Energy Policy 42 (2012) 164–173

Contents lists available at SciVerse ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Designation and influence of household increasing block electricity tariffs in China

Boqiang Lin[a,b,*], Zhujun Jiang[c]

[a] New Huadu Business School, Minjiang University, Fuzhou 350108, China
[b] China Center for Energy Economics Research, Xiamen University, B201 College of Economics, Xiamen, PR China, 361005
[c] Institute for Advanced Research, Shanghai University of Finance and Economics, 110 College of Economics, Shanghai, PR China, 200433

ARTICLE INFO

Article history:
Received 13 February 2011
Accepted 22 November 2011
Available online 13 January 2012

Keywords:
Increasing block tariffs
Mechanism design
Equity and Efficiency

ABSTRACT

Electricity is the guarantee of normal life, and the electricity price is widely concerned. As a developing country in the transition stage, abundant policy implications are included in the electricity price in China, thus, whether to adjust the resident electricity price is a dilemma for the government. However, the current single tariff system cannot cope with the complex social and environmental problems. A new price mechanism is indeed needed. This paper tries to design an increasing block tariffs system with the consideration of residential income and electricity consumption. The result indicates that the increasing block tariffs system with four-tier structure is more reasonable for China. Although the increasing block tariffs will result in the increase of electricity price, it is still acceptable and affordable. The increasing block tariffs will greatly improve the equity and efficiency, and promote the electricity saving and emissions reduction. Moreover, the power companies will increase tariffs revenue, which would use to the transmission networks investment in poor area. In order to the offset the limitations of the increasing block tariffs, the government should adopt some complementary measures.

1. Introduction

China's residential electricity consumption has kept high growth in recent years, at an annual growth rate of 13% during the past 20 years. However, China's per capita residential electricity consumption remains at a relatively low level. In 2008, it reached 303.8 kW h, which only accounted for one fifteenth of the U.S.' (Fig. 1) and one seventh of Japan's.[1] Undoubtedly, more electricity will be used to substitute traditional energy with the accelerating of urbanization process. It could be expected that residential electricity demand will maintain high growth in China. Moreover, considering the important role of electricity in daily life, electricity tariff attracts great attention, which makes the electricity price a very sensitive issue for resident.

As a developing country in the transition stage, abundant policy implications are included in the electricity price in China. Given significant social inequalities that inevitably result from an economy's transitional friction, and considering issues such as the affordability of electricity and ensuing social stability, transitional electricity subsidies (by cross subsidies) could arguably be both reasonable(Lin and Jiang, 2011). Therefore, it is understandable why the government is reluctant to raise residential electricity price.[2]

However, with the rise of energy price, the drawbacks of the electricity pricing mechanism gradually expose. First, the cross-subsidies for residential electricity consumption twist the price and hinder the electricity marketization reform. Second, as there is no price differentiation for households with different incomes, the universal subsidies tend to be regressive, disproportionally benefit the rich. Lin and Jiang et al. (2009) finds that the 22% of low-income people only shared 10.1% of the electricity subsidy, while the top 27% of high-income people received 45%. Hence, the electricity pricing mechanism is unfair and inefficient.

The energy and environmental problems, such as energy scarcity, environment deterioration, are also increasingly prominent in China. For a good price mechanism, it should not only guarantee the basic needs, but also encourage energy conservation and environmental protection. However, the current single price mechanism can not meet the two requirements. The Independent Pricing and Regulatory Authority (IPART) (2003) points out that non-tiered tariff structures are unable to

* Corresponding author at: China Center for Energy Economics Research, Xiamen University, B201 College of Economics, Xiamen, PR China, 361005.
Tel.: +86 0592 2186076; fax: +86 0592 2186075.
E-mail address: bqlin@xmu.edu.cn (B. Lin).

[1] Because of the data limit, the data of per capita residential electricity consumption in Japan is in 2006.

[2] According to the 〈Draft of Suggestions on Accelerating the Process of Electricity Price Reform〉 issued by the National Development and Reform Commission (NDRC), since September 20th, 2009, the average sale electricity price increases by 2.8 cent, but the residential electricity price keeps invariant.

0301-4215/$ - see front matter
doi:10.1016/j.enpol.2011.11.062

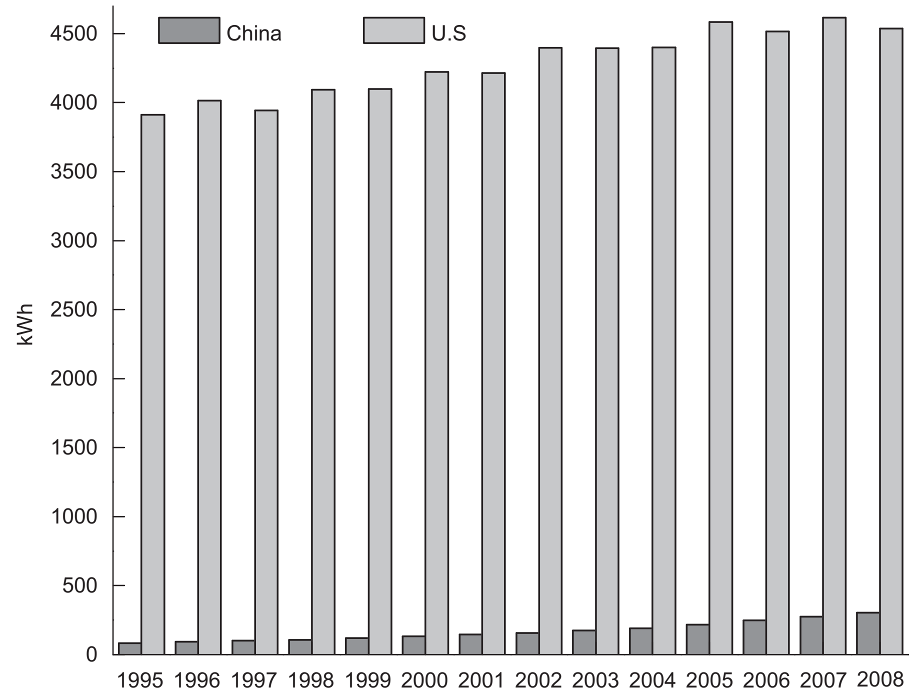

Fig. 1. Per capita residential electricity consumption.
Source: China Statistical Yearbook (2009), National Bureau of Statistic of China; U.S. Energy Information Administration, http://www.eia.gov/electricity/data.cfm.

communicate cost information to consumers and therefore create inefficient outcomes. First, the cost of electricity generation increases with the need to increase network capacity, thus, electricity prices should increase with consumption level. Second, in order to recover the costs in full, the flat price tariff must reflect the average cost of electricity production. Accordingly, those who consume less electricity than the average are forced to subsidize those consuming more than the average amount of electricity. However, the "under consume" residents are always in the low income group, while the "over consume" residents are oppositely in the high one. Thus, it is urgent to reform the residential electricity price, and it becomes a dilemma for the government.

