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Impact factors of household energy-saving behavior: An empirical study of Shandong Province in China

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ABSTRACT

As China gradually completes the process of industrialization, its industrial energy consumption growth is now slowing and even decreasing. Meanwhile, household energy consumption in the residential sector has seen steady growth. This paper aims to explore the mechanisms of factors affecting urban household energy-saving behavior including the habitual energy-saving behaviors and purchasing energy-saving behaviors. A structural equation model is built to analyze the influencing routes and effects of individual objective and subjective characteristic factors, external influencing factors, and energy-saving intentions on shaping energy-saving behaviors. The empirical results drawing on the survey data collected in Shandong province show that external influencing factors that have two kinds of mediating effects through energy-saving intentions and individual subjective characteristic factors are the most crucial factors to energy-saving behaviors. Values included in individual subjective factors and quality of energy-saving products included in external influencing factors have greatest effects on energy-saving behaviors.

1. Introduction

Attributing to the fast-growing economy and high growth of per capita income in the last decade in China (annual growth being 10.4% for urban residents and 12.9% for rural residents) (China Statistical Yearbook, 2017), household domestic energy consumption (i.e., residential energy consumption) is becoming more and more significant. Since 2012, Chinese residential energy consumption has become the second largest energy consumption sector behind only the industrial sector. In 2015, residential energy consumption reached 50,099 tons of standard coal equivalent (tce), which comprised as much as 11.7% of the total Chinese energy consumption (China Energy Statistical Yearbook, 2016). Consequently, China's 13th Five-Year (2016–2020) Plan and the 2016 Energy Work Guidance have paid great attention to household energy consumption.

The household energy consumption is engendered by people's daily behaviors including the ownership behavior of energy-consuming end uses and end-use usage behavior, which is more heterogeneous and difficult to regulate than of other sectors. As a result, the effectiveness of energy conservation policies on household sector become much uncertain. Therefore, to reduce household energy consumption, it seems more reasonable to start from the behavioral perspective, in other words, the sustainability in the household sector to a large extent relies on whether energy-saving behavior is adopted or not.

Energy-saving behavior can be defined as the behaviors through which people try to reduce overall energy use (Barr et al., 2005). Generally, it is divided into two categories (Barr et al., 2005; Black et al., 1985; Dillman et al., 1983; Raaij and Verhallen, 1983; Stern, 1992): (1) habitual energy-saving behaviors with repetitive efforts to reduce energy use by curtailment measures (e.g., turning the power off when not using the appliances, choosing a shower instead of a bath, using daily public transports or on foot instead of private cars, and avoiding or reducing the usage of air conditioners); and (2) one-shot purchasing behaviors targeting the purchase of more-efficient technology and the replacement of the old technology (e.g., buying energy-saving lamps, choosing electric vehicle instead of gasoline cars, and purchasing simple packaging and recyclable products).

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In recent years, research on energy-saving behaviors has gradually caught more and more attention of scholars throughout the world (Barr et al., 2005; Hori et al., 2013; Jackson, 2005; Kang et al., 2012; Wang et al., 2014a; Webb et al., 2013; Yue et al., 2013). Household energy-saving behaviors are revealed to be affected by many factors, which can be summarized into three main sources: individual characteristic factors, external influencing factors and energy-saving intentions (Bartkus et al., 1999; Chan and Yam, 1995; Haron et al., 2005; Reiss and White, 2006; Wang et al., 2014b). The individual characteristic factors can be further classified into objective and subjective characteristic factors. The former is also known as sociodemographic characteristics, such as gender, age, income and education background (Alibeli, 2009; Schwepker and Cornwell, 1991). The individual subjective characteristic factors indicate the factors mainly reflecting individual behavioral attitude, preference, subjective norm and perceived behavioral control, such as environmental awareness, sense of responsibility, values and energy-saving knowledge (Bartkus et al., 1999; Chan and Yam, 1995; Gärling et al., 2003; Haron et al., 2005; Reiss and White, 2006; Wang et al., 2014b). Regarding the external influencing factors related to the market, society and government, for example, persuasion and demonstration, social norms, prices, policies and regulations and other extrinsic factors, it is highlighted that their influences cannot be neglected (Carlsson-Kanyama et al., 2005; Egmond et al., 2005; Lindén and Carlsson-Kanyama, 2002; Sardianou, 2007; Steg, 2008). Energy-saving intention is a kind of behavioral intention. Some studies mentioned behavioral intention was the most direct antecedent variable of behavior, which represented the degree to which a person is ready to perform a certain behavior (Ajzen, 1991, 2002; Chen, 2013; Fishbein and Ajzen, 1975). This study defines the energy-saving intention as the tendency to implement the energy-saving behavior.

Based on the previous literature, this paper will consider the impacts of all these three sources: the individual subjective and objective characteristic factors (e.g., gender, age, occupation, degree of concern, sense of responsibility, values), external influencing factors (e.g., the quality of energy-saving products, social norms, publicity and education) and energy-saving intentions, on shaping household energy-saving behaviors including habitual energy-saving behaviors and purchase behaviors. A unified model, including all the elements we have already mentioned, will be set up to analyze the mechanisms of motions and interrelationships of the various factors influencing energy-saving behaviors. This study draws on the empirical context of Jinan city, the capital of Shandong Province that is one of the provinces with the most developed economy and highest energy consumption in China. The population, GDP and energy consumption of Shandong province is about 7.2%, 9.1% and 9% in the total of China in 2016, respectively. We handed out 350 questionnaires to residents in Jinan City, and 297 valid responses were finally obtained for supporting this analysis.

The remaining part of this paper is structured as follows. A literature review in the second section summarizes the articles on household energy-saving behaviors and analyzes factors that influence those behaviors. Section 3 introduces our structural equation model (SEM), determines variables, raises hypotheses and establishes the research model. Section 4 explains the survey design and the collected data. Section 5 shows the model results and discussions for the empirical study. This study ends with conclusions, policy implications and limitation in Section 6.

2. Literature review

2.1. Summary of influencing factors

More and more scholars have realized the importance of analyzing household energy consumption from the behavioral perspective. Identifying the factors that influence household energy consumption is the basis for exploring the effects, paths and mechanisms of shaping individual energy-saving behaviors. Table 1 lists some relevant literature. In summary, existing research has shed light on the influence of demographic variables (e.g., age, gender), individual subjective characteristic factors (e.g., values, energy knowledge) and external influencing factors (e.g., social norms, policies) on the adoption of energy-saving behaviors, by employing the survey data collected in some specific cities or regions. For example, Kang et al. (2012) examined the impacts of individual subjective characteristic factors (e.g., energy-saving consciousness and energy-saving knowledge) on residents' energy-saving behaviors, and significantly positive effect were revealed. Feng and Reisner (2011) adopted regression analysis to analyze the impacts of demographic and individual subjective characteristic factors. They found that individuals who had more environmental knowledge, treated environmental issues more seriously and support environmental resource conservation were more likely to implement energy-efficient behaviors, and females did a better job than males. Several studies further paid attention to the impacts of external influencing factors on the energy-saving behaviors in addition to the influence of demographic variables and individual subjective characteristic factors (Gadenne et al., 2011). Moreover, some researchers argued that individual objective and subjective factors affected energy-saving behaviors through acting on their energy-saving intentions (Wang et al., 2014b; Webb et al., 2013), and the behavioral intention played the most important role in explaining the behaviors (Wang et al., 2014b). Concerning the effect paths of the influencing factors on the energy-saving behavior, majority of existing studies analyzed the direct effects of influencing factors (Feng and Reisner, 2011; Kang et al., 2012; Nordlund and Garvill, 2003; Webb et al., 2013), while only limited scholars further demonstrated the indirect or mediating effects between influencing factors and energy-saving behaviors. For instance, Wang et al. (2014b) suggested that energy knowledge exerted an indirect influence on energy-saving behaviors via environmental attitudes. We can conclude that though many studies have examined the mechanisms of shaping energy-saving behavior, most of them only accommodate one or several dimensions of the above-mentioned factors, which are not comprehensive enough at this moment. Besides, the influential pathways need to be expanded to dig more into the behavioral mechanism for shaping energy-saving behavior.

