



Analysis of the mediating role of social network embeddedness on low-carbon household behaviour: Evidence from China

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ABSTRACT

Based on Social Network Theory and the Planned Behaviour Theory, this paper adopts a multi-group analysis of structural equation model and uses the low-carbon behavioural intention as a mediator to analyse the role of social network embeddedness in influencing residents' low-carbon household behaviours. Based on the reliability test of the scale and the first-order confirmatory factor analysis, the direct and mediating effect dual models are used to verify the proposed research hypothesis; furthermore, based on demographic and family characteristics, a multi-group structural equation model analysis is conducted. The empirical results show that social network embeddedness will significantly improve residents' low-carbon household behaviours and reduce household carbon emissions. Social networks will embed residents' low-carbon household behaviours through direct effects and incomplete mediation of low-carbon behavioural intentions as mediators. Multi-group analysis result shows that female and highly-educated groups exhibited better low-carbon household behaviours, and different family scales, monthly incomes and consumption, housing size, and living area show significant influences on low-carbon household behaviours.

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1. Introduction

Increasing greenhouse gas emissions have led to an increase in global average temperatures, which have resulted in melting ice sheets, ozone holes, extreme weather, drought, desertification, and rising sea levels. Therefore, global climate change caused by greenhouse gas emissions has become one of the major threats to sustainable development in the world today (Kahn, 2009; Geng, 2018). It is estimated that five million people worldwide die every year from air pollution, famine, and disease caused by climate change and excessive carbon emissions (Chinese Academy of Sciences Sustainable Development Strategy Research Group, 2009; Guo, 2018). The increase in greenhouse gas emissions from human activities, especially the increase in CO₂ emissions, is the main cause of climate warming. Therefore, the development of a low-carbon economy and a low-carbon society has become the

basic consensus among humankind to cope with global warming (IPCC, 2013; Zhang, 2018).

China's nominal carbon emissions have surpassed those of the USA, ranking first in the world, and China is under pressure to reduce her emissions from the international community (Wang and He, 2011). Wei et al. (2007) assessed the carbon emissions of urban and rural residents in China from 1999 to 2002 and found that 30% of all carbon emissions come from residents' daily consumption patterns and lifestyles. According to the "China Statistical Yearbook 2016", the energy consumption of residents in China accounted for 11.65% of China's total energy consumption in 2015, and this proportion is increasing at a rate of 5.1% per year as the living standards of her residents' increase. The acceleration of China's urbanisation process and the continuous reduction of number of poor people have led to the rising demand for energy, and household energy consumption has become an important contributor to total energy consumption (Reinders et al., 2003). The increase in family income and the improvements in lifestyles have steadily increased the role of energy consumption, especially in terms of households, household appliances, housing, and private transportation (Wang and Shi, 2009). Although industrial carbon emissions remain the main component of China's carbon emissions, as the energy demand of ordinary families has been upgraded from "eat and wear" to

Abbreviations: SNT, Social Network Theory; PBT, Planned Behaviour Theory; SEM, Structural Equation Model; CFA, Confirmatory Factor Analysis; LBI, Low-carbon Behavioural Intention; SNE, Social Network Embeddedness; LHB, Low-carbon Household Behaviours.

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“residence and travel”, the carbon emissions associated with residents’ lives will rise rapidly (Qiu, 2009; Peng and Zhu, 2010). Therefore, how to curb the rapid growth of residents’ carbon emissions is a key issue for China as she builds low-carbon city and develop an ecologically sound civilisation.

The rising energy demand from residents is mainly reflected in household energy consumption, and the household energy consumption behaviours of residents are highly susceptible to social networks, such as relatives, friends, and communities (Hori et al., 2013; Kristina, 2005; Niamir et al., 2018). The normative pressure from social networks has a huge impact on residents’ low-carbon behaviours, choices, and awareness. Residents will also change their low-carbon behavioural tendencies due to their psychological role, which may lead to changes in low-carbon behaviours throughout families (Kristina and Söderholm, 2010). From the perspective of external factors, the development of mobile terminals such as the Internet and mobile telephones has enriched residents’ social interactions, and the frequency and scope of social interactions have increased. With the emergence of sharing economy, WeChat, Weibo and etc, it has made social networks increasingly become a key factor affecting residents’ low-carbon behaviours. According to statistics, the daily energy consumption of urban resident accounts for about 26% of annual energy consumption, of which “face consumption” and luxury consumption cause great waste (Wang, 2012). Residents will generate more demand in terms of food, clothing, housing, and transportation to meet the needs and vanity of their social activities, which will inevitably lead to further increase in household energy consumption. Therefore, the research on low-carbon household behaviours (LHB) of residents based on social network embeddedness (SNE) has a strong theoretical basis and practical significance.