The increasing block tariffs (IBTs) can be seen as the breakthrough point of the residential electricity pricing reform. The IBTs has often been promoted, and indeed, adopted as a solution to address social equity, cost recovery, efficiency, and environmental concerns (Borenstein, 2008; Filipović and Tanić, 2009). The IBTs divides household electricity consumption into several blocks, and a certain price is applied to a defined block. The price of electricity will be low for consumption up to a certain limit, whereby any consumption exceeding this limit will be charged a higher price.

The theoretical basis for IBTs is Ramsey pricing, which obeys the rule "contrast with elasticity". It is reasonable that IBTs have been popular (Whittington, 1992): First, it relieves the pressure on low-income households; second, it helps to encourages energy saving by setting higher price for the consumption which exceeds the essential need. In addition, income would be transferred from high-income people to the low-income by cross-subsidies. Therefore, the IBTs for electricity will increase the efficiency of distribution, promote social justice, guarantee the basic electricity needs of low-income populations, and encourage efficient electricity use.

According to the "Proposals on implementation of increasing block tariffs in the residential sector" issued by the National Development and Reform Commission (NDRC) in Oct 9th, 2010, it is expected to divide household electricity consumption into three blocks. The NDRC's design attracts great attention. So, in this paper, we try to make an in-depth analysis of the IBTs in China. The remainder of the paper is organized as follows. Section 2 reviews the present literature on IBTs. Section 3 analyzes the existing increasing block tariffs in the electricity market. Section 4 designs an IBTs mechanisms for China residential electricity. Section 5 estimates the effects of IBTs, which is followed by conclusions and suggestions in section 6.

2. Literature review

The application of IBTs is widespread in the water and electricity sectors. Porter (1996) pointed out that with the constraint of compensation cost, the IBTs was an optimal method of second best pricing compared to marginal cost pricing. Agthe and Billings (1987) analyzed the impacts of the IBTs on social income and equity in the water sector. The results indicated that by widening gaps among blocks, the IBTs would be implemented effectively and the equity would be improved. In a survey of water utilities in Asia, the Asian Development Bank (ADB) (1993) found that the majority of utilities in their sample (20 out of the 32) used an IBT structure. ADB believed that the social equity could be greatly improved by cross-subsidies from high-income to low-income residents. Low price on the first block would ensure the low-income residents be able to afford the basic electricity demand. There are two reasons for collecting a higher price for high-income people. First, costs are higher with more residential electricity consumption that is usually peak hours; second, higher prices can restrain electrical waste and promote energy efficiency. Bar-Shira et al. (2005) found that switching from a single to a block price regime, would yield a 7% reduction in average water use while maintaining the same average price. Fankhauser and Tepic (2006), Borenstein (2008) discussed the equity effects of using IBTs in electricity markets. Whether or not IBTs can deliver preferred equity outcomes relative to other tariff structures depends crucially on the consumer's ability to understand and respond to price signals. Therefore, some studies focus on consumers' responsiveness to the demand for electricity in face of price changes (Billings and Agthe, 1980; Espey et al., 1997; Dalhuisen et al., 2003; Nauges and Blundell, 2001; Olivier, 2006; Haney et al., 2009; Borenstein, 2009). In response to increasing block tariffs, it appears that high electricity consumption residents will reduce their electricity consumption while the low electricity consumption ones benefit from "lifeline style" price subsidies. The availability of information in a comprehensive form is found to be very important for consumers' abilities to respond to price signals (Faruqui and George, 2006; Reiss and White, 2005).

Many economists, such as Wilchens (1991), Yaron (1991) and Zusman (1997), hold the view that the IBTs could achieve the redistribution of income. However, other scholars hold different views (Boland and Whittington, 2000). Whittington (1992, 2003) argued that the IBTs in developing countries might not achieve the goal of alleviating poverty; instead it might make the situation worse because of the lack of access to the network and larger number of poor households. Dahan and Nisan (2007) also indicated that low income households with more family members may face higher tariffs than high income households with less family members. Borenstein (2008, 2009) analyzed the equity effects of IBTs on electricity, and find that it did have income redistribution effects, but the effects were limited and might be less significant than expected, this result is supported by Buliding Research Establishment (BRE) (2009) and Meran and Hirschhausen (2009).

The domestic studies on the resident electricity pricing mechanism are rare. Chen et al. (2005) introduced the strategy of block rate tariffs to residential electricity use. Qi and Zhang et al. (2009) analyzed China's cross-subsidies of electricity with Ramsey pricing. Lin and Jiang et al. (2009) found that the current non-target electricity subsidies lacked equity and efficiency. High income residents received the majority of subsidies, which was contrary to the original objective. Even there are some studies relating to the pricing mechanism for resident electricity, few have referred to the IBTs, let alone the design of IBTs. NDRC's proposal about implementing the increasing block residential electricity makes this issue more urgent than before. This paper will focus on the design of IBTs for residential electricity use and its effects in China.

3. Current situations of IBTs

The IBTs for electricity has been implemented in many developed countries or regions, such as the United States, Japan, India, Korea, Malaysia and China's Hong Kong, Taiwan, and so on. The U.S. applies the "lifeline" tariff in the initial block for poor households. The first block in Japan is the electricity consumption to maintain essential need. The price of the first block is 75% of the second block which almost equals the average cost of electricity. The price of the third block reflects the upward trend of marginal costs of generation, aiming to promote energy conservation. In Taiwan, there is a five-tiered structure, with the consideration of season (Table 1). Taking the three-tier structure as an example, the expenditure under the IBTs can be established by formula (1).

$$E=\begin{cases} q\cdot p_1 & q\le q_1 \\ q_1\cdot p_1+(q-q_1)\cdot p_2 & q_1<q\le q_2 \\ q_1\cdot p_1+(q_2-q_1)\cdot p_2+(q-q_2)\cdot p_3 & q_2<q \end{cases} \tag{1}$$

where, E is the expenditure on electricity consumption; q_i is the threshold of electricity consumption in the ith block; q is the real amount of electricity use; p_i is the price in the ith block.

