Title: Evaluation on the efficiency of Chinese energy-saving household appliance subsidy policy: An economic benefit perspective

Hongguang Nie

Nhguang@126.com

School of Economics and Management, Changchun University of science and technology

Changchun, China

Ting Zhou

Zhouting96228@163.com

School of Economics and Management, Changchun University of science and technology

Haiyan Lu'*

Haiyanlu@stu.edu.cn

Shantou University Business School, Shantou, China

Shupeng Huang

HuangS18@cardiff.ac.uk

Cardiff University Business School, Cardiff, UK

Evaluation of the efficiency of Chinese energy-saving household appliance subsidy policy: An economic benefit perspective

Abstract:

China has made great efforts to control energy consumption and reduce environmental pressure in recent decades. In the residential sector, the dramatic increase in the ownership of household appliances has driven the growth of electricity consumption, which calls for effective energy-saving policies. In this study, we exemplified the sales of refrigerators in Beijing, aiming to evaluate the effectiveness of current subsidy policies for stimulating the purchase of energy-efficient household appliances. In specific, we first selected ten pairs of refrigerators from six brands having similar functions, however different in their energy efficiency grades (EEG). By applying a combination of net present value (NPV) difference method and Conversion Method of Electrical Engineering Coefficient, we calculated and compared the changes in the NPV difference and dynamic investment payback period (DIPP) to evaluate the effectiveness of the policy. The results revealed that economic benefits were mainly generated in EEG2; thereby we suggest that the government can cancel subsidies for EEG2 refrigerators, and increase the subsidy amount for EGG1 refrigerators at a potential rate of 24% in the future.

Keywords: energy saving subsidy; energy efficiency label; economic benefit; household appliance

1. Introduction

Global warming is a world-wide problem raising substantial social and governmental attention (Faheemullah et al., 2015; Ji et al., 2019). Governments tend to promote the energy-saving subsidy policies for reducing greenhouse gases and slowing down the global warming effect (Bian et al., 2013; Galarraga et al.,2011; Gillingham et al.,2009). Therefore, it is necessary to have an appropriate energy-saving policy (Linares and Labandeira, 2010; Xia et al., 2019; Xu et al., 2019), having potential to reduce global carbon dioxide (CO_2) emissions by 10% to 15% (International Energy Agency, 2009). The Chinese government has been formulating energy-saving policies since the 1980s and has issued a series of regulation measures and incentive policies for energy conservation (Li et al., 2020; Yuan et al., 2009). In 2009, the Chinese government had pledged to cut carbon intensity by 40-45% by 2020 compared with the 2005 level (Hu,2009; Yuan et al.,2012). To achieve this, in 2011, the State Council issued the *'Comprehensive Work Plan for Energy Conservation and Emission Reduction during the 12th Five-Year Plan Period'* and specified the low-carbon index for measuring energy conservation and emission reductions. In the 13th Five-Year Plan, it was indicated that by 2020, energy intensity should decrease by 15% compared with 2015 (Yu et al., 2018). According to the *'Implementation Plan for Further Optimizing Supply, Promoting Steady Growth of Consumption, and Facilitating the Formation of a Strong Domestic Market (2019)',* jointly issued by the National Development and Reform Commission (NDRC), another nine ministries in China, the Chinese central government encourages regional governments to implement specific subsidies for energy-saving household appliances tailored to local conditions (Gov.cn, 2019). To address the central government's policy, a nationwide subsidy policy on energy-efficient appliances was widely implemented. In Beijing, for example, the regional governments have adopted a three-year subsidy policy for energy-efficient appliances since February 2019. An effective energy-efficient subsidy could stimulate consumers to purchase more energy-efficient appliances by improving their economic benefits (Allcott et al., 2015; Ma et al., 2013). For rational consumers, they will make decisions based on the tradeoff of upfront price and the electricity expenditure after purchasing (Gerardenet al., 2017; Xie and Zhao, 2018). Even though energy-efficient appliances can consume less electricity than normal products, the purchasing price could be higher. In this regard, the economic benefits of energy-efficient products are ambiguous. A subsidy can improve the economic benefits to reduce the total payment of energy-efficient appliances by decreasing upfront price. As such, to what extent a subsidy policy can effectively influence consumers' economic benefits is arguable. To a large extent, an appropriately designed and implemented policy can improve the energy-efficient products' economic benefits , utilizing minimum cost input or vice versa. Therefore, the following research question was addressed in this study: ***What are the economic benefits of purchasing energy-efficient products and to what extent the current Chinese energy-efficient subsidy influence on the cost comparison of products with different EEGs?***

This rest of the paper is organised as follows. The literature review is given in the second section, and Chinese energy-efficiency labelling policy and the subsidy policy for energy-efficient household appliances is reviewed in the third section. We then present our methodology, including data collection and analysis methods, in the fourth section. The results and relevant discussions are presented in the fifth section, followed by our conclusion.

2. Literature overview

A stream of existing studies have focused on the adoption of energy-efficient products and related subsidy policies. Energy-efficient products prompt a potential reduction in energy consumption and CO_2 emissions, however consumers appear to be hesitated in acceptance for energy-efficient products due to low or perceived economic benefit leading to an energy-efficiency gap (Gerardenet al., 2017) that individuals make decisions about energy efficiency leads to a slower diffusion of energy-efficient products than other alternative optimal decision consumers would make (Gillingham and Palmer, 2014). Several studies that explore the reasons forthe energy-efficiency gap and classify the key barriers to the adoption of energy-efficient products as market failures including environmental externalities, inefficient pricing of energy and lacking of information (Cohen et al., 2017; Gillingham and Palmer, 2014; Kallbekken et al., 2013). To bridge the energy-efficiency gap, energy-saving policies, such as information strategies, efficiency standards regulation, and economic incentives, have been implemented in various countries (Gillingham and Palmer, 2014; Tietenberg, 2009).

Information strategies refer to providing consumers with adequate information to solve the problem of information asymmetry, which have been proven to be effective in bridging the energy-efficiency gap (Jeong and Kim, 2015; Stadelmann and Schubert, 2018; Zhou and Bukenya, 2016). The more clear and simplified information is provided for energy-efficient products, the more likely these products will capture consumers' intention (Ek and Söderholm, 2010; Shen and Saijo,2009). In contrast, complicated energy-efficiency information will be likely to decrease purchase intention among those consumers having low level of literacy (Abrahamse et al., 2007).

Efficiency standard regulation demonstrate that the government sets efficiency standards for energy-using products, and supervises the enterprises according to the standards, aiming at promoting the energy efficiency of energy-using products (Tao and Yu, 2011). Tao and Yu (2011) evaluated the effectiveness of the efficiency standards regulation for household refrigerators and concluded that on one hand, the implementation of efficiency standards regulation can reduce both electricity consumption and carbon emissions with a large potential. On the other hand , the consequences of applying the efficiency standards greatly increase manufacturing cost and retail price. Parry et al. (2014) evaluated the efficiency standard regulation program and indicated that the efficiency standard regulation program can effectively deal with market failure including environmental externalities and information asymmetry. However, for environmental externalities, the preferred approach is emission pricing measures, and for information asymmetry, information programs can play an important role. In either case, efficiency standards appear to be a second-best measure due to the disadvantage of high policy cost.

Energy-efficient subsidy policy is an effective economic incentive to reduce energy consumption andto deal with market failures including environmental externalities, information asymmetries and so on. (Allcott et al., 2015). The effectiveness of the energy-efficient subsidy on energy conservation has been evaluated and proven to be significant (Allcott et al., 2015; Wang et al.,2017). Furthermore,when the targets and levels of subsidies are appropriate, the subsidy policy could be regard as the most cost-effective measure to save energy and reduce emissions (Allcott and Greenstone, 2017; Datta and Guliti, 2014; Filippini et al., 2014).