2. Literature review

2.1. Residents’ low-carbon household behaviours research

Compared with Chinese scholars, foreign scholars pay more attention to the research into LHBs of residents. The IPCC revised “IPCC National Greenhouse Gas Emission Inventory Guide 2006” provides a calculation method for household carbon emissions, which divides household carbon emissions into three parts: electricity carbon emission, gas carbon emission, and heating-related carbon emissions. Kristina (2005) conducted a continuous study of Swedish families and pointed out the interaction among residents, businesses, and media, and the influence of residents’ social interactions on family energy-saving activities. Residents who often discuss low-carbon behaviours with people close to them are more willing to practice low-carbon behaviours. They are also more interested, and knowledgeable in this regard, and more interaction with the people around them will make residents think that this is the right point of view. The author further points out that information transmitted through social interaction and media guidance has an impact on household energy-saving decisions (Kristina and Söderholm, 2010). Poortinga et al. (2003) studied people’s preferences for different energy-saving methods and pointed out that people’s energy-saving strategies have the greatest impact on energy-saving methods. Scott (2004) pointed out that the ownership of Irish home energy-saving products is surprisingly low, possibly due to lack of information and a non-proprietary lack of ownership thereof. Hori et al. (2013) conducted a survey of energy-saving behaviours in five major Asian cities, pointing out that global warming awareness, environmental behaviour, and social interaction have had a major impact on energy-saving behaviours, and income and age have a weak positive impact on energy-saving behaviours. Hamamoto (2013) analysed the net benefits of

consumers’ energy-saving measures and pointed out that promoting energy-saving behaviours requires not only policies that provide economic incentives, but also interventions to influence the psychological factors driving family behaviour. Padmakanthi et al. (2009) explored the financial and economic feasibility of adopting energy-saving technologies among Sri Lankan families and finds that energy-saving technologies are economically profitable and economically viable. Melo et al. (2010) used econometric methods to model home ownership to predict household electricity consumption. Niamir et al. (2018) presented an agent-based model to track aggregated impacts of behavioural changes among heterogeneous households. These studies have studied the relationship between household behaviours and energy consumption from different perspectives, and tried to find ways in which to reduce household energy consumption through modelling, questionnaires, and quantitative analysis.

Relatively speaking, Chinese scholars are more concerned with studies from the overall perspective of low-carbon behaviours of residents. Geng et al. (2004) conducted a dynamic analysis of the entropy evolution characteristics of urban residents’ energy consumption structure in Wuxi from 1990 to 2002, and pointed out that they are highly correlated with the actual disposable income of urban residents and the total energy consumption *per capita*. Zhang et al. (2011a,b) divided the energy consumption of households into direct and indirect parts, and measured the indirect energy consumption and corresponding carbon emissions of Chinese households through lifestyle analysis. Wang et al. (2010) analysed the six factors influencing China’s low-carbon consumption model from macro- and micro-aspects and pointed out that family income and family scale are the main factors therein. Feng et al. (2011) explored the dynamic characteristics of urban residents’ energy consumption and carbon emissions in China from 1999 to 2007, and analysed their potential influencing factors. Niamir et al. (2018) pointed out that there is little difference in the amount of energy used by urban and rural families in the western part of the Loess Plateau, but the effective use of energy from the large and medium cities, to counties to rural areas declines in turn, forming a distinct step feature. Lu et al. (2014) used grounded research to define the basic concept of the carbon lock-in phenomenon in household energy consumption, and explored the structure, internal inertia, and path dependence of high-carbon energy consumption in a carbon-lock expression. Wang et al. (2011, 2016) researched the recycling willingness and behaviour towards e-waste and household solid waste of urban residents, and pointed out that the convenience of recycling facilities and service, residential conditions, recycling habit and economic benefits are four determinants of Chinese residents’ willingness on recycling. Fan (2018) studied the subsidy strategy of low-carbon diffusion by considering heterogeneous agents’ behaviour. Ding et al. (2018) summarized twenty-four popularly predictors of urban residential low-carbon behaviour. To sum up, Chinese scholars pay more attention to the analysis of the differences in household energy consumption between different regions of China and between urban and rural residents, and explore the factors influencing them through grounded theory, questionnaires, and quantitative analysis. Although this method allows us to understand the low-carbon behaviours of a certain type or region of residents from a holistic perspective, it is still lacking in depth, especially in research on energy consumption behaviours of households based on social network perspectives, which remains rare.

2.2. Social network embeddedness research

Granovetter tried to solve the classical problem of social theory such that behaviours and institutions are affected by social

relationships (Granovetter, 1985). Feld (1997) found that the amount of structural embedding of the relationship between two people is defined as the degree of overlap between the social relationships between the two individuals and may reflect the extent of the common activity that links these people to others. Montgomery (1998) attempted to formalise Granovetter's embeddedness argument and proposes that role theory will provide a better meta-theoretical perspective for embeddedness. Chatfield et al. (2000) draw on embedded sociological theory and cross-case analysis to compare how three initiators of a complex EDI network achieve different levels of strategic payment. Rao et al. (2000), based on embeddedness studies, suggest that, when members of a group defect to foreign groups, the organisation receives clues about identity differences, but the organisational response to such clues depends on their social relationships with groups within, and outside, the group and defectors. These scholars generally base their work on social theory, and strive to introduce embeddedness research into different research fields and perspectives, which will promote the development of embeddedness research.