Table 1 indicates that due to different national context, the design and the structure of IBTs vary among different countries. Generally speaking, the initial block is designed to meet household needs for essential purposes, and the volume is higher in developed countries compared to that in developing countries.

Acting as pilot programs, China's provinces such as Zhejiang, Fujian, and Sichuan have begun to implement the IBTs in the electricity sector since 2004, 2004 and 2006, respectively. Details are listed in Table 2.

Though the IBTs for electricity have been carried out in the above provinces, the gaps between the prices of each block are so small that most residents are insensitive to the price change. The unsatisfying result suggests that the structure of the IBTs is very important and directly affects this mechanism's efficiency.

On October 9th, 2010, the NDRC issued two schemes of the increasing block electricity tariffs, which divided residential electricity consumption into three blocks: the essential electricity demand,

Table 1
The IBTs in the U.S, Japan, and Taiwan (Monthly electricity use per household, kW h).
Sources: The IBTs for electricity of Florida, the U.S. comes from Gainesville Regional Utilities (GRU), calculating your electric bill, www.gru.com; The IBTs for electricity of Japan comes from Department of Price, National Development and State Commission (2009): Insights and Implications from the electricity price reform of Japan and Korea; Prices: theory and practice. The IBTs for electricity of Taiwan comes from the Taiwan Power Company, http://www.taipower.com.tw.

	Florida, the U.S.	Japan	Taiwan, China
The first block	≤ 250	≤ 120	≤ 110
The second block	251–750	121–250	111–330
The third block	>750	>250	331–500
The fourth block	-	-	501–700
The fifth block	-	-	>700

Table 2
Structures of IBTs in residential electricity use in China.

	Zhejiang		Fujian		Sichuan	
	Monthly volume per household (kW h)	Price (CNY/kW h)	Monthly volume per household (kW h)	Price (CNY/kW h)	Monthly volume per household (kW h)	Price (CNY/kW h)
The first block	≤ 50	0.538	≤ 150	0.446	≤ 60	0.472
The second block	51–200	0.568	151–400	0.466	61–100	0.552
The third block	>200	0.638	>400	0.566	101–150	0.582
The fourth block	-	-	-	-	>151	0.632

the normal electricity demand and the extravagant electricity demand (Table 3). In the following, this paper will discuss if the schemes issued by the NDRC is reasonable, if not, new IBTs will be designed.

4. The design of IBTs for residential electricity use in China

The key of the IBTs design includes: the number of block, the volume and price in different block, the three parts will be discussed in details in the next sections of the paper.

4.1. Numbers of blocks

Theoretically, the larger gaps are between incomes, the more tiers should be set to ensure the efficiency of income redistribution. However, considering the higher requirement on voltage equipment and administrative costs, the common structure of IBTs in developed countries usually consists of three to six tiers.

China's urbanization level is still low, representing only 45.7% in 2008. The income, expenditure and life style among different groups differ greatly. Table 4 shows that rural residents have a lower living standard than their urban counterparts. Furthermore, as Table 5 demonstrates, we find large gaps between rural and urban low-income households by analyzing the ownership of electrical appliances.

Tables 4 and 5 indicate that it is necessary to separate the rural and urban households, but the schemes in Table 3 do not consider the difference between rural and urban residents. If the difference is neglected, two adverse results may occur: first, the volume of electricity use in the first block is too low, and it could not satisfy the basic electricity demand of rural and urban low income residents at the same time; second, the volume in the first block might be set too high to fulfill the desired goal. Thus, we believe that it will be more reasonable and practical to adopt the IBTs with four-tier structure rather than the three-tier structure proposed by the NDRC. The description of the design is specified in Table 6.

4.2. Setting the volume of electricity consumption in each block

The second step is to estimate the electricity consumption in each block. Hughes (2004) equally divided the total population

Table 3
Residential electricity tariffs schemes issued by NDRC.

	First block	Second block	Third block
Scheme 1			
Electricity use (kW h/month)	< 110	110–210	> 210
Electricity price (CNY/kW h)	Keep current price for three years	Increase more than 0.05 for the exceeded part	Increase more than 0.2 for the exceeded part
Coverage (%)	70	90	-
Scheme 2			
Electricity use (kW h/month)	< 140	140–270	> 270
Electricity price (CNY/kW h)	Increase more than 0.01 for the exceeded part	Increase more than 0.05 for the exceeded part	Increase more than 0.2 for the exceeded part
Coverage (%)	80	95	-

Table 4
Resident per capita disposable income and consumption expenditures (2008, CNY).
Source: China Statistical Yearbook (2009), National Bureau of Statistic of China.

Rural resident	Rural resident		Urban resident	Urban resident	
	Income	Consumption expenditure		Income	Consumption expenditure
Low income	1,499.8	2,144.8	lowest income	4,753.6	4,532.9
Lower middle income	2,935.0	2,652.8	Low income	7,363.3	6,195.3
Middle income	4,203.1	3,286.4	Lower middle income	10,195.6	7,993.7
Upper middle income	5,928.6	4,191.3	Middle income	13,984.2	10,344.7
High income	11,290.2	6,853.7	Upper middle income	19,254.1	13,316.6
			High income	26,250.1	17,888.2
			Highest income	43,613.8	26,982.1

Table 5
Electrical appliances of low-income resident in 2008 (One per 100 households).
Source: China Statistical Yearbook (2009), National Bureau of Statistic of China.

Electrical appliances	Average in rural areas	Lowest income in urban areas	Low income in urban areas	Lower Middle income in urban areas
Washing machine	49.11	83.58	89.05	93.35
Refrigerator	30.19	71.91	83.73	91.95
Air conditioner	9.82	29.63	54.79	73.55
Color TV set	99.22	109.58	117.70	122.88
Computer	5.36	20.27	34.24	47.61

Table 6
The design of the blocks.