In addition, environmental awareness and social interaction have been investigated as influential factors in the adoption of energy-efficient products (Jia et al., 2018; Li et al., 2019; Nie et al., 2019). However, most scholars still believe that economic benefit is the most important determinant in stimulating consumers to adopt energy-efficient products (Gerardenet al., 2017). Feng et al. (2010) found that approximately one-third of consumers only consider the price of energy-efficient products, rarely taking the costs of electricity consumption into consideration. And more scholars believed that both overall economic benefits and energy prices are both important factors for consumers to consider when making purchase decisions (Fuerst and Singh, 2018; Mills and Schleich， 2010; Panzone，2013).

The aforementioned studies revealed that even though various factors influence the adoption of energy-efficient products, their economic benefits are fundamentally important. Among various policies, the economic incentive policies played an outstanding role in promoting the adoption of energy-efficient products especially when the targets and levels of subsidies were appropriate.

In this study, we evaluated the efficiency of Chinese energy-efficient subsidy policy by directly investigating the economic benefits of labelled household appliances with different energy efficiency grade (EEG) levels in the absence and presence of subsidies. Net present value (NPV) and dynamic investment payback period (DIPP) were shown to be effectively measure the economic benefits of labelled appliances (Enongene et al., 2017). NPV differences were used to measure the difference in benefits between appliances with different EEG levels, as these benefits definitely drive consumers' purchase decisions (Enongene et al., 2017; Gerarden et al, 2017). We chose refrigerator as our research focus because refrigerators, compared with other household appliances, consume more electricity (Tao and Yu, 2011). Moreover, due to the fact that refrigerators must be charged an entire day without being turned off, the EEG level can significantly influence on household electricity consumption. We acknowledge that it can be difficult to collect a pair of refrigerators with identical functions but different EEG levels. Thus, we selected refrigerators with similar functions at different EEG levels from the same brands, and we proposed a novel adjustment method to adjust refrigerator functions mathematically to the same level.

3. Chinese energy-efficiency labelling and household appliance subsidy policy

3.1 Energy-efficiency labelling policy

The energy-efficiency label is one of the most important types of environmental labels, contributing to the reduction of energy consumption (Gillingham and Palmer, 2014). As the original version of the energy-efficiency labelling policy, in early 1998, the 'Energy Conservation Law of the People's Republic of China' required companies to explicitly indicate the energy consumption level of their products on product labels and in manuals (Zhou et al.,2010). In 2004, to further develop energy-saving technologies and improve energy efficiency, the Chinese government designed and issued the ‘Measures for the Administration of Energy Efficiency Labels’, which was the first formal energy-efficiency labelling policy in China. In 2016, to further improve the efficiency of energy consumption and contribute to the development of energy-saving technologies, the Chinese government amended and implemented the ‘Measures for the Administration of Energy Efficiency Labels’. Based on the policy, energy-using products in China are categorised into five EEG levels, from EEG1 to EEG5, where EEG 1 represents the highest energy-efficiency level and EEG 5 represents the lowest energy-efficiency level. Among these, EEG 3 represents the average energy-efficiency level in the market, while EEG 4 means that the energy-efficiency level is below the average. Products ranked at the EEG 5 level are restricted from market entrance under the policy.

3.2 Subsidy policy for energy-efficient household appliances

Even though energy efficiency labels provide information about the energy-efficiency levels of household appliances, higher prices of energy-efficient household appliances constrains consumers’ purchase intentions. As such, energy-efficient household appliance subsidy policies have been adopted by the government. In 2009, the Chinese government implemented a household appliances trade-in policy aiming at stimulating the demand for domestic household appliances, saving energy, reducing emissions and eventually contributing to the development of a domestic circular economic ecosystem. In 2012, the Chinese government implemented a one-year energy-efficient household appliance subsidy policy to support the development of the market of energy-efficient products and lead consumers towards green consumption. In 2019, the NDRC, Ministry of Industry and Information Technology (MIIT), Ministry of Commerce and another seven government agencies issued the 'Implementation Plan for Further Optimizing Supply, Promoting Steady Growth of Consumption, and Facilitating the Formation of a Strong Domestic Market (2019)'. This policy states that local governments will support the sales of green smart household appliances. Appropriate subsidy policies can be adopted and applied to stimulate the sale of these high-quality, high energy-efficiency household appliances.

Beijing is the pioneer in promoting energy-efficient products in China. In 2015, Beijing began to implement a three-year subsidy policy to encourage the purchase of energy-efficient products, which attracted substantial attentions from consumers. Furthermore, a new three-year subsidy policy, implemented by the Beijing government in 2019, also significantly generated the sale of energy-efficient products. Under this policy, the sale of energy-efficient household appliances has experienced high market growth. From 1 February to 6 March 2019, the total sales of energy-efficient products were 338 million RMB, 20% higher than the previous year. Subsidy policies will further encourage consumers to choose energy-efficient products. To further stimulate the sale of energy-efficient products, the new three-year subsidy policy implemented in Beijing will subsidise products like energy-efficient household appliances, depending on their EEG levels, with a subsidy rate ranging from 8% to 13%. Specifically, EEG1 and EEG2 energy-efficient household appliances will receive a subsidy rate of 13% and 8% respectively, with a highest subsidy amount set at 800RMB per item.

In this context, this paper aims to evaluate the efficiency of the recent three-year policy implemented in Beijing. Refrigerators were chosen as the research focus because of their continuous operation and high-power consumption. As Chinese refrigerators only have three EEG levels, namely EEG1, EEG2 and EEG3, according to the policy, only EEG1 and EEG2 refrigerators will receive the subsidy (13% and 8%), while refrigerators at and below EEG3 levels will not receive the subsidy. Therefore, this study will compare and examine the economic benefits and policy efficiency between refrigerators at EEG1 and EEG2 levels.

4. Methodology

4.1 Approach of NPV difference in the refrigerator lifecycle

As the fundamental elements of the decisions on purchasing household appliances, total cost was used to measure the economic benefits of purchasing energy-efficient products. And the minimising cost that consists of equipment purchase cost and discounted operating cost indicates the optimal economic benefit (Gerarden et al., 2017). To provide information about the economic benefits of refrigerators with different EEG levels, the NPV difference approach (Horngren et al.,2013) was adopted to measure the gap between a pair of refrigerators with different EEG levels. In detail, we first calculated the NPV of each type of refrigerator, after which we calculated the NPV difference between the two types. Specifically, NPV difference measures the NPV of purchasing a refrigerator with a lower EEG level minus the NPV of purchasing a refrigerator with a higher EEG level. If the NPV difference is positive, the refrigerator with the higher EEG level can be said to generate more economic benefits for consumers or vice versa. To better measure the economic benefits of refrigerators at different EEG levels, the NPV and NPV difference calculated in this paper were considered for refrigerators over their entire lifecycle. In existing studies, the lifecycle of an appliance includes its purchase, use, maintenance and recycling (Zhou and Zhen, 2018). Compared with appliances which need frequent maintenance, refrigerators are regarded as durables, meaning they require much less maintenance (Yu and Guo, 2016). In this regard, the present study considered the stages of purchase, use and recycling in the lifecycle in line with previous studies (Stadelmann and Schubert, 2018; Tao and Yu, 2011), and the cost generated in these stages was considered as the refrigerators' economic benefits.

We evaluated a refrigerator’s economic benefits by considering four different scenarios for its service life: 4 years, 8 years, 12 years and 16 years. A positive calculated NPV difference indicates a better economic benefit of a higher EEG-level appliance. Meanwhile, the efficiency of the subsidy policy was measured by comparing the NPV difference in the absence and presence of subsidies.