Chinese scholars are also engaged in SNE, and the research therein cover three aspects: first, a sociological perspective in which Lin et al. (2003) clarified and tested many propositions about the relationship between embedded resources and social economic achievements in social networks. Xiao (1999) introduced the formation and development, basic principles, and main theories of western social network research, and reviewed the main contributions and limitations of social network research and its significance to the development of Chinese sociology. Bian et al. (2001) proposed four theoretical hypotheses about the role of social networks in professional mobility in the transitional economy, based on a review of the sociological theory of the different roles of social networks in a market economy and redistributive economic system. Secondly, the individual perspective, in which Liang et al. (2005) found that the relationship between employee organisational performance and voluntary separation is a duality (retention and loss), multi-path, multi-incentive relationship system. Lu (2008) pointed out that individuals in a more favourable social network structure will have more opportunities to become technology entrepreneurs. Tang et al. (2012) conducted a logistic regression analysis of 442 samples, and proposed a theoretical model of social network influence on the formation of individual entrepreneurial intentions. Thirdly, the organisational perspective, in which Yao et al. (2003) expounded the relationship between social networks and corporate growth, and pointed out that Social Network Theory (SNT) can be better applied in the fields of enterprise organisational structure, corporate strategic alliance, and the development of small and medium-sized enterprises. Zhang et al. (2011a,b) explained the generational mechanism of enterprise innovation network from the perspective of social capital and structural hole theory from the perspective of SNT analysis. With Chinese scholars' attention to social network research continuing to increase, these three perspectives have gradually become the main channels through which Chinese scholars carry out SNE research. As China's "innovation and entrepreneurship" trend has become more important, scholars who conduct research based on individual perspectives pay more attention to the social network analysis of enterprise employees or entrepreneurs, but there is little research into the relationship between low-carbon behaviours and social networks.

3. Theoretical models and research hypotheses

There are many explorations on the influencing factors of low-carbon behaviours, these studies mainly use the planned

behaviour theory to illustrate the relationship between the subjects' behaviours, willingness and ability. Embeddedness, as one of the important perspectives in social network theory, is closely related to social network theory. In order to explore the role of embeddedness and low-carbon behaviours and mediating variables, it is necessary to introduce social network theory and planned behaviour theory into this study at the same time. These two theories complement each other and construct the theoretical framework of this study.

The basic idea of SNT is that people in social situations think and act in a similar way because of the ties between them (Granovetter, 1985). SNT studies a series of relationships and ties formed by established social agents, and explains social behaviours as social network systems (Mitchell, 1969; Tichy et al., 1979). Granovetter (1973) suggested that weak relationships between individuals may be more important and influential in influencing the attitudes and behaviours of members of society than strong relationships. Kilduff (2010) explored four forward-looking and interrelated research hotspots that dominate SNT research, namely, embeddedness, relationships among network agents, network structure patterns, and social utility of network connections. Among them, embeddedness is one of the core assumptions of SNT. It refers to the tendency to continue to stay in a social network and to continuously create and update network relationships over time (Granovetter, 1985). Compared with normal network relationships, embedded social network relationships are more powerful due to high trust among agents, frequent information interaction, and problem-solving capabilities (Uzzi, 1996). The size of the social network, the heterogeneity of the agents, and the strong or weak relationship are important factors affecting the embeddedness (Granovetter, 1973, 1985), therefore, residents' LHB is likely to be affected by the social network relationship in which they live. Based on this, the following hypothesis is proposed:

H1. Social network embeddedness will significantly positively affect residents' low-carbon household behaviours.

Planned behaviour theory (PBT) suggests that behavioural intention is the best way to predict and explain individual behaviours (Fishbein and Ajzen, 1980). The theory assumes that people are acting rationally and will decide whether, or not, to take action by systematically using the information available; people's actions are guided by conscious motives, not unconscious spontaneous actions; and people will consider the meaning of their actions before deciding whether to take action (Ajzen and Fishbein, 1980). Based on these assumptions, the PBT was originally called the theory of reasoned action (Ajzen and Driver, 1992). According to this theory, behavioural intention is a direct factor in determining behaviour, which is influenced by behavioural attitudes and subjective norms. The behavioural intention refers to the motivational factors that affect the individual's behaviours, indicating the degree to which the individual is willing to try a certain behaviour and expend effort in doing so; attitude is an evaluation of an individual's love or dislike of certain behaviour; subjective norms refer to the social pressures an individual perceives when deciding whether to perform a particular behaviour. Subjective norms are usually determined by the individual's social relationships (such as relatives, friends, neighbours, etc.) and their location in the social network. Based on this, the following hypothesis is proposed:

H2. Social network embeddedness is significantly positively correlated with residents' low-carbon behavioural intentions.

Ajzen (1985) added the perceived behaviour control (PBC) variable to the theory of reasoned action, thus forming PBT. According to the PBT, when an individual perceives complete control over performing a specific behaviour, and the behavioural intention can directly predict the behavioural outcome. Many scholars proved

that individuals may strongly hope to implement behaviours, but may not have the necessary opportunities and resources to implement actual behaviours (Kuhl, 1984), such as knowledge (Triandis, 1980) and ability (Liska, 1984). PBC and behavioural intention directly determine the behaviour of the agent (Ajzen, 2001), so to a certain extent, the residents' LBI can directly determine their LHB. Based on the above analysis and H2, the following hypothesis is proposed:

H3. Low-carbon behavioural intention mediates social network embeddedness and low-carbon household behaviours.