	First block	Second block	Third block	Fourth block
Electricity demand	Essential demand for rural resident	Essential demand for urban resident	Normal electricity demand	Excessive electricity demand
Classifications	Necessity	Necessity	Normal good	Luxury good
Households	Impoverished	Low income	Middle income	High income

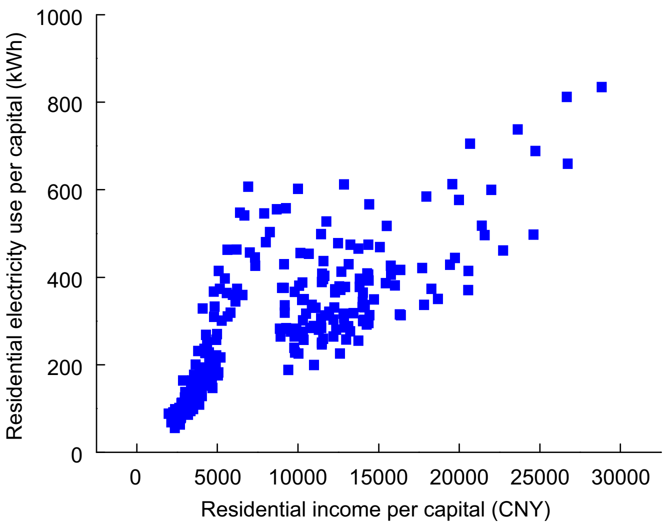

Fig. 2. Relationship between residential electricity use and income.
Source: China Economic Information Net, http://www.cei.gov.cn.

into five groups and set the boundary volume according to the electricity use of each group. This method may not be suitable for China as the income disparity among residents is extremely large, and the classification just by averaging the population would result in great errors. Based on a survey of 45 cities in 12 countries, Barnes et al. (2004) showed that demand for electricity increased with income level. The figure below, describing the relationship between China's residential electricity use and per capita income, also testifies this result (Fig. 2). In addition, income is usually used as a measurement for the households' ability to pay the electricity fee. Thus, we will design the electricity consumption of each block based on income, combining the electricity use of all appliances.

4.2.1. *Grouping of households*

First, we need to identify the targets of each block. According to the classification in the Chinese Statistical Yearbook 2009, we divide the residents into four income brackets based on their per capita disposable income, while taking the per capita consumption expenditure into account. The four groups are: the poverty group (the per capita annual disposable income is below CNY 5000, the per capita annual consumption expenditure is below CNY 4000); the low income group (the per capita annual disposable income is CNY 5000–10,000, the per capita annual consumption expenditure is CNY 4000–8000); the middle income group (the per capita annual disposable income is CNY 10,000–20,000, the per capita annual consumption expenditure is CNY 8000–16,000); the high income group (the per capita annual disposable income is above CNY 20,000, the per capita annual consumption expenditure is above CNY 16,000).

Then we estimate the number of households in each block. According to the Chinese Statistical Yearbook 2008, the average family size in the rural areas, towns and cities are 3.29, 3.18 and 2.91, respectively. This indicates that in general, low income household tends to have more family number. Based on the inverse relationship between income and family size, and the value of Chinese Statistical Yearbook, we assume that: the family size of poverty group is 3.5 persons per household, the low income group is 3.2, the middle income group is 3 and the high income group is 2.8. The results are presented in Table 7.

4.2.2. *Electricity consumption of different income groups*

As only the electricity consumption data of rural and urban residents are available, considering that electrical appliances directly affect electricity consumption, we will analyze the electricity demand of different income groups by estimating their use of electrical appliances and then deducing the electricity consumption.

The ability of the IBTs to deliver equity on its promise of effectively targeting at the poor depends on setting the volume of electricity in the initial block equal to the essential electricity needs. It is meaningless to set a high volume in the first block, otherwise the non-poor households will get more benefits from the low price. The "lifeline" volume is always used. Lin and Jiang et al. (2009) indicates that the lowest monthly electricity demand of the poverty group to maintain the essential life is about 30 kW h per household. Considering that the IBTs is designed for the future, electricity demand will rise in line with the income increase, 40 kW h in the first block is set.

The electricity use in the second block is to meet the basic demand of low income urban households, so it should not be too high. Apart from electrical appliances owned by the rural low income household, other electrical appliances such as refrigerators, washing machines and electric cookers should be included. The estimated electricity demand for basic living is about 65 kW h per month (Table 8). Considering the large increase potential, the electricity consumption in the second block is set at 80 kW h per month.

The third block focuses on the urban middle and upper middle income households. The method to estimate the electricity demand is similar as before, but there are also some differences. First, with the increase of income, modern electrical appliances such as computer and microwave oven should be included.[3] Second, the time spent on electrical appliances is different. Higher income households tend to use more power with more time. In addition, according to the analysis in Table 1, the electricity consumption of the latter block is approximately two to three times more than the previous one. Barnes et al. (2005) also showed that the electricity consumption of middle income households was about two times more than that for low income households, and the electricity consumption gap between middle and high income households was even larger. Which means, the higher the block is, the larger is the gap of electricity consumption. So, electricity consumption of the third block should be approximately 80–180 kW h. If consumption exceeds 180 kW h, it would be allocated to the fourth block.

[3] According to the Statistical Yearbook 2009, for each one hundred households, the middle and upper middle income households have 95.4 and 121.7 air conditioners, respectively.

Table 7
The population and family size of the four groups.

	Per capita disposable income (CNY)	Per capita consumption expenditures(CNY)	Population (million)	Percentage (%)	Family size (persons per household)
Poverty group	< 5,000	< 4,000	432.83	32.59	3.5
Low income group	5,000–10,000	4,000–8,000	531.21	40.00	3.2
Middle income group	10,000–20,000	8,000–16,000	242.66	18.27	3.0
High income group	> 20,000	> 16,000	121.33	9.14	2.8

Table 8
Electricity consumption of urban low income households.

Electrical Appliances	Quantity	Power (W)	Use Time (h)	Monthly Consumption (kW h)
Electric Lamp	2	60	5	18.0
Television	1	100	4	12
Electric Cooker	1	500	0.5	7.5
Washing Machine	1	400	0.2	2.4
Refrigerators	1	-	24 (on time)	18
Electric Fans[a]	2	60	6	7.2
Total	-	-	-	65.1

Notes: (a) The average size of televisions in low-income households is 21 cubic inches (1/3 dm). (b) The washing machines include wave wheels which take 40 min for each wash. (c) The average electricity consumption of refrigerators is 0.6 kW h per 24 h.

[a] Assuming the use time of electric fans are four months every year. Then the monthly electricity consumption of electric fans is: the quantities of electricity consumption multiplied by one third.

Comparing to the IBTs design proposed by the NDRC (Table 3), we find that the electricity volume of the first block in our design is much smaller than NDRC's. The first block in this paper targets only at the poor rural residents, which covers about 30% residents, while it is at least 70% in the NDRC's schemes. The wide coverage may have some adverse impacts on the effectiveness of IBTs, and could not impel the high-income resident to save energy.

4.2.3. Electricity price of each block

In general, larger gap of electricity price among different blocks can improve the efficiency of IBTs. As shown in Table 1, the proportion of Florida's three-tiered residential rate structure is 1: 2.5: 3.8, and is 1: 1.4: 1.9: 2.1: 2.4 in Taiwan's five- tiered structure. While the price gap of China's IBTs is too small to work, such as the proportion is just 1: 1.05: 1.18 in Zhejiang province as shown in Table 2.