To compare the NPV of appliances with different EEG levels, we adopted the following formulae to calculate the NPV difference (NPVD):

$$NPVD = \sum_{0}^{t} \frac{C_t + M_t}{(1+r)^t} - C_0 + \triangle RI \qquad (1)$$

where:

$C_0 = P_{high} - P'_{low}$

$C_t = EC'_{low} - EC_{high}$

$EC_{high} = E_{ahigh} * 0.55 * 365$

$EC'_{low} = E'_{alow} * 0.55 * 365$

where NPVD is net present value difference between higher EEG-level refrigerators and lower EEG-level refrigerators, C_t is the cost difference of electricity consumption between lower EEG-level refrigerators and higher EEG-level refrigerators in year *t*, which essentially reflects the cost saved by the higher EEG-level refrigerators compared with the lower EEG-level refrigerators. C_o is the cost difference in year *0*, which is the price difference between higher EEG-level refrigerators and lower EEG-level refrigerators. M_t represents difference in maintenance costs between higher and lower EEG-level refrigerators. Since refrigerators require very little maintenance over their lifecycle –and even if they do, there was no significant difference in the maintenance costs of refrigerators with different EEG levels in each pair after adjustment in this study – we assumed $M_t = 0$ for $t > 0$. $\triangle$RI here stands for difference in refrigerator recycling between both refrigerators. When we calculated NPV differences between both refrigerators, we considered the entire lifecycle of refrigerators from purchase to use to recycling, so we needed to consider the value of a refrigerator after its service life, such as the value obtained from recycling. However, it should be noted that after adjustment, refrigerators were regarded as identical with the exception of their EEGs. Therefore, the values generated in the process of recycling should be the same for both refrigerators, which means the difference concerning the recycling value was zero. P_{high} is the price of refrigerators with a higher EEG level, while P'_{low} is the adjusted price of refrigerators with a lower EEG level, a calculation which will be discussed in detail in the following sub-section. EC_{high} are the annual costs of electricity consumption of refrigerators with a higher EEG level, while EC'_{low} are the adjusted annual costs of electricity consumption of refrigerators with a lower EEG level. E_{ahigh} and E'_{alow} is the daily electricity consumption for refrigerators with a higher EEG level and the adjusted daily electricity consumption for refrigerators with a lower EEG level, respectively, a calculation which will also be discussed in the following sub-section. Notably, we assumed 365 days each year, and we set the price of electricity at 0.55RMB/kWh (Chen and Zuo, 2018). Finally, r stands for discount rate. To be consistent with the savings benchmark interest rate of the People's Bank of China, r was 2.75%.

In addition, consumers will also take the investment payback period into consideration. The shorter the period is, the lower risk consumers will have. To measure the period for an investment's payback, we adopted a widely used indicator: dynamic investment payback period (DIPP). This indicator represents the period from the beginning of the investment to the time at which the cumulative discounted cash flow is equal to zero. This can be calculated using the following formula:

$$P_t = (T_{NPVD\geqslant 0} - 1) + \frac{|N_{T-1}|}{N_T} \quad (2)$$

where:

P_t----------------Dynamic investment payback period

$T_{NPVD\geqslant 0}$------The period from the present year to the year in which the NPVD initially becomes positive.

N_T-------------The NPVD in the period from the present year to the year in which the NPVD initially becomes positive.

$|N_{T-1}|$ -------The absolute value of the NPVD in the period from the present year to the year before the NPVD initially becomes positive.

4.2 An approach to adjusting refrigerators' price, volume and electricity consumption

As it can be difficult to find a pair of refrigerators which are identical in their volume and function but different in their EEG levels, it would have been inappropriate to directly calculate NPV difference based on the price and electricity consumption of different refrigerators. As such, in this research, we managed to eliminate all other influences from refrigerators' functions (e.g. refrigerator volume, compartment numbers) and focused instead on measuring the economic benefits conferred by refrigerators with different EEG levels. Towards this end, we adjusted the price of refrigerators with a lower EEG level by multiplying an adjustment coefficient that was equal to the ratio of adjusted volume of a refrigerator with a higher EEG level and a lower EEG level. Specifically,

$$P'_{low}=P_{low} * V'_{high}/V'_{low} \quad (3)$$

where：

P'_{low}-----adjusted price for refrigerators with a lower EEG level

P_{low}----- price for refrigerators with a lower EEG level

V'_{high}----adjusted volume of refrigerators with a higher EEG level

V'_{low}----adjusted volume of refrigerators with a lower EEG level

Here, the actual volume of refrigerators with both higher and lower EEG levels can be standardised according to the formula below to ensure that a pair of refrigerators are comparable (Yu et al., 2012).

$$V'=\sum_{c=1}^{n} V_c * F_C * W_C * CC * BI \quad (4)$$

where:

V'-------adjusted volume of refrigerators

V_C------Measured volume of a certain type of compartment

F_C-------Compartment type factor; when it is a frost-free refrigerator with a compartment with forced convection, the value is equal to 1.5; otherwise, it is equal to 1.0.

W_C------The weighting coefficient of each type of compartment, detailed information of which is included in Appendix A.

CC-------Climate type correction factor[1]

BI--------Refrigerator type indicator; when it is an embedded refrigerator, this value is

1.2; otherwise, it is 1.0.

n--------The number of different types of compartments

Moreover, as different volumes can lead to different degrees of electricity consumption, it was necessary to adjust electricity consumption when calculating the NPV difference for the costs of using both refrigerators. To do this, we referred to the Chinese GB12021.2-2015 programme, which is ‘The maximum allowable values of the energy consumption and energy efficiency grade for household refrigerators’ (Gov.cn,2015), together with the adoption of the formulae used in the study by Yu et al. (2012) to adjust the refrigerator’s electricity consumption accordingly. The adjusted electricity consumption of the refrigerator with a lower EEG level was calculated as follows:

$$E'_{alow} = \eta_a * E'_{base\text{-}l} \quad (5)$$

where:

η_a -------The standard energy efficiency index, which is shown in Appendix B.

$E'_{base\text{-}l}$----adjusted basic electricity consumption of lower EEG level refrigerators.

Noting the adjustment of basic electricity consumption of less efficient refrigerators, it makes more sense to compare electricity consumption between less efficient and more efficient refrigerators at the same volume. In detail, the $E'_{base\text{-}l}$ was obtained from formula (6) by replacing the volume data for less efficient refrigerators with the volume data for more efficient refrigerators when calculating basic electricity consumption for less efficient refrigerators. The η_a can be calculated from the following formulae combined with formula (4) above. The detailed formulae are as follows:

$$E_{base}=(M*V'+ N + CH + Dc) * Sr / 365 \quad (6)$$

$$ŋ_a= E_a/ E_{base} \quad (7)$$

where：

E_{base}-----basic electricity consumption for a refrigerator

M--------constant, here equal to 0.697 (KW.h/L)

N---------constant, here equal to 272（KW.h）

CH-------The correction factor of temperature-varying compartment[2]

Dc--------The correction factor of door number; when the number of refrigerator doors ≥ 4, Dc is 50; for other types, Dc is 0

Sr---------Function correction factor[3]

E_a--------Actual electricity consumption labelled in the refrigerator

4.3 Data collection

We selected six refrigerator brands – namely Haier, Midea, Ronshen, Meiling, Hisense and Konka – as our samples for the following underlying reasons. First, the ZhongYiKang database (2019) was used to provide authoritative data on China's household appliance market. We collected the data from the leading refrigerator brands with top-seven market share from 2015 to 2017 and the average prices in each brand (Figure 1). To cross check the sampling strategy, we then collected the brands with top-eight market share from the *All View Cloud* database *(*http://www.avc-mr.com/) in 2018 (Figure 2). Comparing the brands in both lists, Haier, Midea, Ronshen and Meiling are listed in the top-five brands; whereas Hisense and Konka are listed in the top-seven brands based on sales and sales volume, respectively. Thus, we selected the six brands above as samples.

================

Fig. 1

================

================

Fig. 2

================

Another factor to be considered in data collection is the price of products. When we considered the current subsidy policy with the rate of 13% for EEG1 refrigerators, the maximum subsidy amount for EEG1 refrigerators was 800 RMB. In other words, if the price of refrigerators with EEG1 is higher than 6154 RMB (13% of which is 800 RMB), then regardless of the price of a product, consumers can only obtain an 800RMB subsidy. The average prices of the six selected refrigerator brands were far less than 6154 RMB (Figure 1), which ensured the consistency of the subsidy rate of each selected refrigerator brand. Even though international brands, such as Siemens, Samsung and Panasonic, embrace their strong market position, according to the ZhongYiKang database (2019), the average prices of Siemens, Samsung and Panasonic were 6408 RMB, 7779 RMB and 8443 RMB, respectively, in 2017, which were all significantly higher than 6154 RMB. Take Samsung as an example, according to the energy-saving subsidy rate, the subsidy for EEG1 refrigerators should be 1011 RMB (13% of average price), which is higher than 800 RMB; as such, the subsidy amount would be 800 RMB, accounting for 10% of the average price. In this case, the subsidy for EEG1 refrigerators has remained at 800 RMB. The subsidy rates of refrigerators with different prices are different, which is not conducive to the comparison and evaluation of the effect of energy-saving subsidies on refrigerators with different EEGs. In this regard, the international brands (Siemens, Samsung and Panasonic) with high prices were excluded from this study.

