)i} + \beta_{(r)i} \ln(X_{(r)}/P_{(r)}) + \sum_{j=1}^{m(r)} \gamma_{(r)ij} \ln(p_{(r)j}) + \sum_k dt_{(r)ik} T_{(r)ik} + \sum_\lambda dz_{(r)i\lambda} Z_{(r)i\lambda} + \varepsilon_{(r)i} \qquad (4)$$

Where r=1,...,7 denotes group, i=1,...,$m(r)$ denotes commodities within group r, $T_{(r)k}$ and $T_{(r)ik}$ are annual dummy (k=1,2,3...,11), $Z_{(r)\lambda}$ and $Z_{(r)i\lambda}$ are regional dummy (λ= 1,2,3). We divide Chinese urban area into four regions using classify analysis according to their expenditure level by SPSS software, $\varepsilon_{(r)}$ and $\varepsilon_{(r)i}$ is the error term. Eq. (3) thus describes the allocation between groups, where $w_{(r)}$ denotes the budget share for group r, $p_{(r)}$ is a group producer price index, x is total expenditure and P finally is the consumer price index. Eq. (4) describes allocation within the rth group. where $w_{(r)i}$ is the within group budget share, $\ln P_{(r)i}$ is the producer price index of the jth good, $x_{(r)}$ is the total expenditure allocated to the rth group and $p_{(r)}$ is the price index for the rth group.

Given estimates of the parameters at each "level", we can calculate price and expenditure elasticities, totally and conditional on the expenditures for each group (Edgerton et al., 1996). Using the main group notation the expenditure and uncompensated price elasticities are:

$$\eta_r = 1 + \frac{\beta_r}{w_r} \qquad (5)$$

$$e_{rs} = \frac{\gamma_{rs} - \beta_r w_s}{w_r} - \delta_{rs} \qquad (6)$$

where η_r denotes the expenditure elasticity and e_{rs} the uncompensated price elasticity; δ_{rs} is equal to one when r =s and zero elsewhere.

Let us denote the expenditure elasticity for the ith good within the rth group of goods as $\eta_{(r)i}$, the group expenditure elasticity for the rth group of goods as $\eta_{(r)}$, and the total expenditure elasticity for the ith good within the rth group of goods as η_i, with an equivalent definition for the budget shares, w. In this case, we can calculate the total expenditure elasticity as

$$\eta_i = \eta_{(r)} \times \eta_{(r)i} \quad (7)$$

In the same way, we can denote the within group price elasticity between the ith and jth goods within the rth group of goods as $e_{(r)ij}$, the group price elasticity as $e_{(r)(s)}$ and the total price elasticities as e_{ij}. The within group price elasticity assumes that group expenditure is unchanged in spite of the price change, while the total price elasticity allows for the relevant changes in group expenditure, and is given by

$$e_{ij} = \delta_{rs} e_{(r)ij} + \eta_{(r)i} w_{(s)j} (\delta_{rs} + e_{(r)(s)}) \quad (8)$$

If we look at Eq. (8) for two goods within the same group, we can see that the total price elasticity consists of two components. The first part is a direct effect, which represents the subgroup elasticity, while the second part is an indirect effect, which is a product of three factors. The first measures the relative change in the group price index when the price of the jth good changes; the second factor measures the effect a change in the price index has on group expenditure, while the third factor measures the effect this change in within group expenditure has on the consumption of the ith good .

We can also observe that if the own between group price elasticity $e_{(r)(r)} = -1$, then the group expenditure is unaffected by the price change and $e_{ij} = e_{(r)ij}$. On the other hand, if $e_{(r)(r)} = 0$, then the price change produces a proportional effect on group expenditure.

2. RESULTS

Following the specification in Eqs. (3) and (4), the demand system for the main groups and for water, electricity and fuels within the housing groups is estimated by iterative Seeming Unrelated Regression (SUR). The results indicate that most of the estimated parameters are significantly different from zero, and that the degree of explanation is good.

2.1 Own price and expenditure elasticities of demand

We have tested linear approximate and full nonlinear models within the AID family, and find nonlinear models performed better than the linear model. Given the parameter estimates, expenditure and price elasticities have been calculated according to Eqs. (5), (6), (7) and (8). The resulting elasticities are presented in Table 1.