Considering the aims of introducing the IBTs, multi-tiered increasing rates can be constructed that the lowest rate is a subsidized rate, and higher rates compensate for this subsidy, as well as for the incremental costs of electricity production. So, relatively low price is set for the first and second blocks while relatively high price for the third and fourth blocks. Boland and Whittington (2003) pointed out that the common characteristic of IBTs, as they were applied in developing countries, was that the first block price was deliberately set below cost. In addition, the "lifeline" tariff is introduced to the first block. China's current residential electricity price has been heavily subsidized and only accounts for about half of the real costs. Moreover, it can be affordable even for the disadvantaged households, so the price in the first block is supposed to be the current level, CNY 0.55 per kW h. The second block is projected to meet the basic electricity needs of low income urban households whose income is still low, so subsidized tariff is still applied, but the subsidized extent is lower than the first block. The price is between that of the first block and marginal cost, which is CNY 0.75 per kW h. Faruqui and George (2006), Filipović and Tanić (2009) proposed that subsidized price should be canceled when the basic electricity demands had been met. Hall and Hanemann (1996) also pointed out that marginal cost pricing should be used for higher blocks. Therefore, we apply the marginal cost to the third block. Price for the fourth block should be high enough to restrain the excessive electricity consumption and make up the cost, so the marginal electricity cost of peak is adopted. According to the estimates of power companies, the cost of electricity supplying during peak times is about CNY 1.4 per kW h. Specific details are showed in Table 9.

Table 9
The IBTs we designed in China.

Blocks	The first block	The second block	The third block	The fourth block
Electricity price (CNY/kW h)	0.55	0.75	1.03	1.40
Electricity consumption (monthly kW h per household)	0–40	40–80	80–180	More than 180

Table 8 indicates that the price gap among different blocks is distinct, and price jumps further at higher consumption thresholds. The electricity price proportion with four blocks is 1: 1.36: 1.86: 2.53, which is similar to the Taiwan's design. Faruqui and George (2006) showed that gaps of the IBTs for electricity which included the lifeline electricity price might be larger than block tariffs which reflected only the supply costs of electricity.

Except the price in the first block, our design is very different from the NDRCs (Table 3), as we have taken the cost cover into account. According to the NDRC's schemes, even for the third block, the price is only about CNY 0.8 per kW h, much lower than the cost. Moreover, the price proportion of blocks is small. All these deficiency in NDRC's design will affect the efficiency of the IBTs.

5. The impacts of the increasing block tariffs

The implementation of IBTs will result in the rise of electricity price, and subsequently have some impacts on residential welfare, electricity demand, equity, and so on. We will give further analysis to this issue in the following section.

5.1. Impacts on household welfare

There are three types of effects on households associated with higher price: first, there are direct effects on the consumption and welfare of household; second, there are indirect effects resulting from higher revenues for utilities; third, there are macro impacts, which are related to the effects of higher price (and reduced subsidies) on government expenditures and revenues. This paper will concentrate on the first type of effects. Freund and Wallich (1997) pointed out that the rise in price would result in the change of consumer surplus and calculate the welfare loss in consumer surplus as a percentage of total expenditure. We follow this method to analyze the welfare change caused by the IBTs designed above.

For the resident in the first block, there is no welfare and expenditures change as the electricity price keeping fixed. For the resident in the other blocks, consumer surplus will be reduced because of the price rise. Take the two-tier IBTs as an example. If electricity price increase from P_1 to P_2, the decreased consumer surplus equals to the increased expenditures caused by the electricity price rise (A+C), plus the amount the consumer would be willing to pay above the initial price (P_1) to consume the initial quantity (B), and subtract the non-welfare loss (C). Thus, the welfare loss is represented graphically by the shaded areas (A+B) (Fig. 3).

Therefore, under the IBTs structure, the change in consumer surplus (DCS) resulting from price rise can be written as:

$$DCS = Q_0(p_2-p_1)[1+e(p_2-p_1)/2p_1]-Q_1(p_2-p_1) \tag{2}$$

where, Q is the electricity consumption, P is the electricity price, e is the price elasticity of residential electricity demand. E is the consumption expenditure of household. The change in consumer surplus as a percentage of household expenditures can be stated as:

$$\begin{aligned} DCS/E &= [Q_0(p_2-p_1)/E][1+e(p_2-p_1)/2p_1]-Q_1(p_2-p_1)/E \\ &= S_0[(p_2-p_1)/p_1][1+e(p_2-p_1)/2p_1]-S_1(p_2-p_1)/p_1 \end{aligned} \tag{3}$$

where, S is the budget share of electricity consumption in household expenditures, and $S=Q^*P/E$.

In the three-tier residential rate structure, changes of the consumer surplus are showed in Fig. 4:

For the resident in the third block, if electricity price rises from P_1 to P_3, the decreased part of consumer surplus equals to the increased electricity expenditures, which is (A+B+C+D), adding the willing consumption quantity under P_3, and taking away the non-welfare loss (A+B). So the decreased consumer surplus

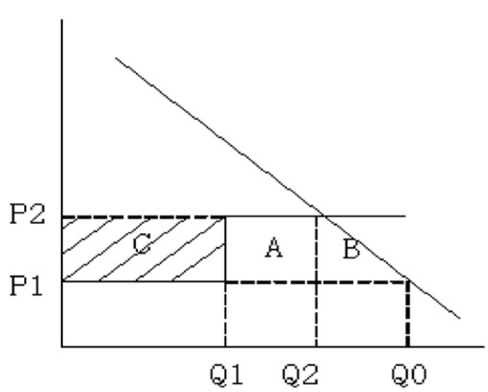

Fig. 3. Welfare loss from a price increase from P_1 to P_2.