In this study, we obtained sales data from *Jingdong* (https://www.jd.com/) and *Suning* (https://www.suning.com/), which are two of the most popular online platforms for purchasing household appliances in China. The reasons why we choose these two online platforms are as follows. First, e-commerce platforms have become a major channel for Chinese residents to purchase household appliances; Second, the product prices of e-commerce platform is uniform, which can reduce the price difference of products obtained from different channels. Ten different pairs of refrigerators with similar functions in each pair were collected. The information was collected in March 2019, and included model, price, EEG level, volume, electricity consumption, climate type, number of doors, embedded or not, frost-free or not, as shown in detail in Table 1. To fit the purpose of this paper, we collected two groups of data on refrigerators. Five pairs of refrigerators were included in Group 1, which was used to compare the economic benefits between EEG 1 and EEG 2; the other five pairs of refrigerators were included in Group 2, which was used to compare the economic benefits between EEG 2 and EEG 3. The principle of matching refrigerators was that each pair of refrigerators had basically the same function, but different EEG levels, which facilitated the analysis of the impact of EEG levels on economic benefits for consumers.

================

Table. 1

================

5. Results and discussion

5.1 Economic benefit analysis

Table 2 shows the NPV difference and DIPP of ten pairs of refrigerators with different EEG levels, which was further categorised into two groups. Group 1 measured the NPV difference between EEG1 and EEG2 refrigerators and their DIPP, whereas Group 2 measured the NPV difference between EEG2 and EEG3 refrigerators and their DIPP. The results in the absence and presence of subsidies indicated the efficiency of the energy-efficient subsidy policy in China.

================

Table. 2

================

The results for DIPP for ten pairs of refrigerators showed how long it would take to recoup the overpaid price for an energy-efficient refrigerator through saving electricity cost. Observations in this study revealed a visible decrease in DIPP after the implementation of the subsidy policy. Figure 3 illustrates the comparison of the DIPP of pairs of refrigerators in the absence and presence of subsidies excluding pairs of 1.1, 1.2 and 1.3, for which the DIPP was greater than 30 even in the presence of subsidies. Both Figure 3 and Table 2 reveal that three pairs of refrigerators – namely 2.1, 2.2 and 2.5 – can obtain zero DIPP in the presence of subsidies. The results indicate that after adopting the subsidy policy, the initial investment (purchase price) of the refrigerators with a higher EEG level was not necessarily higher than that of the refrigerators with a lower EEG level in these pairs.

When we examined four scenarios of service life (e.g. 4, 8, 12, 16 years), the number of recoverable pairs in each scenario increased with the implementation of the subsidy policy (shown in Figure 4). In more detail, with the implementation of the subsidy policy, the recoverable pairs increased from 1 to 4, 4 to 6, and 4 to 6 in four-year, eight-year, and 12-year service life, respectively. Taking eight to ten years into consideration as the average service life of refrigerators in China (Liu et al., 2005), we can see that the DIPP for more than one-half of the refrigerator pairs is within eight years. As such, to some extent, the current subsidy policy contributed to encouraging consumers to buy higher EEG-level refrigerators.

===============

Fig. 3

================

================

Fig. 4

================

The economic benefits gap between EEG1 and EEG2, and between EEG2 and EEG3 was analysed by investigating the NPV difference and the DIPP in each pair in Group 1 and Group 2 respectively. Further investigation showed that EEG2 refrigerators yield larger economic benefits than EEG1 and EEG3 refrigerators, which indicated that most energy-efficient refrigerators are not cost-optimal choices for consumers. As shown in Table 2, in Group 1, the NPV difference in the first three pairs were negative in four scenarios, indicating that even though the refrigerators' service life lasts for 16 years, the economic benefits of EEG1 refrigerators are still lower than those of EEG2 refrigerators. For pair 1.4, although the NPV difference became positive in the 16-year service life scenario, the values under the 12-year scenario were negative. Drawing on this, the economic benefits for EEG1 refrigerators are still lower than those of EEG2 refrigerators if the service life is limited to 12 years; moreover, the EEG1 refrigerators' benefits can only exceed those of EEG2 refrigerators when their service life reaches 16 years. Compared with the first four pairs, pair 1.5 can first reach the positive NPV difference under the eight-year service life, meaning that EEG1 refrigerators can confer higher economic benefits than EEG2 refrigerators from the eighth year. However, as we mentioned above, the service life of refrigerators in China is normally from eight to ten years (Liu et al.,2005), and our results reflect that for most consumers, EEG2 refrigerators will confer more economic benefits than EEG1 refrigerators.

Table 2 indicates that the NPV difference in the first three pairs remained negative for the four scenarios after obtaining the subsidy. For those refrigerators, subsidy policy cannot change the fact that EEG2 refrigerators have higher economic benefits than EEG1 refrigerators. On the contrary, for the other two pairs (1.4 and 1.5), the DIPPs decreased significantly, indicating that the subsidy can increase the economic benefits of EEG1 refrigerators; however, the economic benefits of EEG1 refrigerators still cannot surpass those of EEG2 refrigerators in the presence of the subsidy. Even when considering the use of 16 years as a standard for refrigerator service life, the subsidy policy does not change the fact that EEG2 refrigerators in the first three pairs (1.1, 1.2 and 1.3) and EEG1 refrigerators in the remaining two pairs (1.4 and 1.5) have better economic benefits. If we use eight years as a standard for refrigerator service life, only in pair 1.4 does the subsidy policy permit the economic benefits of EEG1 refrigerators to exceed those of EEG2 refrigerators. In other words, the influence of the subsidy policy is quite limited with respect to EEG1 refrigerators.

Group 2 demonstrated that most of the results can achieve a positive NPV difference in the 16-year scenario even without a subsidy. EEG2 refrigerators can have higher economic benefits than EEG3 refrigerators in the 16-year service life. If the service life is limited to 12 years, there are still three pairs (2.1, 2.2 and 2.5) which have a positive NPV difference. Furthermore, if we consider eight years for refrigerator service life, only two pairs with a positive NPV difference can be identified. Thus, EEG3 refrigerators can have higher economic benefits than EEG2 refrigerators in three pairs.

When examining the efficiency of the energy-efficient subsidy policy on Group 2 refrigerators, we found that, in the 16-year scenario, four pairs refrigerators (2.1, 2.2, 2.4 and 2.5) had a positive NPV difference in the absence and presence of subsidies. In this case, the subsidy policy had limited influence. However, when examining the efficiency of the policy in the 12-year and eight-year scenarios, the efficiency of the subsidy policy can be identified. For the 12-years scenario, the number of pairs with a positive NPV difference increases from three to four, whereas for the eight-year scenario, the number of pairs with a positive NPV difference increases from two to four. Therefore, for a long service life (e.g. 16 years), the subsidy policy worked less efficiently; whereas, for a shorter service life (e.g. 12 years, eight years), the efficiency of the subsidy policy emerged.

Drawing on these results, when we consider the service life as 16 years, a comparison of the NPV difference between EEG2 and EEG3 refrigerators indicates that the influence of the subsidy policy on consumers' decision making is limited, and that consumers can obtain higher economic benefits by purchasing EEG2 refrigerators in pairs 2.1, 2.2, 2.4 and 2.5, as well as by purchasing EEG3 refrigerators in pair 2.3. Only when we consider the service life as eight years does the subsidy policy change consumers’ purchase decisions for higher EEG-level refrigerators in two pairs, 2.1

and 2.4. However, under the eight-year scenario, although the subsidy policy can mainly influence consumers' purchase decisions on Group 2 refrigerators, its influence on Group 1 refrigerators is quite weak and only consumers' purchase decisions in pair 1.4 are changed.