2.2. Individual characteristic factors

In considering affective energy-saving behaviors, the existing research on individual factors concentrates on both objective and subjective characteristic factors.

2.2.1. Individual objective characteristic factors

Many researchers treat individual objective characteristic factors as sociodemographic variables, such as gender, education background, income or whether there is a child in the household. Some studies held the view that the individual objective characteristic factors had significant effect on energy-saving behaviors (Feng and Reisner, 2011; Martinsson et al., 2011; Poortinga et al., 2003; Yue et al., 2013). For example, Poortinga et al. (2003) found that education background was significantly related to energy-saving behaviors and was strongly correlated with the adoption of different energy-saving measures. Yu et al. (2013) found that household income and household size had significant influence on the purchase and usage of energy-saving appliances. However, some studies got the opposite results, and they found that

Table 1
Relevant literature related to energy-saving behavior analysis (Source: Author analysis).

Author (year)	Valid data sample	Survey area	Method	Influencing factors			Intention	Behavior	Considering mediating effects or indirect effects
				Demographic variables	Individual subjective characteristic factors	External influencing factors			
Yue et al. (2013)	638	Nanjing and other 5 cities	Regression analysis	✓	✓	✓		Energy-saving behavior	
Wang et al. (2014a)	1403	50 villages among these 35 selected regions	SEM		✓	✓	✓	Sustainable Consumption Behavior	
Webb et al. (2013)	200	Online surveys in a major Australian city	SEM		✓		✓	Energy-saving behaviors	
Gadenne et al. (2011)	218	Three 'environmentally friendly' firms	MANOVA analysis	✓	✓	✓		Environmental behaviors	
Yang et al. (2016)	526	Hefei, Anyang, Beijing	SEM	✓	✓			Energy curtailment behavior	
Hori et al. (2013)	215	Dalian and other 4 cities	Regression analysis	✓	✓	✓		Energy-saving behavior; environmental behavior	
Wang et al. (2014b)	276	Beijing	SEM	✓	✓		✓	Energy-saving behavior	Energy knowledge→energy-saving behaviors via attitudes
Liu et al. (2012)	336	Suzhou	SEM		✓	✓	✓	Green purchasing behavior	
Feng and Reisner. (2011)	347	Shaanxi Province	Regression model	✓	✓			Individual behaviors; public behaviors	
Kang et al. (2012)	280	Busan	Regression analysis		✓			Energy-saving behavior	
Wang et al. (2011)	816	Beijing	logit regression analysis	✓	✓			Electricity saving behavior	
Nordlund and Garvill (2003)	2500	Sweden	SEM		✓			Reducing personal car use	

occupation had little to do with behaviors, and the household's education background or family size did not affect energy-saving activities (Curtis et al., 1984; Sardianou, 2007; Wang et al., 2014b). In addition, some studies cannot conclude a significant correlation between socio-demographic variables (e.g., gender, occupation, family members' age, and education level) and energy-saving behavior (Gatersleben et al., 2002; Olli et al., 2001); Therefore, the impacts of individual objective characteristics on energy-saving behavior are diverse and no consensus has been reached for some variables probably due to the differences of empirical contexts and data.

2.2.2. Individual subjective characteristic factors

Another group of research focusing on the relationship between individual subjective characteristic factors and energy-saving behaviors is available (Hori et al., 2013; Kang et al., 2012; Liu et al., 2012; Wang et al., 2011, 2014b; Webb et al., 2013; Yang et al., 2016; Yue et al., 2013). For example, some researchers shed light on the impacts of environmental concerns and energy knowledge, and found they were critical in affecting households' adoption of energy-saving behaviors (Han et al., 2013; Steg, 2008). Some studies on energy-saving behavior showed that moral sense and responsibility were important variables that affect environmental behavior (Liu et al., 2012; Wang et al., 2014b; Yang et al., 2016). Previous studies also have demonstrated that individuals with strong confidence of control ability had a positive effect on energy-saving behaviors (Baker et al., 2007; Cheng et al., 2006; Conner and Abraham, 2001). Scott and Rowlands (2000) observed that environmental responsibility and personal norms had a significant impact on conscious energy-saving behavior. Webster and Zhang (2004) investigated the impacts of social responsibility on ecological consumption and found that socially responsible people were more likely to actively participate in community activities and purchase green-packaged products. Han et al. (2013) found that the energy-saving behavior of Dutch households was related to their knowledge about saving energy. The lack of energy-saving knowledge would impede household energy saving (Harland et al., 2007). Arı and Yılmaz (2016) modeled family recycling behavior and explored the effects of attitudes to recovery, recovery subjective norms and recovery perceptional behavior-control factors were decisive in affecting recycling behaviors. Based on these studies, it is necessary to take individual subjective factors into consideration. Finally, we select degree of concern, sense of responsibility, values, energy knowledge and control view as the representative for the individual subjective factors in this study.

2.3. External influencing factors

External influencing factors such as policies and regulations have also been investigated, but by only few researchers (Dillman et al., 1983; Ertz et al., 2016; Gadenne et al., 2011; Stern, 1992; Yue et al., 2013). Yue et al. (2013) argued that situational factors such as social

norms had significant positive moderating effects on energy-saving behavior via the influence of behavioral ability and energy-saving awareness. Ertz et al. (2016) examined the direct impact of contextual factors (perceived busyness, perceived wealth, perceived power) on energy-saving behaviors and the indirect effects of attitude variables on these behaviors. Sardianou (2007) administered a questionnaire survey on Greek household conditions and found that publicity and education factors were positively related to household energy-saving behaviors. Wang et al. (2011) found that economic benefits, policy and social norms had the positive influence on electricity saving behaviors. Rui and Antunes (2011) studied the purchases of efficient energy and energy-efficient equipment by European consumers, and found that quality was the most important factor influencing their behavior. Wang et al. (2014b) suggested financial incentives could be adopted to help promote environmental behaviors among Beijing's residents. Schultz et al. (2007) demonstrated that proper combination of descriptive and imperative norms were best able to promote the implementation of energy-saving behavior. Given the significant impact of external influencing factors on energy-saving behaviors, this study select quality of energy-saving products, publicity and education, subjective norms, and policies and regulations as the representative external influencing factors, while the infrastructural or social external factors that might influence the energy-saving behaviors are not considered here.