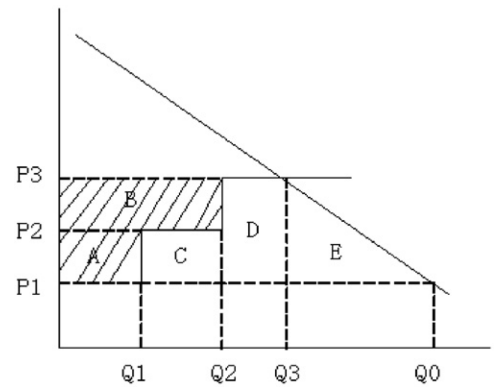

Fig. 4. Welfare loss from a price increase from P_1 to P_3.

induced by the price increase in the third block takes the following form:

$$DCS = Q_0(p_3-p_1)[1+e(p_3-p_1)/2p_1]-Q_1(p_2-p_1)-Q_2(p_3-p_2) \tag{4}$$

The change in consumer surplus as a percentage of household expenditures can be expressed as:

$$\begin{aligned} DCS/E &= [Q_0(p_3-p_1)/E][1+e(p_3-p_1)/2p_1]-Q_1(p_2-p_1)/E \\ &\quad -Q_2(p_3-p_2)/E \\ &= S_0[(p_3-p_1)/p_1][1+e(p_3-p_1)/2p_1]-S_1(p_2-p_1)/p_1 \\ &\quad -S_2(p_3-p_2)/p_2 \end{aligned} \tag{5}$$

Then, we can deduce the function of changes of consumer surplus under the block tariffs mechanism which has more than three blocks. The formula is as follows:

$$DSE/E = S_0[(p_i-p_1)/p_1][1+e(p_i-p_1)/2p_1]-\sum_{i=2}^{n} S_{i-1}(p_i-p_{i-1})/p_{i-1} \tag{6}$$

From function (2), it is seen that price elasticity is the premise to estimate the welfare change. However, because of the limited data, we could not estimate price elasticity of all blocks. By analyzing the electricity consumption characteristic of different groups and referring literatures, we make some assumptions. The second block mainly includes low income urban households; they often have as many electrical appliances as the middle-income residents. But their limited income constrains that they can not use the electrical appliances immoderately. These households are very sensitive to price. Lin and Jiang et al. (2009) concluded that the price elasticity of urban resident was -0.2149. With the consideration that the price elasticity of low income urban households may be higher than the average, we assume the price elasticity of the second block is -0.25. The third block includes the middle-income households; we use the national average price elasticity to express the elasticity in this block, which is -0.158 estimated by Lin and Jiang (2011). Households with high income in the fourth block are not sensitive to price change, so their price elasticity will be relative low, and we assume the price elasticity of them is -0.1.

Based on the discussion above, we estimate the welfare loss resulting from the implementation of the IBTs. The results are listed in Table 10.

The results show that the welfare of the poor in the first block keeps fixed owing to the unchanged electricity price. Welfare in other three blocks is all reduced, with different degree. The higher the block is, the more welfare loss. However, even for the high income residents who suffer the biggest welfare loss, it only accounts for 1.14% of the total consumption expenditures, which is too small to inspire the sensitivity of high income residents, that is, this loss can be acceptable.

In addition, the increase of electricity price will also lead to the change of consumption behavior, and in turn causing change in tariff expenditures (Table 11):

As showed in Table 11, electricity bills will increase under the IBTs structure, except for the resident in the first block. And the higher the block is, the more electricity bills increase. The charge of the high income resident in the fourth block will increase most, amounting to CNY 474.83 per capita per year. The international experiences and tests have shown that, resident in developing countries will feel obvious pressure if electricity bills account for 5–6% of the disposable income. World Health Organization (WHO) indicates that 10% is the residential tolerance threshold on the share of electricity expenses in total income. Table 11 shows that even after implementing the IBTs, electricity expenses of the high income resident only account for 2.99% of their disposable income, which is still within the tolerable limit. The proportion of electricity expenses for poor resident is relative low, which can guarantee their essential electricity demand. Therefore, our design of the IBTs could not induce large impacts on households, and it is feasible.

Table 10
Welfare change caused by the IBTs.

	Decreased consumer surplus(CNY)	Welfare loss (%)
The first block	0.00	0.00
The second block	23.62	0.36
The third block	87.48	0.88
The fourth block	228.95	1.14

Table 11
Change of per capita electricity charge.

	Tariffs after IBTs (CNY)	Expenses change after IBTs (CNY)	The proportion of tariffs to disposable income (%)
The first block	66.29	0.00	1.87
The second block	173.26	28.25	2.04
The third block	387.56	133.45	2.65
The fourth block	932.39	474.83	2.99

5.2. Impacts on equity and efficiency

One principle of electricity tariff design is the equity and efficiency. However, the current non-target cross-subsidies mechanism for resident electricity is inefficient. Whether or not the IBTs will improve the efficiency is an issue concerned. We will apply the method used by Angel-Urdinola et al. (2006) to analyze the equity effects under the IBTs mechanism. The key indicator is the proportion of subsidies received by poor resident to the total subsidies, which is presented asΩ:

$$\Omega = \frac{S_P}{S_H}\frac{H}{P} = \frac{\sum_{i=1}^{P} q_i(p_i - C)}{\sum_{i=1}^{H} q_i(p_i - C)}\frac{H}{P} \tag{7}$$

where, S_P is the subsidies received by poor resident; S_H is the total subsidies; P is the number of poor resident, and H is the total population. C is the cost of electricity supply; (p_i–C) is the subsidies of per unit electricity consumption.

Distribution of electricity subsidies before and after the implementation of the IBTs is showed in Table 12:

As high income residents always consume more energy than the poor, the non-target subsidies mechanism will result in the rich benefit more, while the poor who really needs the subsidies only get little. Table 12 indicates that before the implementation of the IBTs, low income residents who account for 32.59% of the total population only received 12.87% of the subsidies, while the high income residents who account for only 9.14% population obtaining 24.91% of subsidies. This is consistent with the analysis of Lin and Jiang et al. (2009). What is more, if the government uses fiscal income as the source of electricity subsidies, it will turn out that the low income residents subsidize the high income, which is obviously unfair.

There are two significant changes in subsidies after the implementation of the IBTs. First, electricity price increase will lead to the decrease of subsidies size. The total subsidies will be reduced by CNY 87.56 billion. Second, there is a remarkable change in the subsidies distribution. Subsidies received by middle and high income residents will decrease significantly, the proportion of subsidies received by high income residents will decrease from 24.91% to 1.7%; while the proportion of subsidies for resident in the first and second block will increase from 47.4% to 73.8%. Thus, under the IBTs mechanism, subsidies become

Table 12
The distribution of subsidies before and after the implementation of the IBTs.

	The proportion of people (%)	Before		After	
		Subsidies (CNY billion)	Percentage (%)	Subsidies (CNY billion)	Percentage (%)
The first block	32.59	24.81	12.87	24.81	23.59
The second block	40.00	66.60	34.56	52.8	50.23
The third block	18.27	53.31	27.66	25.74	24.48
The fourth block	9.14	48.00	24.91	1.79	1.70
Total	100.00	192.71	100.00	105.15	100.00

Table 13
Impact of the IBTs on consumption and the revenue of power companies.