5.2 Scenario analysis of subsidy rate for EEG1 refrigerators

As our analysis revealed that the economic benefits of EEG2 refrigerators are always generally higher than those of EEG1 and EEG3 refrigerators when considering four different service life scenarios, we further investigated what subsidy rate is appropriate for informing the development of a new subsidy policy.

Currently, EEG1 and EEG2 refrigerators dominate the Chinese refrigerator market, while the EEG3 refrigerator market share is relatively low; thereby, we only considered EEG1 and EEG2 refrigerators in our scenario analysis. Based on the previous analysis, it was assumed that subsidy rates for EEG1 refrigerator were 13%, 15%, 17%, 19%, 21%, 23%, 24% and 25%, and that no subsidy was given to EEG2 refrigerators. Table 2 indicates that most EEG2 refrigerators can have higher economic benefits than EEG3 refrigerators even without subsidies under 16 years of service life. In other words, consumers are willing to purchase EEG2 rather than EEG3 refrigerators regardless of the subsidy policy. In addition, we can identify from Table 2 that even in the presence of subsidies, the economic benefits of most EEG1 refrigerators are still always lower than those of EEG2 refrigerators. Therefore, the subsidy rate is considered to be higher than the current rate (13%). The relevant results are shown in Table 3, in which the DIPP for each pair of refrigerators under different subsidy rates are presented.

================

Table. 3

================

Based on the government regulation that the maximum service life for household refrigerators should be no more than 16 years, we compared the DIPP within 16 years. Table 3 indicates that when the rate is 13%, the DIPP of two pairs exceeds 16 years (1.1 and 1.3). When the rate increases to 19%, only the DIPP of one pair is more than 16 years (1.1). When the rate further increases to 24%, all DIPPs are less than 16 years. Moreover, we also calculated the results under 25.5% (not listed in Table 3) and found the longest period to be just 9.7, meaning that the DIPP for all pairs was less than 10 years. Our results show that if 24% subsidies are given to EEG1 refrigerators and subsidies for EEG2 refrigerators are removed, the economic benefits for EEG1 refrigerators will be higher than those of EEG2 refrigerators in 16 years. If the subsidy rate increases to 25.5%, the economic benefits for EEG1 refrigerators will be higher than those of EEG2 refrigerators in less than ten years for all pairs.

5.3 Discussion on subsidy policy implementation

The policy evaluation implies that the current energy-efficient subsidy policy has been encouraging consumers to purchase more energy-efficient (EEG2) appliances instead of the most efficient (EEG1) alternatives. Drawing on the results, we conclude that the current energy-efficient subsidy policy has not been implemented efficiently. Based on our analysis, we argue that future policy should adjust the subsidy strategies. Given the purchasing interests of EEG2 refrigerators, to allocate the policy more efficiently, the subsidy could be reduced in EEG2, but increased in EEG1 products.

Based on the results of the economic benefits evaluation and scenario analysis, we inform the government on policy adjustment strategy and argue that to bridge the cost-effective gap between EEG1 and EEG2 refrigerators, the Chinese government can cancel the subsidies for EEG2 refrigerators and increase the subsidy rate of EEG1 refrigerators from 13% to 24%. The current subsidy rate for EEG1 and EEG2 refrigerators is 13% and 8% respectively, by assuming that same price is set for EEG1 and EEG2 refrigerators, the difference between the current subsidy rate and our target subsidy rate is just 3% (24%-13%-8%). This means that the cost for increasing the subsidy rate for EEG1 will not significantly increase the government budget. In addition, the results of scenario analysis indicate that when the subsidy rate is up to 24% for EEG1 refrigerators, the sampled EEG1 refrigerators can have higher economic benefits than EEG2 refrigerators under 16-year service life, meaning that the electricity consumption cost saved by EEG1 refrigerators within the service life can compensate the price difference between EEG1 and EEG2 refrigerators. With the increase of subsidy on EEG1 refrigerators, more households can afford the initial investment (Matosović and Tomšić, 2018), and that can potentially persuade consumers to switch their buying preference of EEG2 refrigerators to EEG1 ones to ultimately achieve the government's energy-saving goal.

6. Conclusion and policy implications

The novel contribution of this study is to evaluate the efficiency of Chinese current energy-efficient household appliance subsidy policy and inform government's redesign of the subsidy policy to improve efficiency. To conduct the evaluation, we quantified the policy efficiency by selecting ten pairs of refrigerators with a similarity in functions but different EEG levels, and the conversion method of electrical engineering coefficient was adopted to make refrigerators with different EEG levels in pairs comparable. By adopting the perspective of the entire lifecycle NPV difference, this study measured the economic benefits of ten pairs of refrigerators in four scenarios to evaluate the policy's efficiency: 4-year, 8-year, 12-year and 16-year service life in the absence and presence of subsidies. The results revealed that economic benefits were mainly generated in EEG2; thereby we suggest that the government can cancel subsidies for EEG2 refrigerators, and increase the subsidy amount for EGG1 refrigerators.

Relevant policy implications are provided by this study. First, central and regional governments can reexamine their policy efficiency in design and implementation, taking advantages from the findings of this study. Second, for the case of efficiency improvement, governments can consider policy adjustment. Generic subsidies may weaken consumers' preference for the most energy-efficient household appliances, which is not consistent with the original goal of the energy-efficient subsidy policy. Our study argues that direct subsidies for the most energy-efficient household appliances would be more efficient. Third, due to the large price gap between household appliances with an EEG1 level and those with an EEG2 level, increasing the subsidy for EEG1 appliances is strongly recommended for the Chinese government. Based on our study, the subsidy rate on household appliances with an EEG1 level should be raised up to 24%, which is fairly higher than the current subsidy rate of 13%.In addition to energy efficiency subsidies, more rational information strategies in policy implementation can also lead to energy-saving actions. The results of our study show that the NPV of a product can suitably reflect the aggregate economic cost of the entire life cycle of the product, which is beyond the consumers' knowledge and awareness. Adding more accurate economic cost information to the existing energy-efficiency information can effectively motivate consumers to purchase energy-efficient products (Davis and Metcalf, 2016). It is concluded that combining more precise subsidy policies and more effective information policies will greatly promote energy-saving behaviour in the Chinese household sector.

This study is shed the light on the analysis of economic benefits, which then draws upon concrete results and discussions, meanwhile the scope of focus could limit the consideration of other factors affecting consumers’ purchasing decisions, apart from the economic benefits. In future studies, psychological elements, information, and regulation factors as mentioned in the literature review can be further combine with economic factors to quantitatively analyse consumers' decisions on purchasing energy-efficient products.

Acknowledgments:

This research is supported by National Natural Sciences Foundation of China (Grant No.71503026), and Foundation for Humanities and Social Sciences of the Ministry of Education of China (Grant No. 20YJC790101). It is also funded by the Shantou University Scientific Research Initiation Grant (STF19027).

Reference

Abrahamse, W., Steg, L., Vlek, C., Rothengatter, T.,2007. The effect of tailored information, goal setting, and tailored feedback on household energy use, energy-related behaviors, and behavioral antecedents. Journal of Environmental Psychology 27, 265-276.

Allcott, H., Greenstone, M., 2017. Measuring the welfare effects of residential energy efficiency programs (No. w23386). National Bureau of Economic Research.

Allcott, H., Knittel, C., Taubinsky, D., 2015. Tagging and targeting of energy efficiency subsidies. American Economic Review 105(5), 187-91.

Banfi, S., Farsi, M., Filippini, M., Jakob, M., 2008. Willingness to pay for energy-saving measures in residential buildings. Energy Economics 30, 503-516.

Bian, Y., He, P., and Xu, H., 2013. Estimation of potential energy saving and carbon dioxide emission reduction in China based on extended non-radial DEA approach. Energy Policy 63, 962-971.