Drawing on the existing literature, we find that different researchers select different influencing factors to analyze energy-saving behaviors by considering different behavioral mechanisms. However, most of them only selected one or several factors, which were not comprehensive enough. Hence, in order to more fully consider the impact of various factors, this study goes beyond the existing research by shedding light on the impacts of all four types of influencing factors mentioned above on shaping household energy-saving behavior, including individual subjective characteristic factors, individual objective characteristic factors, external influencing factors and energy-saving intentions. Besides, not only were these selected influencing factors less comprehensive in previous research, but they also had dissimilar influential paths. Majority of research have investigated the direct influential relationship among individual characteristic factors, external influencing factors, energy-saving intentions, and energy-saving behaviors. While limited articles have explored the mediating effects (indirect effects), and this might overestimate or underestimate the impact of factors. Therefore, this study will further discuss the mediating effects in addition to the direct effects between influencing factors and energy-saving behaviors, hoping to provide more in-depth insights on the mechanism and policy suggestion for promoting energy-saving behaviors.

3. Methods

In order to clarify the direct and indirect relationships between main factors and household energy-saving behaviors, a structural equation model (SEM) with latent variables is built considering SEM cannot only deal with multiple dependent variables simultaneously, but also can estimate the fit coherence of the whole model.

3.1. Structural equation model

SEM is a multivariate statistical model that can analyze the causal relationships between variables based on the covariance matrix of variables; thus, it is also known as covariance structure analysis (Reisinger et al., 1999). Structural Equation Model can establish a unified model to consider multiple dependent variables simultaneously and explore the internal mechanisms between influencing factors and energy-saving behaviors. Furthermore, it can also estimate not only the direct effects between different factors but also the indirect effects so as to analyze the mediating effects based on one model and can allow independent and dependent variables to contain measurement errors. We conduct data analysis and simulation verification using AMOS 23.0 software.

SEM can be divided into two categories: the measurement model, and the structural model.

(1) Measurement model

Because the assumed hypothesis cannot be measured directly, the observed, recorded, or measured variables are combined to construct latent variables using the measurement model. The relationship between the latent variable and the observed variable is usually written as follows:

$$X = \Lambda x\xi + \delta \tag{1}$$

$$Y = \Lambda y\eta + \varepsilon \tag{2}$$

where, ξ is an exogenous latent variable; η is an endogenous latent variable; X is a vector composed by the exogenous observed variable; δ is an error term of the exogenous index X; Y is a vector composed by the endogenous observed variable; ε is an error term of the endogenous index Y; Λx indicates the relationship between exogenous observed variable and exogenous latent variable; Λy indicates the relationship between endogenous observed variable and endogenous latent variable.

(2) Structural model

The structural model depicts the causal relationships between latent variables, usually in a linear form. The measurement model enables the latent variables of the structural model to be estimated, albeit indirectly. The structural equation is usually written as follows:

$$\eta = B\eta + \Gamma\xi + \zeta \tag{3}$$

where, η is an endogenous latent variable, ξ is an exogenous latent variable; B indicates the relationship between endogenous latent variables; Γ indicates the influence of the exogenous latent variable on the endogenous latent variable; ζ is an error term of the structural equation.

3.2. Model framework and hypotheses

Fig. 1 shows a simplified model for explaining the hypothesized relationships among individual subjective characteristic factors, external influencing factors, energy-saving intentions, and energy-saving behaviors. Individual objective characteristic factors including age, gender, occupation, highest education level for household members and monthly household disposable income are added to the model as control variables. We assume that the individual subjective characteristic factors and external influencing factors are directly influential to energy-saving intentions (H1, H3) and energy-saving behaviors (H2, H4). Energy-saving intentions are assumed to have significant influence on energy-saving behaviors (H5). The proposed model structure can also investigate whether the individual and external factors indirectly affects energy-saving behaviors via energy-saving intentions. In addition, the external influencing factors might affect individual subjective characteristic factors and then indirectly influence energy-saving behaviors. These assumptions can be traced in Figs. 1 and 2 by the arrows in the path.

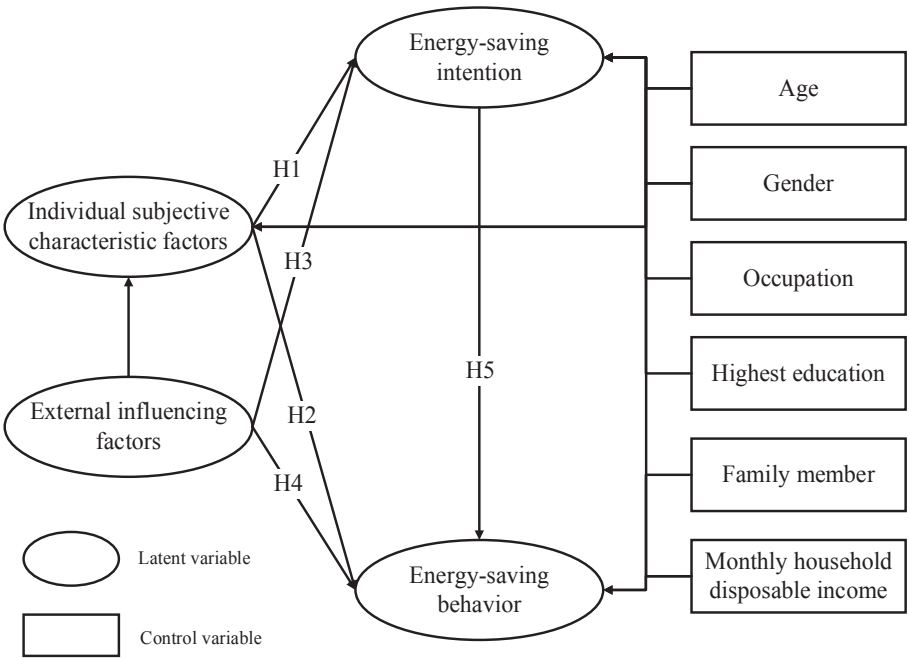

Fig. 1. Simplified urban household energy-saving behavior model.

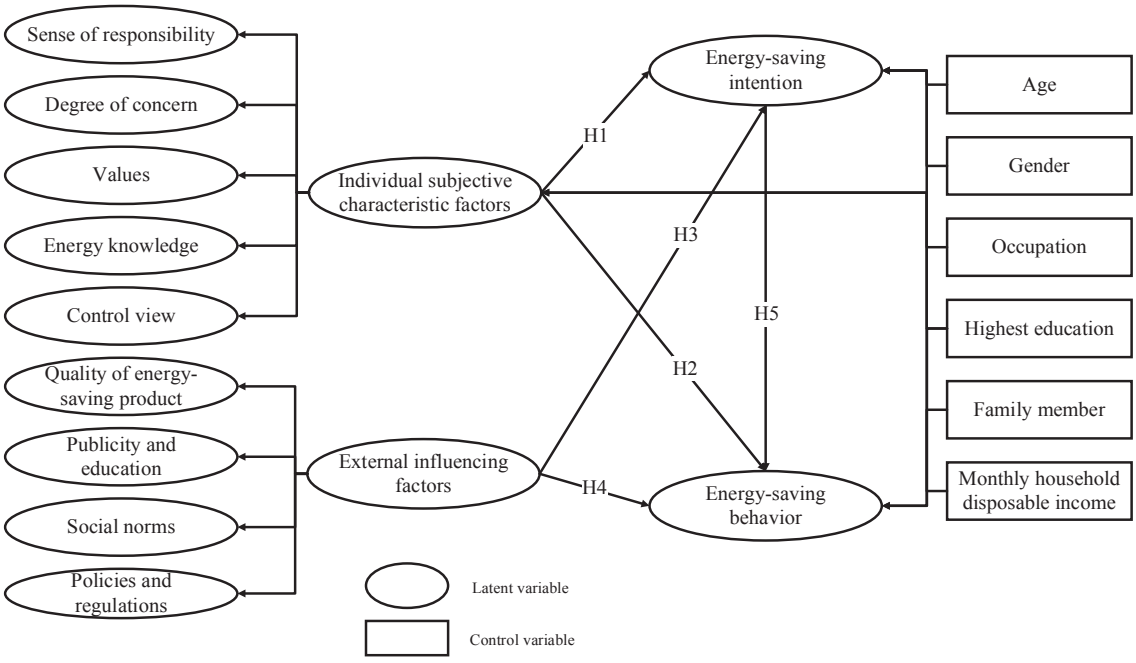

Fig. 2. Urban household energy consumption behavior model.