The variables used in the study and their relationship to each other can be seen from the theoretical model (Fig. 1).

4. Scale design and data collection

4.1. Scale design and pilot study

The questionnaire includes four parts: SNE, LBI, LHB, and demographic variables. The SNE mainly refers to the scales developed by Burt (2004), Gulati (1998), and Brüderl and Preisendörfer (1998), and integrates the three dimensions of size (SI), heterogeneity (HE), and strength (ST) into the same scale. The LBI mainly refer to the research contributions of scholars Chan (2010), Mi (2011), and Frick et al. (2004), and use low-carbon behavioural ability (AB), behavioural knowledge (KN), and behavioural attitude (AT) to represent residents' LBI. LHB refers to the research results of Lin and Yu (2003). LHB is divided into two dimensions: household usage (HU) and household customs (HC) for in-depth discussion and analysis. The reference of the scale and variables are shown as Table 1. The demographic variable scale mainly includes four characteristics of residents: gender, age, education, and marital status, as well as five family characteristics: family scale, monthly income, monthly consumption, housing size, and living area.

This paper made appropriate changes to each item to make it more accessible to facilitate understanding among older, or less well-educated, respondents, thus avoiding unnecessary deviations. The modification of the questionnaire items combines the specific problem situation and expert opinions, and the questionnaire has also passed the reliability test of pilot study. In the scale (except for the demographic variables), a Likert scale is used, as shown in

Appendix. In the SNE part, a Likert 7-point scale is used, and the scale from 1 to 7 represents degrees low to high; In the LHB and LBI part, the Likert 5-point scale is used, and the scale from 1 to 5 represents degrees low to high.

Before the formal questionnaire was issued, a small sample pilot study was first conducted among the students and teachers of the University of International Business and Economics. The reliability and validity of the questionnaire were initially tested, and some of the items were revised to form the final questionnaire. In addition, nine related questions were set in the questionnaire to ensure its credibility and rigour (the questionnaire was checked on this basis).

4.2. Data collection

The study selected the families of university students as a target, and distributed the paper-based questionnaire to the students in the form of active registration (each received 1–10 questionnaires). Participants will bring the questionnaire back to the family's home region for distribution and completion during the holidays, and collect them after term starts. The questionnaire was issued in mid-January 2018 and was completed in April 2018. A total of 467 questionnaires were distributed and 447 were recovered (a recovery rate of 95.7%). Through recycling, and eliminating blanks, missing answers, unsatisfactory attitudes, obvious regularity, and obvious inconsistencies in the issue of interdependence, 355 valid questionnaires were obtained (an effective response rate of 79.4%).

5. Empirical results and analysis

5.1. Reliability and validity test of the scale

Through reliability test, the Cronbach's α coefficient (0.607–0.872) of each part of the questionnaire was greater than the standard value of 0.6 (He et al., 2011), as shown in Table 2. The scales used in the study are mature scales, and have been corrected by experts in the field and pre-tested, so each scale has good content validity. Through the two-tailed test of Pearson correlation coefficient, the correlation coefficient of each variable reached a significant level, and the variables were basically low-mid correlations. The correlation coefficient between each variable and the overall items is highly correlated at 0.4 or higher, indicating that each variable is a concept with a significant difference, and the discriminant validity is verified.

Through the results of the first-order confirmatory factor analysis (CFA), the factor loading of each item is greater than 0.5 (0.504–0.844), and the corresponding C.R. values are greater than 2. In addition, the fitness indices of the measurement model are CMIN/DF = 2.33 (<3), NFI = 0.931 (>0.9), NNFI = 0.932 (>0.9), CFI = 0.958 (>0.9), IFI = 0.959 (>0.9), GFI = 0.973 (>0.9), AGFI = 0.943 (>0.9), RMSEA = 0.061 (<0.08), etc., all of which are excellent, indicating that the measurement model is ideally fitted, and the scale has good structural validity.

5.2. Research hypothesis testing and multi-group analysis

5.2.1. Hypothesis testing and mediating analysis

The mediating effect is verified by two structural equation models (SEM) of direct effect and mediating effect (Fig. 2). In the direct effect model, SNE is used as an exogenous latent variable, and LHB is used as endogenous latent variables. The results are shown in Table 3. The model performed well on each fitness index, indicating that the model was a good fit. The impact of SNE on LHB was positive ($\alpha = 0.258, P = 0.010, Y = 0.258X + \epsilon_1$), so H1 was verified. This shows that the size, heterogeneity, and strength of the social network of residents will have a significant positive impact on their

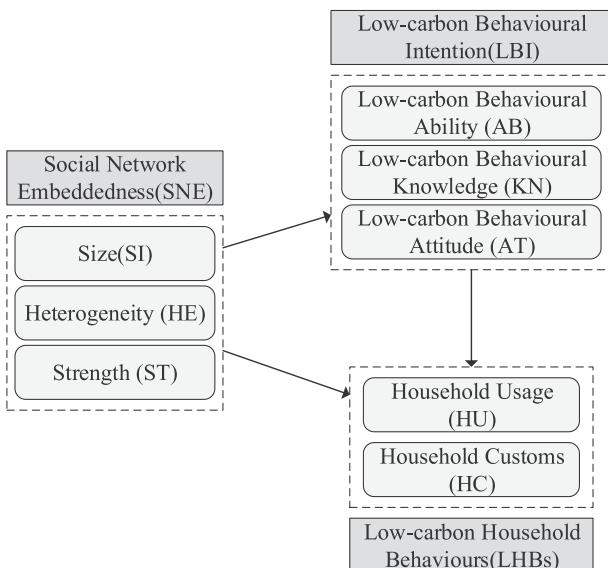


Fig. 1. The theoretical model of research.