As the table reveals, own price elasticities for water, electricity and fuels have a negative sign,

Table 1 Estimated expenditure elasticity and own price elasticity

	Expenditure elasticity	Own price elasticity	Total expenditure elasticity	Total own price elasticity
Main groups				
Food	1.11* (0.04)	-0.16*(0.09)		
Clothing	0.12 (0.11)	-0.55*(0.18)		
Household appliances	1.13*(0.13)	-0.13 (0.34)		
Health care	0.47*(0.10)	0.10 (0.18)		
Transport	1.34*(0.08)	0.25*(0.11)		
Education	1.27*(0.07)	0.27*(0.10)		
Housing	1.17*(0.10)	0.03*(0.21)		
Housing				
Water	0.38*(0.04)	-0.21*(0.08)	0.44	-0.15
Electricity	0.52*(0.03)	-0.38*(0.05)	0.60	-0.11
Fuel	0.37*(0.03)	-0.44*(0.05)	0.44	-0.31

Note: The figures in the parentheses are standard error. * represent significance level at 1%.

meaning the price for water, electricity and fuels increase will reduce demand for them. For example, if the price of "water" increases by 10%, "water" demand will decrease by 1.5%, "electricity" demand will decrease by 1.1%. A corresponding increase in the price for "fuels" reduces the demand for "fuels" by 3.1%. And the demand for "water", "electricity" and "fuels" is relatively insensitive to changes in the own price. Electricity is most insensitive comparing to the other fuels, implying its price is the lowest. In most cases the own price elasticities lie between 0 and − 1, which implies that a higher price of a good (with the other prices held constant) leads to an increase of the budget share for the same good, in spite of lower consumption of that good. It seems that only small price rising are unable to make a suitable impact for consumer's behaviors because energy price is deregulation in China (Hang and Tu, 2007).

Moreover, all of them have positive and low expenditure elasticities (less than 1), implying that they are necessities for urban household.

The elasticities found in this study are in line with elasticities in other studies on Chinese data. Shen et al. (1999 and 2006) estimates the expenditure and own price elasticities for water were 0.56 and − 0.33 according to urban household data in 1999 and 0.25 and -0.41 using simple survey data in Shenzhen city in 2004 respectively. Based on time series data from 1985 to 2002 in Nanjing city, Yin and Yuan (2005) estimates the expenditure and own piece elasticities for water to be 0.43 and -0.29 and Qi et al. (2002), who also uses time series data for Jinan city from1992 to 1999 estimates the expenditure and own price elasticities for electricity to be 0.58 and -0.32.

2.2 The trend in demand elasticities for water, electricity and fuels

The estimated total own-price and expenditure elasticities for different period: 1995-1997, 1998-2000, 2001-2003 and 2004-2006 for urban household are presented in Fig.3 and Fig.4. We can see from Fig.3. , expenditure elasticities for water, electricity and fuels declined from 0.70, 1.07and 0.97 to 0.17, 0.40 and 0.1 respectively during this period, the change from comparatively

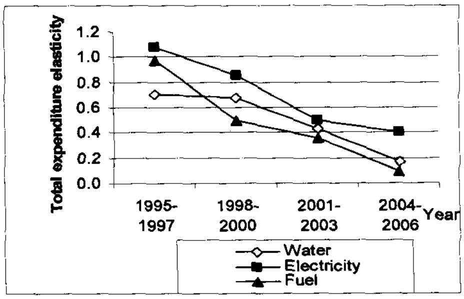

Fig.3. Total expenditure elasticity for water, electricity and fuels in urban household

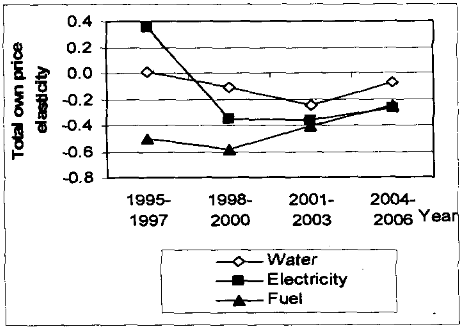

Fig.4. Total price elasticity for water, electricity and fuels in urban household

high expenditure elasticity to low elasticity, it implies household payment power for water, electricity and fuels is improved with the income rising and can bear the price rising because of price reform now. Especially, expenditure elasticity for electricity declined from 1.07 to 0.4 which suggest that electricity became necessary from luxury with the use popularization and income increase.