3.3. Conceptual variable definition

The main variables are given in Fig. 2. Based on the review results, five factors were used to represent the influences of individual subjective characteristics, including degree of concern, sense of responsibility, environmental values, energy knowledge and control view (Alibeli, 2009; Arcury et al., 1985; Bartkus et al., 1999; Gärling et al., 2003; Haron et al., 2005; Kim Y., 2005; Scott and Willits, 1994). Specifically, degree of concern, which is similar to environmental concerns, environmental attitudes, means how much individuals care about energy and related issues (Steg, 2008). Sense of responsibility is defined as moral or duty sense when individuals consume energy (Gärling et al., 2003). The concept of environmental values is drawing on the NEP (New Environmental Paradigm) concept proposed by Dunlap (2002), which means the general and fundamental attitudes of individuals towards the environment and environmental issues. Energy knowledge refers to the knowledge and skills needed for rational choice of energy-saving behaviors (Schahn and Holzer, 1990). Following Sun (2006) and Chen (2009), this study takes control view as a research

variable and explains it as the individual's own idea about whether their energy-saving behaviors can change the status quo and help tackle energy problems. The external influencing factors can be regarded as situation factors affecting household energy consumption behaviors. We selected four variables: quality of energy-saving products, publicity and education, social norms, and policies and regulations (Carlsson-Kanyama et al., 2005; Egmond et al., 2005; Lindén and Carlsson-Kanyama, 2002; Sardianou, 2007) to explore their impact on energy-saving intentions and energy-saving behaviors, and their relationships with individual characteristics. The full model is shown in Fig. 2.

4. Survey and data

To fulfill this study, we designed and carried out a questionnaire survey (shown in Appendix Table A.1). The questionnaire in this study consists of four parts: demographic factors, energy-saving behaviors, energy-saving intentions and influencing factors for energy-saving behavior. Drawing on questions used in previous research, we specifically added questions for this analysis.

4.1. Survey design and sampling

There are two subscales of energy-saving behaviors: the purchasing behaviors and habitual energy-saving behaviors. The habitual energy-saving behaviors were assessed using questions from the existing studies (Barr et al., 2005; Chen, 2009; Lindén and Klintman, 2003; Stern, 1992). We select six habitual energy-saving behaviors which are always used (B1-B6 shown in Appendix Table A.1), such as taking the power off when do not use the appliances, choosing a shower instead of a bath, using daily public transport or on foot than using private cars, avoiding or reducing usage of air conditioners and turning off the lights when leaving room. The purchasing behaviors targeting more-efficient technology are measured by three frequently focused behaviors in the previous studies (B7-B9 shown in Appendix Table A.1) (Chen, 2009; Gyberg and Palm, 2009; Lindén and Klintman, 2003; Rui and Antunes, 2011), including choosing energy-saving lamps, preferring energy-efficient vehicle when buying a car, choosing simple packaging and recyclable products when purchasing similar products. However, B1-B4 are excluded because they do not pass the validity test after the pilot survey, and B5-B9 are left. Energy-saving intention is designed based on Chen (2013) and explained by four questions like willing to spend more money buying energy-saving products, intending to pay more attention to low-carbon dynamic news, willing to use driving skills to reduce fuel consumption and wanting to change the lifestyles of high-carbon consumer behavior.

Fifteen items measuring individual subjective characteristic factors are borrowed from Hsu and Roth (1998), Chen (2009) and Tanner and Kast (2003), which can be grouped into five first-order latent variables, including degree of concern, sense of responsibility, values, control view and energy knowledge. Each factor is measured by three or four questions, for instance, degree of concern is measured by if the respondents concerned about the energy problems reported by media, whether felt worried or nervous when hearing or seeing issues about energy and paid little attention to energy consumption or not. The measurements of external influencing factors are adapted from Stern (2000), Sun (2006) and Chen (2009) that composed by nine items which can be grouped into four first-order latent variables, including quality of energy-saving products, publicity and education, social norms and policies and regulations. For example, social norms are measured by questions such as whether the respondents' behavior are affected by the surrounding persons like families and friends or not, and whether the respondents care about other people's adoption of energy-saving behaviors or not. Policies and regulations are measured by two questions related to whether respondents agree that the relevant policies and regulations have effect on energy-saving behaviors or play an important role in promoting energy-saving behaviors.

In this study, energy-saving behavior, energy-saving intentions and influencing factors were all measured with the Likert scale. We divided energy-saving behaviors into “ never do,” “ occasionally do,” “sometimes do,” “always do” or “ every time do” where the score reflected the respondents' frequency of behavior. Energy-saving intentions and influencing factors were divided into “strongly disagree,” “do not agree,” “uncertain,” “agree” or “strongly agree”. We assigned 1 to 5 points to these actions and attitudes. In principle, the higher the score is, the stronger household intention to energy-saving becomes, and the more frequent energy-saving behaviors are.

Jinan city, whose annual GDP reached 98.76 billion dollars in 2016, is selected as the empirical context as it is a typical city under fast urbanization in China. It is the capital of Shandong province, one of the biggest industrial provinces in China. A large increment of household energy consumption can be foreseen if no interventions are implemented for Jinan. To ensure the reliability and validity of the questionnaire, we selected 50 Jinan citizens to conduct pilot survey in 2016. The questionnaire was then revised and a formal version formed. We conducted surveys in commercial and residential neighborhoods, by randomly visiting the government departments, schools, insurance companies, shopping malls and residential streets during October–December 2016. The candidate respondents in these areas were invited based on a convenient sampling method and those who agreed to participate in the survey were asked to fill in the questionnaire by a face-to-face interview. The sample is selected with gender and age proportions following the distribution of national and regional population. A total of 350 interviews were completed and 297 valid responses were obtained.

4.2. Data

Table 2 shows the descriptive statistics of the survey data. It can be seen that the randomly selected respondents have diverse age, educational level, occupation, family type, and household income. The proportion of male is 51.2% and employment rate is 70.9%, which are consistent with the statistical data of the Shandong province (50.8% and 67.3%, respectively) (Shandong Statistical Yearbook, 2016).