Table 1
The references of the scale and variables.

Latent Variables	References
Social Network Size (SI)	Burt (1995); Poortinga et al. (2003)
Social Network Strength (ST)	Brüderl (1998); Scott (2004)
Social Network Heterogeneity (HE)	Gulati (1998)
Low-carbon Household Behaviour (LHB)	Lin and Yu (2003)
Low-carbon Knowledge (LK)	Scott (2004); Hsu and Roth (1998); Frick (2004)
Behavioural Ability (AB)	Mi (2011)
Behavioural Attitude(AT)	Scott (2004); Chan (2010);

Table 2
Correlation coefficient between variables and reliability test of each dimension(N = 355).

	MEAN	SD	HU	HC	AB	AT	KN	SI	HE	ST	Total	Cronbach's α
HU	3.461	0.909	1								.615**	0.761(7)
HC	3.626	0.793	.712**	1							.586**	0.607(5)
AB	3.103	0.779	.288**	.233**	1						.541**	0.758(4)
AT	3.906	0.707	.333**	.349**	.269**	1					.527**	0.789(4)
KN	2.507	0.864	.267**	.296**	.262**	.152**	1				.602**	0.872(12)
SI	4.278	1.049	.211**	.191**	.242**	.188**	.352**	1			.657**	0.737(3)
HE	4.172	1.025	-.064	-.116*	.064	.047	.119*	.146**	1		.359**	0.853(3)
ST	5.213	0.893	.082	.078	.160**	.200**	.222**	.435**	.201**	1	.553**	0.611(3)

Note: ** p < 0.05; * p < 0.1 (two-tailed test). The number in brackets is the number of items.

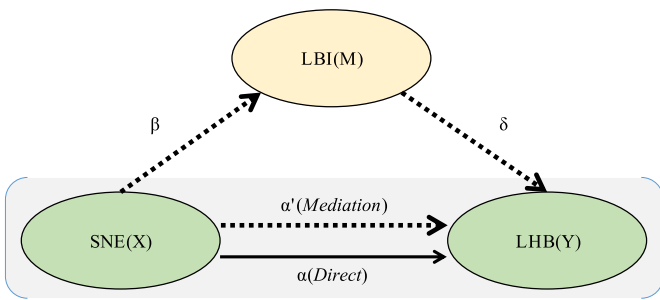


Fig. 2. Conceptual model of direct effect and mediation test.

LHB. The higher the degree of social network embedding, the lower the carbon emissions of households: this result supports the research conclusions of other scholars.

On this basis, the mediating effect of LBI is verified, that is, the LBI is added to the direct effect model as a mediator variable. The

model results are shown in Table 4. The results show that the fitness indices of the model all meet the standard, indicating that the model is a good fit. Among them, the influence of SNE on LBI was positive ($\beta = 0.634, P < 0.001, M = 0.634X + \epsilon_2$), and H2 was verified. Furthermore, when LBI are significantly related to LHB, if SNE is significantly related to LHB, it is not completely mediating; if not, it is completely mediating. According to Table 4, the LBI and the LHB are positive ($\delta = 0.846, P < 0.001, Y = 0.846M + \epsilon_3$), so the mediation is established, and H3 is verified; SNE and LHB was negative ($\alpha' = -0.316, P < 0.05, Y = -0.316X + 0.846M + \epsilon_4$), so it was not completely mediating. The result shows that SNE not only directly affects residents' LHB, but also affects it through LBI. Social network embeddedness has a negative effect on the direct effect of low-carbon household behaviours (-0.316).

From the living practice of human-being's, the size, strength and heterogeneity of social networks will correspondingly expand the social frequencies of residents, leading to more carbon emissions in areas such as "clothing, food, household, travel, etc." Therefore, social network embeddedness increases the carbon emissions of

Table 3
The results of direct effect model test.

Path		Standardized Regression Weights	Regression Weights	C.R.	P value	
LHB	<-	SNE	0.258	0.189	2.590	0.010
Model Fit Summary	CMIN/DF	2.396	GFI	0.982	RMR	0.049
	AGFI	0.934	RMSEA	0.070	NFI	0.957
	NNFI	0.919	CFI	0.967	IFI	0.968

Table 4
The results of mediating effect model test.