Blocks	Contained blocks	Yearly electricity consumption (billion kW h)	price (CNY/kW h)	Yearly electricity expenses (CNY billion)
The first block	1,2,3,4	173.83	0.55	96.02
The second block	2,3,4	121.89	0.75	91.42
The third block	3,4	61.11	1.03	62.94
The fourth block	4	32.43	1.40	45.4
Total	-	389.27	-	295.79

more targeted and effective, the equity and efficiency have been greatly improved, which demonstrates the effectiveness of the IBTs designed in this paper.

5.3. Impacts on the consumption and income of power companies

The IBTs will increase the overall tariff level and result in less electricity consumption, subsequently changing the revenue of power companies. Taking 2008 as an example; Table 13 describes the impact of the IBTs on power companies' income.

The resident electricity consumption was 403.5 billion kW h in 2008, if implementing the IBTs, electricity consumption will be reduced by 26.68 billion kW hkW h, accounting for 6.6% of total resident electricity consumption. Specifically, electricity use in the second block will be reduced by 6.23 billion kW h, 10.61 billion kW hkW h in the third block, and 9.84 billion kW h in the fourth block. It is not surprise that electricity consumption in the third block will decrease most: for one thing, the number of resident in the third block is two times more that in the fourth block; for another, the price elasticity of the demand of resident in the third block is higher than that in the fourth block. Since the residential electricity price is inelastic, the revenue of power companies will increase by CNY 72.9 billion after implementing the IBTs.

5.4. Impacts on emissions

As China's power structure is dominated by coal power, the reduction of electricity consumption will decrease emissions. As calculated above, resident electricity consumption will be reduced by 26.68 billion kW h, which will induce coal demand decrease by 7.54 million ton, subsequently resulting in 14.11 million tons of CO_2 emissions reduction.[4]

6. Conclusions and suggestions

6.1. Conclusions

The NDRC issued a scheme of IBTs for residential electricity in Oct 9th, 2010, which was a significant progress for residential electricity reform and arouse widely discussion. This paper attempts to design an IBTs for China's residential electricity, and analyze its potential impacts. This leads to several conclusions:

First, the IBT with four-tier structure would be more reasonable for China with the consideration of difference between rural and urban resident. The first block is designed for impoverished resident, in which the volume of electricity consumption is 40 kW h per household, and the price keeps fixed. The volume of the second block is 41–80 kW h, and electricity price increases to CNY 0.75 per kW h. The monthly electricity use for the third block is 81–180 kW h, and the price is the marginal cost of electricity supply. The electricity consumption of the fourth block is 180 kW h per household, with the peak marginal electricity price of CNY 1.40 per kW h.

Second, the IBTs will decrease the welfare of resident except for the poor, and the higher the block is, the more welfare loss, but the effect is small. Under the IBTs, the increased electricity expenditure is still acceptable for all residents. Furthermore, the IBTs will improve the efficiency of the resident electricity subsidy mechanism, subsidies for middle and high income resident will be greatly reduced, while the proportion for resident in the first and second block will increase from 47.4% to 73.8%.

Third, the IBTs could promote energy saving and emissions reduction. Under the IBTs, residential electricity consumption will be reduced by 26.68 billion kW h in 2008, and subsequently results in the CO_2 emissions reduction by 17.43 million ton. In addition, the income of power companies will increase by CNY 72.9 billion.

6.2. Suggestions

China's resident electricity price is relative low, and there is no distinction for different income groups, which will encourage ineffective electricity consumption in high income households. And what is more, the non-target subsidies mechanism implies that most of the subsidies are received by high income resident, which runs counter to the initial aim. The IBTs cannot only promote social equity and the efficiency of the subsidies mechanism, but also improve energy efficiency and encourage energy conservation. It is indeed a breakthrough for the reform of China's resident electricity pricing, and the most feasible policy in current context.

However, there are also some limitations of the IBTs:

First, the IBTs system works on the assumption that low income residents are also low electricity users (Filipović and Tanić, 2009). However, it is not completely true. For example, some low income households with large family member may consume more electricity and be classified into the higher block. Consequently, they have to bear higher electricity expenditure which they may not afford.

Second, there is still "subsidy leakage" in the IBTs. For one thing, middle and upper income households still get benefit because of the low price in the first block; for another, the poorest residents, who have no availability of electrical networks, cannot gain any benefits from the IBTs.

Thirdly, the IBTs can only work when each household has a private metered connection. However, in some remote areas, electricity is supplied by the rural collective networks and quite a number of the impoverished residents share public electric meters, which means the electricity use measured by electric meter is the total consumption of several households and will be relatively high. Thus, these poor households will be sorted into the higher block. Whittington (1992) pointed out that in developing countries, the IBTs for electricity might add burdens to poor households' access to electrical networks.

In order to avoid the limitations of the IBTs, and ensure this mechanism to be effective, the government should take some steps as complement. Such as increasing the investments in electric infrastructure and networks coverage in remote areas, implementing the "one household, one electricity meter" program. As residents in remote areas are always very poor, the cost of reconstruction may put heavier burden on them than the tariffs. The government may consider sharing the cost from three sources: additional revenue of power companies, fiscal budget and resident's pay.

In addition, much attention should be given to the first block when designing the IBTs (Boland and Whittington, 2000). The first is to improve the targeting, by means testing, proxy means testing, geographical targeting, demographic targeting self-targeting and other methods. For example, in general, the geographic areas of poor household with large family number is in the remote countryside, the volume of electricity use in the first block in these areas could be higher than that in city. In order to offset the benefit that high income residents get from the low

[4] According to the Annual Report of Electricity Regulatory (2008), the average coal consumption for power supply is 349 g/kWh. The generation of coal-fired power plant is 2779.3 billion kWh, accounting about 80.9% of total electricity supply. So we assume that 80.9% of the electricity demand reduction come from the coal-fired power plant, and only consider the emission of coal.

price in the first block, higher price that exceeds the marginal cost in higher block may be adopted.

Furthermore, per capita electricity consumption is relatively low in China, it is in a dynamically increasing process, so that the threshold of the electricity use and price should vary with the change of household electricity consumption and the supply costs. That is, the IBTs should be a dynamic adjustment mechanism.

Acknowledgements

The paper is supported by New Huadu Business School Research Fund, Ministry of Education Foundation (Funding No. 10JZD0018), Basic Research Universities Special Foundation (Funding No. 2010221051), National Social Science Foundation (Funding No. 08AJY022), National Social Science Foundation (Funding No. 09&ZD050), Shanghai Leading Academic Discipline Project (Project No. B801), Research Fund of the Peking University–Lincoln Institute Center for Urban Development and Land Policy.