5. Results and discussions

5.1. Reliability, validity test, and normality test

First, the study needs to check the reliability and validity of the measurement model because they are the prerequisite for obtaining valid results for the structural model. The internal consistency reliability is mainly verified by the Cronbach's alpha coefficient. As shown in Table 3, the Cronbach's alpha coefficients of the variables including degree of concern, sense of responsibility, values, energy knowledge, control view, quality of energy-saving products, publicity and education, social norms and policies are lying between 0.721 and 0.906, which are greater than 0.7. This supports the reliability of latent variables. In this study, all of the involved individual objective characteristic factors are not significant, probably because different individuals with the same socio-demographic variable attributes might have diverse choices. However, including them as the control variables increased the accuracy of the model. Therefore, we still keep them in the model, but exclude

Table 2
Descriptive statistics of survey sample.

Demographic variables	Category	Number of people	Percentage
Gender	Male	152	51.2
	Female	145	48.8
Age	Under 18 years old	3	1.0
	18–30 years old	84	28.3
	31–40 years old	104	35
	41–50 years old	75	25.3
	51–60 years old	24	8.1
	More than 60 years old	7	2.4
Education background	Junior high school and below	17	17.7
	High school or secondary school	56	34.9
	College	76	23.6
	Bachelor degree	121	15.7
	Bachelor degree or above	27	8.1
Family style	Living alone	23	7.7
	Married, no children or not living with their children	56	18.9
	Two-generation family	169	56.9
	Three- or four- generation family	49	16.5
Occupation	Retirement and housewives	16	6.9
	Student	13	5.4
	Government department staff	26	8.8
	General worker or service person	79	28.1
	Teacher	69	18.2
	Engineer	3	1.0
	General office staff	16	5.4
	Manager	28	9.4
	Others	47	16.8
Average monthly household income	Under USD 302.24	17	5.7
	USD 302.24–755.61	121	40.7
	USD 755.61–1511.21	132	44.4
	USD 1511.21–4533.64	19	6.4
	Above USD 4533.64	8	2.7

Source: Author analysis.

Table 3
Model accuracy indexes of the measurement model.

Latent variable	Observed variable		Cronbach's α	Factor loading	AVE
Degree of concern	X11	I am very concerned about the energy problems reported by media.	0.844	0.93	0.654
	X12	I feel worried or nervous when I hear or see issues about energy.		0.78	
	X13	I usually pay little attention to energy consumption and details of its use.		0.70	
Sense of responsibility	X21	I am willing to sacrifice personal interests to save energy and for environmental protection.	0.838	0.91	0.653
	X22	In order to save energy and protect environment I do not hesitate to offend some people.		0.80	
	X23	Energy issues are related to the whole society, and everyone has the responsibility to save energy.		0.70	
Values	X31	Human beings should respect nature and live in harmony with nature.	0.906	0.89	0.719
	X32	Nature and the environment have the same value as human beings.		0.90	
	X33	We should not exploit new natural resources to protect nature and the environment.		0.72	
	X34	Economic development is the most important, and environmental issues can be considered later.		0.87	
Energy knowledge	X41	How much do you know about the purchasing energy-saving behaviors in questions 1–3?	0.747	0.88	0.618
	X42	How much do you know about habitual energy-saving behaviors in questions 4–9?		0.68	
Control view	X51	We can improve and solve some environmental problems if we work hard.	0.845	0.89	0.675
	X52	It will help to improve and solve some environmental problems if we take some actions.		0.90	
	X53	It is impossible for ordinary people to improve and solve environmental problems.		0.65	
Quality of energy-saving product	Y11	The public praise of energy-efficient products is an important factor in determining whether I should buy them or not.	0.721	0.83	0.575
	Y12	The quality of energy-saving products is an important factor in determining whether I should buy them or not.		0.68	
Publicity and education	Y21	We should improve the strength of publicity and education, and guide more people to implement energy-saving behaviors.	0.796	0.81	0.656
	Y22	My energy-saving behavior will be affected by the information I get from newspapers, television and other media.		0.81	
Social norms	Y31	My energy-saving behavior will be affected by my families, friends and teachers.	0.767	0.71	0.576
	Y32	If people around me are engaging in energy-saving behavior, I will also engage in more energy-saving behaviors.		0.64	
	Y33	There are few people around me who are concerned about energy conservation, and I need more help and co-participation.		0.83	
Policies and regulations	Y41	I undertake energy-saving behavior because of relevant policies and regulations.	0.753	0.75	0.601
	Y42	Policies and regulations play an important role in promoting and encouraging me to engage in energy-saving behaviors.		0.80	

Source: Author analysis.

them in the follow-up result analysis and relevant figures and tables. The validity of the test model can be reflected by the average variance extracted from the structure (AVE). The validity of the measurement model is confirmed because all AVE values are greater than 0.5. Regarding the structural model, all the fitness indexes are qualified according to the test criterion (see Table 4), indicating an acceptable model accuracy (Raykov and Marcoulides, 2006). Finally, the model results are given in Fig. 3.

5.2. Effects of individual subjective characteristic factors, external influencing factors and energy-saving intentions

The proposed model in Fig. 3 explains 59.7% of the variance of energy-saving behaviors and 37.7% of the variance of energy-saving intentions. Table 5 shows the results of the finally determined structural model. The results of the five hypotheses are statistically significant and H1, H2, H3, H4, H5 are found to have positive effects on energy-saving intentions and/or energy-saving behaviors. The paths and effects are given in Table 5. Individual subjective characteristic factors and external influencing factors have a positive effect on energy-saving intentions and energy-saving behaviors, and energy-saving intentions have a positive effect on energy-saving behaviors. Table 6 shows the total effect of external influencing factors on energy-saving behaviors is the greatest. And we found the direct effect of individual subjective characteristic factors on energy-saving behaviors are greater than that of external influencing factors, in contrast, the indirect effect is far less than that of external influencing factors. Therefore, it can be seen that the effects of the external influencing factors on energy-saving behaviors such as taking the power off when do not use the appliances for a long time or choosing energy-saving lamps are mainly derived from indirect effects.

5.3. Analysis of the mediating effect of external influencing factors

In order to further clarify and decompose the indirect effects of external influencing factors on energy-saving behaviors, we build three independent mediation models for individual subjective characteristic factors, external influencing factors, energy-saving intentions and energy-saving behaviors (Fig. 4–1,2,3). The direct, indirect, and total effects between variables are obtained from the path analysis, which can provide a better understanding of the mediating effects (Tables 7–1,7-2,7-3). As mentioned above, the impact of external influencing factors on energy-saving behavior is mainly due to indirect effects, and the specific sources and size of the indirect effects can be revealed by models 4-1 and 4-2. External influencing factors exert an indirect effect on energy-saving behaviors through energy-saving intentions and individual subjective characteristic factors. And the individual subjective factors further directly act on energy-saving behavior and indirectly act on it through energy-saving intentions (see model 4-3). This implies that the external influencing factors affect energy-saving behaviors via three channels, leading to greater overall effects than the individual subjective characteristic factors. Moreover, we could also find that energy-saving intention is an important factor that not only has positive direct impact on energy-saving behaviors, but also plays an important role in forwarding the mediating effects from individual subjective characteristic factors and external influencing factors to energy-saving behaviors.