Fig.4. shows that own-price elasticities for water and electricity change from positive sign to negative sign, implying the demand for water and electricity becomes to reduce with price rising from keeping consumption although price rising. And the absolute value of own-price elasticity for fuels reduces from 0.50 to 0.25, it means the effect of price for consumption becoming less and less. This change reflects the interplay between income and price in household consumption about Water, electricity and fuels. Fig.4. also tells us the most sensitive period for water and electricity own-price elasticity is around 2002 and for fuels it is around 1999. It reflects impacting process of consumer's

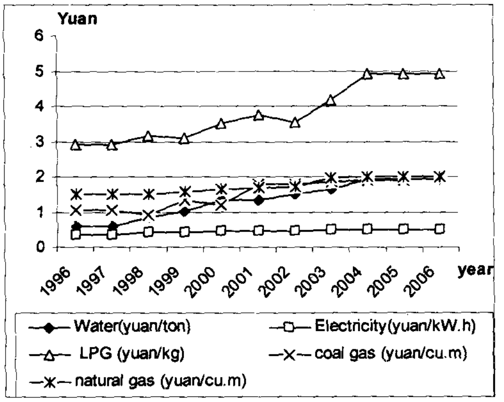

Fig.5. Average prices for water, electricity and fuels in 36 big cities

behavior by the china's price reform. Household income increases with china's economic reform beginning in the 1978, but the related price policies for water and energy have lagged behind this trend. Water price rose substantially from 1998 and levied wastewater treatment fee from 1999, it reached 1.9yuan/ton in 2006, raising 217% comparing the price in 1995. Electricity price reform began from 1985 but has remained steady since 1997 due to them remain under tight governmental regulation, in comparison with coal and oil prices (Hang and Tu, 2007). It is the cheapest energy for residents (see Fig.5.) and has an opposite influence on consumer's behaviors. For example we compare the price polices for water and electricity and find the rising of water price reduced the per capita water consumption while the declining electricity price increased its consumption. In 1992, energy price reform accelerated and large quantities of coal and oil were moved from plan to market allocation, it means residents can buy coal and oil products though market not the supplying ticket issued by government and their price also rise in accordance with the local or globe energy price. Comparing cheaper electricity price it is second fuel choice so that urban household fuels consumption declined 38.2% from 1995 to 2006.

3. CONCLUSIONS AND POLICY IMPLICATION

One of the key issues in public policy in general, and perhaps in sustainable consumption policy in particular, is how consumers respond to changes in policy. In this paper the issue is how consumers respond to changes in water and energy prices. To achieve the objective we estimated the household demand elasticities for water, electricity and fuel from 1995 to 2006 in China. The main conclusions can be summarized as follows: (1)household demand for water reduce increased continuously from 1998 until 2006,which implies pricing reform had a small and significant impact on household water consumption in China. Overall, raising water prices substantially and collecting treatment fee is an effective policy tool for reduce water consumption; (2) household demand for electricity is most inelastic, which indicates that the price effect is probably weaker than that of other factors such as income effect and lifestyle changes, one of the reasons is low electricity price since 1997 and the other reason is the electric appliances are getting popular and improvement in housing condition. This demand depends heavily on variables other than prices. It suggests that pricing reform for electricity is necessary and urgent now in China; (3) the price elasticity of fuel is higher than that of electricity, which implies that household demand for fuel probably replaces in part by electricity, reducing consumption also proves the transiting process. Environmental tax for energy will probably encourage household choosing more clean energy type and improve energy consumption efficiency.

With the rapidly increasing household consumption in the entire world including China, the relationship between household consumption and environment is receiving more attention than before (Jeroen C.J.M, 2008). Our study gains insight in to the effectiveness of Chinese price reform to regulate household consumption for water and energy and make a first step to supply useful information about the sensitivity of consumption to factors that can be influenced or controlled by policies for design of policies oriented towards sustainable consumption. Future researches will provide more study on policy assessment to stimulate sustainable consumption.

ACKNOWLEDGEMENT

The authors would like to acknowledge the financial support from the Global Environment Research Fund in FY2008 (Hc-086), "Study on the Strategic Urban Planning and Assessment of Low-Carbon Cities" (Hidefumi IMURA).

REFERENCES

Ada, F.i.C. and Jeroen ,C.J.M. V.D.B.(2004) A Micro-Econometric Analysis of Determinants of Unsustainable Consumption in The Netherlands. *Environmental and Resource Economics*, No. 27, 367–389.