Path		Standardized Regression Weights	Regression Weights	C.R.	P value	
LBI	<-	SNE	0.634	0.373	6.159	***
LHB	<-	LBI	0.846	1.387	4.491	***
LHB	<-	SNE	-0.316	-0.304	-2.275	.023
Model Fit Summary	CMIN/DF	2.331	GFI	0.973	RMR	0.040
	AGFI	0.943	RMSEA	0.061	NFI	0.931
	NNFI	0.931	CFI	0.958	IFI	0.959

Note: *** P < 0.001.

residents, that is, has negative impact on residents' low-carbon household behaviour. Specifically, social network relationships (such as relatives, friends, and neighbours, etc.) will bring direct pressure and influence to residents' low-carbon behaviours to a certain extent through social norms and the herd mentality; on the other hand, social network relationships are embedded in residents' LBI (such as behavioural attitudes, behavioural abilities and low-carbon knowledge), which further promotes residents' tendencies to implement low-carbon activities. The results of hypothesis validation are shown in Table 5, and the results of structural equation model test are shown in Fig. 3.

It is worth noting that, in the face of mediating effects, SNE and LHB are negatively significant, that is, the SNE directly increases the household carbon emissions of residents, which seems to be inconsistent with the results in the direct effect model. To explore the mechanism of how SNE affects LHB, the direct effect, indirect effect, and total effect values of the three paths are tested (see Table 6). The results show that the direct effect of SNE on residents' LHB is -0.316 , the indirect effect is 0.536 (i.e., 0.634×0.846), and the total effect is 0.220 (i.e., $-0.316 + 0.536$). This conclusion is the same as the direct effect, which proves that the SNE will significantly improve residents' LHB and reduce household carbon emissions.

5.2.2. Multi-group structural equation model analysis based on demographic characteristics

Gender, age, marital status, and education level were added as control variables to the SEM for direct and mediating effects (Table 7). The results show that the fitness indices of the models reach the standard (except for the PGFI index), indicating that the model fitting is satisfactory. From the gender grouping, the female group was significant in the direct effect ($\alpha = 0.270, P < 0.05$) and the male group was not significant. In the mediating effect, the female group was completely mediated ($\beta = 0.611, P < 0.001; \delta = 1.045, P < 0.01$) and the mediating effect of male group is not established, indicating that women's performance in LHB is more vulnerable to social norms than male, and female are more susceptible to social circle and change their behavioural intentions. From the age group, the two groups were not significant in the direct effect, so the mediating effect was also not established in the two groups, but the LHB in the lower age group was more susceptible to their behavioural intentions. As far as marriage is concerned, there is no significant difference between the two groups in the direct effect, so the two groups are not established in the mediating effect, indicating that the marital status has little effect on the LHB of residents. From the perspective of education, in the direct effect, the highly-educated group was significant ($\alpha = 0.300, P < 0.05$) and the lower-education group was not significant. In the mediating effect, the three paths of the low-education group were not significant and the highly-educated group is completely mediation ($\beta = 0.611, P < 0.001; \delta = 1.044, P < 0.01$), indicating that SNE has no effect on the LHB of the low-education group, while the highly-educated group seems to be more susceptible to social networks.

Based on demographic characteristics, there are large differences in gender and education variables. The possible reason is that

Table 5 The results of hypothesis validation.

Hypothesis	Path	Judgement
H1	LHB ← SNE	Yes
H2	LBI ← SNE	Yes
H3	LHB ← LBI	Yes

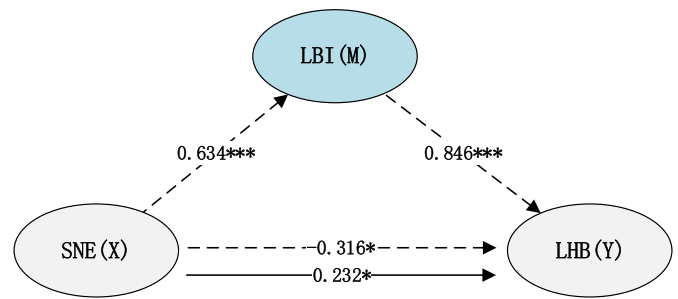


Fig. 3. The results of structural equation model test.

Table 6 Direct, indirect and total effects between latent variables.

Path	Direct	Indirect	Total
SNE → LHB	-0.316	0.536	0.220
SNE → LBI	0.634	-	0.634
LBI → LHB	0.846	-	0.846

female generally involved frequently in household chores (such as laundry, cooking, etc.) than male, which exposed women to more household equipment and required related skills in energy consumption. Further, they are usually frugal and tend to pay more attention to energy consumption to save household spending. At the same time, they are sensitive, their decisions are easily influenced by other people's suggestions and opinions from social network. From educational level perspective, the peers' good performance may be the reason that highly-educated people perform better in low-carbon behaviour, especially in terms of behavioural ability and low-carbon knowledge, which also brings the positive pressure, influence, and incentives to them. In addition, they may be more concerned about their image and status which makes them more reflective and self-critical.