5.4. Effects of first-order latent variables

The specific effects of first-order latent variables on energy-saving behaviors can be measured by analyzing how much they can explain individual subjective characteristic factors and external influencing factors, and then affecting energy-saving intentions and energy-saving behaviors. Table 8 lists the influence coefficients between first-order latent variables and second-order latent variables including individual subjective characteristic factors and external influencing factors. It can be seen that the coefficients of all first-order latent variables are significantly positive. Combined with the coefficients between second-order variables, the effects of first-order latent variables on energy-saving behaviors can be derived.

(1) Effects of different individual subjective characteristic factors

Concerning the first-order latent variables for shaping individual subjective characteristic factors, values have the greatest impact. And the stronger household environmental values are, the more possible for individuals or households to adopt energy-saving behaviors. Values towards energy-saving and green consumption may affect households' motivation to buy energy-saving products or implement energy-saving behaviors such as avoiding or reducing usage of air conditioners. This is consistent with some scholars' findings that environmental and ethical consumer values, especially those such as universalism and altruism, will actively promote moral obligations and personal norms (Chen and Chang, 2012; Eze and Ndubisi, 2013). The second factor is energy knowledge whose effect on explaining individual subjective characteristic factors is 0.69, indicating that knowledge plays an important role on stimulating individuals to adopt energy-saving behaviors like taking the power off when do not use the appliances for a long time in daily life. This result is consistent with the case of Dutch household found by Han et al. (2013). In other words, the lack of energy-saving knowledge will cause obstacles for energy saving (Harland et al., 2007; Tanner and Kast, 2003; Vermeir and Verbeke, 2006). The control view has a positive effect on energy-saving behaviors. Individuals with strong self-confidence and ability will have a positive impact on intention and behaviors, thereby improving household self-confidence in implementing energy-saving behaviors. The degree of concern (coefficient is 0.68) and the sense of responsibility (0.64) have an important contribution for explaining individual subjective characteristic factors and then affect the choice of energy-saving behaviors and products like choosing simple packaging and recyclable products when purchasing similar products. The greater the degree of concern and the sense of responsibility are, the greater the positive impacts on energy-saving behaviors are. These are consistent with existing findings (Gärling, 2003; Reiss and White, 2006; Wang et al., 2014a,b). Those suggest that improving household degree of concern and sense of responsibility for the environment could

Table 4
Energy-saving behavior SEM fitting index.

Index	CMIN	DF	CMIN/DF	GFI	AGFI	NFI	IFI	TLI	CFI	RMSEA
Model results	1014.082	682	1.487	0.858	0.837	0.826	0.935	0.926	0.935	0.041
Standard			< 3	> 0.8	> 0.8	> 0.8	> 0.9	> 0.8	> 0.9	< 0.05
Model accuracy			Excellent	Good	Good	Good	Excellent	Excellent	Excellent	Excellent

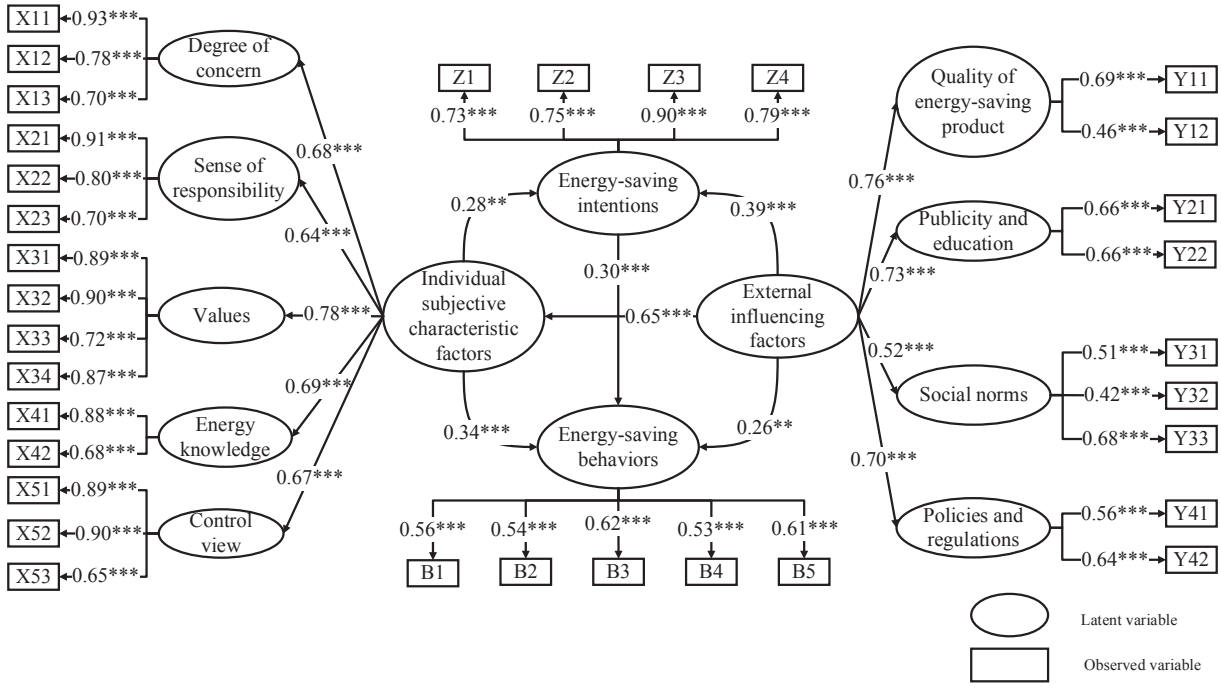

Fig. 3. Final energy-saving behavior model results. Note: 1. *p < 0.05; **p < 0.01; ***p < 0.001. 2. Results for the control variables are not shown here since they are all statistically insignificant.

Table 5
Latent variable path coefficients.

Hypothesis	Path			UnStd. coefficient	Z-value	P	Result
H1	Energy -saving intentions	←	Individual subjective characteristic factor	0.409	2.278	**	Positive correlation
H2	Energy-saving behavior	←	Individual subjective characteristic factor	0.673	3.783	***	Positive correlation
H3	Energy -saving intentions	←	External influencing factors	0.402	3.584	***	Positive correlation
H4	Energy-saving behavior	←	External influencing factors	0.367	2.783	**	Positive correlation
H5	Energy-saving behavior	←	Energy -saving intentions	0.406	4.079	***	Positive correlation

Note: *p < 0.05; **p < 0.01; ***p < 0.001.
Source: Author analysis.

Table 6
The effects of influencing factors.

Action pathways	Direct effect	Indirect effect	Total effect
Individual subjective characteristic factors →Energy-saving behaviors	0.339***	0.084***	0.422***
External influencing factors →Energy-saving behaviors	0.264***	0.391***	0.655***

Note: *p < 0.05; **p < 0.01; ***p < 0.001.
Source: Author analysis.

encourage energy-saving behaviors.