Brian W. Gould and Hector J. Villarreal (2006) An assessment of the current structure of food demand in urban China *Agricultural Economics*, No.34, 1-16.

Chen Jing, Chen Dan, Chu Linlin and Chen Xiang (2007) Quantitative analysis on payment ability of urban households for water use (in Chinese). *Journal of Hydraulic Engineering*, No.8, 1016-1020.

Deaton A. and Muellbauer J. (1980) An almost ideal demand system, *The American Economic Review*, No.70, 312–326.

Edgerton, D.L., Assarsson, B., Hummelmose, A., Laurila, I.P., Rickertsen, K., and Vale, P.H. (1996) The Econometrics of Demand Systems: With Applications to Food Demand in the Nordic Countries, *Kluwer Academic Publishers*, Boston, 304pp.

Fan Maoqing and Ren Ruoen (2007) Study on consumption structure of urban household based on heterogeneous preferences (in Chinese). *China soft science*, No. 10, 37-46.

Geng Haiqing, Gu Shuzhong and Guo Dongmei (2004) Analyses on evolution of household energy consumption structure based on information entropy (in Chinese).*Journal of natural resources*, No. 19, 257-262.

Guan Weihua, Gu chaolin and Lin zhenshan (2006) Study on the change of energy consumption structure in China (in Chinese).*Journal of natural resources*, No. 21, 401-407.

Hang Leiming and Tu Meizeng (2007)Ttheimpacts of energy prices on energy intensity:Evidence from China. *Energy Policy*, No. 35, 2978-2988.

Haripriya, Gundimeda and Gunnar, KöhlinFuel(2008) Fuel demand elasticities for energy and environmental policies: Indian sample survey evidence. *Energy Economics* , No. 30, 517-546.

Jeroen C.J.M. van den bergh(2008) Environmetal regulation of household :An empirical review of economic and psychological factors. *Ecological Economics* , No. 66, 559-574.

Jesus C.Dumagan and Timothy D. Mount (1992) Measuring the consumer welfare effects of carbon penalties: Theory and applications to household energy demand. *Energy Economics* , No.14, 82-93.

Linderhof, V.G.M(2001) Household demand for energy, water and the collection of waste: a microeconometric analysis. *Labyrint publication*, Capelle aan den IJssel, 161pp.

Ma Hengyuan, Rae Allan, Huang Jikun and Rozelle Scott (2004) Chinese animal product consumption in the 1990s. *The Australian Journal of Agricultural and Resource Economics*, No.48, 569-590.

National bureau of statistics of China (1996-2007) China Urban Life and Price Yearbook, *China statistics press*, Beijing, various year editions.

Norwegian Ministry of the Environment (1994): Report of the Symposium on Sustainable consumption. *Norwegian Ministry of the Environment*, Oslo.

Qi Qihui, Xiao Guoquan, Zeng Ming, Zhao Qingbo and Shan Baoguo (2002) Linear expenditure system Model for residential electricity Demand Forecasting (in Chinese). *Modern electric power*, No.2, 76-82.

Runar, Brännlund, Tarek Ghalwash and Jonas Nordström(2007) Increased energy efficiency and the rebound effect: Effects on consumption and emissions. *Energy Economics*, No. 29, 1-17.

Shen Dajun, Chen wen and Luo Jianping (2006) Econometric analysis and application on urban household water use (in Chinese). *Journal of Hydraulic Engineering*, No.5, 593-597.

Shen Dajun, Yang Xiaoliu, Wang Hao, Wang Dangxian and Ma Jing (1999) Analysis of urban residential water demand function in China (in Chinese). *Journal of Hydraulic Engineering*, No.12, 6-10.

Sinton, JonathanE.,ed.(2004) China Energy Databook (CD-ROM). *Lawrence Berkeley National Laboratory*. LBNL-53856.

Tarek Ghalwash(2007) Energy taxes as a signaling device: An empirical analysis of consumer preferences. *Energy Policy*, No.35, 29-38.

Yin Jianli and Yuan Ruhua (2005) Analysis of the elasticity of Nanjing domestic water demand (in Chinese). *South-to-North Transfers and Water Science & Technology*, No. 3, 46-48.

Zhuang renan and Abbott Philip (2007) Price elastricities of key agricultural commodities in China. *China Economic Review*, No.18, 155-169.