5.2.3. Multi-group structural equation model analysis based on residential family characteristics

Through the analysis of multi-group SEM based on family characteristics, the results show that the model perform well on each index. Therefore, the model is ideally fitted, as shown in Table 8. Among them, in terms of family scale, the small-scale group was significant in the direct effect ($\alpha = 0.284, P < 0.05$) and the large-scale group was not significant. In the mediating effect, the small-scale group was completely mediated ($\beta = 0.772, P < 0.001; \delta = 1.413, P < 0.05$) and the mediating effect of the large-scale group was not established. It shows that smaller families are more susceptible to the influence of their social network in LHB, and the change in their low-carbon behaviours is more obvious. From the perspective of family monthly income, low-income families were significant in direct effect terms ($\alpha = 0.366, P < 0.05$) and high-income families were not significant. In the mediating effect, the low-income families were completely mediated ($\beta = 0.763, P < 0.001; \delta = 1.110, P < 0.05$) and the mediating effect of the high-income group was not established, indicating that low-income families are more susceptible to social network relationships. The likely reason is that low-income families are more concerned with economic costs and are therefore more willing to acquire energy-saving and low-carbon related skills and knowledge from their social networks. From the perspective of family monthly consumption, in the direct effect, low-consumption families are significant ($\alpha = 0.322, P < 0.01$) and high-consumption families are insignificant. In the mediating effect, low-consumption families

Table 7
The result of multi-group structural equation model analysis based on demographic characteristics.

Path	Gender(45.6%/54.4%)		Age (50.7%/49.3%)		Marriage(53.8%/46.2%)		Education(18.3%/81.7%)	
	Female	Male	Low	High	Yes	No	Low	High
SNE→LHB	.270**	.209	.234	.227	.209	.300	−0.033	.300*
SNE→LBI	.611***	.804***	.698***	.751***	.706***	.727***	0.639	.611***
LBI→LHB	1.045**	1.284	.918**	1.515*	1.260*	1.025*	1.985	1.044**
Model Fit Summary		CMIN 228.343	DF 136	CMIN/DF 1.679	CFI 0.959	GFI 0.962	AGFI 0.921	NFI 0.908
		NNFI 0.932	IFI 0.960	RMR 0.051	RMSEA 0.022	PNFI 0.551	PCFI 0.582	PGFI 0.455

Note: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$. The age grouping criteria are under 30 years old/30 years old and above; the education grouping criteria are undergraduate/undergraduate and above.

Table 8
The direct and mediating effects of multi-group structural equation model analysis based on family characteristics.

Path	Scale (83.1%/16.9%)		Income (55.2%/44.8%)		Consumption (67%/33%)		Size (60.3%/39.7%)		Area (82.5%/17.5%)	
	Small	Large	Low	High	Low	high	Small	Large	Urban	Rural
SNE→LHB	.284*	.080	.366*	.041	.322**	.032	.163	.286*	.322**	.286**
SNE→LBI	.772***	.884	.763***	.642***	.756***	.676**	.715***	.745***	.793***	0.201
LBI→LHB	1.413*	.671	1.110*	1.063**	1.370*	.883*	1.423*	.960**	1.283**	1.064
Model Fit Summary		CMIN/DF 1.678	CFI 0.958	GFI 0.962	AGFI 0.920	NFI 0.906	TLI 0.931	IFI 0.960	RMR 0.050	RMSEA 0.020

Note: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$. The family scale grouping criteria is three or less/more than three people; the family monthly income grouping criteria is less than 10,000 yuan/10,000 yuan and above; the family monthly consumption group criteria is 5,000 yuan or less/more than 5,000 yuan; the housing size grouping criteria is 120 square meters or less/more than 120 square meters.

were completely mediated ($\beta = 0.756$, $P < 0.001$; $\delta = 1.370$, $P < 0.05$) and the mediating effect of high-consumption families was not established. This shows that low-income families are more susceptible to social network relationships in LHB. This result is similar with the results for low-income families, indicating that economic capacity is an important factor in family LHB. From the perspective of housing size, the small-size group is insignificant in the direct effect and the large-size group is significant ($\alpha = 0.286$, $P < 0.05$). In the mediating effect, the small-size group is not established and the large-size group is completely mediated ($\beta = 0.745$, $P < 0.001$; $\delta = 0.960$, $P < 0.01$). This shows that families with large houses are more concerned with household energy consumption and more susceptible to the social network relationship. The likely reason is that large houses require more energy consumption (such as electricity, heating, etc.), so they pay more attention to energy conservation. As far as the living area is concerned, in the direct effect, both urban ($\alpha = 0.322$, $P < 0.01$) and rural ($\alpha = 0.286$, $P < 0.01$) groups of residents are significant. In the mediating effect, the urban group is completely mediated ($\beta = 0.793$, $P < 0.001$; $\delta = 1.283$, $P < 0.01$), while the mediating effect of the rural group is not established and the paths are not significant. This shows that urban families are more susceptible to social network relationships in terms of household energy consumption. The likely reason is that urban families have a higher social interaction frequency, a wider social range, and a more socially diverse approach to issues than rural families.

Through multi-group analysis based on family characteristics, residents' LHB are significantly different in family scale, monthly income, monthly consumption, housing size, and living area. The possible reasons maybe explained from two aspects: vulnerable social change and economic cost savings. Among them, both small size-families and urban groups are subject to change due to the influence of social network relationships. Small-size families are easier to change because of their small population and low-energy consuming equipment. Urban families are more vulnerable to the

pressures and norms of social relationships to change their tendency to low-carbon behaviours. Families with low incomes, low consumption and large houses may be particularly concerned about household energy conservation behaviours in consideration of economic costs, which also makes them perform better in LHB.