(2) Effects of different external influencing factors

The external influencing factors related to market, society and government also have significant impacts on energy-saving behaviors. Regarding the first-order latent variables that are used to explain the external influencing factors, the contribution of quality of energy-saving products is the largest (0.76), implying the quality of energy-saving products is more influential to household decisions on purchasing energy-saving products compared to other first-order latent variables like publicity and education, social norms, and policies and regulations. This result is consistent with the findings that awareness of poor product quality is an important barrier to green-buying activity (Smith and Andrews, 2013). The explanation effect of social norms on the external influencing factors is the least compared to other three variables, indicating that social norms are less influential for promoting energy-saving behaviors. Publicity and education have an important impact on the choice of energy-saving behaviors. Positive publicity and education through media, governments, schools and other sectors could change individual's attitudes and then guiding households to implement more energy-saving behaviors such as using daily public transports or on foot rather than private cars. The choice of energy-saving behaviors is closely related to relevant government laws and regulations. In other words, the government can formulate policies and regulations on energy conservation to

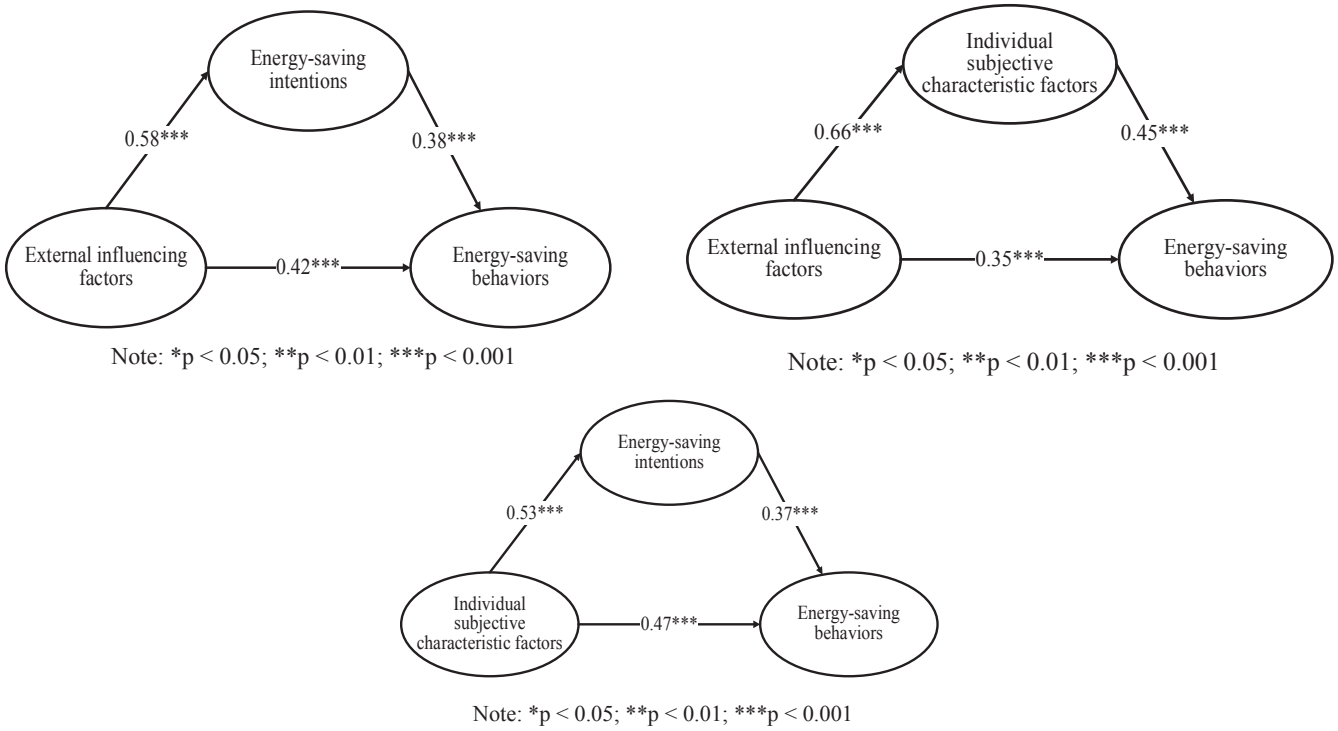

Fig. 4. 1Mediation model 1. 2 mediation model 2. 3 mediation model 3.

Table 7–1
Analysis of the mediating effects between variables (Mediation Model 1).

	Action pathways	Direct effect	Indirect effect	Total effect
Mediation Model 1 (Fig. 4–1)	External influencing factors →Energy-saving behaviors	0.425***	0.219***	0.643***
	External influencing factors →Energy-saving intentions	0.575***	–	0.575***
	Energy-saving intentions →Energy-saving behaviors	0.380***	–	0.380***

Note: *p < 0.05; **p < 0.01; ***p < 0.001.

Table 7–2
Analysis of the mediating effects between variables (Mediation Model 2).

	Action pathways	Direct effect	Indirect effect	Total effect
Mediation Model 2 (Fig. 4–2)	External influencing factors →Energy-saving behaviors	0.347***	0.295***	0.641***
	External influencing factors →Individual subjective characteristic factors	0.656***	–	0.656***
	Individual subjective characteristic factors →Energy-saving behaviors	0.449***	–	0.449***

Note: *p < 0.05; **p < 0.01; ***p < 0.001.

Table 7–3
Analysis of the mediating effects between variables (Mediation Model 3).

	Action pathways	Direct effect	Indirect effect	Total effect
Mediation Model 3 (Fig. 4–3)	Individual subjective characteristic factors →Energy-saving behaviors	0.470***	0.200***	0.670***
	Individual subjective characteristic factors →Energy-saving intentions	0.534***	–	0.534***
	Energy-saving intentions →Energy-saving behaviors	0.375***	–	0.375***

Note: *p < 0.05; **p < 0.01; ***p < 0.001.
Source: Author analysis.

Table 8
The influence coefficients of the first-order latent variables.

Latent variables	Second-order latent variables	Std. coefficient
Individual subjective characteristic factors	Degree of concern	0.68
	Sense of responsibility	0.64
	Environmental values	0.78
	Energy knowledge	0.69
	Control view	0.67
External influencing factors	Quality of energy-saving product	0.76
	Publicity and education	0.73
	Social norms	0.52
	Policies and regulations	0.70

Source: Author analysis.

encourage household energy-saving behaviors.

6. Conclusions and policy implications

6.1. Conclusions

This study provides more comprehensive insights on the mechanisms of how individual subjective, external influencing factors and energy-saving intentions act on energy-saving behaviors, by establishing a unified structural equation model to accommodate all elements together. In addition to the direct effects, the mediating effects or indirect effects of the influential factors on energy-saving behaviors are also discussed. This study takes Jinan city in Shandong province as the empirical context and a questionnaire survey was conducted to support this analysis. Several conclusions are summarized as follows.

Individual subjective characteristic factors including degree of concern, sense of responsibility, environmental values, energy knowledge and control view, as well as the external influencing factors like quality of energy-saving products, publicity and education, social norms and policies and regulations have significant impacts on shaping and changing energy-saving behaviors. While individual objective characteristic factors are found statistically insignificant in this empirical analysis as the control variables, probably due to diverse effects for different socio-demographic groups. The total effects of external influencing factors on energy-saving behaviors are greater than that of the individual subjective characteristic factors. The reason is that in addition to the direct effect, the external influencing factors affect energy-saving behaviors via energy-saving intentions and the individual subjective characteristic factors.

Values and energy knowledge belonging to individual subjective characteristic factors have the greatest impacts on shaping household energy-saving behaviors. Quality of energy-saving products is the most important factors among external influencing factors on affecting energy-saving behaviors. Therefore, multifaceted policies are necessary for promoting household energy-saving behaviors.