Carroll, J., Denny, E., Lyons, S., 2016. The effects of energy cost labelling on appliance purchasing decisions: Trial results from Ireland. Journal of Consumer Policy 39, 23-40.

Chen,Y.J., Zuo, Y., 2018. Research on price elasticity and cross-subsidy of industrial and residential power users. China Price (07), 56-59.(in Chinese)

Cohen, F., Glachant, M., Söderberg, M., 2017. Consumer myopia, imperfect competition and the energy efficiency gap: Evidence from the UK refrigerator market. European Economic Review 93, 1-23.

Datta, S., Gulati, S., 2014. Utility rebates for ENERGY STARappliances: Are they effective? Journal of Environmental Economics and Management 68(3), 480-506.

Davis, L. W., Metcalf, G. E., 2016. Does Better Information Lead to Better Choices? Evidence from Energy-Efficiency Labels. *Jo*urnal of the Association of Environmental and Resource Economists, 3(3), 589-625.

Ek, K., Söderholm, P., 2010. The devil is in the details: Household electricity saving behavior and the role of information. Energy Policy 38, 1578-1587.

Enongene, K.E., Murray, P., Holland, J., Abanda, F.H., 2017. Energy savings and economic benefits of transition towards efficient lighting in residential buildings in Cameroon. Renewable and Sustainable Energy Reviews 78, 731-742.

Feng, D.S., Sovacool, B.K.,Vu, K.M.,2010. The barriers to energy efficiency in China: Assessing household electricity savings and consumer behavior in Liaoning Province. Energy Policy 38, 1202-1209.

Filippini, M., Hunt, L. C., Zorić, J., 2014. Impact of energy policy instruments on the estimated level of underlying energy efficiency in the EU residential sector. Energy policy 69, 73-81.

Fuerst, F., Singh, R., 2018. How present bias forestalls energy efficiency upgrades: A study of household appliance purchases in India. Journal of Cleaner Production 186 , 558-569.

Galarraga, I., González-Eguino, M., Markandya, A.,2011. Willingness to pay and price elasticities of demand for energy-efficient appliances: Combining the hedonic approach and demand systems. Energy Economics 33, 66-74.

Gerarden, T. D., Newell, R. G., Stavins, R. N., 2017. Assessing the energy-efficiency gap. Journal of Economic Literature 55(4), 1486-1525.

Gillingham, K., Newell, R.G., Palmer, K., 2009. Energy Efficiency Economics and Policy. Annual Review of Resource Economics 1, 597-620.

Gillingham, K., Palmer, K., 2014. Bridging the energy efficiency gap: Policy insights from economic theory and empirical evidence. Review of Environmental Economics and Policy 8(1), 18-38.

Gov. cn, 2015.GB12021.2-2015 The maximum allowable values of the energy consumption and energy efficiency grade for household refrigerators.<www.sac.gov.cn>(18.09.2015)

Gov. cn., 2019.The circular on the implementation plan for further optimizing supply to promote steady growth of consumption and the formation of a strong domestic market (2019) was issued<http://www.gov.cn/xinwen/2019-01/29/content_5361940.htm> (29.01.2019)

Gram-Hanssen, K., Bartiaux, F., Jensen,O.M., Cantaert, M., 2007. Do home owners use energy labels? A comparison between Denmark and Belgium. Energy Policy 35, 2879-2988.

Horngren, C.T., Sundem, G.L., Schatzberg,J.O., Burgstahler, D., 2013. Introduction to management accounting. Pearson Higher Ed.

Hu, J., 2009. Presentation at climate change summit meeting in New York.

IEA, 2009. Implementing energy efficiency policies: are IEA member countries on track? OECD/IEA, Paris.

Jeong, G.C., Kim,Y.J., 2015. The effects of energy efficiency and environmental labels on appliance choice in South Korea. Energy Efficiency 8, 559–576.

Jia, J.J., Xu, J.H., Fan, Y., Ji, Q., 2018. Willingness to accept energy-saving measures and adoption barriers in the residential sector: An empirical analysis in Beijing, China. Renewable and Sustainable Energy Reviews 95: 56-73.

Ji, Q., Li,J.,Sun, X., 2019. New Challenge and Research Development in Global Energy Financialization. Emerging Markets Finance and Trade 55, 2669-2672.

Kallbekken, S., Sælen, H., Hermansen, E. A., 2013. Bridging the energy efficiency gap: A field experiment on lifetime energy costs and household appliances. Journal of Consumer Policy 36(1), 1-16.

Li, J., Zhang, J., Zhang, D., Ji, Q., 2019. Does gender inequality affect household green consumption behaviour in China? Energy Policy 135, 111071.

Linares, P., Labandeira, K., 2010. Energy Efficiency: Economics and Policy. Journal of Economic Surveys 24, 573-592.

Liu,X.L., Yang,J.X., Wang, R.S., 2005. Estimation of WEEE generation in China. China Population, Resources and Environment (05), 117-121. (in Chinese)

Li, Y., Ji,Q., Zhang, D., 2020. Technological catching up and innovation policies in China: What is behind this largely successful story? Technological Forecasting and Social Change 153, 119918.

Ma, G., Andrews-Speed, P., Zhang, J., 2013. Chinese consumer attitudes towards energy saving: The case of household electrical appliances in Chongqing. Energy Policy56, 591-602.

Matosović, M., Tomšić, Ž., 2018. Modeling energy efficiency investment choices – a case study on Croatia's residential sector. Energy Sources, Part B: Economics, Planning, and Policy13(7), 311-319.

Mills, B., Schleich, J., 2010. What's driving energy efficient appliance label awareness and purchase propensity?. Energy Policy 38, 814-825.

Nie, H., Vasseur, V., Fan, Y., Xu, J., 2019. Exploring reasons behind careful-use, energy-saving behavioursinresidential sector based on the theory of planned behaviour: Evidencefrom Changchun, China. Journal of Cleaner Production 230, 29-37.

Panzone, L.A., 2013. Saving money vs investing money: Do energy ratings influence consumer demand for energy efficient goods?. Energy Economics 38, 51-63.

Parry, I. W., Evans, D., Oates, W. E., 2014. Are energy efficiency standards justified?. Journal of Environmental Economics and Management 67(2), 104-125.

Shaikh, F., Ji, Q., Fan, Y., 2015. The diagnosis of an electricity crisis and alternative energy development in Pakistan. Renewable and Sustainable Energy Reviews 52,1172-1185.

Shen,J.Y., Saijo, T., 2009. Does an energy efficiency label alter consumers' purchasing decisions? A latent class approach based on a stated choice experiment in Shanghai. Journal of Environmental Management 90, 3561-3573.

Stadelmann, M., Schubert, R., 2018. How Do Different Designs of Energy Labels Influence Purchases of Household Appliances? A Field Study in Switzerland. Ecological Economics 144, 112-123.

Tao, J., Yu, S., 2011. Implementation of energy efficiency standards of household refrigerator/freezer in China: Potential environmental and economic impacts. Applied Energy 88(5), 1890-1905.

Tietenberg, T. 2009. Reflections: Energy efficiency policy: A pipe dream or a pipeline to the future? Review of Environmental Economics and Policy 3(2): 304–20.

Toutiao.com,2019. South China Gome fully opened the energy-saving subsidy policy for home appliances. <https://www.toutiao.com/i6676727867549680141/> (06.04.2019).

Wang,Z.H., Wang, X.M., Guo, D.X.,2017. Policy implications of the purchasing intentions towards energy-efficient appliances among China's urban residents: Do subsidies work?. Energy Policy 102, 430-439.

Wu, J., Lv, L., Sun, J., Ji, X., 2015. A comprehensive analysis of China's regional energy saving and emission reduction efficiency: From production and treatment perspectives. Energy Policy 84, 166-176.

Xia, Y., Kong, Y., Ji, Q., Zhang, D., 2019. Impacts of China-US trade conflicts on the energy sector. China Economic Review 58, 101360.