References

Agthe, D.E., Billings, R.B., 1987. Equity, price elasticity, and household income under increasing block rates for water. American Journal of Economics and Sociology 46 (3), 273–286.

Angel-Urdinola, D., Cosgrove-Davies, M., Wodon, Q., 2006. Rwanda: electricity tariff reform. In: Coudouel, A., Dani, A., Paternostro, S. (Eds.), Poverty and Social Impact Analysis of Reforms: Lessons and Examples from Implementation. , The World Bank, Washington, DC.

Asian Development Bank, 1993. Water Utilities Handbook: Asian and Pacific Region. Manila, Philippines.

Bar-Shira., Z., Finkelshtain, I., Simhon, A., 2005. Regulating irrigation via block-rate pricing: an econometric analysis. American Journal of Agricultural Economics 88 (4), 986–999.

Barnes, D.F., Krutilla, K., Hyde, W.F., 2004. The urban household energy transition: energy, poverty, and the environment in the developing world. World Bank, Energy Sector Management Assistance Programme.

Barnes, D.F., Krutilla, K., Hyde, W.F., 2005. The Urban Household Energy Transition: Social and Environmental Impacts in the Developing World. Resources for the Future, Washington, DC.

Billings, R., Agthe, D.E., 1980. Price elasticities for water: a case of increasing block rates. Land Economics 56 (1), 73–84.

Boland, J.J., Whittington, D., 2000. The political economy of water tariff design in developing countries: increasing block tariffs versus uniform price with rebate. In: Dinar, A. (Ed.), In The Political Economy of Water Pricing Reform. , Oxford University Press, New York, pp. 215–235.

Borenstein, S., 2008. Equity effects of increasing-block electricity pricing. UC Berkeley: Center for the Study of Energy Markets (CSEM) Working Paper Series, CSEM WP 180.

Borenstein, S., 2009. To what electricity price do consumers respond? residential demand elasticity under increasing-block pricing. Working paper presented to NBER summer workshop, Environmental and Energy Economics.

Buliding Research Establishment (BRE), 2009. An investigation of the effect of rising block tariffs and fuel poverty. BRE Client report number 255–112.

Chen, T.X., Zhang, B.H., Liu, J.H., et al., 2005. Strategy of grading pricing model on residental power consumption. Power Demand Side Management (3).

Dahan, M., Nisan, U., 2007. Unintended consequences of increasing block tariffs: pricing policy in urban water. Water Resources Research 43 (3), 1–10.

Dalhuisen, J.M., Florax, R.J.G.M., de Groot, H.L.F., Nijkamp, P., 2003. Price and income elasticities of residential water demand: a meta-analysis. Land Economics 79 (2), 292–308.

Espey, M., Espey, J., Shaw, W.D., 1997. Price elasticity of residential demand for water: A meta- analysis. Water Resources Research 33 (6), 1369–1374.

Fankhauser, S., Tepic, S., 2006. Can poor consumers pay for energy and water? an affordability analysis for transition countries. Energy Policy 35 (2), 1038–1049.

Faruqui, A., George, S., 2006. Pushing the envelope on rate design. The Electricity Journal 19 (2), 33–42.

Filipović, S., Tanić, G., 2009. The Policy of Consumer Protection in the Electricity Market. Economic Annals 53 (178–179), 157–182.

Freund, C.L., Wallich, C.I., 1997. Public-sector price reforms in transition economies: who gains? who loses? the case of household energy prices in Poland. Economic Development and Cultural Change 46 (1), 35–59.

Haney, B., Jamasb, T., Pollitt, M.G., 2009. Smart metering and electricity demand: technology, economics and international experience. University of Cambridge Electricity Policy Research Group Working Paper, EPRG0903, Cambridge Working Paper in Economics 0905.

Hall, D.C., Hanemann, W.M., 1996. Urban Water Rate Design Based on Marginal Cost, In Marginal Cost Rate Design and Wholesale Water Markets, Volume 1 of Advances in the Economics of Environmental Resources. JAI Press, Inc., Greenwich, Connecticut 95–122.

Independent Pricing and Regulatory Authority (IPART), 2003. Inclining block tariffs for electricity network services. Secretariat Discussion Paper DP64, June, NSW.

Hughes, L., 2004. The Inverted Block Rate: An Alternative to Flat Rate Billing. Energy Research Group, Dalhousie University, Halifax.

Lin, B.Q., Jiang, Z.J., Lin, J., 2009. Targeted electricity-subsidy contributes to equity and efficiency (in Chinese). Journal of Financial Research 11, 48–58.

Lin, B.Q., Jiang, Z.J., 2011. Estimates of energy subsidies in China and impact of energy subsidy reform. Energy Economics 33 (2), 273–283.

Meran, G., Hirschhausen, C.V., 2009. Increasing block tariffs in the water sector – a semi-welfarist approach. Discussion Papers of DIW Berlin 902, DIW Berlin, German Institute for Economic Research.

Nauges, C., Blundell R., 2001. Estimating residential water demand under block rate pricing: a non parametric approach. Working Paper, University College, London.

Olivier, A., 2006. Water tariff increase in Manaus (Brazil): an evaluation of the impact on households. Working Papers, DIAL (Développement, Institutions & Analyses de Long terme).

Porter, R.C., 1996. The Economics of Water and Waste: a Case Study of Jakarta, Indonesia. Ashgate Publishing Limited.

Qi, F., Zhang, L.Z., Wei, B., Que., G.H., 2009. An application of Ramsey pricing in solving the cross-subsidies in Chinese electricity tariffs. Institute of Electrical and Electronics Engineers, 442–447.

Reiss, P.C., White, M.W., 2005. Household electricity demand, revisited. The Review of Economic Studies 72 (3), 835–883.

Whittington, D., 1992. Possible adverse effects of increasing block water tariffs in developing countries. Economic Development and Cultural Change 41 (1), 75–87.

Whittington, D., 2003. Municipal water pricing and tariff design: a reform agenda for south Asia. Water Policy 5 (1), 61–76.

Yaron, D., 1991. Quotas and pricing in agriculture. Economic Quaterly 150 (2), 465–478.

Zusman, P., 1997. Informational imperfections in water resource systems and the political economy of water supply and pricing in israel. In: Parker, D.D., Tsur, Y. (Eds.), Decentralization and Coordination of Water Resource Management. Kluwer Academic Publishers, 133–154.