6.2. Policy implications

This study has important implications for household energy-saving behaviors. Specifically,

(1) Individual subjective characteristic factors are very important for changing energy-saving behaviors, therefore, policies should be designed to help individuals establish environmental values, sense of responsibility for energy saving and environmental protection behaviors. We can learn from the existing advanced or successful measures so as to encourage people to engage in energy-saving behaviors and buy energy-saving products, for example, the national emission reduction policy[1] implemented by Japan, energy-saving publicity and creative competitions created by a domestic school,[2] and a low-carbon generalized system of preferences (GSP) promotion platform[3] used in Guangdong Provincial.

(2) It is found that external influencing factors not only directly impact energy-saving behaviors, but also affect the individual subjective characteristic factors firstly, and then have a further effect on energy-saving behaviors. Therefore, energy planners or policy makers could influence energy-saving behaviors by awareness campaign targeting the general public and meanwhile consciously guide households to improve their energy-saving concerns, values, energy knowledge and control view to implement energy-saving behaviors. We can borrow the experience from the developed countries, for example, Japan promoted "visualization,"[4] California launched a specific "showerhead standard" as a water-saving measure,[5] and the Singapore government encouraged households to buy energy-efficient appliances and imposed punitive taxes on high-energy cars.[6] In

[1] Japan implemented a practical activity to reduce emissions called "One person, One day and One kilogram," which advocated reducing the frequency of showering, using reusable shopping bags and other methods to achieve energy-saving behaviors. By increasing the participation of the whole society and strengthening the influence of degree of concern, values, sense of responsibilities and social norms, households can be guided to participate more in energy saving and environmental protection activities.

[2] Wuhou District, Sichuan Province held an energy saving and innovation competition for primary school students in the region. The events included activities such as energy-saving creative painting, energy-saving gold ideas, an energy-saving essay subject and energy-saving handwork. The games help the students form energy-saving values, enhance their sense of responsibility and embed energy-saving knowledge.

[3] In June 2016, Guangdong Province produced a low-carbon and the Internet model to promote green consumption. The provincial government had not only developed a provincial-level carbon GSP promotion platform, but also created websites and apps that conveyed low-carbon knowledge, energy-saving products and technologies to help households increase their environmental values, degree of concern and energy-saving knowledge.

[4] By using various types of electric meters, gas meters and other kinds of meters, the energy consumption and CO_2 emissions of a single machine can be measured at any time, which would be convenient for people to observe their daily energy-consuming activities and enhance their social norms gradually. They also implement an energy-saving consumption labeling system, which was established according to different energy consumption levels and play the role of policy standard.

[5] California introduced two water-saving measures, one of which required the nation's most water-efficient showerhead to use less water than the current model. According to this policy, starting from July 2018, the showerheads sold in California should be limited to no more than 1.8 gallons of water per minute. This indicates that the government makes positive energy-saving policy and regulation for energy-saving products to help save water.

[6] The Singapore government advocates that Singaporeans bought energy-saving appliances autonomously. In addition, they claimed that government should impose punitive taxes on high-energy consumption vehicles and meanwhile encourage people to use public transport to guide people to save energy.

addition, some studies have shown that economic policies (e.g., government subsidy policies and preferential tax policies) can significantly affect household energy-saving behaviors, and could also encourage households to buy energy efficient appliances (Lee, 2009; Sardianou, 2007).

It is obvious that there are many kinds of measures can shape household energy-saving behaviors. Government should guarantee the execution of the proposed policies and regulations. At the same time, enterprises should strengthen their research abilities to produce more efficient and high-quality energy-saving products.

6.3. Limitation and future research

This study takes a statistical approach to explore the interrelationships between the various influencing factors and their effects on energy-saving behaviors. Although this study has made some progress on considering more comprehensive mechanisms of shaping energy-saving behavior, it has some limitations. For example, to improve the representativeness of the survey data, larger sample would be better. The influencing factors can be expanded in the future study by taking the influence of, for instance, energy price, infrastructure, and technology development into account. In addition, further study can be considered based on the rules found in our study, using a behavior-oriented approach to describe the formation process of energy-saving behavior, then assess the concrete effect of policies on behavior changing.

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Appendix

Table A.1
Questions included in the questionnaire.

Constructs		Items
Degree of concern	X11	I am very concerned about the energy problems reported by media.
	X12	I feel worried or nervous when I hear or see issues about energy.
	X13	I usually pay little attention to energy consumption and details of its use.
Sense of responsibility	X21	I am willing to sacrifice personal interests to save energy and for environmental protection.
	X22	In order to save energy and protect environment I do not hesitate to offend some people.
	X23	Energy issues are related to the whole society, and everyone has the responsibility to save energy.
Values	X31	Human beings should respect nature and live in harmony with nature.
	X32	Nature and the environment have the same value as human beings.
	X33	We should not exploit new natural resources to protect nature and the environment.
	X34	Economic development is the most important, and environmental issues can be considered later.
Energy knowledge	X41	How much do you know about the purchasing energy-saving behavior in questions 7–9?
	X42	How much do you know about habitual energy-saving behaviors in questions 1–6?
Control view	X51	We can improve and solve some environmental problems if we work hard.
	X52	It will help to improve and solve some environmental problems if we take some actions.
	X53	It is impossible for ordinary people to improve and solve environmental problems.
Quality of energy-saving product	Y11	The public praise of energy-efficient products is an important factor in determining whether I should buy them or not.
	Y12	The quality of energy-saving products is an important factor in determining whether I should buy them or not.
Publicity and education	Y21	We should improve the strength of publicity and education, and guide more people to implement energy-saving behaviors.
	Y22	My energy-saving behavior will be affected by the information I get from newspapers, television and other media.
Social norms	Y31	My energy-saving behavior will be affected by my families, friends and teachers.
	Y32	If people around me are engaging in energy-saving behavior, I will also engage in more energy-saving behaviors.
	Y33	There are few people around me who are concerned about energy conservation, and I need more help and co-participation.
Policies and regulations	Y41	I undertake energy-saving behavior because of relevant policies and regulations.
	Y42	Policies and regulations play an important role in promoting and encouraging me to engage in energy-saving behaviors.
Energy-saving intention	Z1	I am willing to spend more money buying energy-saving products.
	Z2	I would like to pay more attention to low-carbon dynamic news, and actively respond to low-carbon consumption.
	Z3	When I driving I am willing to use driving skills to reduce fuel consumption.
	Z4	I am willing to sacrifice some of the convenience to change the lifestyle of high-carbon consumer behaviors.
Energy-saving behavior	B1	When you do not use the appliances for a long time, you will take the power off to reduce the TV, air conditioners, computers, drinking fountains, microwave ovens and other household appliances standby power consumption.
	B2	You will choose a shower instead of a bath.
	B3	Use daily public transports, such as buses, bikes or on foot.
	B4	You will save water when bathing in public baths
	B5	When you leave the room, you will turn off the lights
	B6	When you are in a public workplace, you will avoid or reduce using air conditioners
	B7	When purchasing lamps, you will choose energy-saving lamps.
	B8	When you buy or plan to buy a car, you will prefer a small displacement car (Fuel saving vehicle).
	B9	When purchasing similar products, you prefer choosing simple packaging and recyclable products.

Source: Author analysis.
Note: B1-B4 are excluded because they do not pass the validity test after the pilot survey, and B5-B9 are left.

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