Xie, B. C., Zhao, W., 2018. Willingness to pay for green electricity in Tianjin, China: Based on the contingent valuation method. Energy Policy 114: 98-107.

Xu, X., Wei, Z., Ji, Q., Wang, C., Gao, G., 2019. Global renewable energy development: influencing factors, trend predictions and countermeasures. Resources Policy 63, 101470.

Yu,Q.W., Chen, L.P., Guo, H.T., 2012. Analysis on consumption of energy-saving electric appliances and energy-saving effect among Beijing urban households. Journal of Beijing Technology and Business University (Social Science) 27(06), 96-103. (in Chinese)

Yu, S., Zheng, S., Zhang, X., Gong, C., Cheng, J., 2018. Realizing China's goals on energy saving and pollution reduction: Industrial structure multi-objective optimization approach. Energy Policy 122, 300-312.

Yu,Y.H., Guo, J., 2016. Identifying electricity-saving potential in rural China: Empirical evidence from a household survey. Energy Policy 94, 1-9.

Yuan, C., Liu, S., Fang, Z., Wu, J.,2009. Research on the energy-saving effect of energy policies in China: 1982-2006. Energy Policy37, 2475-2480.

Yuan, J.H., Hou, Y., Xu, M., 2012. China's 2020 carbon intensity target: Consistency, implementations, and policy implications. Renewable and Sustainable Energy Reviews 16, 4970-4981.

Zhao, X., Li, H., Wu., L., Qi, Y.,2014. Implementation of energy-saving policies in

China: How local governments assisted industrial enterprises in achieving energy-saving targets. Energy Policy 66, 170-184.

Zhou, H., Bukenya, J.O., 2016. Information inefficiency and willingness-to-pay for energy-efficient technology: A stated preference approach for China Energy Label. Energy Policy 91, 12-21.

Zhou, M., Zhen, W.T., 2018. Life cycle sustainability assessment of new energy vehicles and traditional automobiles. Enterprise Economy (01), 129-134. (in Chinese)

Zhou, N., Levine, M.D., Price, L., 2010. Overview of current energy-efficiency policies in China. Energy Policy 38, 6439-6452.

Zhou, N., Fridley, D., McNeil, M., Zheng, N., Letschert, V., Ke, J., Saheb, Y., 2011. Analysis of potential energy saving and CO2 emission reduction of home appliances and commercial equipments in China. Energy Policy 39, 4541-4550.

Appendix A

Weighting coefficient W_C of each type of refrigerator

Compartment type	Cold room	Cooling room	Ice greenhouse	Ice making room	0 star room	1 star room	2 star room	3 star room	4 star room	Wine storage room
T_C/℃	4	12	2	0	0	-6	-12	-18	-18	12
W_C	1.00	0.65	1.15	1.25	1.25	1.55	1.85	2.15	2.15	0.65

For the compartment type not included in the table, the weighting factor W_C is calculated according to the formula:

$$W_C = \frac{25 - T_C}{20}$$

T_C----The design temperature of a type of compartment, or the characteristic temperature specified by the manufacturer, in degrees Celsius (°C)

Appendix B

Energy efficiency index conversion of refrigerator energy efficiency rating

Energy efficiency rating	Refrigerated freezer	Wine storage cabinet	Horizontal refrigerated freezer	Other types
	Standard energy efficiency index η_a	Standard energy efficiency index η_a	Standard energy efficiency index η_a	Standard energy efficiency index η_a
1	$\eta_a \leqslant 25\%$	$\eta_a \leqslant 55\%$	$\eta_a \leqslant 35\%$	$\eta_a \leqslant 45\%$
2	$25\% < \eta_a \leqslant 35\%$	$55\% < \eta_a \leqslant 70\%$	$35\% < \eta_a \leqslant 45\%$	$45\% < \eta_a \leqslant 55\%$
3	$35\% < \eta_a \leqslant 50\%$	$70\% < \eta_a \leqslant 80\%$	$45\% < \eta_a \leqslant 55\%$	$55\% < \eta_a \leqslant 65\%$
4	$50\% < \eta_a \leqslant 60\%$	$80\% < \eta_a \leqslant 90\%$	$55\% < \eta_a \leqslant 65\%$	$65\% < \eta_a \leqslant 75\%$
5	$60\% < \eta_a \leqslant 70\%$	$90\% < \eta_a \leqslant 100\%$	$65\% < \eta_a \leqslant 75\%$	$75\% < \eta_a \leqslant 85\%$

Table(s)

Table 1

Specific parameters of the sample refrigerators

Group 1	Brand	Model	EEG	Price (￥)	Power （KW.h）	Refrigeration compartment volume（L）	Temperature-variable compartment volume（L）	Freezer compartment volume（L）	Climate type	Number of doors	Embedded	Frost-free refrigerator
1.1	Haier	BCD- 328WDPD	1	3899	0.65	181	30	117	T	4	YES	YES
		BCD- 520WDPD	2	4399	0.98	324	24	172	T	2	YES	YES
1.2	Haier	BCD-217WDVLU1	1	3299	0.58	117	29	71	T	3	YES	YES
		BCD-258WDVLU1	2	3299	0.69	144	40	74	T	3	YES	YES
1.3	Midea	BCD-230WTPZM(E)	1	3399	0.51	116	40	74	T	3	NO	YES
		BCD-228WTPZM(E)	2	2499	0.60	119	38	71	T	3	NO	YES
1.4	Midea	BCD-326WGPZM	1	4699	0.59	176	32	118	T	3	YES	YES
		BCD-320WGPZM	2	3799	0.95	185	111	24	T	4	YES	YES
1.5	Hisense	BCD-629WTVBP/Q	1	3899	0.99	406	-	223	T	2	YES	YES
		BCD-535WTVBP/Q	2	2999	1.09	346	-	189	T	2	YES	YES

Group 2	**Brand**	**Model**	**EEG**	**Price (￥)**	**Power （KW.h）**	**Refrigeration chamber volume（L）**	**Changing greenhouse / star volume（L）**	**Freezer compartment volume（L）**	**Climate type**	**Number of doors**	**Embedded**	**Frost-free refrigerator**
2.1	Haier	BCD-189WDPV	2	1899	0.70	120	-	69	ST	2	NO	YES
		BCD-149WDPV	3	1439	0.66	95	-	54	ST	2	NO	YES
2.2	Ronshen	BCD-217D11N	2	1499	0.51	118	-	99	ST	3	YES	NO
		BCD-218D11N	3	1399	0.63	119	-	99	ST	3	YES	NO
2.3	Ronshen	BCD-590WD11HY	2	4399	1.14	379	-	211	ST	2	YES	YES
		BCD-526WD11HY	3	2899	1.24	337	-	189	ST	2	YES	YES
2.4	Meling	BCD-205WECX	2	2499	0.56	137	-	68	ST	2	YES	YES
		BCD-185WECX	3	1899	0.68	123	-	62	ST	2	YES	YES
2.5	Konka	BCD-551WEGX5S	2	2999	1.21	360	25	166	T	2	YES	YES
		BCD-430WEGX5S	3	2299	1.39	275	20	135	T	2	YES	YES

Table 2

NPV difference and DIPP in absence and presence of subsidy in each scenario

Group	Without energy saving subsidy policy					With energy saving subsidy policy				
	4	**8**	**12**	**16**	**DIPP（Year）**	**4**	**8**	**12**	**16**	**DIPP（Year）**
1.1	-1066.45	-1014.59	-968.06	-926.32	>30	-781.56	-729.70	-683.17	-641.43	>30
1.2	-479.97	-440.23	-404.58	-372.60	>30	-273.08	-233.34	-197.69	-165.71	>30
1.3	-805.26	-739.93	-681.32	-628.74	>30	-565.07	-499.74	-441.13	-388.54	>30
1.4	-537.73	-276.42	-41.97	168.36	12.77	-236.46	24.85	259.30	469.63	7.60
1.5	-168.13	15.73	180.69	328.68	7.64	56.66	240.53	405.48	553.48	2.85
2.1	-45.85	-20.59	2.07	22.39	11.62	106.07	131.33	153.99	174.31	0
2.2	-9.92	70.90	143.41	208.46	4.47	110.00	190.82	263.30	328.38	0
2.3	-987.37	-843.92	-715.22	-599.75	>30	-635.45	-492.00	-363.30	-247.83	26.41
2.4	-276.84	-171.10	-76.24	8.87	15.57	-76.92	28.82	123.68	208.79	6.87
2.5	282.49	583.54	853.63	1095.95	0.61	522.41	823.46	1093.55	1335.87	0