6. Conclusions and implications

6.1. Research conclusion

Based on SNT and PBT, this paper explores the impact of SNE on residents' LHB through questionnaire survey and multi-group SEM analysis, and tests the mediating role of LBI. The following conclusions are drawn:

- (1) The results based on the direct effect test show that SNE will significantly improve residents' LHB and reduce household carbon emissions. Residents' improvements in the three dimensions of social network size, heterogeneity, and strength will directly promote the implementation of LHB and the reduction of household energy consumption, which support the research conclusions of other scholars.
- (2) The results based on the mediating effect test show that the social network embeds residents' LHB through two channels. The first is the direct effect (based on SNT) that social networks are directly embedded in the LHB of residents. Secondly, the mediating effect (based on PBT) means that the social network embedded the residents' LBI, and then influenced residents' LHB through the incomplete mediation of LBI. This conclusion reveals the internal mechanism of SNE in residents' LHB, that is, the choice and behaviour of residents in household energy consumption will be positively affected by the social network relationship within which they live.

- (3) The research results based on demographic characteristics shows that the gender and educational level groups are quite different in performance, the female and highly-educated groups perform better in LHB. The analysis results based on family characteristics shows that residents' LHB are significantly different in five groups (family scale, monthly income, monthly consumption, housing size, and living area). Among them, small size families, low-incomes families, low-consumption families, families with large houses, and urban groups performed better in reducing energy consumption.

6.2. Policy advice

With the steady growth of China's economy, the material and cultural life of urban and rural residents is increasingly rich, and the demand for energy in individual households, especially for household electricity, gas, and heating, is gradually increasing. At the same time, the rise of the Internet, mobile terminals, the sharing economy, Weibo, and WeChat have enriched the social activities of residents. Residents, to meet their own needs in social activities, or through vanity, will increase the energy consumption of their families to a certain extent.

- (1) Attention should be paid to SNE channels and improve the basic services of social activities. The expansion of the size and scope of residents' social networks will lead to an increase in the degree of SNE, thereby increasing residents' LHB. However, due to the spontaneity and initiative of social activities, we usually cannot easily constrain the size of residents' social networks. Therefore, building good social infrastructure and harmonious social advocacy at national and social levels will be helpful. The attention should be continually paid to relatives (family education), friends (social propaganda), neighbours (community propaganda) and other related agents on LHB of residents, and strive to strengthen the education and publicity of the above three aspects. In addition, policy-makers should pay more attention to the differences in the behaviours of different residents and families in LHB, so that relevant low-carbon policies benefit different types of residents and their families.
- (2) The low-carbon values and the sense of environmental responsibility of residents should be cultivated. Because social networks have transmission mechanisms (Granovetter, 1985), respondents and families who lack low-carbon knowledge will spread biased values in their social networks. The bias of low-carbon values stems from the lack of low-carbon knowledge and awareness among residents. Therefore, education about low-carbon environmental awareness and knowledge based on different channels such as family, community, school, and mass media need to be expanded, so that more residents can understand and recognise the seriousness of environmental problems. This will enable residents to take the initiative to practice low-carbon behaviours on their own, and actively influence and drive people around them to protect the environment. It should be noted that, in the process of publicity- and education-related work, it should be based on different characteristics of residents (such as gender and education), and strive to achieve continuous tracking, summary and feedback. This is conducive to the long-term benefits of environmental-protection-related work.
- (3) Resident's low-carbon habits should be cultivated to reduce household energy consumption. The unreasonable

operations and wasteful behaviours of residents in the use of gas, appliances, and heating has become an important source of household carbon emissions. Improper behaviours mainly come from the daily usage of residents at a subconscious level, especially the habitual behaviours that residents have not realised will generate significant carbon emissions. Therefore, residents should be encouraged to participate in low-carbon environmental protection activities at different levels to improve their low-carbon awareness, knowledge, skills in continuous practice, experience, and communication. It is necessary to pay attention to the differences in the daily life of residents in different regions (urban and rural), therefore, it is possible to integrate low-carbon environmental protection experiences and practical activities into the lives of urban and rural residents.

6.3. Research limitations and prospects

As a result of the study using paper version of the questionnaire, its distribution channels and collection methods have certain limitations, which is one of the reasons why this study only obtained 293 effective samples. In order to make up for the small amount of data, in the future study should be combined with the network questionnaire and paper version of the questionnaire two forms, which can effectively expand the questionnaire audience and effective sample volume. In addition, it should be explained that the target groups involved in the study are based on the relatives and friends of students in the same university, which to a certain extent reduces the heterogeneity of the questionnaire data. Therefore, in the future study, the sample distribution channels should be expanded as far as possible in order to improve the heterogeneity of the sample.

Limited by the availability of mature scales and demographic characteristics data, this study has not been able to explore in greater depth and detail about the specific performance of demographic characteristics in the embeddedness of social networks. However, this is acceptable because this study is based primarily on the structural perspective of social networking (i.e. size, strength and heterogeneity) rather than on demographic characteristics. In addition, the low-carbon behavioural differences in demographic characteristics are also covered in the items used in this study. Moreover, the research on "embeddedness" is mainly reflected in the path analysis of the mediating model. In the future study, the behavioural performance and differences of heterogeneous groups embedded in social networks should actively explored by scholars.

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Appendix A. Supplementary data

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