Table 3

Dynamic investment payback periods under multiple subsidy rates

Group	13%	15%	17%	19%	21%	23%	24%	25%
1.1	>30	>30	>30	>30	28.90	19.12	15.06	11.4
1.2	9.23	2.61	0	0	0	0	0	0
1.3	>30	27.06	20.34	14.66	9.73	5.39	3.40	0.51
1.4	2.95	1.66	0.40	0	0	0	0	0
1.5	0	0	0	0	0	0	0	0

Figure(s)

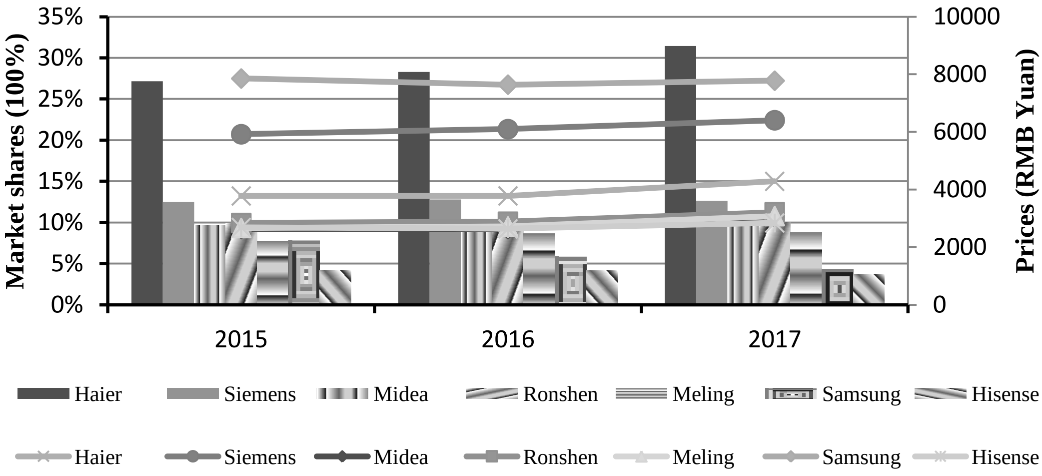

Fig.1 Market shares and average prices of the top 7 refrigerator brands in China from 2015 to 2017 (based on sales). Note: The bar and line corresponds to the market share of the main axis and the price of the secondary axis respectively.

Data sources: http://www.jiadian.com.cn/2019/199/

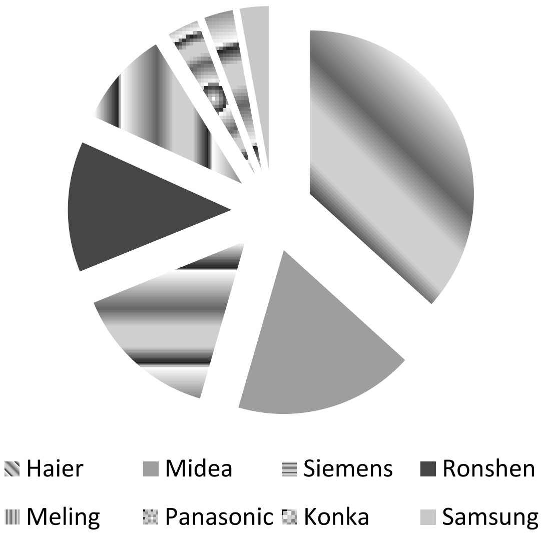

Fig.2 Market shares of the top 7 refrigerator brands in China in 2018 (based on sales volume). Data sources: http://www.avc-mr.com/

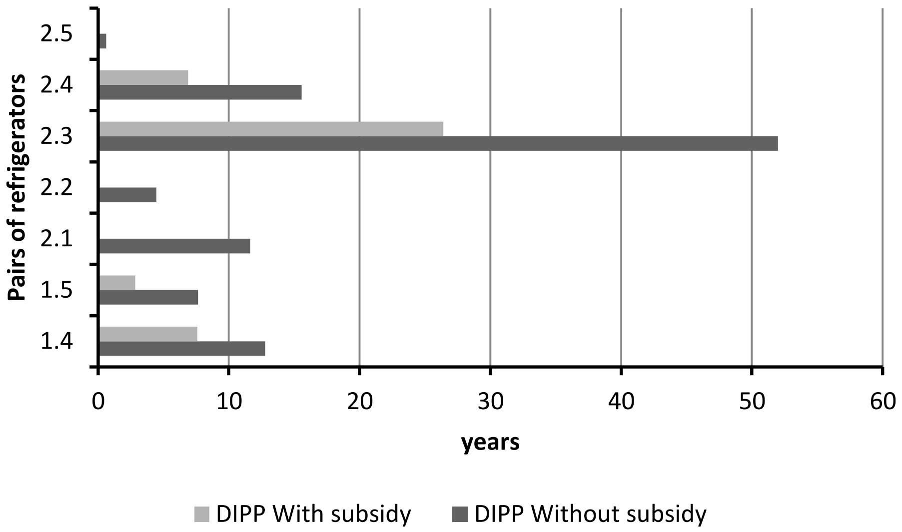

Fig.3 The DIPP for Partial samples in absence and presence of subsidy

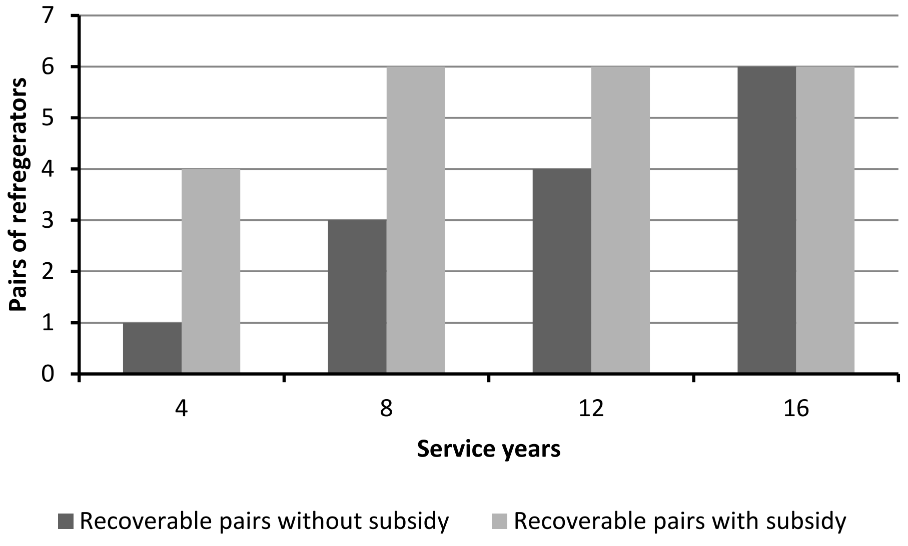

Fig.4 The number of refrigerator pairs in which investment differentials are recoverable

Highlights

The main findings of this study could be highlighted as:

- China's energy-saving subsidy policy does not reduce the purchasing price for refrigerators.
- Refrigerators at EEG2 have higher economic benefits than EEG1 ones regardless the subsidy policy.
- The influence of the policy on purchasing preference is depended on the products' service life.
- Government needs to adjust the weight of subsidy at different levels to improve policy efficiency.

Credit Author Statement

Each author's contributions could be outline as follow:

Hongguang Nie: Framing the original ideas, conceptualization, funding acquisition, supervision

Ting Zhou: data collection, analysis

Haiyan Lu: Reshaping the discussions and contributions of the paper, Writing, reviewing, editing, funding acquisition,

Shupeng Huang: assisting data analysis